A Level Design and Technology: Product Design

Materials

You need to be able to provide detailed and justified explanations of why specific materials and combinations of materials are suitable for given applications, with reference to:

- physical and mechanical properties and working characteristics
- product function
- aesthetics
- cost

You also need to have a good understanding of physical and working properties of materials, including;

- malleability
- toughness
- hardness
- resistance to corrosion and degradation
- thermal conductivity
- electrical conductivity.

You should know and understand the classifications of the following materials and be able to name examples that belong to each category:

- metals (ferrous, non-ferrous, alloys)
- woods (hardwoods, softwoods, manufactured boards)
- polymers (thermoplastics, thermoset polymers, elastomers)
- papers and boards
- composites
- smart materials
- modern materials.

Science/Maths Link:

- You need to be able to calculate materials sizes and costs.
- You need to be able to analyse data that could be taken from materials testing.

Materials Testing

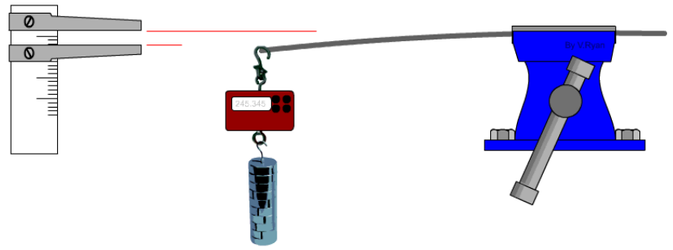
You should be able to describe how workshop and industrial tests are set up and what will be tested, measured and compared, including:

- tensile strength
- toughness
- hardness
- malleability
- corrosion
- conductivity

The tensile strength of a material can be defined as, 'the ability of a material to stretch without breaking or snapping'.

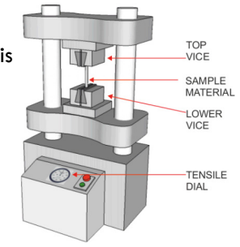
Tensile Testing: Workshop Test

A simple workshop test can be seen below. A piece of material is clamped in a vice. A fixed weight is hung from the end. The amount of deflection, is a measure of its resistance and tensile strength. A selection of materials of the same section, cut to exactly the same size, can be tested in this way.



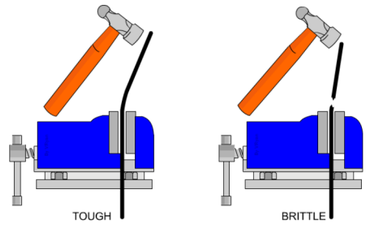
Tensile Testing: Industrial Test

A sample test material is securely clamped between the top and lower vices. The tensile dial is set to '0'. A motor is turned on, slowly moving the top vice away from the lower vice, stretching the test material. When the test material 'snaps', the final tensile dial reading is taken, displaying the tensile strength of the sample.



Toughness Testing: Workshop Test

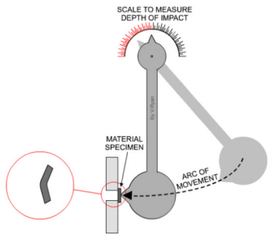
The toughness of a material can be defined as, 'the ability of a material to absorb sudden shock without breaking or shattering.



A simple school workshop test is to hit a sample of material with a hammer, whilst it is secured in an engineers vice. If it survives the blow, without bending too far, it can be said to be tough. If it shatters, it can be said to be brittle.

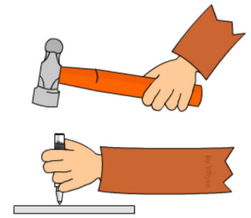
Toughness Testing: Industrial Test

The industrial device below measures toughness. The pendulum is allowed to 'swing' from a set starting position. The resulting 'distortion' to the sample material can be measured on the scale. This gives an indication of the materials toughness.



Hardness Testing: Workshop Test

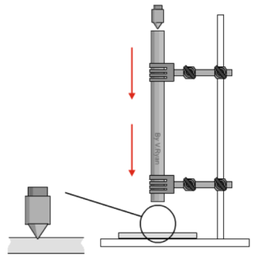
The hardness of a material can be defined as, 'the ability of a material to resist scratching, wear and tear and indentation'. The hardness of a material can be defined as, 'the ability of a material to resist scratching, wear and tear and indentation'.



Using a centre punch to 'indent' the surface of a material, is a basic test. Different materials require a different amount of force to form an indent. This makes it possible to compare the hardness of a selection of materials.

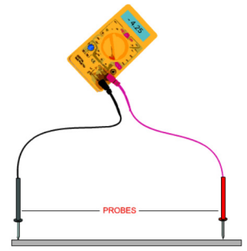
Hardness Testing: Industrial Test

A more sophisticated method of measuring the hardness of a material, is to drop a 'plug' down a tube. When the 'plug' hits the material below, the surface will suffer an indent. The indent produced on different materials, can be compared. Consequently, the smaller the indent, the harder the material.



Conductivity Testing

The conductivity of a material can be defined as, 'the ability of a material to conduct electricity or heat'.
A test for electrical conductivity is seen below. A voltmeter is used to measure resistance. The probes are set to the same distance on each sample. The resistance is a measure of the materials conductivity.

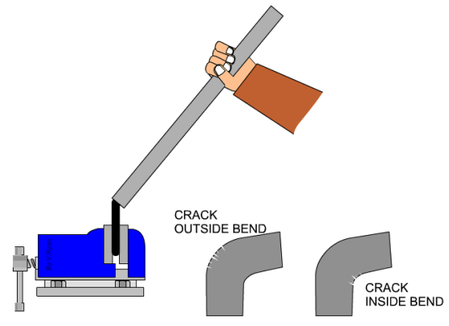


A test for heat conductivity/transfer is seen below. A bunsen burner is placed at one end of a piece of material and a temperature meter at the other end. The time it takes for the temperature to change at the opposite end of the material is recorded. If a selection of materials of the same length and section are tested in this way, their conductivity can be compared.

Malleability Testing

The malleability of a material can be defined as, 'the ability of a material to be reshaped in all directions without cracking'.

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



Corrosion Testing

Salt spray testing is an accelerated corrosion test that produces a corrosive attack to coated samples in order to evaluate (mostly comparatively) the suitability of the coating for use as a protective finish.

A range of materials could be placed outside and the corrosion observed as a crude workshop test.

A Level Design and Technology: Product Design

Paper and Board

You should be able to describe the performance characteristics of papers and boards, including:

- he ability to be scored
- cutting
- folding
- surface qualities for printing
- impact resistance
- recyclability and/or biodegradability

You should be able to explain why different papers and boards are suitable for different applications, including:

- layout paper: sketch pads
- cartridge paper: printing
- tracing paper: copying images
- bleed proof paper: marker rendering
- treated paper: photographic printing
- watercolour paper: painting
- corrugated card: packaging
- bleached card: greeting cards and high quality packaging
- mount board: modelling
- duplex card: food packaging
- foil backed and laminated card: drinks packaging
- metal effect card: gift packaging
- moulded paper pulp: eco-friendly packaging.

Science/Maths Link

You need to know about:

- The efficient use of materials in the construction of containers through 2D net design.
- The effective selection of materials to allow for recyclability, biodegradability and stability.

Paper and Board Forming Processes

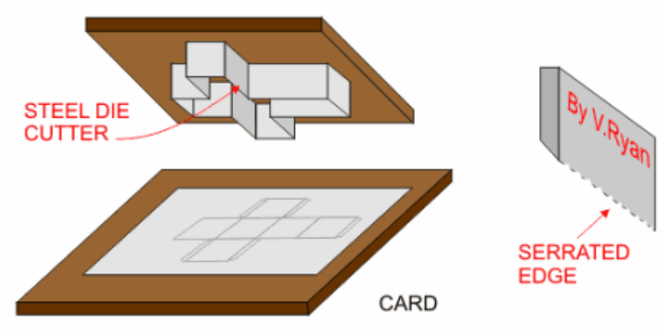
Die Cutting

In industry a company may need to manufacture thousands of the same net / package, every day. A STIKA machine or any similar machine will not be able to manufacture such large quantities. When large numbers have to be manufactured a DIE CUTTER is normally used as part of a production line.

1. The design is completed using a computer system and CAD software. The designer is careful to ensure the shape is accurate and that fold lines are in the correct place.

2. In a printers workshop, the blank pieces of card (perhaps rectangular in shape) are prepared and colour is added, as well as the printing. This may be achieved through the use of sprays, layers of coloured paper or automated screen printing.

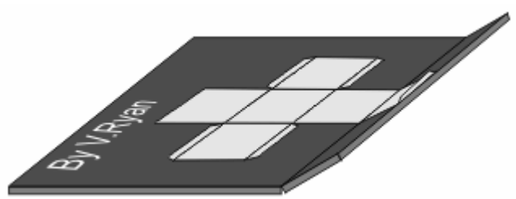
3. Back in the factory a die cutter is set up. This is made up of several hardened steel blades. The layout of the blades match the exact size as the net. A die cutter is basically a steel stamp that is used to cut and shape the net. It is designed to cut through the card on some lines whilst slightly cutting others (these are the fold lines or crease lines).



The steel die cutter is made up of specially hardened steel cutters. Each is like a blade, with a serrated edge. Sometimes the blades can be rearranged to form other shapes of net.

The die cutter is pressed into the card by the force of the machine. The 'stamped out' net is then automatically placed on a folding table. Parts of the table move/fold, forming the basic package. People sometimes finish the more delicate folding operations. (This depends on the complexity of the package).

In industry most of these operations are carried out by one large packaging machine that is able perform a series operations including, printing/colouring, die cutting and folding.

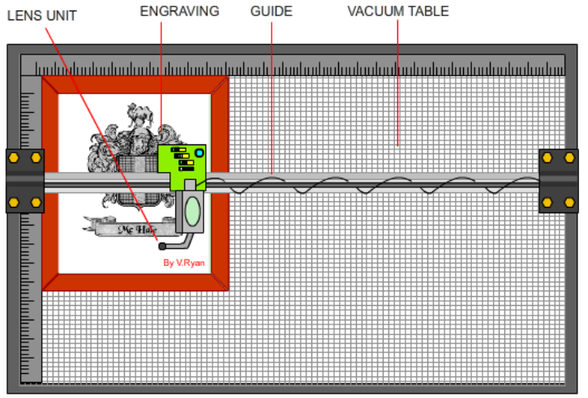


Laser Cutting

Laser cutting / etching machines are quite simple in the way they work. The lens system that controls the position of the laser is itself moved by a motorised slide control system. This allows movement in any direction. The control system moves according to the programme being used by the machine. The diagram shows the LID open - however, the laser will not operate unless the lid is closed. This is a safety feature.

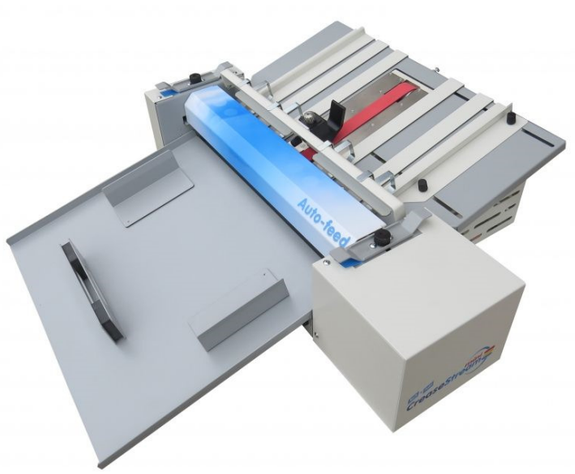
The work/material being engraved or cut by the laser is held firmly in position on a vacuum bed. The work/material is normally positioned in the top left corner as shown on the diagram below. The machine operates with three axis, X, Y and Z. The top left corner is regarded as coordinates (0,0,0), this is sometimes called zero point or the start point.
The diagram below shows a coat of arms being etched on a sheet of transparent glass. The lens unit focuses the laser in exactly the right position as it cuts / etches.

The laser is deflected from it source within the machine through a series of precision lenses/mirrors and focussed accurately on the area to be cut/etched. The laser removes small dots of material, up to 1200 dots per inch. This means that it is able to cut extremely accurate shapes and produce astonishingly detailed etchings. The laser cutter is similar to an ink jet printer. The printer sprays ink onto the paper in a series of dots that make up a picture or text. The laser cutter removes material in a series of dots producing pictures / etchings and shapes cut away from the surface of the material.



The microprocessor controlled height guide ensures that the laser cuts to the correct depth.The microprocessor controlled height guide ensures that the laser cuts to the correct depth.

If a circular or curved product such as a glass container is to be etched then a motorised roller system is used. The rollers are controlled by the microprocessor, rotating the glass at exactly the right speed and direction. This allows etching to be produced accurately on the surface. The height guide ensures that the laser is set to the correctly at all times. This system allows uneven surfaces to be etched as well as surfaces that are uniform.



Creasing/Bending

Often, creasing/bending of paper and boards is achieved during the die cutting process. A blunt cutter is used to crease/ bend the paper/board.

Similarly, a creasing/folding machine can be used for products such as brochures of prospectuses.

A Level Design and Technology: Product Design

Paper and Board Finishing Processes

You should be aware of the ways that paper and board can be finished to enhance heir appearance or for improved function.

Laminating

Printing "finishes" such as lamination and Spot UV varnishes are used to increase both the perceived value and quality of a printed item (such as a brochure, folder or data sheet) and also provide ink-protection.

Depending on the desired result and project budget, each of the print finishes has it's own pros and cons and in any print situation the suitability of a laminate or varnish needs to be considered carefully.

Lamination is the process of using an ultra thin plastic film which can be applied to almost any paper or board and is more commonly used in gloss, silk and matt finishes. A lamination will cover the whole side or sides of a document and cannot be used to cover a specific area alone.

Lamination Advantages:

– can be used to enhance the appearance of standard paper boards at relatively low cost and is generally cheaper than a spot uv varnish in most cases

– will make a paper more durable and long lasting and can actually offer some water/grease resistance

– eliminates cracking of ink on creases

– no set up costs

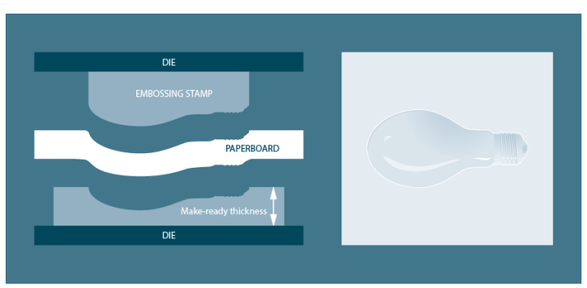
Lamination Disadvantages:

– can only be used to cover a whole side of a document

– matt lamination over a dark colour will show scratches and finger prints, more so than gloss

Embossing/debossing

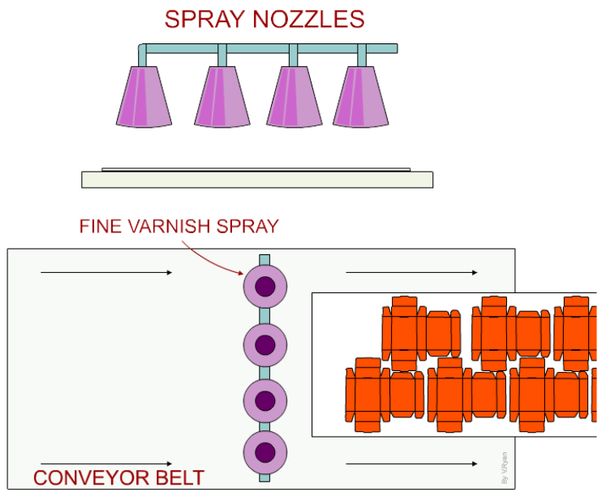
Embossing involves raising areas of a card surface above the level of the rest. The diagram below shows a coat of arms that has been embossed on green card. The images stands out from the card as it has been produced by a stamp which presses the card to the correct shape. This process adds cost to the printing process but gives the card a 3D effect. Debossing is the opposite of embossing.



Varnishing

Fine varnish can be sprayed on to the surface of card. When dry this gives a gloss finish and helps protect the printing underneath. The printing and colour work must be completed before this process takes place. Also, folding a package takes place after the varnish has been applied.

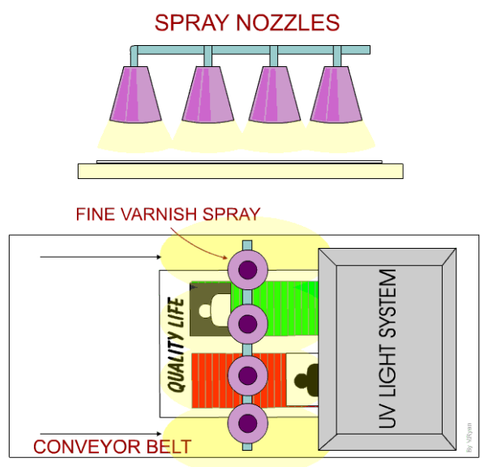
Different types of varnish are available. The most popular are oil and water based varnishes. In either case, the varnish takes at least two hours to dry. This may be a disadvantage especially if the card is being used for a package - as it means it can not be folded straight away.



UV Varnishing

Special varnishes dry almost straight away if they are exposed to ultra violet light. (UV light). The varnish is sprayed on to the paper / card in the same way as other varnishes. However, after spraying the card passes underneath UV lights which dries the varnish almost instantaneously.

One disadvantage is that this type of machinery is expensive to purchase. However, it produces an excellent gloss finish to the card / paper.



UV Spot Varnishing

UV (ultra violet) Varnish is a liquid coating used to 'mask off' any area of a design and enhance it (ie. varnishing text, logos or images whilst leaving the remainder of the page unaffected). Unlike a lamination, UV varnishes come in an array of finishes and not only include gloss and matt but also glitter and colour-flip versions as well as many others.

UV Varnish Advantages:

– can be used to enhance specific areas such as text, logos or images rather than cover a whole page

– additional substances can be added to varnish to increases its versatility such as glitter

– can be used in conjunction with a laminate and printed over the top to create a more creative and diverse result

UV Varnish Disadvantages:

– if printed over a crease in a document it will crack in the same way ink does

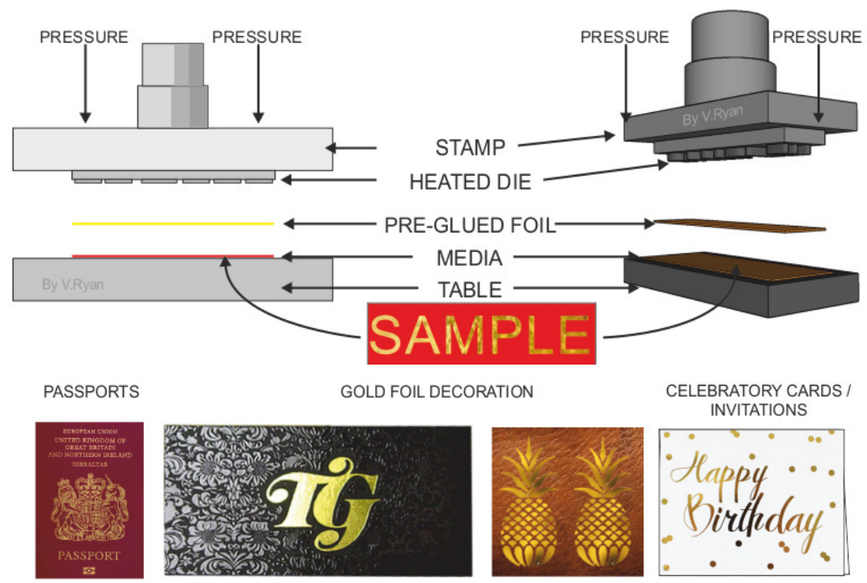
– if printed over text or images will be subject to 'make ready' die charges which increases its cost

– due to additional set up required UV varnishing is a longer process than lamination

Foil Blocking

In its simplest form, Foil Block Printing (sometimes called Hot Foil Stamping) is where a pre-glued metallic foil, is pressed by a heated die, into the surface of a material. This is a permanent way of applying a quality finish to materials, such as card, for packaging. This process can also be used to apply a finish to other materials including leather.

The foil is metallic, but comes in a range of colours including gold, copper, red and purple. It is even possible to block print holographic foils, creating 3D effects. Foils are also available as satin, gloss and matt.



A Level Design and Technology: Product Design

Paper and Board Printing Processes

You should be aware of the different types of printing processes and their suitability for specific products and scales of production.

Screen Printing

As its name implies, this printing technique relies on a screen, which is a woven piece of fabric. Certain areas of this mesh are coated with a non-permeable material. In the remaining open spaces ink can be pushed through the mesh onto a substrate. The **advantage** of screen printing is that the surface of the recipient does not have to be flat and that the ink can adhere to a wide range of materials, such as paper, textiles, glass, ceramics, wood, and metal.

The image below shows a screen printing press that is used to print t-shirts.

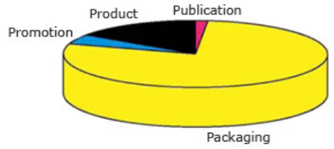
Screen printing is used to print **small runs** of posters, display boards, fabrics, wallpaper and control panels of electronic products.

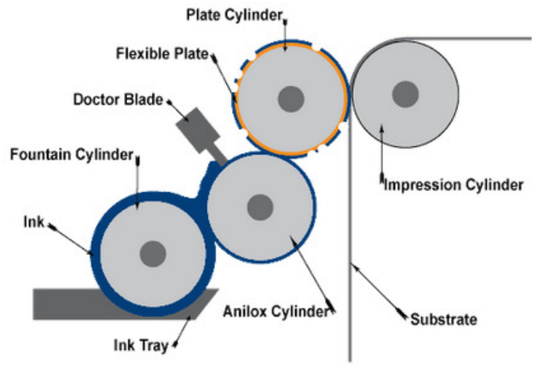
Advantages: long lasting, big order friendly, excellent finish, more ink, versatile (can print on lots of different substrates).

Disadvantages: Not practical for small orders, the more colours there are the more expensive it is, not environmentally friendly due to excessive water waste.

Flexographic Printing

In flexography the content that needs to be printed is on a relief of a printing plate, which is made from rubber. This plate is inked and that inked image is subsequently transferred to the printing surface. The process can be used to print on paper as well as plastics, metals, cellophane and other materials. Flexo is mainly used for packaging and labels and to a lesser extent also for newspapers, usually **large runs.**





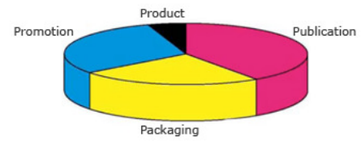
Advantages: Quick, variety of ink types, low cost once set up.

Disadvantages: Complex system, expensive set up due to four different printing plates., long set up times.

Offset Lithography

In offset lithography a printing plate, which is most often made from aluminum, contains an image of the content that needs to be printed. When the plate is inked, only this image part holds ink. That inked image is subsequently transferred (or offset) from the plate to a rubber blanket and then to the printing surface. The process can be used to print on paper, cardboard, plastic or other materials, but these have to have a flat surface.

Below is a picture of a 4 colour sheet-fed printing press. At the far end is the intake where individual sheets of paper are automatically fed into the press. The 4 towers or printing units each print one colour, typically black get printed first, followed by cyan, magenta and yellow. The stack of printed sheets is visible on the front of the machine, underneath the press console & monitor which the press operator uses to control the press.



Offset is nowadays the most widely used printing technique for an extensive range of products such as books, newspapers, stationery, corrugated board, posters, etc. **It is used for mass production**.

Advantages: consistent high image quality, quick and easy production of plates, longer printing life, cheapest method for large runs, can be used on lots of different materials.

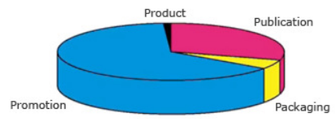
Disadvantages: image quality not as sharp as some other printing processes, time and cost of set up is high, so is usually unsuitable for smaller print runs as it is not economical.

Digital Printing

Digital printing can be done in various ways. Two technologies dominate the industry:

Inkjet – In an inkjet printer the image that needs to be printed is created by small droplets of ink that are propelled from the nozzles of one or more print heads. Inkjet devices can print on a wide range of substrates such as paper, plastic, canvas or even doors and floor tiles. Inkjet printing is used a lot for posters and signage. It is also economical for short run publications such as photo books or small runs of books. In-line inkjet printers are sometimes combined with other types of presses to print variable data, such as the mailing addresses on direct mail pieces.

Xerography – In xerographic printers, such as laser printers, the image that needs to be printed is formed by selectively applying a charge to a metal cylinder called a drum. The electrical charge is used to attract toner particles. These particles are transferred to the media that is being printed on. To make sure the toner is fixed properly, the substrate passes through a fuser that melts the toner into the medium. Laser printers are not only used in offices but also for small run printing of books, brochures and other types of document. These printers are also used for transactional printing (bills, bank documents, etc) and direct mail.



Advantages:
more eco-friendly due to lack of creating printing plates, initial set up is very quick because of the same reason, no initial costs, can print in small batches, easy to customise each print.

Disadvantages: colour matching is less accurate, limited range of printing materials, more expensive in higher quantity runs.

In summary, the choice of printing method depends on a range of factors, with each presenting advantages and disadvantages.

- **Quantity**
- **Quality**
- **Material choice**
- **Cost**

A Level Design and Technology: Product Design

Performance Characteristics of Woods

You should be aware of the different stock forms of timber, including:

Rough Sawn

When wood is cut to a basic size on a circular saw, it is called 'rough sawn'. The edges and sides are not smooth. This is usually the first stage of preparing wood for further, more accurate work. Wood can be purchased rough sawn or planed. Rough sawn timber is cheaper. Rough sawn wood is often used on building sites, where the wood surface finish is not critical or not likely to be seen. A company / business that has a machine planer may buy rough sawn boards and plane them to size themselves, saving money.

Planed Square Edge (PSE) and Planed All Round (PAR)

Wood boards are normally planed on a planer / thicknesser (sometimes called a combination planer). This prepares the wood by planing the edges and sides accurately, smoothing surfaces. This type of machine can be used to 'square' edges, so that they are straight and level. Planed wood is purchased by companies who do not possess a machine planer or find it is cheaper or more convenient for timer to arrive on their premises, planed and ready to use. Planed timer is more expensive than rough sawn.

Natural Timber 

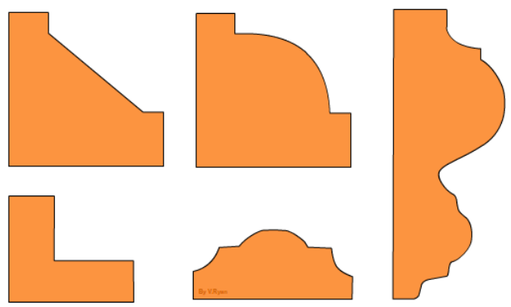
Natural wood can be supplied as boards. These are a rectangular section and vary in length. Natural woods are also supplied in square sections. These are available in a range of measurements. A typical measurements is: 50x50x600mm.

Manufactured Boards

Manmade boards are available in a range of materials such as MDF, blockboard and plywood. Full boards are usually 1220x2440mm. Half boards are also available.

Mouldings

Wood can be supplied in the form of mouldings which have a variety of sections.
Mouldings are used for decorative edges and can be found on traditional furniture.



You should be able to describe the performance characteristics of woods, including:

- grain pattern
- grain direction
- surface defects
- warpage
- shrinkage
- splitting
- joining
- forming
- steam bending
- laminating
- machining qualities
- resistance to decay
- moisture resistance
- toxicity.

Examples

You should be familiar with the following woods and wood products:

softwoods:
- pine
- spruce
- Douglas fir
- redwood
- cedar
- larch

hardwoods:
- oak
- ash
- mahogany
- teak
- birch
- beech

manufactured boards:
- plywood
- marine plywood
- aeroply
- flexible plywood
- chipboard
- medium density fibreboard (MDF)

veneers and melamine formaldehyde laminates.

Enhancement of Woods

Natural timber combined with resins and lamination can give enhanced properties, e.g. increased strength and stability. Timber products can also be enhanced with preservatives, finishes and coatings.

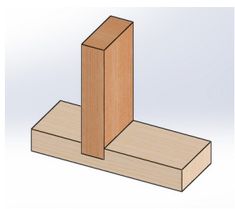
Wood Processes

You should be aware of how timber can be joined to form different products.
You should be able to describe the different methods.
You should be able to explain the suitability of the different joining methods for a range of
specific products and scales of production.

Addition/Fabrication Processes:
Traditional Wood Jointing

Dovetail Joint

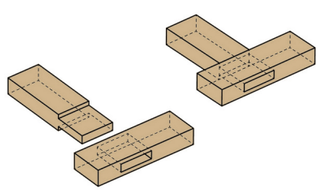
Comb Joint



Housing Joint

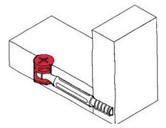
Half Lap Joint

Dowel Joint

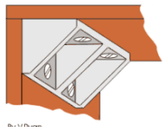


Mortise and Tenon Joint

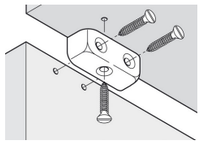
Component Jointing
Knock Down Fittings can be used to join woods together, these are especially used in flat-pack furniture.



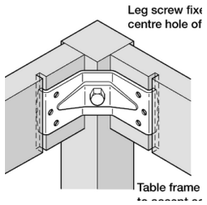
Cam Fitting



Rigid Joint



Modesty Block



Corner Brace

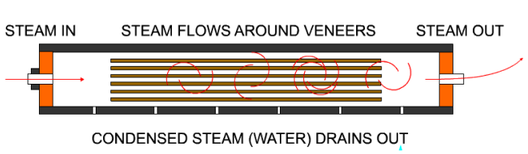
Cross Dowels

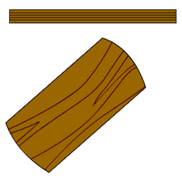
Connecting Nuts and Bolts

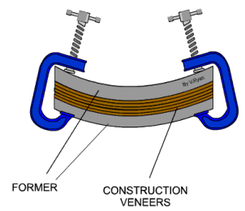
You should be aware of how timber can be formed into 3D products. You should be able to describe the different processes.

Laminating/Steam Bending

Thin layers of veneer are steam treated first. They are placed in steam chamber. Steam is introduced at one end and excess steam/pressure escapes at the opposite end. Condensed steam (water) drains away. As the steam flows from one end of the tube to the other end, moisture is absorbed by the veneer. After a period of time, the veneers are removed. They are now pliable and it is possible to bend them to the required shape, using a former.







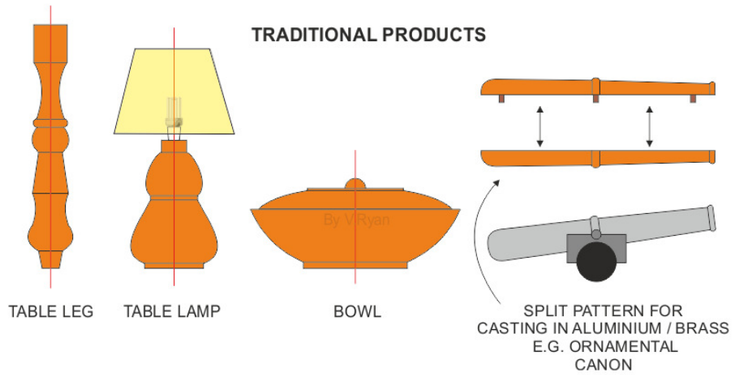
This process enables curved products to be manufactured.
Lamination is the process of layering thin pieces of wood on top of each other with an adhesive between each layer.

A Level Design and Technology: Product Design

Wood Wasting Processes

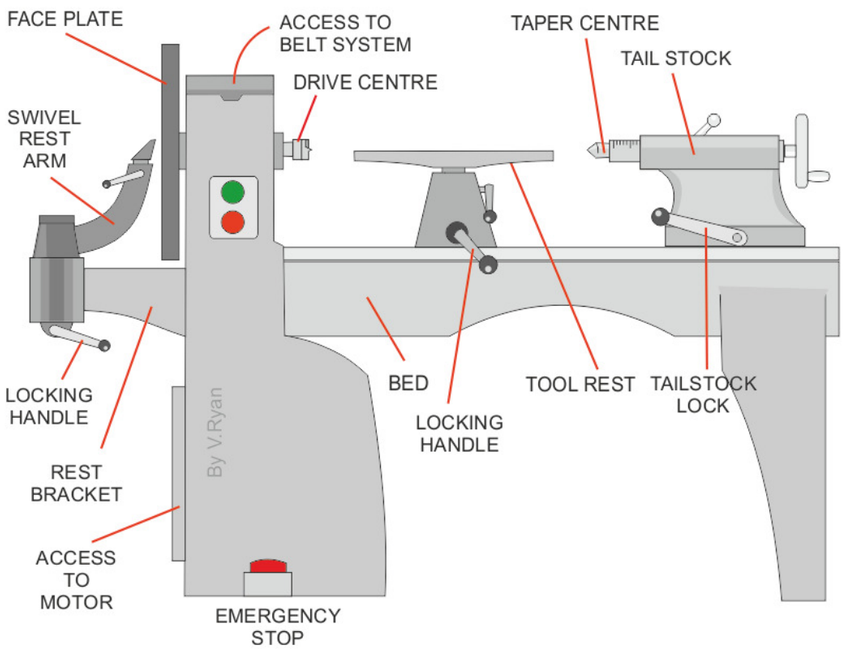
Turning between centres and the use of the chuck and faceplate (wood lathe)

Natural wood can be formed and shaped in many ways. However, wood turning is one of the most interesting ways. Numerous traditional examples of wood turning can be found in most homes and work places. These include, table lamps, table legs, and bowls. However, wood turning skills are as useful today as they have always been. Some examples of traditional and modern turned products are seen below.



A typical wood turning lathe is seen below. Wood turning takes place either at the face plate (bowls) or between the two centres, the drive centre and the tail stock centre.

For example, if a table leg is being turned, this is carried out between the two centres. However, if a bowl is being turned, the blank is usually screwed to the face plate.

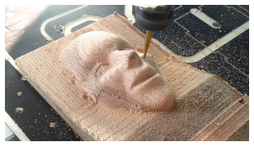


Milling

Milling is the process of machining using rotary cutters to remove material by advancing a cutter into a workpiece. This may be done varying direction on one or several axes, cutter head speed, and pressure. Milling covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes for machining custom parts to precise tolerances.

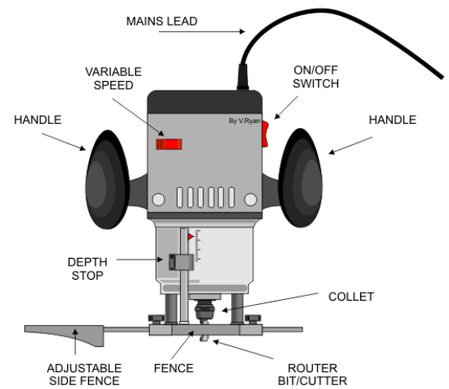
Milling is a cutting process that uses a milling cutter to remove material from the surface of a workpiece. The milling cutter is a rotary cutting tool, often with multiple cutting points. As opposed to drilling, where the tool is advanced along its rotation axis, the cutter in milling is usually moved perpendicular to its axis so that cutting occurs on the circumference of the cutter. As the milling cutter enters the workpiece, the cutting edges (flutes or teeth) of the tool repeatedly cut into and exit from the material, shaving off chips (swarf) from the workpiece with each pass. The cutting action is shear deformation; material is pushed off the workpiece in tiny clumps that hang together to a greater or lesser extent (depending on the material) to form chips. This makes metal cutting somewhat different (in its mechanics) from slicing softer materials with a blade.

The milling process removes material by performing many separate, small cuts. This is accomplished by using a cutter with many teeth, spinning the cutter at high speed, or advancing the material through the cutter slowly; most often it is some combination of these three approaches. The speeds and feeds used are varied to suit a combination of variables. The speed at which the piece advances through the cutter is called feed rate, or just feed; it is most often measured in length of material per full revolution of the cutter.



CNC Milling

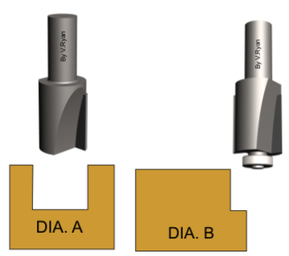
Some milling is computer numerical controlled (CNC), driven by a form of CAD file. It allows complex forms to be created, particularly if a 5-axis machine is used.



Routering to produce slots, holes and profiles

Machine routers are extremely versatile machines. They are generally used to cut grooves in natural wood and manmade boards. They have a cutter that rotates at high speed - as the operator pushes the router forwards the cutter removes the wood in its path. They can be very dangerous if not used with care and attention to safety rules.

Diagram A and B show the same typical plain router bit. The router bit has two hardened steel cutters, ground to an angle of approximately 30 degrees. As they rotate they remove the waste wood.
Sometimes a bearing will be fitted to the router bit (DIA. B). This is normally done when the outside edge of a piece of wood is to be rebated or a mould applied to the edge.



CNC Routing

A computer numerical control (CNC) router is a computer-controlled cutting machine related to the hand-held router used for cutting various hard materials, such as wood, composites, aluminium, steel, plastics, glass, and foams. CNC routers can perform the tasks of many carpentry shop machines such as the panel saw, the spindle moulder, and the boring machine. They can also cut mortises and tenons.

A CNC router is very similar in concept to a CNC milling machine. Instead of routing by hand, tool paths are controlled via computer numerical control. The CNC router is one of many kinds of tools that have CNC variants.

A CNC router typically produces consistent and high-quality work and improves factory productivity. Unlike a jig router, the CNC router can produce a one-off as effectively as repeated identical production. Automation and precision are the key benefits of CNC router tables.

A CNC router can reduce waste, the frequency of errors, and the time the finished product takes to get to market.

A Level Design and Technology: Product Design

Wood Finishes

You should be aware of the ways that woods can be finished to enhance their appearance or prevent decay.

Applied finishes:

Polyurethane Varnish

Polyurethane varnish is highly durable. Oil-based polyurethane is a highly durable finish, but it is also easy to apply. It is resistant to heat, chemicals, and wear and tear such as scratches. When applied according to directions, oil-based polyurethane supplies a lustrous finish that deepens the color of the wood. Water-based polyurethane will not penetrate the wood as deeply, and also does not add color to the wood.

If applied incorrectly or in too many layers, polyurethane varnish can cause wood surfaces to look plasticlike. Many types of this varnish are not UV resistant and can yellow over time. It may also be difficult to add other types of finishes to surfaces varnished with polyurethane, as they may have trouble adhering. Thinning polyurethane varnish with mineral spirits can help to alleviate the plastic-like surface.

Acrylic Varnish

Acrylic Varnish is a clear, high-build wood lacquer, particularly well suited to areas where a high build with exceptional clarity is required, yet a high degree of physical and chemical resistance is not such as wooden bedroom furniture, skirting boards, architraves and other interior trim, fixtures and fittings.

Water Based Paints

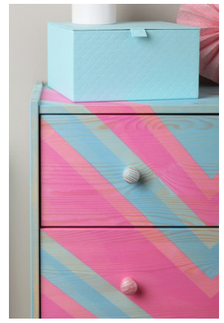
Water-based paints dominate the market for interior paints and they are the most popular choice for DIY and professionals. They can be used on walls, ceilings, interior and exterior wood and metal (such as front doors and skirting boards) and still provide the durability of traditional solvent-based paints. When using water-based paints on furniture projects it is generally recommended to apply a primer before your topcoat to promote adhesion between the surface and the paint. However, unlike chalk paint projects, there is no need to wax or protect your furniture once the topcoat has been applied.

Water-based paints have become so popular for many reasons:

- Many of them are low odour, such as our Biora range of luxury interior paints for walls and celings. This creates a more pleasant painting experience and is far more child friendly.
- They are environmentally friendly due to their low levels of VOCs (volatile organic compounds - the toxins that are released in to the atmosphere).
- They typically dry faster than other paint types – our Biora range is touch dry after one hour and re-coatable after two hours.
- Many paints have self levelling properties so it's easier to achieve a smooth, professional finish, free from brush marks.
- Clean-up is much easier. There is no need for white spirit or other cleaning products - simply rinse brushes and trays in warm clean water.

Stains

A wood stain penetrates the wood, meaning it colours the wood without obscuring the grain. Woodstains are slightly different to wood paint, in that it brings out the beauty of the wood grain instead of covering it. Some stains offer protection.



Colour Wash

A subtle translucent colour wash for wood

Pearlescent finish

For use on bare wood

For interior use

Wax Finishes

Sold in liquid, paste, and solid stick forms, waxes are formulated in a host of colors. You'll find them in clear, amber, a range of wood tones and even white. Some waxes are softer, some are harder, but even the hardest waxes are softer than lacquers and varnishes. The fact that they are soft means they offer very little protection against scratches and wear. Waxes are derived from a variety of mineral, vegetable and animal sources. As a finish, waxes don't penetrate wood, but rather sit atop it. They will prevent it from oxidizing (turning gray) but don't particularly enhance the wood. In other words, once a coat of clear wax dries on the wood, it will look like freshly cut, but unfinished, wood.

Liquid or paste wax typically contains some solvent, and the wax "cures" as the solvent evaporates. Virtually all waxes will dissolve in mineral spirits or naphtha, which is handy to know should you ever need to remove wax, either from wood or on top of a finish. Most waxes melt at very low temperatures, so they don't offer much in the way of heat resistance. However, they do shed water, which helps them resist food and drink spills. You can apply wax over any other finish and it will give the surface a soft sheen and smooth feel, but don't put other finishes over wax. To apply liquid or paste wax, simply rub it on and wipe it off. A Scotchbrite™ pad or fine steel wool makes a good applicator; then wipe with paper shop towels. If you wipe the wax off immediately, it will leave a dull sheen as it dries. For more shine, let it dry, then buff it with a soft cloth.

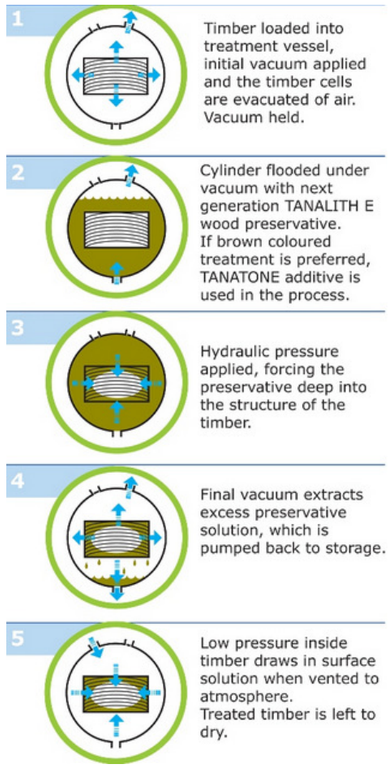
Danish Oil

Danish oil, often referred to as an oil finish, is actually a thin oil and varnish mixture. The oil helps bring out wood's beauty, while the varnish resin offers somewhat more protection against chemicals, heat, scratches and stains than either oil or wax. It comes in a variety of colours as well as natural (clear). Apply it liberally to the wood, let it soak in for 15 minutes, reapply, then wipe off the surface. Applied no more than one coat per day, you can build up a finish as thick, beautiful, and durable as varnish, with no brushes to clean or brush marks to rub out. Multiple coats of Danish Oil is durable enough for most products, even kitchen cabinets or a dining room table.

Teak Oil

Teak Oil contains a traditional blend of solvents and Linseed oil. It's suitable for replacing the natural sheen that wood can lose after long periods drying in the sun. This is a popular wood treatment to replace natural oils removed by weathering. Teak Oil can be used internally or externally on unpolished wood surfaces and is especially suited for use on hardwood garden furniture.

Pressure treating with chemical preservatives



Pressure treatment is a process that forces chemical preservatives into the wood. Wood is placed inside a closed cylinder, then vacuum and pressure are applied to force the preservatives into the wood. The preservatives help protect the wood from attack by termites, other insects, and fungal decay.

Water-based Creosote, and Oil-based are the three broad classes of preservatives typically used when pressure-treating wood.

Wood treated with water-based preservatives is typically used in residential, commercial and industrial building structures. Creosote is primarily used for treating railway sleepers, guardrail posts, and timbers used in marine structures. Oil-based preservatives are most often used for treating telegraph and electrical poles.

A Level Design and Technology: Product Design

Performance Characteristics of Metals

You should be aware of the different stock forms of metals, including:

- sheet
- plate
- bar:
  - flat
  - round
  - square
  - hexagonal
- tube:
  - round
  - square
  - rectangular
  - hexagonal
- structural:
  - H beam
  - I beam
  - tee
  - channel
  - angle

You should be able to describe the performance characteristics of metals, including:

- hardness
- toughness
- malleability
- elasticity
- tensile strength
- density
- resistance to corrosion
- thermal conductivity
- electrical conductivity
- melting points
- ability to be alloyed
- ability to be joined with heat processes
- ability to take applied coatings and finishes

You should be familiar with the following metals:

ferrous:
- low carbon steel
- stainless steel
- high speed steel (HSS)
- medium carbon steel
- cast iron

non-ferrous:
- aluminium
- copper
- zinc
- silver
- gold
- titanium
- tin

ferrous alloys:
- stainless steel
- die steel (tool steel)

non-ferrous alloys:
- bronze
- brass
- duralumin
- pewter

Enhancement of Metals
Case Hardening

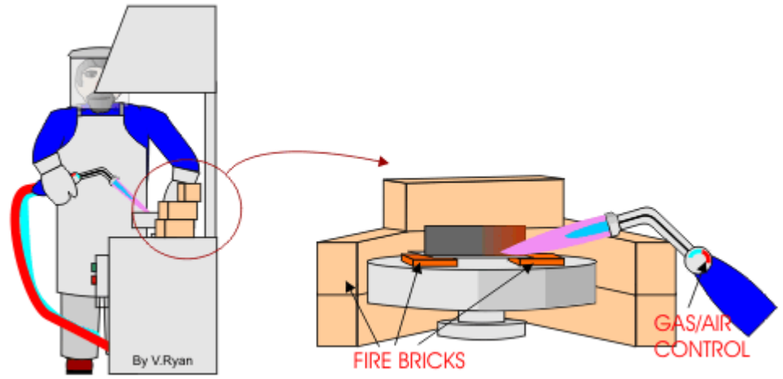
Case hardening is a technique in which the metal surface is reinforced by the adding of a fine layer at the top of another metal alloy that is generally more durable. Case hardening steel is normally used to increase the object life. This is particularly significant for the manufacture of machine parts, carbon steel forgings, and carbon steel pinions. Case hardening is also utilized for other applications. Case hardening is also called surface hardening. Case hardening has been in use for many centuries, and was frequently used for producing horseshoes and different kinds of cooking utensils that were subjected to substantial wear and tear. Case hardening is essentially a group of processes that are used to increase the surface hardness to an extent that is higher than that of the bulk material. Case hardening is performed normally locally on the top surface, and for a limited depth. Greater hardness is usually related with better wear and fatigue resistance.

The addition of carbon to the iron surfaces is common. Case hardening involves the use of metal that has low carbon contents, and combining it with a metal that has more carbon content. The grouping of metals is likely to produce the product that is much harder. The adding of the low carbon metal creates a material that can be molded easily into the desired shapes. The surface improvement not only increases the product strength, but also assists to avoid the iron weakening. Consequently, items like fireplace equipment, cast iron wash pan, and frying utensils would continue to be serviceable for long periods of time. Case hardening is frequently utilized in the constructing industry for reinforcing girders, metal doors, and metal panels. Case hardening is generally performed after the formation of the component into its ultimate form.

Carbon is penetrated into the metal skin to create mild steel that has an external covering with more carbon than the nucleus. The mild steel is subjected to heating at a particular temperature, till it is bright red. While the mild steel is soft, it is immersed into a carbon compound that covers the outer surface. One dipping may not be adequate, and several re-heating and dipping may be necessary. This procedure will produce a skin that is rich in carbon. Subsequently, the metal is reheated and dropped in water for hardening. Case hardening is useful for objects that need to be hardened externally to endure wear and tear, but soft internally to withstand shock.

Enhancement of Metals
Hardening and Tempering

Steel can be treated by intense heat to give it different properties of hardness and softness. This depends on the amount of carbon in the steel (only high carbon steel can be hardened and tempered).



CARBON CONTENT OF COMMON STEELS: Mild steel: 0.4% carbon, Medium carbon steel approximately 0.8% carbon, High Carbon Steel approximately 1.2% carbon (this steel is also known as Tool Steel and includes Silver Steel and Gauge Plate).

Mild steel and medium carbon steel do not have enough carbon to change their crystalline structure and consequently cannot be hardened and tempered. Medium carbon steel may become slightly tougher although it cannot be harden to the point where it cannot be filed or cut with a hacksaw (the classic test of whether steel has been hardened).

If steel is heated until it glows red and is quenched in clean water immediately, it becomes very hard but also brittle. This means it is likely to break or snap if put under great pressure. On the other hand, if the red hot steel is allowed to cool slowly, the resulting steel will be easier to cut, shape and file as it will be relatively soft. However, the industrial heat treatment of steel is a very complex and precise science.

In a school workshop most heat treatment of metals takes place on a brazing hearth. A rotating table and fire bricks are essential. The fire bricks reflect the intense heat back on to the metal being heated. This is achieved by arranging the bricks in a semi-circle behind the metal being heated. Without the bricks, heat would escape and this would limit the temperature that could be reached.

HARDENING AND TEMPERING

Heat treatment of steel in a school workshop is normally a two stage process. For example, if a high carbon steel or silver steel screw driver blade has been manufactured, at some point it will have to be ''hardened' to prevent it wearing down when used. On the other hand it will have to be 'tempered'. This second heating process reduces the hardness a little but toughens the steel. It also significantly reduces the brittleness of the steel so that it does not break easily. The whole process is called 'hardening and tempering'.

STAGE ONE:
The screw driver blade is heated, slowly at first, warming up the whole blade. Then the heat is concentrated on the area at the end of the blade. This gradually becomes 'red' hot.

STAGE TWO:
The screw driver blade is removed quickly from the brazing heart, with blacksmiths tongs and plunged into clean, cold water. Steam boils off from the water as the steel cools rapidly. At this stage the blade is very hard but brittle and will break easily.

STAGE THREE:
The screw driver blade is cleaned with emery cloth and heated again on the brazing hearth. Heat is concentrated at the end of the steel blade. The steel must be watched very carefully as it changes colour quite quickly. A blue line of heat will appear near the end of the blade and it travels towards the tip as the temperature rises along the blade. When the line of blue reaches the tip the brazing torch is turned off. The blue indicates the correct temperature of 'tempering'.

STAGE FOUR:
The screw driver blade is placed on a steel surface, such as an anvil face. This conducts the heat away and allows slow cooling of the screw driver blade. When cold, the blade should be tough and hard wearing and unlikely to break or snap. This is due to the tempering process.

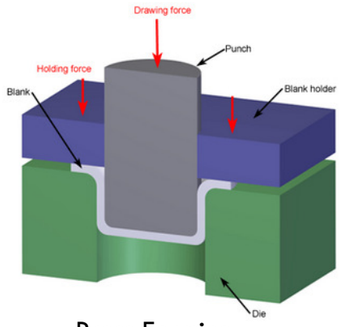
A Level Design and Technology: Product Design

Metal Processes

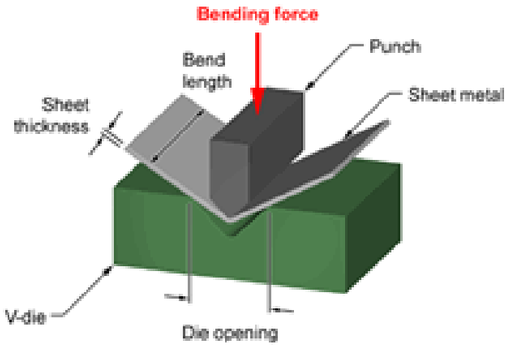
You should be aware of how metals can be shaped into 3D products. You should be able to describe the different forming methods.

You should be able to explain the suitability of the different forming methods for a range of specific products and scales of production.

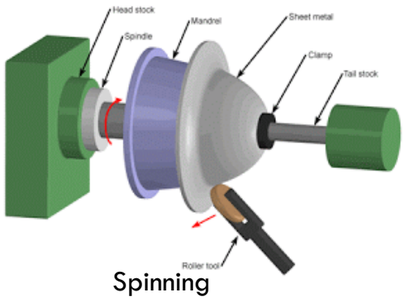
Specific processes to include:



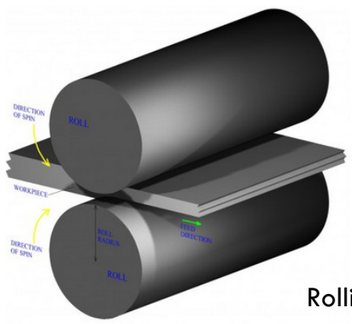
Press Forming



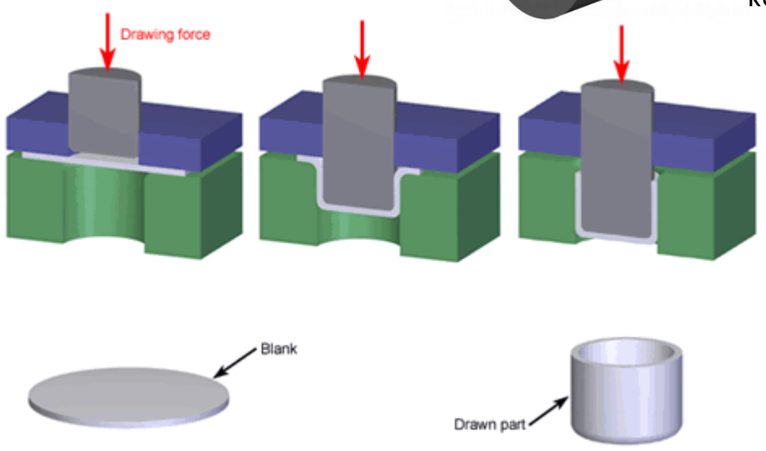
Bending



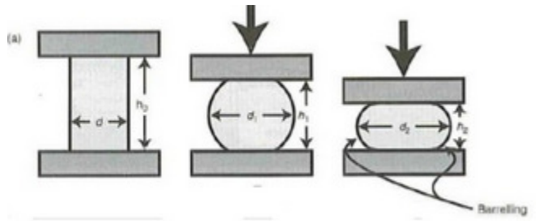
Spinning



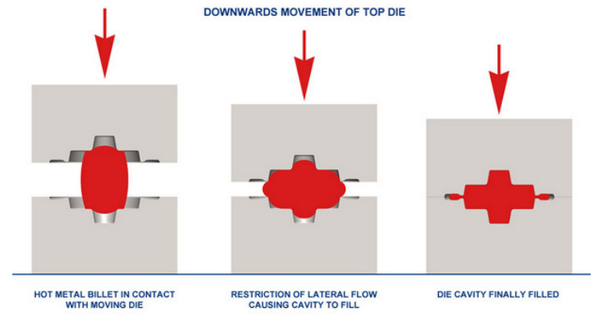
Rolling



Deep Drawing (cupping is part of this)

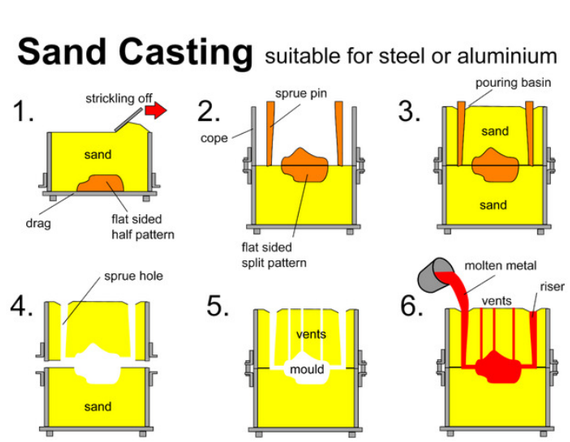


Forging



Drop Forging

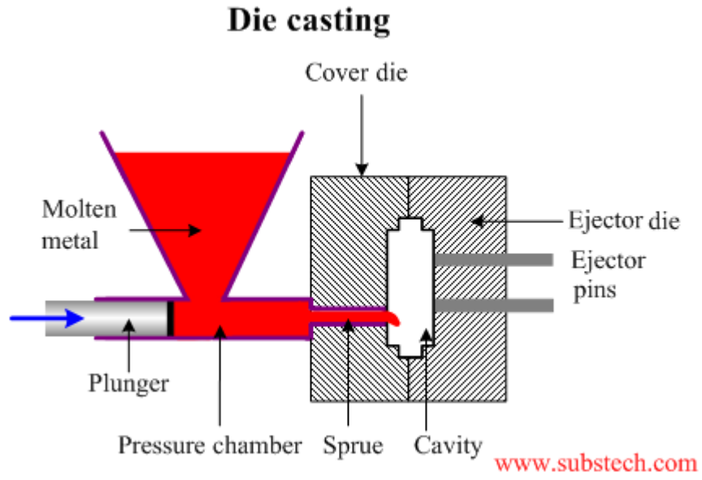
Casting Processes



This involves packing a moulding material (traditionally a mixture of sand and clay) around a pattern of the casting. This is usually made of a hardwood and will be larger than the requirements of the finished casting to allow for shrinkage. The mould is then split so that the pattern can be removed.

Advantages
This process can be used for a large range of sizes and for small or large production runs. It is the cheapest casting process available for small production runs and can sometimes be economical for large production runs.

Disadvantages
The surface finish and tolerances of the finished casting are poor. This form of casting can significantly alter the mechanical properties of the material being cast. The time required to cast a components can be excessive due to the need to allow the casting to cool before removing it from the mould.



- **Advantages**
  Excellent dimensional accuracy
- Smooth cast surfaces
  Thinner walls can be cast as compared to sand and permanent mold casting
- Inserts can be cast-in (such as threaded inserts, heating elements, and high strength bearing surfaces).
- Reduces or eliminates secondary machining operations.
- Rapid production rates
- Casting of low fluidity metals.

Disadvantages

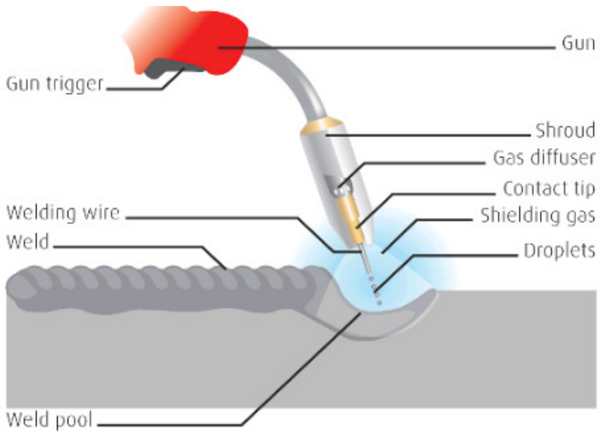
- very high capital cost. Both the casting equipment required and the dies and related components are very costly, as compared to most other casting processes. Therefore, to make die casting an economic process, a large production volume is needed.
- In the standard die casting process the final casting will have a small amount of porosity. This prevents any heat treating or welding, because the heat causes the gas in the pores to expand, which causes micro-cracks inside the part and exfoliation of the surface. Thus a related disadvantage of die casting is that it is only for parts in which softness is acceptable. Parts needing hardening (through hardening or case hardening) and tempering are not cast in dies.

A Level Design and Technology: Product Design

Electricity-based Joining

You should be aware of the different permanent and temporary joining methods for metals.
You should be able to describe the different methods.
You should be able to explain the suitability of the different joining methods for a range of specific products and scales of production.
Addition/fabrication processes:

MIG Welding

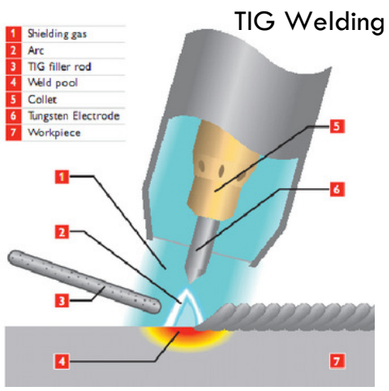


Advantages of MIG welding are:

- High quality welds can be produced much faster
- Since a flux is not used, there is no chance for the entrapment of slag in the weld metal resulting in high quality welds
- The gas shield protects the arc so that there is very little loss of alloying elements. Only minor weld spatter is produced
- MIG welding is versatile and can be used with a wide variety of metals and alloys
- The MIG process can be operated several ways, including semi and fully automatic

Two Disadvantages are:

- The MIG welding cannot be used in the vertical or overhead welding positions because of the high heat input and the fluidity of the weld puddle

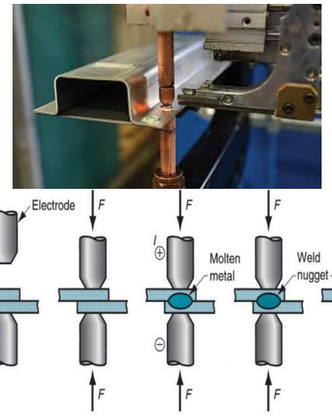


Advantages of TIG welding

1. Non-consumable **electrodes** - It helps to provide flawless joints because it is not needed to stop for replacing the electrode as in consumable electrode welding. That also contributes to reducing downtime in production.
2. No flux is required because inert gas shields molten metal. So no slag and slag inclusion problems.
3. High quality and strong welding achieved by TIG.
4. Cleaner and more appealing joints. Sometimes they don't need finishing process.
5. They are suitable for welding of very thin sections.
6. The versatility of method. They can work with and without filler metal.
7. A wide range of metal can be welded. Nonferrous metals like aluminium, copper and dissimilar metal can be welded without any challenge.
8. Non-corrosive and ductile joints.
9. The minimum amount of flames and spark. Less distortion due to small heat zone.
10. It can be done in both automatic and manual.

Disadvantage of TIG welding

1. TIG is a time-consuming process - They are slower than any other welding process. Lower filler deposition rate.
2. More complicated - Highly skilled and professional workers are needed to perform TIG welding.
3. Safety issue - Welders, are exposed to high intensity of light which can cause eye damage.
4. High initial cost.
5. It cannot use in thicker sheets of metal.



Spot Welding

Advantages

Spot welding is quick and easy. There is no need to use any fluxes or filler metal to create a join by spot welding, and there is no dangerous open flame.

Automated machines can spot weld in factories to speed up production

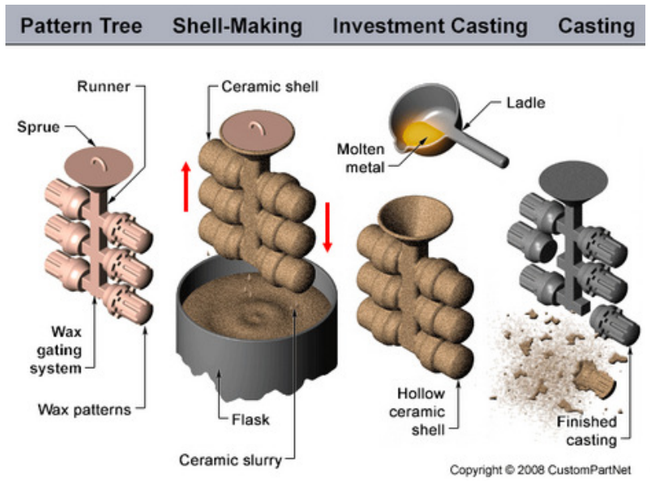
Disadvantages

The electrodes have to be able to reach both sides of the pieces of metal that are being joined together.

The size and shapes of the electrodes will determine the size and strength of the weld.

Casting Processes

Investment Casting



Advantages
possible to make more intricate forms—even forms with undercuts. Also, the casting that is produced has a very smooth surface, which is created without a parting line—something that would be unavoidable in some other processes.

Highly accurate.

Versatile. Also, many different metals and alloys can be used in investment casting, diminishing the need for designers to worry about the production of the casting they have visualised.

An example of a larger-sized product that can be made using investment casting is turbine blades with complex shapes for power generation industries. The blades can be single-crystal, directionally solidified, or conventional equiaxed blades. The firearm industry is another example of where investment casting is used, but for smaller precision parts. Some of these parts include firearm receivers, triggers, and hammers.

Disadvantages
Size limitation. Usually, only smaller castings can be made using this process.

Initial cost.

Low Temperature Casting

- **Advantages**
  Low temperature required
- Fluidity—allows the molten metal to achieve intricate designs

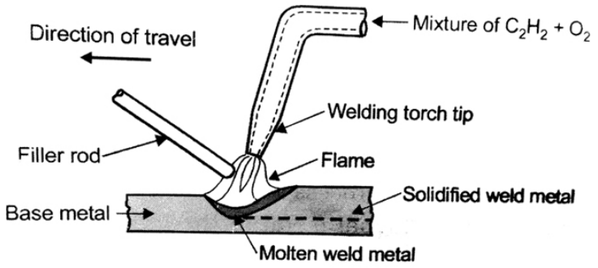
Disadvantages

- Labour intensive
- Only suitable for small runs

A Level Design and Technology: Product Design

Heat-based joining

Oxyacetylene Welding



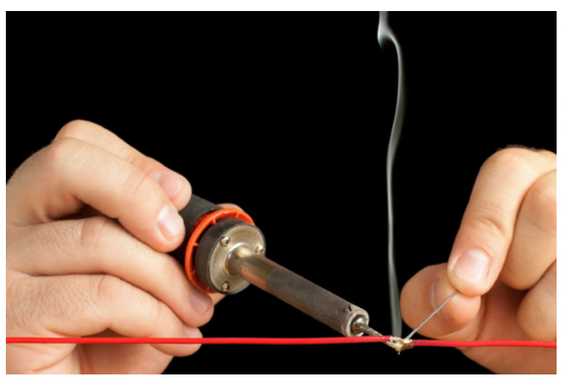
Advantages of Oxy-Acetylene Welding :

- Simple process
- The equipment is cheaper than most other types of welding rigs (MIG/TIG welding)
- The equipment is more portable than most other types of welding rigs (MIG/TIG welding)
- Oxy/Acetylene equipment can also be used to "flame-cut" large pieces of material.

Disadvantages of Oxy-Acetylene Welding :

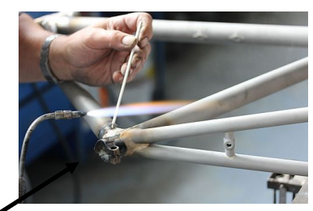
- Oxy/Acetylene weld lines are much rougher in appearance than other kinds of welds, and require more finishing if neatness is required.
- Oxy/Acetylene welds have large heat affected zones (areas around the weld line that have had their mechanical properties adversely affected by the welding process).

Soft/Hard Soldering



Advantages:
Low power is required;
Low process temperature;
No thermal distortions and residual stresses in the joint parts;
Microstructure is not affected by heat;
Easily automated process;
Dissimilar materials may be joined;
High variety of materials may be joined;
Thin wall parts may be joined;
Moderate skill of the operator is required.

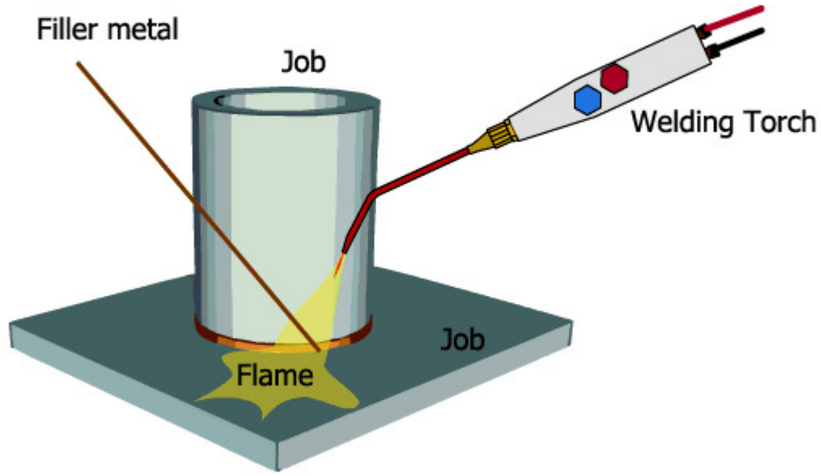
Disadvantages
Careful removal of the flux residuals is required in order to prevent corrosion;
Large sections cannot be joined;
Fluxes may contain toxic components;
Soldering joints can not be used in high temperature applications;
Low strength of joints.



Hard soldering requires higher temperatures (usually flame), it leads to a stronger join.

Brazing

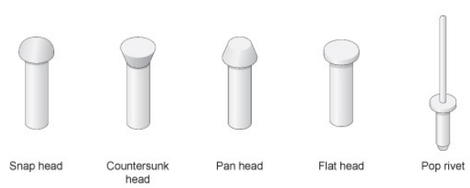
Brazing is a way of bonding materials by melting a filler metal or alloy between the components. The filler metals used in brazing must have a lower melting point than that of the material being joined. Brazing forms very strong, permanent joints.



Advantages
Brazing does not melt the base metal of the joint, it allows much tighter control over tolerances and produces a clean joint without the need for secondary finishing.
Non-similar metals and non-metals (i.e. metalized ceramics) can be brazed together.
Brazing produces less thermal distortion than welding due to the uniform heating of a brazed piece.
Complex and multi-part assemblies can be brazed cost-effectively. Welded joints must sometimes be ground flush, a costly secondary operation that brazing does not require because it produces a clean joint.
Another advantage is that the brazing can be coated or clad for protective purposes.
Brazing is easily adapted to mass production and it is easy to automate because the individual process parameters are less sensitive to variation.

Disadvantages
The lack of joint strength as compared to a welded joint due to the softer filler metals used. The strength of the brazed joint is likely to be less than that of the base metal(s) but greater than the filler metal.
Brazed joints can be damaged under high service temperatures. Brazed joints require a high degree of base-metal cleanliness when done in an industrial setting. Some brazing applications require the use of adequate fluxing agents to control cleanliness. The joint colour is often different from that of the base metal, creating an aesthetic disadvantage.

Non-Heat Joining Methods
Riveting
Rivets are used to join metal, plastics and plywood. The rivet is placed in a hole drilled through both pieces of material, and its end beaten into a dome. A tool called a rivet set or a rivet snap is used to to finish the joint. Some rivets are countersunk.
Pop rivets are used where there is only access to one side of the work. They are used to join thin sheets of material together.

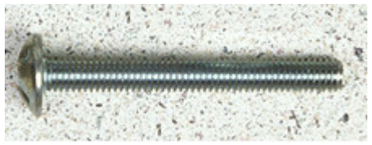


Temporary joining methods and fasteners:
Self tapping screws
A self-tapping screw is a screw which can tap its own hole as it is driven into the material.

Self-tapping screws have a wide range of tip and thread patterns, and are available with almost any possible screw head design. Common features are the screw thread covering the whole length of the screw from tip to head and a pronounced thread hard enough for the intended substrate, often case-hardened.

For hard substrates such as metal or hard plastics, the self-tapping ability is often created by cutting a gap in the continuity of the thread on the screw, generating a flute and cutting edge similar to those on a tap. Thus, whereas a regular machine screw cannot tap its own hole in a metal substrate, a self-tapping one can (within reasonable limits of substrate hardness and depth).

Machine screws
Machine screws are special screws for joining metal components. Holes have to be pre-drilled into the component. They must have the correct internal thread.

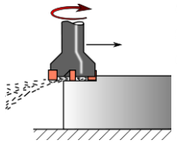


Nuts and bolts
Have a screw thread which fits into a threaded hole or a hexagonal nut, and are normally used to join two or more pieces of metal or plastic. A bolt is only threaded for part of its length. Bolts normally have hexagonal heads.

A Level Design and Technology: Product Design

Metal Processes: Wasting
You should be aware of the different wasting processes. You should be able to describe the different processes. You should be able to explain the suitability of the different wasting processes for a range of specific components and products.

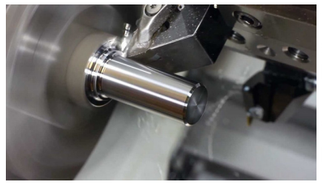
Milling



Milling machines are tools designed to machine metal, wood, and other solid materials. Often automated, milling machines can be positioned in either vertical or horizontal orientation to carve out materials based on a pre-existing design. These designs are often CAD directed, and many milling machines are CNC-operated, although manually and traditionally -automated milling devices are also common. Milling machines are capable of dynamic movement, both of the tool and the work piece, and many milling machines can perform multi-axis machining.

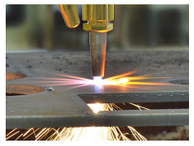
Because of variations in orientation, operation and application, milling machines have varying functions and different operating principles.

Turning
Turning involves rotation of the workpiece while the cutting tool moves in a linear motion. This results in a cylindrical shape. A lathe is the machine of choice for all turning operations.
Like most machining operations, turning is either done manually or automatically.



The downside to manual turning is it requires continuous supervision. Automatic turning does not. With Computer Numerical Control, or CNC, you program all the movements, speeds, and tooling changes into a computer. These instructions then get sent to the lathe for completion. CNC allows for consistency and efficiency of high production runs.

Single point cutting tools used in turning come in various shapes. They're placed at different angles for a variety of outcomes.

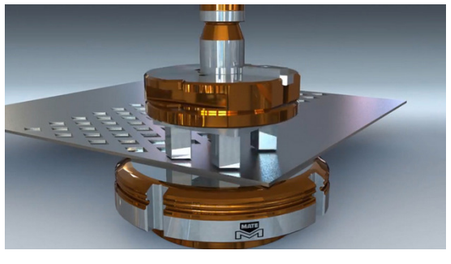


Flame Cutting
Flame cutting is the process of cutting a shape from a steel plate using oxygen and fuel gas.

Plasma Cutting
Plasma cutting is a process that cuts through electrically conductive materials by means of an accelerated jet of hot plasma. Typical materials cut with a plasma torch include steel, Stainless steel, aluminium, brass and copper, although other conductive metals may be cut as well.

Laser Cutting
Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications, but is also starting to be used by schools, small businesses, and hobbyists. Laser cutting works by directing the output of a high-power laser most commonly through optics.

Punching/Stamping
A stamping die is a special, one-of-a-kind precision tool that cuts and forms sheet metal into a desired shape or profile. The die's cutting and forming sections typically are made from special types of hardenable steel called tool steel. Dies also can contain cutting and forming sections made from carbide or various other hard, wear-resistant materials.



Stamping is a cold-forming operation, which means that no heat is introduced into the die or the sheet material intentionally. However, because heat is generated from friction during the cutting and forming process, stamped parts often exit the dies very hot.

Dies range in size from those used to make microelectronics, which can fit in the palm of your hand, to those that are 20 ft. square and 10 ft. thick that are used to make entire automobile body sides.

You should be aware of the ways that metals can be finished to enhance their appearance or prevent corrosion.
Cellulose Paint
Historically, this paint type was used utilised widely in the automotive industry, since cars require incredibly hard paintwork in order to survive the general wear and tear of their usage and cellulose paint coatings, once cured, provide an incredibly durable coating.

Acrylic Paint
Acrylic paint is often used because it is fast-drying, hard-wearing and it keeps its color well, even when exposed to the elements. When you are painting metal with acrylic paints, you will need to use a primer in order for it to adhere correctly. Painting metal with acrylic paint helps it stand up to the elements.

Electro-plating
Electroplating is a process that uses an electric current to reduce dissolved metal cations so that they form a thin coherent metal coating on an electrode.

Dip Coating
Hot dip coating is a great process for adding corrosion protection, increasing friction or grip, or simply adding aesthetics and protection to most any metal. Many types of polymers are available with many colour choices, sheen, and texture. To further enhance the dip coating process, a primer can be applied to the metal prior to coating to gain a virtually non removable bond. Other additives to the polymer can add flame retardancy and ultraviolet stabilisation.

Powder Coating
The powder coating process is very similar to a painting process except that the "paint" is a dry powder rather than a liquid. The powder sticks to the parts due to electrostatic charging of the powder and grounding of the parts. Any substrate can be used that can tolerate the heat of curing the powder and that can be electrically grounded to enhance charged particle attachment. The powder flows and cures during the application of heat.

Galvanising
Galvanisation or galvanising is the process of applying a protective zinc coating to steel or iron, to prevent rusting. The most common method is hot-dip galvanising, in which the parts are submerged in a bath of molten zinc.

Sealants
The most widely used, and most versatile sealant to use for metals is silicone. Silicone has many uses for sealing many types of metal structures and substrates. It is used on metal roofs, window installation, marine structures and plumbing applications. The various metals it can be applied to are iron, copper, aluminium, steel, stainless steel and galvanized steel. Polyurethane is a very common type of metal sealant. It comes in both a semi-solid form for sealing joints and in a liquid form for sealing large surfaces of metal.

Preservatives
Examples of preservatives include friction reducing protective silicone coatings for maintenance applications. Types of coatings include anti-stick, corrosion resistant and rust preventive coatings. Features include non-flammable, non-cfc, solvent-less and corrosion resistance. Protective coatings are applicable for use in neutralising fingerprints, condensation and atmospheric corrosion on moulds, dies and tooling metals.

Anodising
Anodising is an electrolytic passivation process used to increase the thickness of the natural oxide layer on the surface of metal parts. The process is called anodising because the part to be treated forms the anode electrode of an electrolytic cell.

Plating
Metal plating provides many benefits to products made from metal and other materials. Plating is a manufacturing process in which a thin layer of metal coats a substrate. This can be achieved through electroplating, which requires an electric current, or through electroless plating, which is in autocatalytic chemical process. In either case, the technique results in one or several of the following benefits: Improved corrosion resistance, Decorative appeal, Increased solderability, Enhanced strength, Reduced friction, Altered conductivity, Enhanced paint adhesion, Increased magnetism.

Coating
Metal coatings are coatings that are applied to metal in order to protect the metal and reduce wear and tear. An unprotected metal will rust and corrode due to environmental exposure. By coating the metal, an extra layer of protection is provided. Metal coatings are often made from polymers, such as epoxy, polyurethane, and moisture cure urethane.

Cathodic Protection
Cathodic protection (CP) is a technique used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell. A simple method of protection connects the metal to be protected to a more easily corroded "sacrificial metal" to act as the anode.

A Level Design and Technology: Product Design

Performance Characteristics of Polymer-based Sheet and Film

You should be able to name different types of polymer based sheet and film.

You should be able to describe the performance characteristics of polymer based sheet and film, including:

- the ability to be scored
- cutting
- folding
- moulding
- transparency
- translucency
- flexibility
- recyclability and/or biodegradability

You should be able to explain why different polymer based sheet and film are suitable for different applications, including:

- foam board: model making
- fluted polypropylene: signs and box construction
- translucent polypropylene sheets: packaging
- styrofoam: modelling and formers
- low density polyethylene sheet: wrapping, packaging and bags
- plastazote foam: protective packaging
- cellulose acetate: packaging
- polylactide sheet and film: biodegradable packaging.

Performance Characteristics of Biodegradable Polymers

You should be able to explain the suitability of biodegradable polymers for given application making reference to relevant physical and/or mechanical properties, including:

- ability to be moulded into 3D products or film
- ability to degrade with the action of UV rays (sunlight), water or enzymes present in soil.

You should understand how biodegradable polymers degrade.

You should be familiar with the following biodegradable polymers:

- corn starch polymers
- potatopak
- biopol (bio-batch additive)
- polyactide (PLA)
- polyhydroxyalkanoate (PHA)
- water soluble: lactide, glycolide (Lactel and ecofilm).

Bioplastics

The theory behind bioplastics is simple: if we could make plastics from kinder chemicals to start with, they'd break down more quickly and easily when we got rid of them. The most familiar bioplastics are made from natural materials such as corn starch and sold under such names as EverCorn™ and NatureWorks—with a distinct emphasis on environmental credentials. Some bioplastics look virtually indistinguishable from traditional petrochemical plastics. Polylactide acid (PLA) looks and behaves like polyethylene and polypropylene and is now widely used for food containers. According to NatureWorks, making PLA saves two thirds the energy you need to make traditional plastics. Unlike traditional plastics and biodegradable plastics, bioplastics generally do not produce a net increase in carbon dioxide gas when they break down (because the plants that were used to make them absorbed the same amount of carbon dioxide to begin with). PLA, for example, produces almost 70 percent less greenhouse gases when it degrades in landfills.

Another good thing about bioplastics is that they're generally compostable: they decay into natural materials that blend harmlessly with soil. Some bioplastics can break down in a matter of weeks. The cornstarch molecules they contain slowly absorb water and swell up, causing them to break apart into small fragments that bacteria can digest more readily. Unfortunately, not all bioplastics compost easily or completely and some leave toxic residues or plastic fragments behind. Some will break down only at high temperatures in industrial-scale, municipal composters or digesters, or in biologically active landfills (also called bioreactor landfills), not on ordinary home compost heaps or in conventional landfills. There are various eco-labeling standards around the world that spell out the difference between home and industrial composting and the amount of time in which a plastic must degrade in order to qualify.

Biodegradable Polymers

If you're in the habit of reading what supermarkets print on their plastic bags, you may have noticed a lot of environmentally friendly statements appearing over the last few years. Some stores now use what are described as photodegradable, oxydegradable (also called oxodegradable or PAC, Pro-oxidant Additive Containing, plastic), or just biodegradable bags (in practice, whatever they're called, it often means the same thing). As the name suggests, these biodegradable plastics contain additives that cause them to decay more rapidly in the presence of light and oxygen (moisture and heat help too). Unlike bioplastics, biodegradable plastics are made of normal (petrochemical) plastics and don't always break down into harmless substances: sometimes they leave behind a toxic residue and that makes them generally (but not always) unsuitable for composting.

Biodegradable bags sound great, but they're not without their problems. In 2014, for example, some members of the European Parliament tried hard to bring about a complete ban on oxydegradable plastics in the EU, with growing doubts over their environmental benefits. Although that proposal was blocked, it lead to more detailed studies of oxydegradable plastics, apparently confirming that they can't be effectively composted or anaerobically digested and don't usually break down in landfills. In the oceans, the water is usually too cold to break down biodegradable plastics, so they either float forever on the surface (just like conventional plastics) or, if they do break down, produce tiny plastic fragments that are harmful to marine life.

Recycled Plastics

One neat solution to the problem of plastic disposal is to recycle old plastic materials (like used milk bottles) into new ones (such as items of clothing). A product called ecoplastic is sold as a replacement for wood for use in outdoor garden furniture and fence posts. Made from high-molecular polyethylene, the manufacturers boast that it's long-lasting, attractive, relatively cheap, and nice to look at.

But there are two problems with recycled plastics. First, plastic that's recycled is generally not used to make the same items the next time around: old recycled plastic bottles don't go to make new plastic bottles, but lower-grade items such as plastic benches and fence posts. Second, you can't automatically assume recycled plastics are better for the environment unless you know they've been made with a net saving of energy and water, a net reduction in greenhouse gas emissions, or some other overall benefit to the environment. Keeping waste out of a landfill and turning it into new things is great, but what if it takes a huge amount of energy to collect and recycle the plastic—more even than making brand new plastic products?

Degradable Polymers

Made from renewable materials, they are designed to degrade (breakdown) in certain conditions. The problem with using degradable polymers and additives is that you then cannot recycle the plastic as it can contaminate other plastics.

Bio-Degradable Polymers

BIOPOL Breaks down over time through exposure to various micro-organisms, used for slow release medication, bone fixings, packaging.
POLYLACTIDE (PLA) - Thin and transparent – perfect for carrier bags, bottles and film, even sutures.
STARCH-BASED POLYMERS—Made from renewable materials e.g corn, potatoes. Used to make capsules for medicine.

Oxo-Degradable Polymers

BIO-BATCH
• These have short degradation times – usually around 5 years - much better than the 100 years predicted for oil based polymers.
• The additives break down the polymers into fine powders to be absorbed by micro-organisms.
• The additive is included in plastics such as PET, PP and PS.
• The biggest issue is that if added to a plastic then that plastic is no longer recyclable.

Water Soluble Polymers

• Products such as liquid detergent tablets will degrade when in contact with warm water.
• They also make large laundry bags to put in clothes that don't break down until in wash – useful for hospital staff who would never come into contact with contaminated clothes.

A Level Design and Technology: Product Design

Performance Characteristics of Polymers

You should be aware of the different stock forms of polymers, including:

- sheet
- film
- granules
- rod and other extruded forms
- foam
- powder

You should be able to describe the performance characteristics of polymers, including:

- toughness
- elasticity
- insulation (thermal and electrical)
- UV resistance
- ability to be moulded
- resistance to chemicals and liquids
- melting points
- suitability for food packaging applications
- biodegradability
- recyclability
- self finishing
- ability to be combined with other polymers and/or additives.

You should be familiar with the following polymers:

thermoplastic:

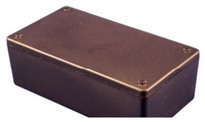
- low density polyethylene (LDPE)
- high density polyethylene (HDPE)
- Polypropylene (PP)
- high impact polystyrene (HIPS)
- acrylonitrile butadiene styrene (ABS)
- polymethylmethacrylate (PMMA aka acrylic)
- nylon
- rigid and flexible polyvinyl chloride (PVC)

thermosets;

- urea formaldehyde (UF)
- melamine formaldehyde (MF)
- polyester resin
- epoxy resin

- Amorphous
- Good resistance against medium temperatures (< 100^{0}C)
- Hard
- tough
- antistatic.
- good resistance against chemicals.
- Poor resistance to UV-light
- Can be painted

- Min temp: -25^{0}C
- Max Temp: 80^{0}C
- Glass Temp: 110^{0}C



- Amorphous (transparent)
  - Is typically coloured to make opaque
- Good UV resistance
- Excellent chemical resistance
- glue able and weld able
- easily machine able & heat bends nicely
- Stiff
- Tough
- hard
  - Tg can be reduced down to -40^{0}c by adding plasticizer
  - Makes PVC suitable for hose pipes etc

- Max Temp: 60^{0}C
- Min Temp: -25^{0}C
- Glass temp (Tg): 83^{0}C

- Excellent for any food related products
  - Not microwaveable
- Machines extremely well (cut, bond, drill etc.)
- Good chemical resistance
- Good impact resistance
- light weight
- Poor UV tolerance
- very low moisture absorption
- high tensile strength
- Not a good candidate for gluing.
- Primarily used for blow moulding
- Colours fade over time

- Min Temp: -100^{0}C
- Max temp: 110^{0}C
- Melting point: 130^{0}C
- Glass temp: -95
- Applications
  - Milk bottles
  - trays and tanks
  - pipe fittings, wear plates, hinges
  - cutting boards.

- Lower density & chemical resistance than HDPE
- More transparent than HDPE
- Less expensive than HDPE
- Colours fade over time
- Poor UV tolerance
- Very soft & pliable

- Max temp 70^{0}c
- Min temp -50^{0}c
- Melting point 120^{0}c
- Glass temp: -110^{0}C

- amporphous
- Trade names: perspex & plexiglass
- Weather resistant (Can withstand sunlight for long durations)
- Difficult to recycle
  - Can be done but is very expensive (not cost effective)
- Stiff (Flexible compared to glass)
- Less breakable than glass
- Scratches easily
- brittle
- Resistant to most chemicals and industrial fumes
- Can be cut by various methods
- Corrosion resistant
- Good electrical insulator

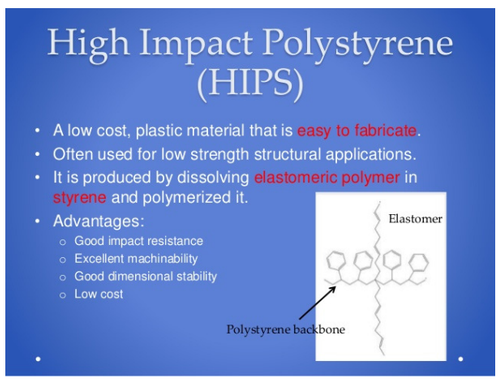
- Poor UV resistance
- Translucent (semi-crystaline)
- Rigid
- Very light
- Excellent chemical resistance
  - food storage applications
  - Medical applications (syringes)
  - Carpets
- Microwaveable

- Max temp 135^{0}C
- Min temp 0^{0}C
- Melting point: 170^{0}C
- Glass temp: -18^{0}C

- Min Temp: 5^{0}C
- Max temp: 41^{0}C
- Glass temperature : 110^{0}C

Physical properties

- **Melting point of about 255- 265 °C**
- **Stability: Stable.**
- **Nylon 6,6 is slightly soluble in boiling water.**
- **It is an amorphous solid.**
- **Glass transition temperature: 50oC.**
- **Amorphous density at 25oC: 1.07 g/cm3.**
- **Crystalline density at 25oC: 1.24 g/cm3.**
- **Molecular weight of repeat unit: 226.32 g/mol.**



Name	Properties	Principal uses
Epoxy resin	Good electrical insulator, hard, brittle unless reinforced, resists chemicals well	Casting and encapsulation, adhesives, bonding of other materials
Melamine formaldehyde	Stiff, hard, strong, resists some chemicals and stains	Laminates for work surfaces, electrical insulation, tableware
Polyester resin	Stiff, hard, brittle unless laminated, good electrical insulator, resists chemicals well	Casting and encapsulation, bonding of other materials
Urea formaldehyde	Stiff, hard, strong, brittle, good electrical insulator	Electrical fittings, handles and control knobs, adhesives

A Level Design and Technology: Product Design

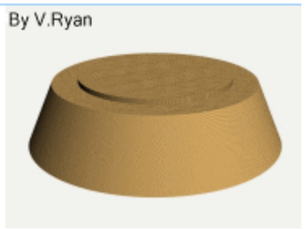
Polymer Processes

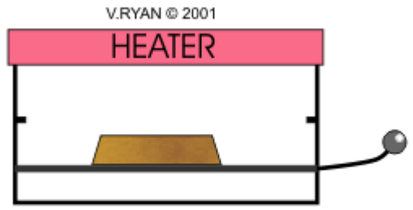
You should be aware of how polymers can be formed into 3D products. They should be able to describe the different forming methods.

Vacuum Forming (Forming)

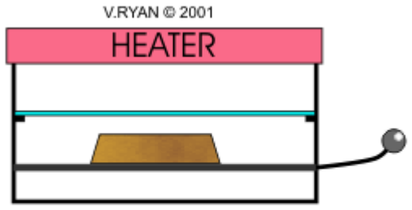
Vacuum forming is a technique that is used to shape a variety of plastics. In school it is used to form/shape thin plastic, usually plastics such as; polythene and perspex. Vacuum forming is used when an unusual shape like a 'dish' or a box-like shape is needed. Below you can see the stages involved in vacuum forming.

Below is an example of a vacuum formed toy. The simple 'lorry' mould has been placed in a vacuum former and a compressed polystyrene sheet has been placed above it. The polystyrene has been heated and then vacuum formed to the shape of the mould.

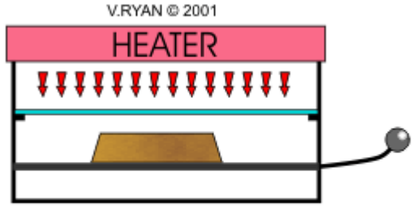




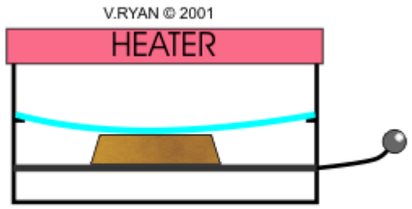
THE MOULD IS PLACED IN THE VACUUM FORMER



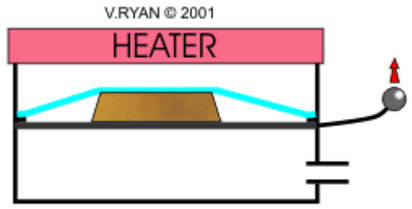
PLASTIC SHEET IS PLACED ABOVE THE MOULD AND CLAMPED SECURELY.



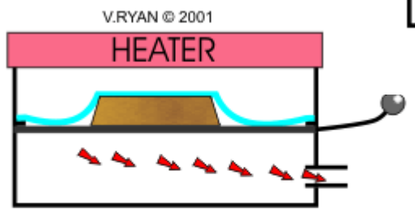
THE ELECTRIC HEATER IS TURNED ON TO WARM THE PLASTIC SHEET.



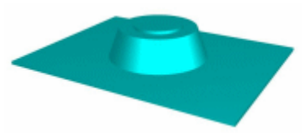
THE PLASTIC BECOMES FLEXIBLE WHEN HEATED



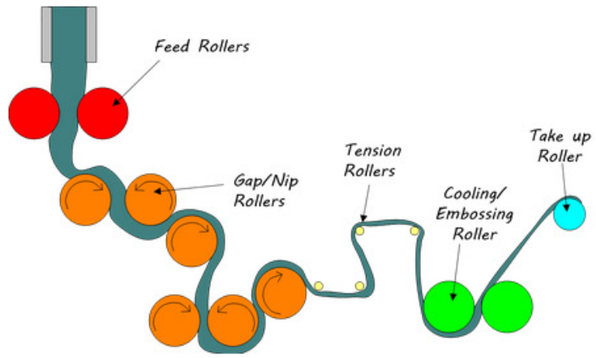
MOULD MOVED UPWARDS



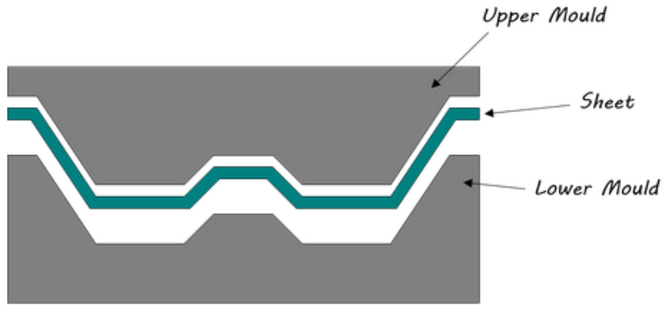
THE AIR IS PUMPED OUT OF THE AREA BELOW THE PLASTIC AND MOULD.



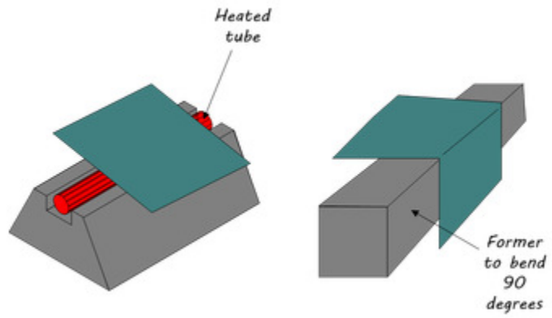
Calendering (Forming)



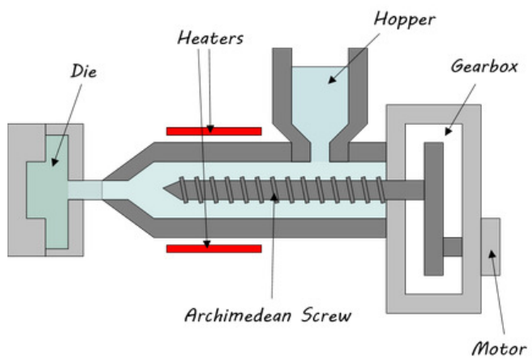
Thermoforming (Forming)



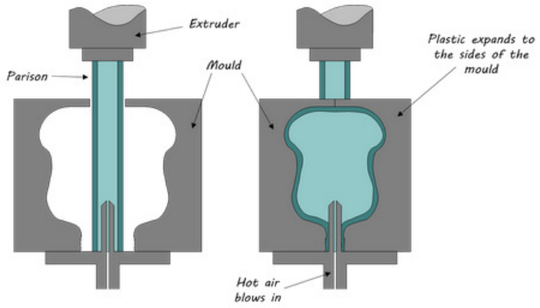
Line Bending (Forming)



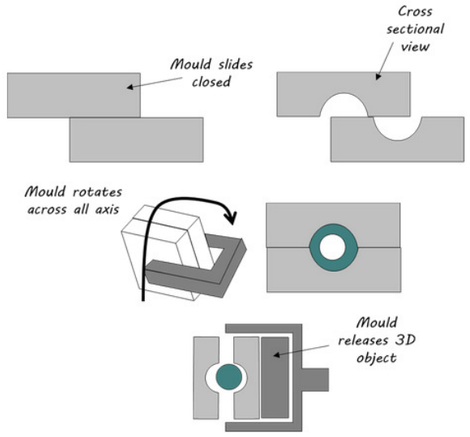
Injection Moulding (Redistribution)



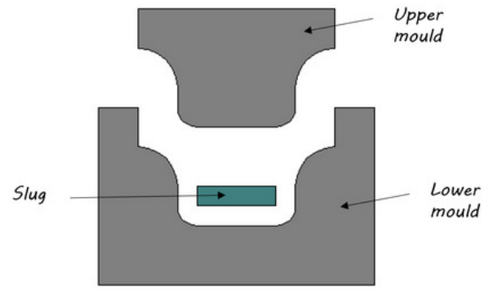
Blow Moulding (redistribution)



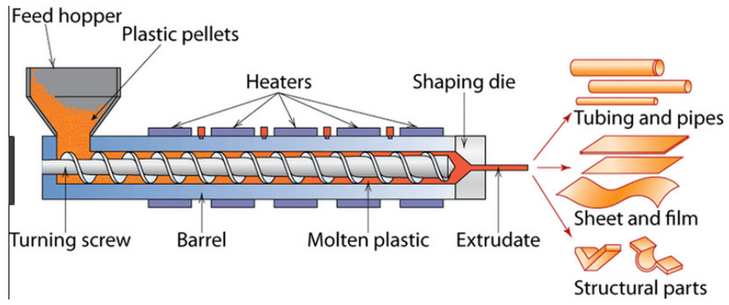
Rotational Moulding (redistribution)



Compression Moulding (redistribution)



Extrusion (redistribution)



A Level Design and Technology: Product Design

Finishes of Polymers

You should be aware of the ways that polymers can be finished to enhance their aesthetics or for improved function.

You should be aware that some polymers are self-finishing and that this should be considered as a polymer finish.

Acrylic Spray Paints

Acrylic Spray Paints are used not only on plastic kits but also on many other surfaces including polycarbonate, wood, glass, ceramics, metal, card, sealed plaster, hardboard, MDF and many other craft, DIY and automotive uses.

Thermoplastic Elastomer (TPE)

The formal definition of a thermoplastic rubber or elastomer (TPE) is "a polymer blend or compound which, above its melt temperature, exhibits a thermoplastic character that enables it to be shaped into a fabricated article and which, within it's design temperature range, possesses elastomeric behaviour without cross-linking during fabrication. This process is reversible and the products can be reprocessed and remoulded.

TPE is often used on cables, grips on power tools and toothbrushes, as well as pen grips.

You should understand how pigments can be added to polymers in the moulding process.

Gel coats when laminating GRP

Pigments can be added to the gelcoat when laminating GRP, this allows the product to become different colours.

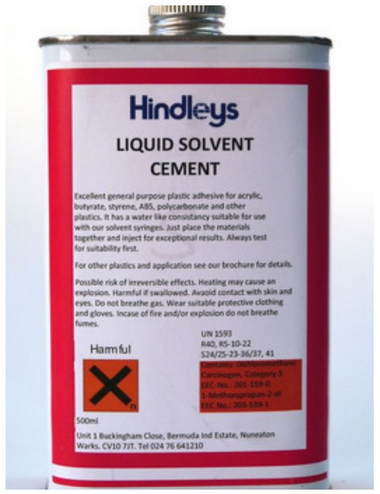
Smart pigments such as thermochromic or phosphorescent

Smart pigments can be added during the manufacturing process to allow the final product to become 'smart'.

Adhesives such as epoxy resins can be used to join plastics, these are two part epoxys that become very hard once cured.

Tensol 12 is a single component cement which hardens due to solvent evaporation to produce a clear bond in cast acrylic sheets.

Liquid Solvent Cement can be used to join plastics very easily.



Enhancement of Polymers

Additives are added to plastics to alter and improve their properties.

FILLERS
• Reduce the bulk of the plastic (makes them cheaper, or can increase strength or hardness) examples are; sawdust and limestone.

FLAME RETARDANT
• Reduce risk of combustion, they create a chemical reaction which can stop combustion.

ANTI-STATIC
• Reduces the effects of static charge that can build up through use.

PLASTICISER
• Reduces the softening temperature and makes them flow easier.

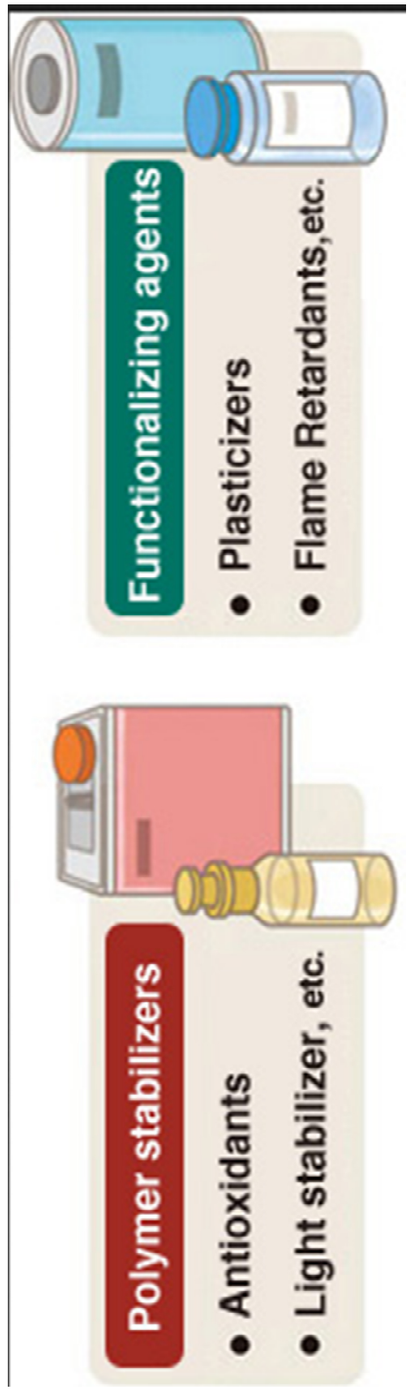
STABILISERS
• Reduces the effect of UV light, stops the plastic degrading in sunlight.

Biodegradability

BIO-BATCH
• These have short degradation times – usually around 5 years - much better than the 100 years predicted for oil based polymers.
• The additives break down the polymers into fine powders to be absorbed by micro organisms.
• The additive is included in plastics such as PET, PP and PS.
• The biggest issue is that if added to a plastic then that plastic is no longer recyclable.

BIOPOL
• Breaks down over time through exposure to various micro-organisms, used for slow release medication, bone fixings, packaging.

You should be familiar with how additives are used in specific polymer products, eg patio furniture, food packaging and carrier bags.



A Level Design and Technology: Product Design

Composites

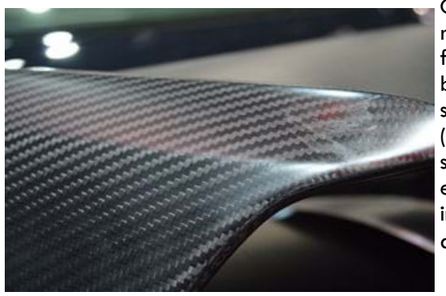
You need to know and understand how materials are combined to make composites with enhanced properties.

You should be able to explain the suitability of composites for given application making reference to relevant physical and/or mechanical properties, including:

- ability to be moulded into a variety of 3D forms
- enhancement of physical and/or mechanical properties
- ease of manufacture for some uses against traditional materials
- improved product performance.

Students should be familiar with the following composites:

Carbon fibre reinforced plastic (CFRP)



CFRP is an extremely strong and light fibre-reinforced plastic which contains carbon fibres. CFRPs can be expensive to produce but are commonly used wherever high strength-to-weight ratio and stiffness (rigidity) are required, such as aerospace, superstructure of ships, automotive, civil engineering, sports equipment, and an increasing number of consumer and technical applications.

Glass reinforced plastic (GRP)

GRP is a material consisting of numerous extremely fine fibres of glass.

Glass fibre has roughly comparable mechanical properties to other fibres such as polymers and carbon fibre. Although not as rigid as carbon fibre, it is much cheaper and significantly less brittle when used in composites. Glass fibres are therefore used as a reinforcing agent for many polymer products; to form a very strong and relatively lightweight fibre-reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), also popularly known as "fiberglass".

Tungsten carbide

Tungsten carbide (chemical formula: WC) is a chemical compound (specifically, a carbide) containing equal parts of tungsten and carbon atoms. In its most basic form, tungsten carbide is a fine grey powder, but it can be pressed and formed into shapes through a process called sintering for use in industrial machinery, cutting tools, abrasives, armour-piercing rounds, other tools and instruments, and jewellery.

Aluminium composite board

Standard white aluminium composite board for a lightweight and weatherproof solution to printing and display.

A sandwich panel is any structure made of three layers: a low-density core, and a thin skin-layer bonded to each side. Sandwich panels are used in applications where a combination of high structural rigidity and low weight is required.

Sandwich panels are an example of a sandwich structured composite: the strength and lightness of this technology makes it popular and widespread. Its versatility means that the panels have many applications and come in many forms: the core and skin materials can vary widely and the core may be a honeycomb or a solid filling.

One obvious application is in aircraft, where mechanical performance and weight-saving are essential. Transportation and automotive applications also exist.

In building and construction, these prefabricated products designed for use as building envelopes. They appear in industrial and office buildings, in clean and cold rooms and also in private houses, whether renovation or new-build. They combine a high-quality product with high flexibility regarding design. They generally have a good energy-efficiency and sustainability.

Concrete, including reinforced concrete

Concrete is a building material made from a mixture of broken stone or gravel, sand, cement, and water, which can be spread or poured into moulds and forms a stone-like mass on hardening.

Concrete can be reinforced using steel grids or rebar, this allows it to span large distances, whilst remaining strong.

Fibre cement

Fibre cement, or Fibre Reinforced Cement (FRC), is a versatile building material developed by James Hardie in the early 1980s. Fibre cement is a composite material made of cement reinforced with cellulose fibres.

James Hardie® fibre cement products are a mixture of:

Cellulose fibre: acts as a filler. From plantation grown Radiate Pine trees.

Portland Cement: binds the ingredients. Made with limestone, clay, and iron.

Sand: creates all weather performance and resilience.

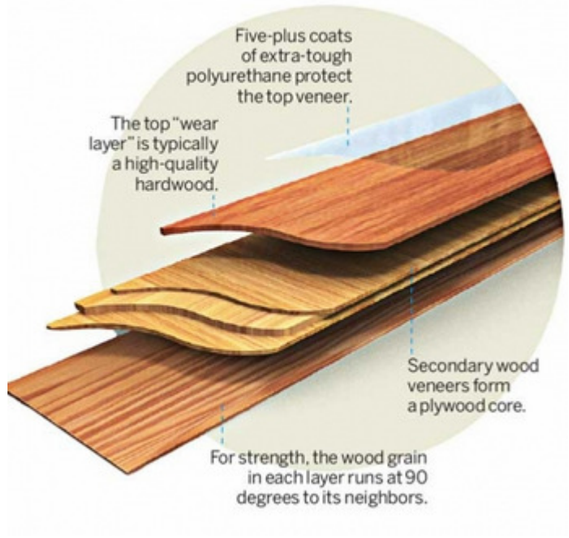
Water: dissolves the wood pulp; activates and hardens the cement.

Plus a small amount of other chemical additives to help the process, or provide structure with particular characteristics.

- Robust & stable
- Weather resistant – doesn't shrink, crack or warp
- Lightweight for easy installation
- Low maintenance
- Eco-friendly

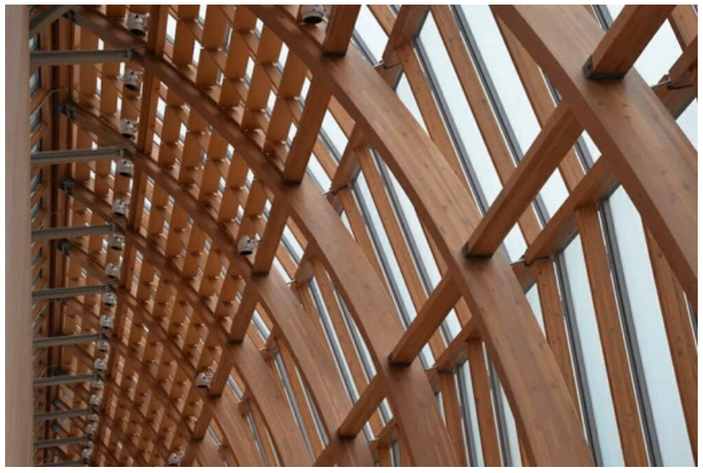
Engineered wood, e.g. glulam (glued laminated timber)

Engineered wood, also called composite wood, man-made wood, or manufactured board, includes a range of derivative wood products which are manufactured by binding or fixing the strands, particles, fibres, or veneers or boards of wood, together with adhesives, or other methods of fixation to form composite materials.



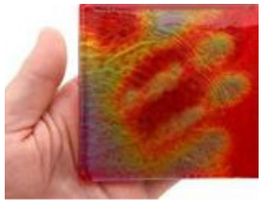
Glulam

Glued laminated timber, also called glulam, is a type of structural engineered wood product comprising a number of layers of dimensioned lumber bonded together with durable, moisture-resistant structural adhesives.



A Level Design and Technology: Product Design

Smart Materials



You should know and understand the term smart material.

You should be able to explain the suitability of smart materials for given applications making reference to how the material responds to external stimuli.

Changes in Temperature

Thermochromic Pigment
P: Can be mixed with acrylic paint. At room temperature it shows its usual colour, but when heated or cooled the colour changes or appears.
A: Thermometers or other heat indicating items.

Changes in Light

Photochromic Pigment
P: The ink reacts to UV light (such as sunshine) by darkening.
A: Sunglasses or other glass products

Phosphorescent Pigment

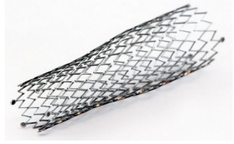
Phosphorescent pigments glow in the dark. They are able to absorb light energy and store it. This stored energy is released as light energy over a period of time.

Phosphorescent pigments are useful for watch faces that glow in the dark. They may also be used in fire safety signs placed near fire extinguishers. In the event of a fire, the position of the fire extinguishers can be seen, even if the lights fail.

Electroluminescent Wire

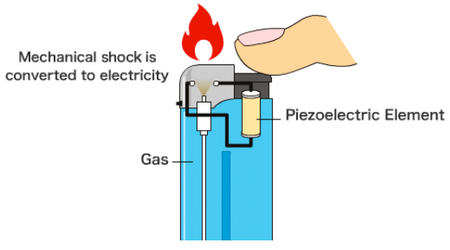
Electroluminescent wire (often abbreviated as EL wire) is a thin copper wire coated in a phosphor which glows when an alternating current is applied to it. It can be used in a wide variety of applications—vehicle and structure decoration, safety and emergency lighting, toys, clothing etc.—much as rope light or Christmas lights are often used. Unlike these types of strand lights, EL wire is not a series of points, but produces a 360 degree unbroken line of visible light. Its thin diameter makes it flexible and ideal for use in a variety of applications such as clothing or costumes.

Changes in Pressure (Force)



Shape Memory Alloy
P: When heat or an electrical current passes through the wire contracts (shortens).
A: Dental braces, mechanisms in sprinklers, used to hold broken bones together, spectacle frames.

Piezoelectric Material



Piezoelectric materials are materials that produce an electric current when they are placed under mechanical stress. The piezoelectric process is also reversible, so if you apply an electric current to these materials, they will actually change shape slightly (a maximum of 4%).

There are several materials that we have known for some time that posses piezoelectric properties, including bone, proteins, crystals (e.g. quartz) and ceramics (e.g. lead zirconate titanate).

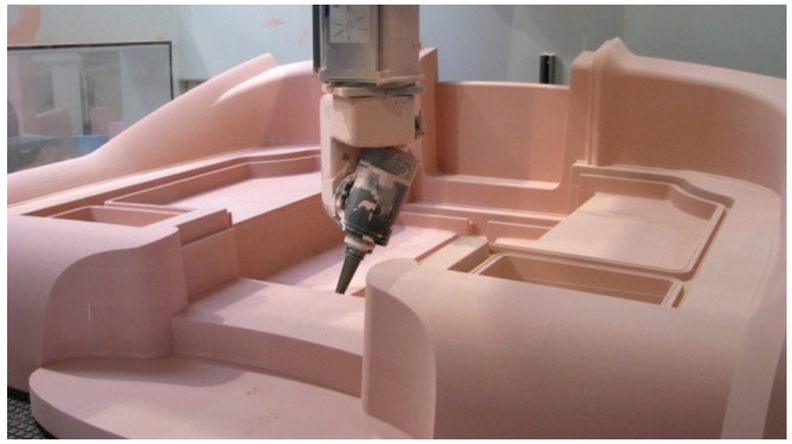
Modern Materials

You should know and understand the term modern material.

"Modern materials are developed through the invention of new or improved processes, for example, as a result of 'man' made materials/ingredients or human intervention, in other words not naturally occurring changes. They are altered to perform a particular function. "

Kevlar

Kevlar is a heat-resistant and strong synthetic fiber, related to other aramids such as Nomex and Technora. Developed by Stephanie Kwolek at DuPont in 1965, this high-strength material was first commercially used in the early 1970s as a replacement for steel in racing tires.

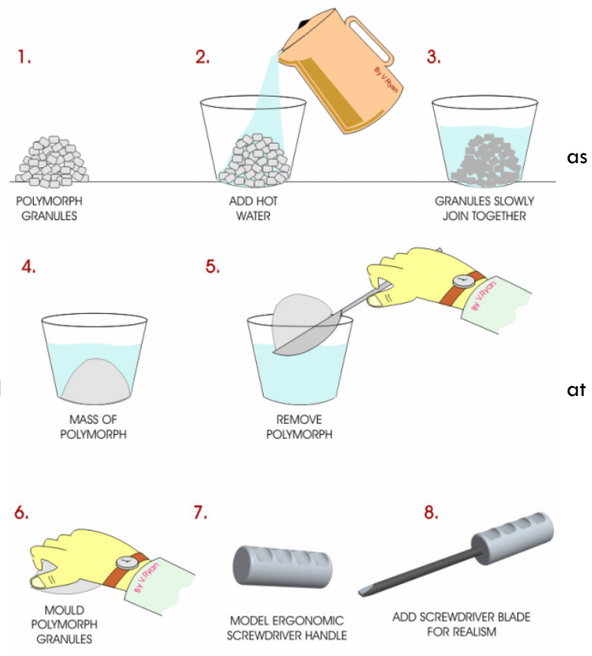


High Density Modelling Foam

This is an easy machining closed cell rigid foam, ideal for 3D prototyping and modelling. It can be machined at high speed with minimal tool wear. The foam is supplied in two densities. Low density foam allows rough models and prototyping at low cost. High density foam, with its greater structural strength and ability to hold surface detail, is ideal for finished models. The high density foam can also be used as a plug for vacuum forming, (painting is recommended to prevent the foam sticking to the styrene). The foam can also be used as a mould for low melting point alloys for applications such as jewellery manufacture.

Polymorph

Polymorph is a thermoplastic material that can be shaped and reshaped any number of times. it is normally supplied as granules that look like small plastic beads. In the classroom it can be heated in hot water and when it reaches 62 degrees centigrade the granules form a mass of 'clear' material. When removed from the hot water it can be shaped into almost any form and on cooling it becomes 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.



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Precious Metal Clay (PMC)

P: Made from 99% gold or silver and 1% clay. It can be shaped room temperature, then heated.
A: Very expensive and mainly used for jewellery, beads and small sculpture.

at

A Level Design and Technology: Product Design

Scales of Production

You should be aware of, and be able to describe, the different scales of production giving example products and specific manufacturing methods.

One-off, bespoke

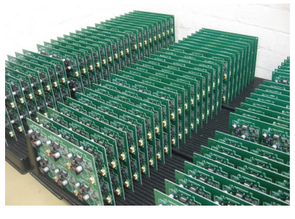
One off production is the manufacture of a single product/item.
This can include large scale projects, such as a bridge, ship, stadium, multi-storey building or tower, Other examples of one offs are - specialist jewellery, made to measure clothing, bespoke furniture and many more.
Specialist companies manufacturing 'one offs', usually employ skilled staff.

Characteristics of one-off production

- Small specialist companies.
- A skilled workforce - eg. engineering / cabinet making.
- Specialist materials often used. eg. specialist modelling materials.
- High quality products manufactured.
- Products expensive, due to the level of skill required to manufacture them and cost of specialist materials.
- A high standard of quality control.
- Products manufactured for a specialist market / clientele.

Batch production

When tens, hundreds or even thousands of the same product, are manufactured on a production line, this is called Batch Production.



Batch production takes place on a production line. A production line is one stage of manufactured followed by another stage. A production line can be made up of several or hundreds of different stages.

Companies tend to order batches of products. Customers usually order one.

Characteristics of batch production

- Production line is set up.
- One task for each stage of manufacture.
- Semi skilled or unskilled workers - Flexible workforce.
- Production line can manufacture different products.
- Production line runs for a limited time.

Mass/line 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 rarely need to be redesigned. Mass production is used for products that are needed in very large numbers, eg socks or jeans. Often, products are made overseas where labour costs are lower.

Mass production, if stringently monitored, typically results in the high-accuracy assembly as production line machines have fixed parameters. Labour costs are often lower for mass-produced products; assembly line production with automated processes requires fewer workers.

Products that are mass-produced are assembled at a quicker rate due to increased automation and efficiency. This helps with prompt distribution and marketing of an organization's products with the potential to create a competitive advantage and higher profits. For example, McDonald's has a competitive advantage due to the speed at which it can produce a meal for the time-conscious customer.

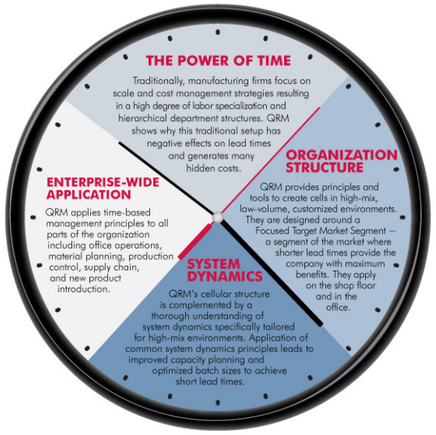
Mass production may result in wasted resources. Establishing an automated assembly line is typically capital-intensive; if there is a production design error, extensive costs may be required to redesign and rebuild mass production processes. Additionally, if one area of mass production is interrupted, the entire production process may be affected.

Employees that are part of a mass production assembly line may lack motivation because tasks are repetitive. This may lead to low employee morale and increased levels of turnover. Mass production may stifle flexibility; production processes can be cumbersome and expensive to change.

Unit production systems (UPS)

The unit production system (UPS) for clothing industries is a flexible material handling system that requires a computerised overhead transportation system to move the garment components automatically from one workstation to the next according to a pre-determined sequence. It replaces the traditional garment production system of handing, bundling, tying and untying, and manually moving garment parts. It provides uninterrupted workflow to the workers and helps to improve work efficiency and product quality. In the fast-moving fashion and apparel industry, this is highly essential.

Quick response manufacturing (QRM)



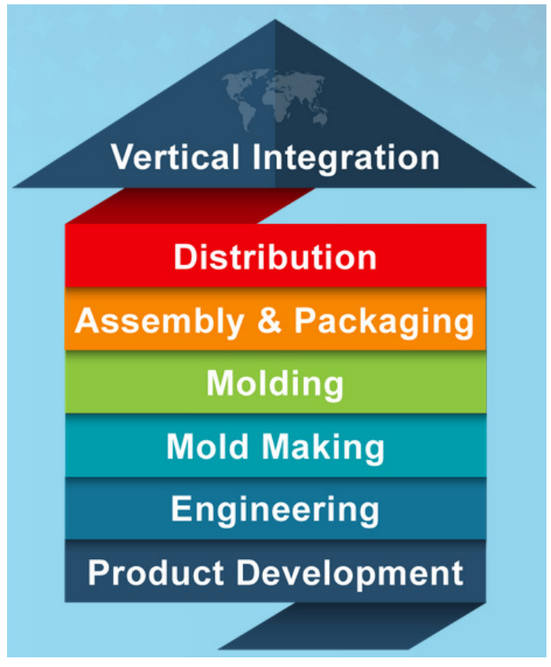
Quick Response Manufacturing (QRM) is a companywide strategy to cut lead times in all phases of manufacturing and office operations. It can bring your products to the market more quickly and help you compete in a rapidly changing manufacturing arena. It will increase profitability by reducing cost, enhance delivery performance and improve quality.

QRM's overarching focus on time as the guiding management strategy is ideally suited for companies offering high-mix, low-volume and custom-engineered products. In fact, many companies making highly customized products and/or a high variability in their product mix have used QRM as an addition to existing Lean, Six Sigma, and other improvement efforts.

Long lead times come with many hidden costs – much more than most managers realize. For almost 20 years, QRM has helped companies of all sizes and industries uncover the causes for long lead times and provided tools to eliminate them.

Vertical in-house production

One of the key challenges that every manufacturing business faces is structuring its value chain. The value chain consists of all businesses and individuals that play a part in the production process, from raw materials suppliers to end customers who buy finished products. Manufacturers typically occupy a space in the middle of this chain, but through vertical integration, they can extend their reach, and profits, within the value chain.



Vertical manufacturing refers to vertical integration of a value chain that a manufacturer undertakes to gain a strategic advantage. Manufacturers achieve vertical integration when they control or own elements within a value chain beyond the central manufacturing component. They can do this by buying other entities or entering into contractual agreements with them to provide goods and services that are part of the manufacturing and distribution process at fixed rates. For example, a manufacturer could buy one of its key suppliers to guarantee access to the raw materials it needs to produce goods. It might also sign a contract with a retailer to guarantee a certain level of sales in the future. Each of these acts is an example of vertical integration in manufacturing.

Advantages

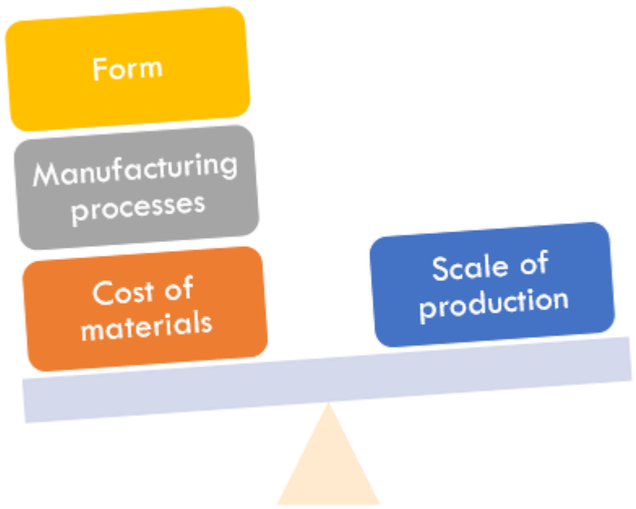
Vertical manufacturing has several distinct advantages over manufacturing without any form of vertical integration. It allows manufacturers to take control of their supply chains, ensuring steady access to components and raw materials. It can also ensure that distribution networks are ready to move products, especially during periods of high demand. Manufacturers that practice vertical integration also stand to earn profits from each step in the process. They save on costs by running their own supply chain instead of paying other independent businesses to fill its various roles.

Disadvantages

Vertical manufacturing can have some drawbacks for businesses that manage it poorly or lock themselves into inflexible arrangements. For example, a manufacturer that signs a contract with a supplier is committed to paying a set price for necessary materials, perhaps several years into the future. If a new supplier emerges with lower prices, competitors will be able to pay less for the same materials and reduce their costs. This leaves the vertically integrated manufacturer at a disadvantage until the contract expires or can be renegotiated.

A Level Design and Technology: Product Design

Efficient Use of Materials



Products are informed by a wide range of factors, particularly:

- **Form**
- **Manufacturing processes**
- **Cost of materials**
- **Scale of production**

These have a significant impact on products, their design and how they are manufactured.

The development of designs which use materials economically and with regard to their characteristics.

It is important to consider costs and economics at every stage of design, product development, prototyping and manufacturing. A client / customer will have a significant view on costs and potential profits, which is usually emphasised at the beginning of the design process. Reducing costs, without a reduction in the quality of a product, should be the aim of every designer.

Reducing costs can be beneficial to the environment. For instance, using cheaper recycled materials, which leads to a cheaper final product, is both an advantage to the manufacturer and customer. This approach also helps reduce the environmental impact of manufacturing.

Further to this, the economic necessity to reduce costs and customer pressure on manufacturers to protect the environment, often leads to innovation in design.

EXAMPLES OF REDUCING COSTS

RECYCLED MATERIALS:
When manufacturing my product I used quality recycled materials, where possible. The materials were cheaper than new materials. Using recycled materials was a contribution to protecting the environment.

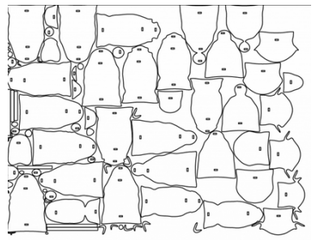
SUSTAINABLE MATERIALS:
We all have the responsibility to use sustainable materials when manufacturing, to protect the environment. I bought my materials from a retailer, who guarantees that they are from a sustainable source. This means that for every tree cut down at least one is planted. Also, I used 'plastics' that have been recycled OR can be recycled, when my product reaches the end of its useful working lifetime.

ENERGY CONSUMPTION - MANUFACTURE:
At all stages of manufacture, I have tried to reduce the consumption of energy. Machines in use have been turned off and hand tools and equipment have been used where possible. Therefore, the cost of manufacture has been reduced.

ENERGY CONSUMPTION - LIFETIME USE:
Many products require electricity to work. Ensure that electrical devices are energy efficient and that they turn themselves off, when not in use.

The use of manufacturing processes which increase accuracy and reduce waste.

When a product is manufactured, inevitably there is some waste. This is usually in the form of excess material. Good design and planning should lead to this waste being kept to the absolute minimum.



Since CNC machines are used extensively in manufacture in modern times, this often reduces waste. A good example is laser cutting. Parts can be nested to reduce the amount of material used.

The savings to be gained when comparing bulk production with one-off production.

Manufacturing Characteristics	One-off	Mass Production
Quantities	Small	Large
Manufacturing method	Small / one person shop	Assembly Lines
Manufacturing source	Human	Humans and/or machines
Labour costs	More	Less
Human error	More	Less
Design changes	Easy	Difficult
Business Model	Made to order	Large inventory / JIT
Production time	High	Low
Quality Assurance	High	Low

As you can see, the custom manufacturing parts would have more human fabrication as oppose to mass production which would rely solely on automation of machines. This greatly influences the cost and lead time for fabrication.

There are clear advantages and disadvantages when using bulk production compared with one-off production.

There are significant cost savings when producing products in bulk as the costs are spread over many more units.

Just In Time Production (JiT)

Goods are produced to order so stock levels are minimal. Keeping low stock levels decreases the costs of storing them helping to increase profits. This increases the flexibility of a firm. It helps reduce waste as you only use what you need

For JIT to be effective you need the following:

Excellent supplier relationships – need the supplies to arrive at exactly the right time

Reliable employees – or stoppages may occur

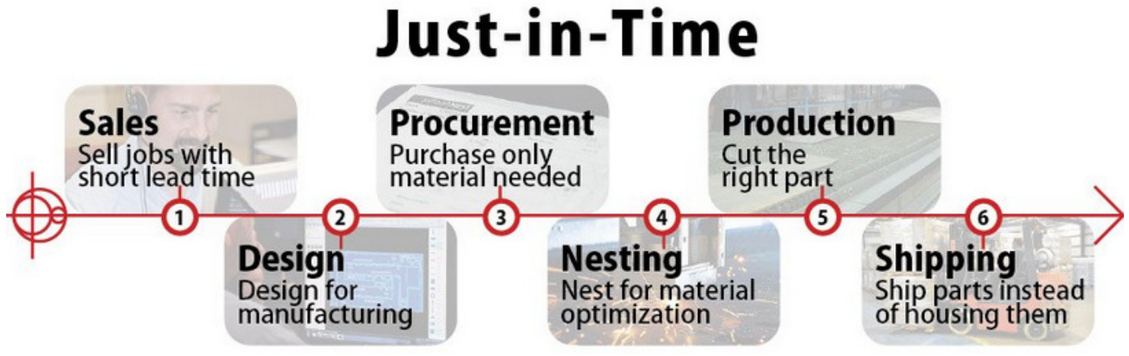
A flexible workforce – need them to be able to work any time and any where

Advantages of JIT

- Increased focus on quality
- Costs are reduced: e.g. Warehousing, Security and insurance
- Less space needed
- Less large outlays for materials

Disadvantages of JIT

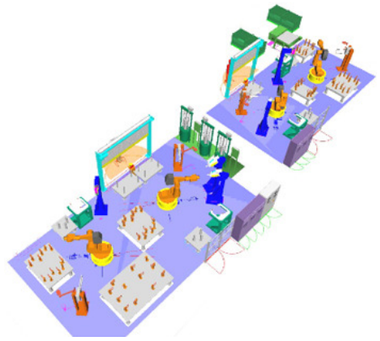
- May be difficult to meet unexpected major increases in demand
- Can be problems caused by suppliers
- Loss of discounts for buying in bulk



A Level Design and Technology: Product Design

The Use of Computer Systems

You should be aware of how computer systems are used to plan and control manufacturing, reduce waste and respond quickly to changes in consumer demand.
You should be able to explain specific industrial manufacturing systems and their use in the production of given products.



Modular/cell production

These systems use a number of production cells or modules that are grouped together to manufacture a component or sub-assembly of a larger product. The cells or modules usually consist of production machines and include inspection and assembly units. Very often the cells are operated by a small multi-skilled workforce but can be fully automated.
Some large manufacturing systems process large batches in sequence through several dedicated process or manufacturing sections. This is often referred to as batch and queue production. Sections usually have large, expensive machines designed to minimise unit costs by mass-producing single identical components with minimal tool changes.
This system largely requires advance orders and long production runs. It can be very wasteful as production can be help up if one section does not function correctly.
Storage space is required for batches between processes.
In modular or cell manufacturing the workstations are arranged in a logical manner to produce one complete item at a time, in a smooth and quick flow through the production process. The rate of production is decided by consumer demand. Production planning for the cells/ modules must be accurately scheduled to ensure tha the correct number of components/sub-assemblies is produced in time for the final assembly of the product. A hold up in one module is not as catastrophic as a hold up in an in-line production system.
Modular/cell production systems require careful positioning of workstations to enable minimal and quick movement of parts from one operation to another.
The workforce is often multi-skilled to offer maximum flexibility and enable rapid change of production.
The machines are often fitted with multiple tools and generally operate a rapid tool changing system. Powered clamping systems offering quick and easy location of the work-piece speed up production times. A standard size of manual locking method, usually in the form of a chuck key or spanner, is used to avoid operators wasting time searching for the correct tool
Key Points

- Functional layout of modules/cells
- Flexible system offering rapid change in production reacting to consumer demand
- High level of job satisfaction; operators work in flexible teams carrying out different tasks, opportunities for training
- All workforce responsible for quality control

Just in time (JIT)

Many modern manufacturing companies such as Toyota, Dell and Rollys Royce operate a JIT system. The philosophy of JIT manufacturing is to meet consumer orders with a quality product with minimal delay and effective use of resources. The JIT system is sometimes referred to a 'lean manufacturing' as it focuses on giving customers value for money by reducing wastage.
The storage of materials and components needed to manufacture products requires space and, where appropriate, special conditions such as heating and ventilation. This adds to the overall manufacturing cost.
Companies set up detailed arrangements with reliable suppliers and distributors to ensure that advance orders are taken and regular deliveries of material and components are made when required for manufacture. The products are distributed as soon as they are completed, removing the need for further storage.
Computerised stock control systems ensure that production is continuous.

Wastage reduced in terms of:

- Storage space for material, components and completed products
- Defective products – all of the workforce have a responsibility for quality
- Money invested in material and components that will not be used and completed products that will not be sold.
- Movement of the product through the factory is kept to a minimum
- Inefficient use of equipment– the system makes maximum use of production machinery and no waiting time between processing operations
- Labour misuse – appropriately skilled workers are used
- Product effectiveness – simplicity is a key feature of the system with the removal of product functions that are not necessary
- Downtime with new product rup up – detailed plans are made to ensure seamless flow from completed product to new product

Key Points

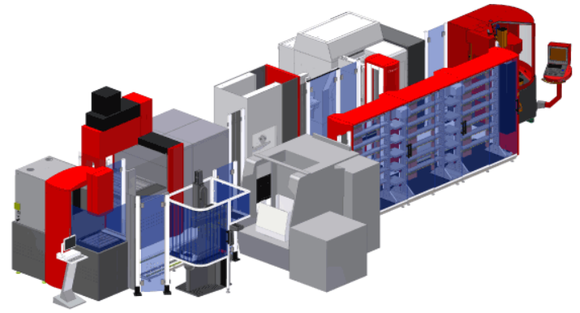
- The partnerships between the manufacturer, suppliers and distributors is critical – if deliveries are late production stops
- Workforce relationships are also very important – staff absence or strike action can halt delay or production
- Workforce must be multi-skilled, flexible, have job satisfaction and be consulted in decision making
- A spirit of cooperation is vital; proposals for improvement ate welcomed by management
- JIT is a very flexible manufacturing system and can react very quickly to changes in consumer demands
- The product is electronically tracked through the system to carefully monitor progress and ensure that the manufacturing schedule is efficient.

Drawbacks of the system include:
Delivery failure – Toyota production was halted as a result of a major fire that prevented supplies arriving
Unsatisfactory workforce relationships may result instrikes or absenteeism, which holds up production
Some environmental concerns over frequent road transport of supplies and despatched items
Requires major suppliers and customers to be relatively close to the manufacturing plant.

Quick Response Manufacturing (see scales of production).

Flexible Manufacturing Systems

A flexible manufacturing system (FMS) is a method for producing goods that is readily adaptable to changes in the product being manufactured, both in type and quantity. Machines and computerised systems are configured to manufacture different parts and handle varying levels of production. A flexible manufacturing system (FMS) gives manufacturing firms an advantage to quickly change a manufacturing environment to improve process efficiency and thus lower production cost.



Advantages and disadvantages
The main benefit is the enhancement of production efficiency, whereby downtime is reduced because the need to shut down the production line to set up for a different product is eliminated. One disadvantage of FMS is its higher up-front cost and the time required to carefully pre-plan the system specifications. Another possible drawback is the higher cost associated with the need for specialised labour to run, monitor and maintain the FMS; however, since the FMS is meant to increase production automation (i.e., reduce labor input), the result is typically a net benefit in terms of cost. Common FMS layouts take the form of line, loop, ladder, and open field.

You should be able to explain the use of computer controlled systems in production, distribution and storage.

Bought-in parts and components, and standardised parts

Bought-in parts and components
Many products make use of similar parts or components. Different makes of computers often have the same make of hard drive or other internal components. Car manufacturers may set up sub-contractor arrangements for the supply of components such as headlamps and engine parts.

Key Points

- No need for production space for the components
- Speeds up overall production
- Quality assured by the component manufacture, specified tolerances
- Specialist companies provide components, cost benefits through economy of scale
- Choice of suppliers if there are service/quality difficulties, cost benefits through price negotiations and loyalty contracts
- Reduces storage costs, components available when required

Standardised parts
Standardised parts are the common items that are required in the manufacture of a wide range of products such as screws, nuts and electronic components (batteries, resistors, capacitors etc.). they are usually small, simple items that are manufactured to guaranteed specifications and are of consistent quality. Other examples include:
In the construction industry standardised components include doors, windows, sinks and other kitchen units
Zips, buttons and other fastening devices are standard components used in the textiles industry
In the manufacture of cars, a chassis may be used as a standard component and used in the production and development of several models.
Key Points

- Minimal interface and tolerance problems; standards usually generated by independent body, for example BSI
- Ease of maintenance; replacement parts for consumers

Students should be aware of, and able to explain, sub-assembly as a separate line of manufacture for certain parts of a product.

A Level Design and Technology: Product Design

Digital Design and Manufacture

Computer Aided Design (CAD)

Computer-Aided Design (CAD) is software that is used by architects, engineers, drafters, artists, and others to create precision drawings or technical illustrations. CAD software can be used to create two-dimensional (2-D) drawings or three-dimensional (3-D) models.

Advantages

- Reduced storage space
- Corrections can be made easily
- Repetitive parts of the drawing can be saved and imported as part of a "CAD library"
- CAD systems can be linked with CAM machines to produce objects straight from the drawings•
- 3D CAD designs can be made to look realistic by using the material library for clients to see
- CAD designs can be easily shared between companies or department using email
- CAD can be used to create simulated environments to show the client

Disadvantages

- Work can be lost if the computer crashes
- Work could be corrupted by viruses
- Work could be stolen or "hacked"
- Time taken to learn how to use the software
- Initial costs of buying a computer system are high.
- Time and cost of training staff
- Continual need for updating software or operating systems
- CAD/CAM systems mean less people need to be employed

Maths/Science Link:

- Use of datum points and geometry when setting out design drawings.
- The use of tolerances in dimensioning.

CAD can be used to develop and present ideas for products, including:

- the use of 2D CAD for working drawings, packages such as 2D Design can be used to create working drawings such as third angle orthographic. Nowadays, orthographic and isometric drawings can be generated from models that have been created in 3D CAD packages.
- 3D CAD can be used to produce presentation drawings, these are often photo-realistic and can be shown to a potential client.

CAD is often used in industrial applications, for example for planning wiring and plumbing for a new building or by architects.

Computer Aided Manufacture (CAM)

You should be aware of, and be able to describe, how CAM is used in the manufacture of products.

Laser cutting (see paper and board processes)
Routing (see metal processes)
Milling (see metal processes)
Turning (see metal processes)

Maths/Science Link:

- Calculating speeds and times for machining.

Plotter cutting

Digitally controlled plotters evolved from earlier fully analogue XY-writers used as output devices for measurement instruments and analogue computers.
Pen plotters print by moving a pen or other instrument across the surface of a piece of paper. This means that plotters are vector graphics devices, rather than raster graphics as with other printers. Pen plotters can draw complex line art, including text, but do so slowly because of the mechanical movement of the pens. They are often incapable of efficiently creating a solid region of colour, but can hatch an area by drawing a number of close, regular lines.

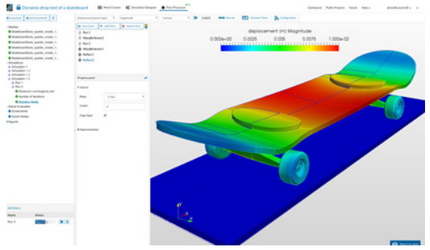
Plotters offered the fastest way to efficiently produce very large drawings or colour high-resolution vector-based artwork when computer memory was very expensive and processor power was very limited, and other types of printers had limited graphic output capabilities.
Pen plotters have essentially become obsolete, and have been replaced by large-format inkjet printers and LED toner based printers. Such devices may still understand vector languages originally designed for plotter use, because in many uses, they offer a more efficient alternative to raster data.

Cutting plotters use knives to cut into a piece of material (such as paper, mylar or vinyl) that is lying on the flat surface area of the plotter. It is achieved because the cutting plotter is connected to a computer, which is equipped with specialized cutting design or drawing computer software programs. Those computer software programs are responsible for sending the necessary cutting dimensions or designs in order to command the cutting knife to produce the correct project cutting needs.

Virtual Modelling

You should be aware of, and be able to describe, how virtual modelling/testing is used in industry prior to product production.

Simulation



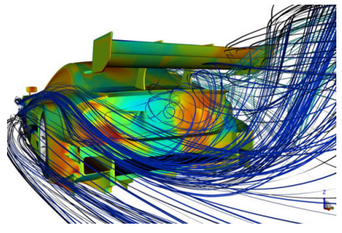
Design and simulation software is becoming increasingly clever and accurate, with latest versions plugging holes and further automating design on an annual basis, making the design engineers' jobs easier and easier. If continued to its logical conclusion, the design rules and facilities included in the computer-aided design (CAD) package, allied with reliable and accurate simulation data, should mean first-time-right products every time. Prototypes would be a thing of the past and, as a consequence, it would obviate the need for the test function as part of the design loop.

Simulation modelling is the process of creating and analysing a digital prototype of a physical model to predict its performance in the real world. Simulation modelling is used to help designers and engineers understand whether, under what conditions, and in which ways a part could fail and what loads it can withstand. Simulation modelling can also help to predict fluid flow and heat transfer patterns. It analyses the approximate working conditions by applying the simulation software.

Simulation modelling allows designers and engineers to avoid repeated building of multiple physical prototypes to analyse designs for new or existing parts. Before creating the physical prototype, users can investigate many digital prototypes.
Using the technique, they can:

- Optimise geometry for weight and strength
- Select materials that meet weight, strength, and budget requirements
- Simulate part failure and identify the loading conditions that cause them
- Assess extreme environmental conditions or loads not easily tested on physical prototypes, such as earthquake shock load
- Verify hand calculations
- Validate the likely safety and survival of a physical prototype before

Computational fluid dynamics (CFD)

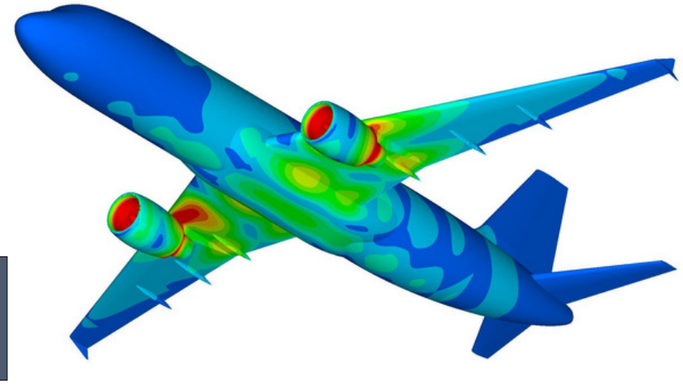


Computational fluid dynamics (CFD) is the use of applied mathematics, physics and computational software to visualize how a gas or liquid flows -- as well as how the gas or liquid affects objects as it flows past. Computational fluid dynamics is based on the Navier-Stokes equations. These equations describe how the velocity, pressure, temperature, and density of a moving fluid are related.

CFD is used for testing aerodynamics and wind resistance, and flow of liquids within/around products

Finite element analysis (FEA)

Finite element analysis (FEA) is a computerised method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow and other physical effects. Finite element analysis shows whether a product will break, wear out or work the way it was designed. FEA is used in component stress analysis.



Maths/Science Link:

- Interpretation of data from CFD or FEA testing.

A Level Design and Technology: Product Design

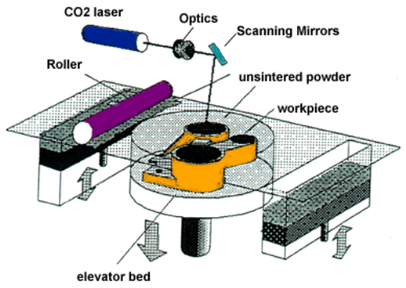
Digital Design and Manufacture

Rapid Prototyping

You should be aware of, and be able to describe, rapid prototyping processes, including 3D printing.

Maths/Science Link:
- Calculating volumes of 3D printed products,
- calculating time/speed for 3D printing.

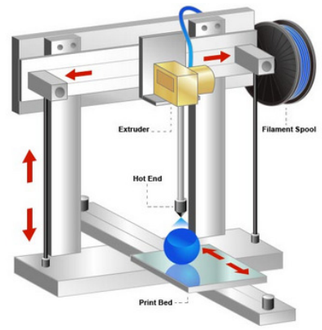
You should understand, and be able to explain, the benefits to designers and manufacturers.



Rapid prototyping involves using a CNC machine to make a working model of a part directly from a CAD program. It can produce complicated 3D shapes, although the material used is often not what would be used in large-scale production. Rapid prototypes are normally used to evaluate a design, but they can be used for enclosures.

There are a range of different rapid-prototyping processes: typically they involve building up a product by depositing layer after layer of material. It often takes many hours, or even days, to produce a part. They are only suitable for making one-off products where cost is not an important factor.

Selective Laser Sintering
A laser is used to melt a cross section of the design in a layer of powdered material. This hardens on top of previous layers, slowly building up the shape. The individual layers are incredibly thin: there might be several million in the final item.



3D printing
Layers of a material are built up into a 3D solid. The most common materials used are wax, starch or some thermoplastics. Complex shapes can be created.

Advantages
- The ability to explore and realize concepts more quickly. This efficiency in time and cost allows teams to move beyond the mere visualization of a product, making it easier to grasp the properties and design of a product.
- Apply repeated designs and incorporate changes that allow for the evaluation and testing of the product. This iterative process provides a roadmap to developing and refining the final product.
- Being able to communicate concepts concisely and effectively. Rapid prototyping takes ideas, images and concepts from flat and 2 dimensional visuals to hands-on products that clients, colleagues and collaborators can then see in action.
- The ability to thoroughly test and refine a concept. Being able to minimize design flaws with a small volume rapid prototype run helps eliminate costly design flaws that might not be evident during an early assessment.
- Save time and money since setup and tooling aren't necessary. Because the same equipment can be used to produce prototypes with different properties and materials, the costs and time outlay are kept to a minimum.

Electronic Data Interchange

You should be aware of, and able to describe, the use of electronic point of sales (EPOS) for marketing purposes and the collection of market research data.

Businesses are increasingly using technology to streamline their business operations and improve the customer experience. Electronic Point of Sale (EPOS) technology is affording small businesses across the globe the tools they need to compete against the corporate competition that dominates our high streets. We've come a long way from the clunky, glorified calculators of the past. Today's EPOS has the potential to revolutionise the way your business runs, offering plenty more benefits than simply somewhere to stash the cash!

Insight: One of the key benefits of EPOS is its capacity to measure and manage business activity in a way that allows you to make insight-driven changes. By building up a clear and accurate view of your business performance, you can set about improving it.
Visibility: There are hundreds of reports available that can be tailored to measure a vast array of information from margins, inventory and sales.
Spot trends: These analytic reports will allow you to spot trends hourly, monthly or seasonally. This will allow you to dedicate the resource you need when you need them, such as having more staff on shift between 6pm and 8pm, or knowing you need to stock extra sun cream in June.
Know what your customers want: Knowing your most popular stock items allow you to discontinue unpopular items, or push surplus stock. You can also see what certain customers are buying and target push promotions to their email or mobile device.
Time: Many business owners testify to never having enough time in the day to do everything required for the betterment of their business. Many admin tasks associated with running a business, such as inventory management, accounting and staffing, are mandatory, mundane and time-consuming. EPOS systems have the capacity to automate features, reducing the time spent faffing in spreadsheets and more time running your business.
Queue management: EPOS systems have the capacity to reduce the average transaction time. This cuts queues, reduces wait times and improves customer satisfaction.
Inventory Management: Inventory management is the bedrock of good business. Poor stock management impedes cash flow, risks wastage, shrinkage and can easily be taken advantage of by unscrupulous staff. Running out of stock is also a huge blow to customer satisfaction, making you look ill-prepared and unprofessional. EPOS not only eliminates the need for time-consuming stock takes, it also eliminates the human error involved with them. When stock is running low, the system can order more, ensuring you never run out. Anomalous data can also flag up employee theft, which costs the retail and hospitality sector millions in revenue each year.
Marketing: No longer restricted to the realm of print and radio, marketing can be a cost-effective way of gaining new customers, retaining old ones and raising brand awareness. By integrating your EPOS with marketing software you can send out direct email campaigns to your customer base alerting them to events and offers, with a view to boosting revenue. This can be done via email newsletters, push promotions via text or by developing your own integrated app.
Staffing: Staffing costs are some of a business's biggest expenses. By accurately tracking footfall you can forecast when your busiest times of day, allowing you to rota on staff accordingly. This ensures you are only paying for the employees you need, when you need them, cutting costs associated by an inflated staff bill.
Customer Retention: The age of internet shopping has seen consumers becoming increasingly disloyal. EPOS systems facilitate a number of ways in which to promote buying behaviours, keep customers coming back and reward loyalty, much in the same way large corporations do.
Loyalty programmes: By offering your customers branded loyalty cards or the opportunity to earn points and promotions via an app on their phone, you incentivise repeat business. This is also a prime opportunity to collect customer data for marketing purposes, meaning you can tailor offers and promotions to specific individuals.
Improved customer experience: Better inventory management systems empower staff to answer customer queries in a matter of moments, not to mention the queue cutting capabilities. This helps ensure customers never abandon a purchase.
Connect your on and offline stores: By linking your e-commerce store with your physical operations you can ensure you never run out of stock, risking complaints, and reputational damage.

Production, planning and control (PPC) networking

You should be aware of, and able to describe, the role of PCC systems in the planning and control of all aspects of manufacturing, including:
• availability of materials
• scheduling of machines and people
• coordinating suppliers and customers.

Production planning and control is a predetermined process which includes the use of human resource, raw materials, machines etc. PPC is the technique to plan each and every step in a long series of separate operation. It helps to take the right decision at the right time and at the right place to achieve maximum efficiency.

The objectives of PPC systems are:
- Systematic planning of production activities to achieve the highest efficiency in production of goods/services.
- To organise the production facilities like machines, men, etc., to achieve stated production objectives with respect to quantity and quality time and cost.
- Optimum scheduling of resources.
- Coordinate with other departments relating to production to achieve regular balanced and uninterrupted production flow.
- To conform to delivery commitments.
- Materials planning and control.
- To be able to make adjustments due to changes in demand and rush orders.

Stage 1: Pre-Planning
Under this phase of production planning, basic ground work on the product design, layout design and work flow are prepared. The operations relating to the availability scope and capacity of men, money materials, machines, time are estimated.
Stage 2: Planning
This is a phase where a complete analysis on routing, estimating and scheduling is done. It also tries to find out the areas of concern for short time and long time so that prominent planning can be prepared.
Stage 3: Control
Under this phase, the functions included are dispatching, follow up, inspection and evaluation. It tries to analyse the expedition of work in progress. This is one of the important phases of the Production Planning and Control.

A Level Design and Technology: Product Design

Health and Safety

Safe Working Practices

You should be aware of, and able to explain, health and safety procedures related to products and manufacturing.

Health and Safety at Work Act (1974)

The Health and Safety at Work Act 1974 (HASAWA) lays down wide-ranging duties on employers. Employers must protect the 'health, safety and welfare' at work of all their employees, as well as others on their premises, including temps, casual workers, the self-employed, clients, visitors and the general public. However, these duties are qualified with the words 'so far as is reasonably practicable'. This means that employers can argue that the costs of a particular safety measure are not justified by the reduction in risk that the measure would produce. But it does not mean they can avoid their responsibilities simply by claiming that they cannot afford improvements.

The Health and Safety Executive (HSE) was set up under HASAWA.
The Act contains powers for the HSE to enforce these employer duties and penalties for non-compliance. HASAWA ensures people involved in the manufacture of products can work safely within limited risk.

Control of Substances Hazardous to Health (COSHH)

COSHH is the law that requires employers to control substances that are hazardous to health. Employers can prevent or reduce workers exposure to hazardous substances by:

- finding out what the health hazards are;
- deciding how to prevent harm to health (risk assessment);
- providing control measures to reduce harm to health;
- making sure they are used;
- keeping all control measures in good working order;
- providing information, instruction and training for employees and others;
- providing monitoring and health surveillance in appropriate cases;
- planning for emergencies.

Most businesses use substances, or products that are mixtures of substances. Some processes create substances. These could cause harm to employees, contractors and other people.
Sometimes substances are easily recognised as harmful. Common substances such as paint, bleach or dust from natural materials may also be harmful.

Safe Working Practices

Companies should establish Safe Work Practices for addressing significant hazards or for dealing with circumstances that may present other significant risks/liabilities for the company. They should reflect your company's approach to controlling hazards.

Some regulations require employers to have written procedures/instructions for specific activities/conditions. The number of practices/procedures and the degree of detail will depend on the range of work activities your company performs. It is important that management and supervision are involved in the development of safe work practices and that they provide adequate training for workers likely to follow these practices.
Safe working practices should be written as a result of conducting a risk assessment.

Safety Precautions

Some manufacturing processes require specific health an safety actions, for example, the use of a respirator during the lay up process, or using adequate extraction when laser cutting materials.

Risk Assessment

A risk assessment is an important step in protecting workers and business, as well as complying with the law. It helps focus on the risks that really matter in the workplace – the ones with the potential to cause real harm. In many instances, straightforward measures can readily control risks, for example ensuring spillages are cleaned up promptly so people do not slip, or cupboard drawers are kept closed to ensure people do not trip.

Risk assessment is the process of assessing the risks to workers' safety and health from workplace hazards. It is an examination of all aspects of work that considers:

- what could cause injury or harm
- whether the hazards could be eliminated and if not
- what control measures are, or should be, in place to control the risks

A hazard can be anything that has the potential to cause harm.
A risk is the chance, high or low, that somebody may be harmed by the hazard.

Safety in Products and Services to the Customer

You should be aware of, and able to explain, how designers and manufacturers ensure products are safe for consumers to use.

Consumer Rights Act (2015)

The Consumer Rights Act came into force on 1 October 2015 which meant from that date new consumer rights became law covering:

- what should happen when goods are faulty;
- what should happen when digital content is faulty;
- how services should match up to what has been agreed, and what should happen when they do not, or when they are not provided with reasonable care and skill;
- unfair terms in a contract;
- what happens when a business is acting in a way which isn't competitive;
- written notice for routine inspections by public enforcers, such as Trading Standards; and
- greater flexibility for public enforcers, such as Trading Standards, to respond to breaches of consumer law, such as seeking redress for consumers who have suffered harm.

Most of these changes were important updates to existing laws. But two new areas of law were also introduced.

- For the first time rights on digital content have been set out in legislation. The Act gives consumers a clear right to the repair or replacement of faulty digital content, such as online film and games, music downloads and e-books. The law here had been unclear and this change has brought us up to date with how digital products have evolved.
- There are now also new, clear rules for what should happen if a service is not provided with reasonable care and skill or as agreed. For example, the business that provided the service must bring it into line with what was agreed with the customer or, if this is not practical, must give some money back.

The Consumer Rights Act 2015 stands alongside Regulations to create a greatly simplified body of consumer law. Taken together, they set out the basic rules which govern how consumers buy and businesses sell to them in the UK.

Sales of Goods Act (1979)

The Sales of Goods Act 1979 is an Act that regulates the sale of goods that are bought and sold in the UK and the binding contract between both parties. The contract of sale states that the transfer of property from a seller to a buyer is completed through a money transaction, known as the price.

Goods must determine a level of satisfactory quality for the price that the consumer is willing to pay, and meeting the description and relevant factors at time of purchase. These factors might include the level of expectation that an item may conjure, for example, second hand goods will provide much less expectation than that of a brand new product which will have a much higher expectation with regards to its quality and will cause concern about expectation if it has a defect.

Goods should be fit for purpose, i.e that they are capable of carrying out the purpose for what they were designed to do. A seller should express the purpose of their goods and has a responsibility to make sure that they attain that state.

The Sale of Goods Act amendment in March 2012 states that if a fault occurs with a product within the first 6 months of purchase, the consumer is entitled to assume that it was sold to them with the defect present. This means that the goods were not of a reasonable standard at the time of purchase and the vendor is in breach of their statutory and contractual obligations, whereby the Act protecting customers through their statutory consumer rights.

Referring back to the original Act of 1979, these consumer rights covers anyone who purchases faulty goods becomes entitled to a free refund (either in full or in part), replacement or repair service, and the onus falls on the retailer to provide this.

British Standards Institute (BSI)

BSI Group, also known as the British Standards Institution, is the national standards body of the United Kingdom. BSI produces technical standards on a wide range of products and services, and also supplies certification and standards-related services to businesses.
Examples might include the testing of PPE including safety goggles and impact testing.

Lion Mark

The Lion Mark was developed in 1988 by the BTHA to perform a function not covered by the CE Mark, namely, to act as a recognisable consumer symbol denoting safety and quality.

The Lion Mark indicates that the toy has been made by a member of the British Toy & Hobby Association and therefore denotes the member's commitment to adhere to the BTHA Code of Practice which includes rules covering ethical and safe manufacture of toys, a ban on any counterfeit goods, an assurance to market responsibly, a commitment to improving sustainability and a desire to promote the value of all play. Unlike the CE Mark, therefore, the Lion Mark is truly a consumer symbol. It means that consumers can be assured that a toy which bears the Lion Mark has been made by a member who believes in making good quality, safe toys.

Manufacturers can offer advice to consumers when they purchase a product; such as:

- manufacturer's instructions
- safety warnings
- aftercare advice

A Level Design and Technology: Product Design
Protecting Designs and Intellectual Property

You should be aware of, and able to explain, the importance of the following to the designer:

Copyright
Copyright is legal right that protects the use of your work once your idea has been physically expressed. The current copyright legislation in the UK is the Copyright, Designs and Patents Act 1988. You can find out more about copyright legislation by visiting the Intellectual Property Office.

Copyright law lays out a framework of rules around how that work can be used. It sets out the rights of the owner, as well as the responsibilities of other people who want to use the work. You can do many things with your copyright work including for example copy, change or sell it, share it online or rent it to someone as well as prevent other people from doing those things.

The UK has one of the strongest creative sectors in the world. According to government statistics published in January 2014, the creative industry generates an average of £8million every hour. Every time you watch an online clip, listen to music, read your favourite blog, or enjoy something creative, you are interacting with copyright in some way. Copyright protects most creative things you create, too.

The period your copyright work is protected for depends on a number of factors such as the type of work you have created and when it was made. For example, when you write a poem your work will be protected until 70 years after your death. But if you act in a play, any rights in your performance are protected for a period of 50 years.

Examples of the different works protected by copyright are:
- Literary works such as books, blogs, articles, poems
- Underlying Musical score, composition, lyrics
- Commercial music
- Photographs
- Artworks
- Film footage

Design Rights
Designs may be subject to three types of protection, copyright, unregistered design rights and may also be registered nationally as registered designs. The actual details of design rights will vary depending on national law. Please see your national patent office for specific details.

What is a design?
The appearance of a product, in particular, the shape, texture, colour, materials used, contours and ornamentation. To qualify as a new design, the overall impression should be different from any existing design.

Who owns the design right?
Typically the creator of the design owns any rights in it, except where the work was commissioned or created during the course of employment, in which case the rights belong to the employer or party that commissioned the work.

Unregistered design rights protect the shape or configuration of a marketable (or potentially marketable) product, and are used to prevent unauthorised copying of an original design. Design rights can also be bought, sold or licensed in a similar manner to copyright. Design rights exist independently of copyright, while copyright may protect documents detailing the design as well as any artistic or literary work incorporated within the finished product, the design right focuses more on the shape, configuration and construction of a product.
In the UK, unregistered design rights have been available since 1989, and have been available since March 2002 throughout the European Community.
Unregistered design rights are automatic and are treated in the similar manner as copyright. For this reason they may be registered with the UK Copyright Service in the same manner as copyright work in order to establish proof of the date and content of the work in case of any later dispute or legal claims.

A **registered design** may be applied for to provide additional cover over and above any design right or copyright protection that may exist in the design. Registered designs are administered by the Office for Harmonization in the Internal Market (Trade Marks and Designs) in the EU, and the Intellectual Property Office in the UK.

In the US designs may be registered as part of the standard patent system via the United States Patent and Trademark Office, where they are treated as 'design patents', (as opposed to 'utility patents').

The benefit of a registered design is that the design may enjoy prolonged protection from copying, although this protection would only be available in countries or territories where the application was made, up to 25 years protection is available in the UK and EC.

Patents
A patent is a legal right granted by the UK Intellectual Property Office for a new invention. It allows the owner of the patent (the patentee) to take legal action against others who use her invention without his permission. The right has a maximum life-time of 20 years in most countries, from the date of the patent application. What a patent does not do is give the owner an automatic right to use the invention. He still needs to take care to avoid infringing other people's rights.

A patent belongs to the inventor, unless he has given the rights to someone else.
Normally, if the inventor is an employee and he makes the invention in the course of his work, the rights belong to the employer.
The owner of the patent may license it, allowing others to use his invention. Alternatively, he can sell it to someone else.

To be patentable, your invention must meet the following conditions:
- It must be new. That is, the invention must never have been made public IN ANY WAY before you apply to the UK Intellectual Property Office, this means that your invention must not have been published by someone else before you.
- It also means that if you want a patent, you MUST NOT tell anyone about your invention, except in confidence, until your application is filed with the UK Intellectual Property Office.
- It must involve an inventive step. This means that the invention must not simply be an obvious development of something that is already known.
- It must be capable of being made or used in any kind of industry, including agriculture. Most inventions satisfy this requirement.
- An invention is typically an apparatus, a product, a manufacturing process etc.

Trademarks
Trademarks are badges of origin. They distinguish the goods or services of one trader from another and can take many forms; for example words, slogans, logos, shapes, colours and sounds. Trademarks are registered for specific goods or services within individual subjects, known as classes.

Logos
The most powerful company logos instantly capture their target audience. Consider the strength of logos as trademarks on restaurant row. A consumer can easily recognize the golden arches and Colonel Sanders. The golden arches obviously refer to McDonald's capital "M" logo. The logo is actually yellow, but the company has trademarked the logo as the "Golden Arches." Kentucky Fried Chicken uses its monogram, KFC, as its trademark name and logo. Another popular logo used to identify KFC's restaurant chain is the image of Colonel Sanders. Each of these logos serves as a company trademark.

Open Design
You should be aware of, and able to explain, the concept of 'open design'.
Specifically referring to the development of products for the common good of society, including potential use.
You should be able to give examples of this in practice, e.g. humanitarian projects and file sharing for 3D printing.

The open-design movement involves the development of physical products, machines and systems through use of publicly shared design information. This includes the making of both free and open-source software (FOSS) as well as open-source hardware. The process is generally facilitated by the Internet and often performed without monetary compensation. The goals and philosophy of the movement are identical to that of the open-source movement, but are implemented for the development of physical products rather than software. Open design is a form of co-creation, where the final product is designed by the users, rather than an external stakeholder such as a private company.

Typically, when a crisis group or organization is faced with a humanitarian emergency, they tend to focus on what has worked in the past because new solutions need to be tested prior to an emergency. We also see that volunteers for these groups/organizations are usually the first to bring an open source tool or project to the table as a potential solution. With a greater influx of open source tools being used in crisis situations, organizations are realizing the power of open source to allow them to adapt technology quickly in a changing environment and to work together across organizations.

Many initiatives are changing the nature of how open source and open data become priorities for humanitarians, such as the UNICEF Innovation Fund, World Bank's Global Facility for Disaster Reduction and Recovery, UN OCHA Humanitarian Data Exchange, Missing Maps and the Grand Bargain.

Websites such as thingiverse and grabCAD allow users to share 3D print files for others to download for free.

A Level Design and Technology: Product Design

Manufacture, Repair, Maintenance and Disposal

You should be aware of, and able to explain, the need to modify designs to make them more efficient to manufacture.

Manufacturers can reduce waste in many ways, some of these are shown on the left.

They can also reduce the number of manufacturing processes—for example combining different parts.

The choice of materials affects the use, care and disposal of products:

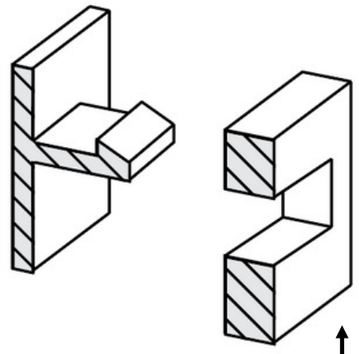
- labelling of materials to aid separation for recycling—manufacturers can ensure that labels are clear. A good example is the use of resin identification labels on polymers.
- Products could be made easier to disassemble or separate, this assists in the repair, maintenance and disposal of products.

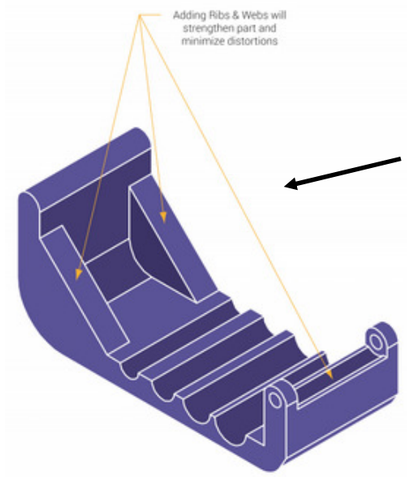
Six R's:

- Manufacturers can reduce the quantity of materials, of toxic materials, of damaging materials and associated energy use, this can then reduce the manufacturer's environmental impact.
- Manufacturers can reuse components and parts.
- They can rethink by using eco friendly alternative materials.
- They recycle materials and/or components into new products, a closed loop system is a good example of this, e.g. blow moulding where flash is removed and sent to the beginning of the process.

Maintenance:

- Manufacturers can include temporary and integral fixings into their products.
- They can use standardised parts, meaning they are readily available for consumers to replace if required.
- They could offer a service for repair/ replacement of parts
- They can offer the ability to upgrade with software downloads.





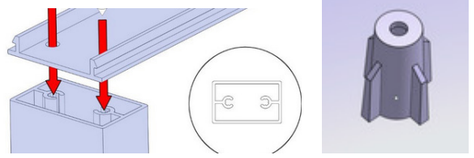
Ease of Manufacture

You should be aware of, and able to explain, the different ways in which a product can be designed to allow for more efficient manufacture.

Ribs and webbing can be introduced to products to reduce material thicknesses, this reduces the amount of polymer required to manufacture the product.

Snap fittings can be added to remove the need for fixings/ adhesives, making them easier to manufacture and disassembly at the end of the product's life.

Internal moulded screw posts can be included for use with self tapping screws, this reduces the amount of operations required to manufacture the parts. Screw ports can also be included in extrusions.



Pre made components can be used to make manufacture easier, standardised patterns and sizes make the acquisition of components easier.

As many polymers are self-finishing, textures can be added in moulding to reduce number of manufacturing processes.

Disassembly

You should be aware of, and able to explain, how a product can be designed and manufactured with disassembly in mind, including integral fixings and active disassembly using smart materials such as SMA and biodegradable parts.

Design for disassembly is the process of designing products so that they can be easily, cost-effectively and rapidly taken apart at the end of the product's life so that components can be reused and/or recycled.
The example above is a dental floss product. It embodies the essence of design for disassembly —simple to assemble and disassembled. It's easy to open, free of glues, screws, or heat sinks. The main component's material is clearly labelled, and the parts are quickly separated.

Designing for disassembly involves, for example:

- The fewer parts you use, the fewer parts there are to take apart.
- As with parts, the fewer fasteners (e.g. glue, screws, etc.) used, the better.
- Common and similar fasteners that require only a few standard tools will help to simplify and speed disassembly.
- Screws are faster to unfasten than nuts and bolts.
- Glues should be avoided.
- Building disassembly instructions into the product will help users understand how to take it apart.

Active disassembly is a developing technology which is associated with the term Active Disassembly using Smart Materials (ADSM). Smart materials such as shape memory alloys (SMA) are now offering the possibility of allowing complex items to be disassembled easily and in a potentially cost-effective manner. Other smart materials employed by AD include, shape memory polymers (SMP), smart layers, sprays, engineering polymers etc. The development of this technology could make recycling of consumer products more common and thus serve to be environmentally friendly.

Screws, rivets, ribbons, bars and clips, specially designed to facilitate AD, can be manufactured from smart materials such as SMAs and SMPs. These will trigger at a pre-determined temperature, depending on the specific application.

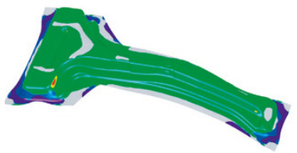
Feasibility Studies

You should be aware of, and able to explain, the use of feasibility studies to assess the practicality for production of proposed designs, including the testing of prototypes with potential consumers.

An example of a feasibility study is in press forming.

A feasibility study enables the quick and easy evaluation of part and process feasibility. Even with the first design of a part geometry, fundamental process capability should be checked for future series production, regardless of whether the CAD model has already been rounded.

At this point in time, there are often preliminary questions regarding whether the part can be manufactured as a single or double part, where exactly the part separation is planned, and whether the required material strength is achievable. Another issue which must be addressed at this stage is the later behaviour of the part in terms of crash, strength, stiffness or durability.



The feasibility analysis allows early feedback on key quality criteria of the forming process.

Feasibility studies can be completed with potential consumers to check the feasibility of the product being successful on the market. If it was found that the product would not be successful, it may not be feasible to continue with the design process.

Maths/Science Link:
Interpret statistical analyses to determine user needs and preferences.
Use data related to human scale and proportion to determine product scale and dimensions.

A Level Design and Technology: Product Design

Enterprise and Marketing in the Development of Products

You should be aware of, and able to explain, the importance of marketing and brand identity.

Maths/Science Link:
Interpretation of market research data, calculating costs and profit.

Customer Identification

Target market identification, by definition, is the method used to sort potential clients for sales and marketing campaigns, advertising and promotions using income, demographic, and lifestyle characteristics of a market and census information. This method is managed in several ways depending on the products and/or services that are the main focus of a business.

Target market identification begins with a study of where sales and marketing efforts produce the maximum results. For example, a law firm mainly offers legal services. However, many law firms specialise in certain types of legal issues. It presents the best picture of target market identification because it specifies where potential clients exist. It is also true for products that are sold to the public. Another example of this is a major food producer of food and beverages. Although the business may have several products, its sales and marketing planning focuses on particular target markets for each product.

Once businesses know the definition of target market identification, the job of market research opens a wider window of opportunity.

Thus, they may study target markets for each product to finely hone the scope of their target market identification

Labelling

Packaging is essential as it is used for the identification of the products in marketing. It enhances the appearance of the label for promoting the product. This is the major importance of labelling in marketing. In addition, labelling also helps to provide the information about a product to the prospective customer. This function fulfils informative purpose of using a tag.

Importance of labelling in marketing:
Marketers use labelling to their products to bring identification. This kind of labelling helps a viewer to differentiate the product from the rest in the shelves of the market. There are several used of the label for the products in the market.

Labelling is used for packaging the product. In marketing, a marketer can also use a sticker inedible products to impart knowledge of the ingredients of the food items. This helps to spread awareness among the customers about the item they are consuming and labelling also helps to mention ingredients.

Packaging

Packing is important in the marketing of a product.

It differentiates a brand from others

There are thousands of products on the market vying for customers' attention. According to The Paper Worker, one-third of a consumer's decision making is based solely on product packaging. To succeed, brand packaging has to stand out and look different from competitors. For example, one of Captain Morgan's most recent products, Cannon Blast, comes in a not-so-standard container. The bottle is actually shaped like a cannon ball. Not only is the design relevant to the name of the product, it's also eye-catching and highly different from what many of its competitors offer.

Packaging colour sways consumer purchase habits

The colours used in product packaging play a key role in consumer buying decisions. The brain reacts to colours in different ways, so packaging colour choice is important. For example, products with white packaging convey simplicity, safety and purity. Colour experts cite that the more colour added to a product's package, the less sophisticated the product is. Other colours, like blue, convey many different meanings. A light sky blue colour is considered more playful, while a dark navy is considered much more professional. Worldwide, blue is the most liked colour, but that doesn't mean you should automatically choose the likable colour. It's important to study the target demographic before deciding on a colour scheme for product packaging.

Product packaging is a marketing tool

A product's packaging can be a helpful marketing tool through in-store advertising. Branded products are easily recognised, so designing packaging with a logo front and centre helps consumers remember a product next time they are shopping.

Packaging creates brand recognition

Brands are memorable. Over the decades, brands like Coke have made minor changes to their packaging and stayed true to their original look. Recognizable brands should not change a thing because many successful brands that changed their logo, colours or packaging have seen a sort of backlash from shoppers after making a big change.

Corporate Identification

Corporate identity is what makes up the physical look of a brand. It usually includes a logo and the supporting devices such as a website, letterhead and business card as well as social media platforms and the 'tone of voice' of a business.

Maintaining a consistent corporate identity is vital if a business wishes to be shown in a professional light. Sticking to a particular palette of colours and fonts, consistent logo positioning and using the same tone of voice throughout printed and online communications will all help to enhance a professional stance.

- A company that invests in corporate identity indicates that it is here to stay. It sends a message that the company is serious about being successful. It gives the customer a sense of trust.
- Corporate identity gives a sense of the culture or personality of the business.
- In creating a consistent identity, a company is ensuring that they will be recognised and remembered.
- A uniform corporate identity becomes instantly recognisable amongst its target audience.
- A strong corporate identity can improve customer awareness and can increase a company's competitive edge.

Global Marketing: the promotion and advertisement of products including the use of new technologies, eg social media, viral marketing

Global marketing is "marketing on a worldwide scale reconciling or taking commercial advantage of global operational differences, similarities and opportunities in order to meet global objectives".

Social Media Marketing can be a powerful branding vehicle when it's part of a comprehensive marketing strategy. It serves as a valuable tool to link prospects to a website, where they can start a conversation with a business. It can also help establish a company as a thought leader by promoting events, articles written, board affiliations, etc.

Many people think of social media marketing as Facebook, LinkedIn, and Twitter but that is the tip of the iceberg.

Social media marketing involves any web platform that prompts dialogue between users. There are numerous industry-specific web platforms where dialogue occurs.

Viral Marketing

Viral marketing is based on natural behaviour, uses pre-existing social networks, and produces increased brand awareness through self-replicating processes similar to the spread of a virus.

Product costing and profit

Product costing is the process of tracking and studying all the various expenses that are accrued in the production and sale of a product, from raw materials purchases to expenses associated with transporting the final product to retail establishments. It is widely regarded as an extremely important component in evaluating and planning overall business strategies.

Awareness of the role of entrepreneurs

An entrepreneur is an individual who sets up and grows a business. They combine different factors of production (such as – land, labour and capital) to try and create a new profitable business venture. Entrepreneurs are themselves an important 'factor of production.' and an essential aspect of a functioning free market economy.

Motives of entrepreneurs

- Profit. Profit is the biggest incentive. If the business is successful, the entrepreneur can pay themselves a large dividend or sell the product
- Income. Unemployed may feel self-employment is best opportunity to gain an income.
- Overcome a particular need. Sometimes, entrepreneurs set up a business to deal with a missing market. For example, Louis Braille was completely blind – this led him to invent the braille system to communicate and read.
- Non-financial motives. Mixed up with profit motive may be other objectives
    - Ethical stance. An entrepreneur may wish to do a different type of business, e.g. an organic farm which doesn't harm the environment.
    - Independence. An entrepreneur may also be motivated by non-financial factors, such as independence to work for themselves or to choose the hours and not have to listen to another boss.
    - Social entrepreneurship. Entrepreneurs don't always act alone. They may form partnerships with other entrepreneurs to create a stronger business or develop a social enterprise which aims at serving the community.

You should be aware of, and able to explain, the collaborative working of designers in the development of new and innovative products, including virtual and face-to-face collaborative working systems.

A Level Design and Technology: Product Design

Design Communication

You should be aware of, and able to explain and demonstrate the skills, in a range of communication and presentation techniques for conveying proposals and intentions to clients, potential users and manufacturers.

Maths/Science Link:

- Scaling drawings.
- Use of datum points and geometry when setting out design drawings.
- Representation of data used to inform design decisions and evaluation of outcomes.
- Presentation of market data, user preferences and outcomes of market research.

Report Writing

A design report is the written record of the project and generally is the only record that lives once the design team disbands at the end of the project.

The report has three sections. The first section describes the problem that was being solved and provides the background to the design. The second section describes the design and the third section evaluates how well the design worked by comparing its performance to the design requirements. The report starts with a short executive summary that contains a synopsis of the three sections.

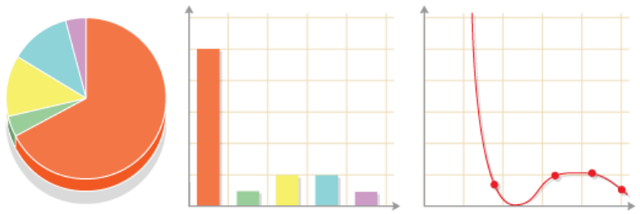
The body of the report is relatively short. Appendices to the report contain supporting information with the details needed by a reader who wishes to fully understand the design.

While this document describes the general content and organisation of a design report, some of the specifics (section headings, length, and format) may be determined by your project client.

The use of graphs, tables and charts

Numerical data is often represented using graphs and charts.

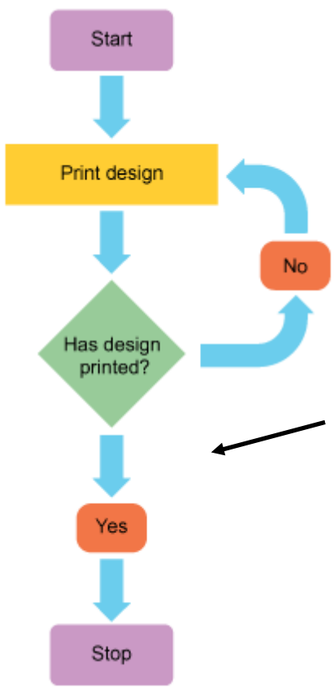
- Pie charts can show fractions of a whole number. 3D pie charts can be created.
- Bar graphs are useful for showing numbers, for example, colour choices. Different coloured bars can be used, and bar charts can be 3D.
- Line graphs are used to show change, for example results over a period of time of how well a product sells.



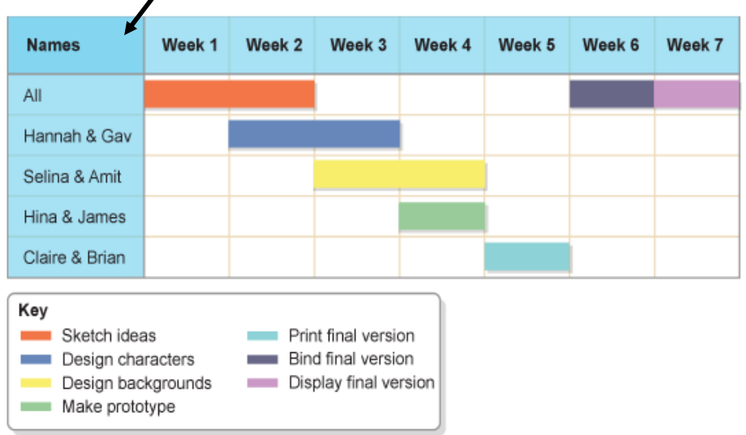
Gantt charts show the different tasks involved in making a product. They are used for complex planning where different tasks can be done at the same time, or where two or more people are working on the same product.

Tables can be used to display information.

Class height (in cms)	Frequency	Cumulative Frequency
150 - 155	12	a
155 - 160	b	25
160 - 165	10	c
165 - 170	d	43
170 - 175	e	48
175 - 180	2	f
Total	g	50

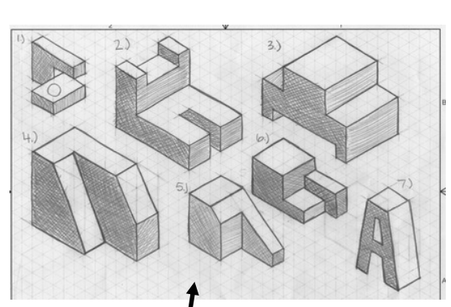


Flow charts describe in words the sequence of operations. Flow charts are useful for simple tasks. Arrows show direction and different shapes show stages:
Rounded rectangle = Start or finish
Diamond = Decision
Rectangle = Process

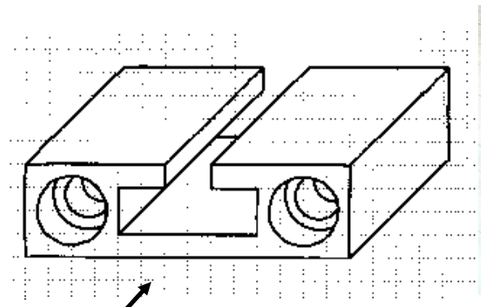


2D/3D sketching

Designers can use a wide range of sketching techniques to communicate design information. Some examples include:



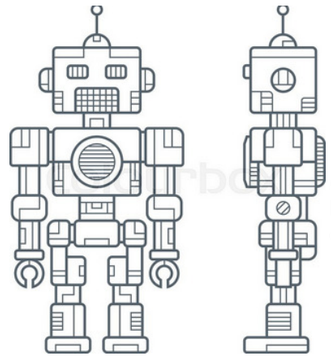
3D—Isometric

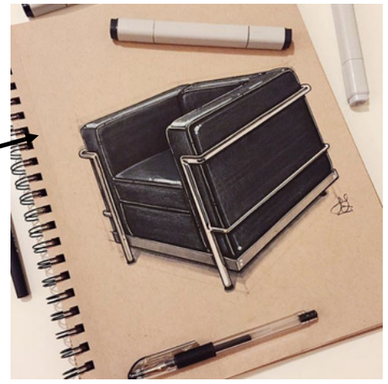


3D—Oblique

3D—Two Point Perspective

2D—Front and Side Views

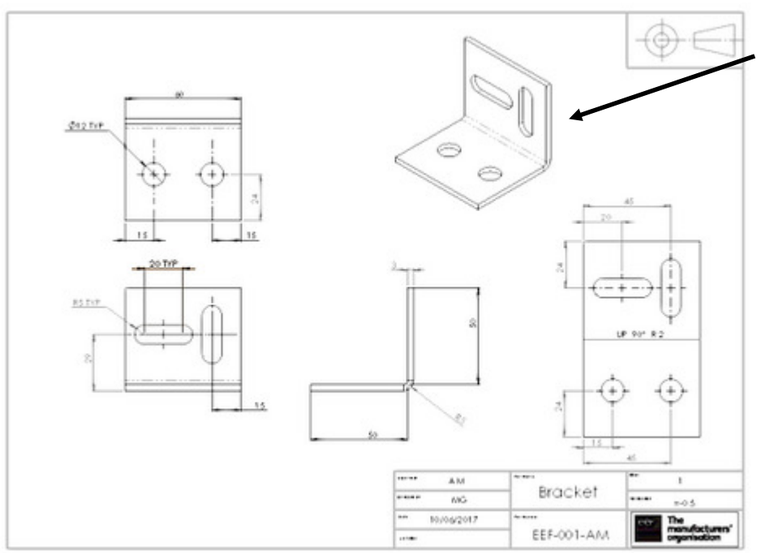




Mixed media and marker rendering can be used to create more realistic drawings.

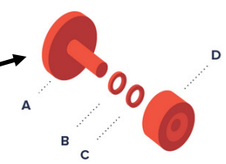
Dimensioning and details for manufacture

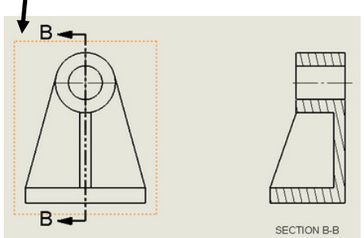
Details for manufacture are often communicated through orthographic drawings. In the UK, third-angle orthographic drawings are produced for manufacturers to work from.



The isometric view allows an engineer to visualise the part/product.

Exploded views and section views both aid in communicating manufacturing information.





A Level Design and Technology: Product Design

Modern Manufacturing Systems

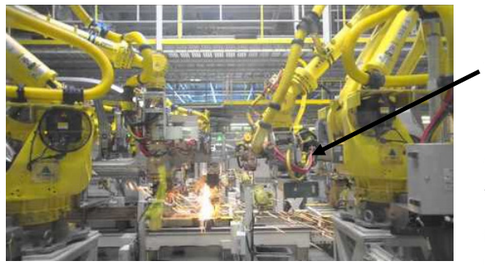
The use of computer systems to plan and control manufacturing, reduce waste and respond quickly to changes in consumer demand.

You should be able to describe how computers are used in modern manufacturing.

Computers have made a massive impact on the speed and accuracy in which products can be made. It is now possible to manufacture high-quality outcomes in a short period of time when previously people would have taken a number of days to make the same products with no guarantee that they would all be of the same standard.

Computer Aided Design (CAD)
CAD is a system that allows designers to create solutions to problems within a computer program through the use of illustrations. Designs can be modelled in 3D and manipulated time and again from all angles. There are many CAD packages available.

Computer Aided Manufacture (CAM)
CAM is a term used to describe any activity where a machine is programmed with several instructions to produce a component from a raw material. CAD packages are commonly used through an interface software to drive the special machine codes that in turn tell the machine what to do and where to cut and shape the material.



A car has many thousands of components that all need to behave in specific ways. Cars have become increasingly complicated, yet each small piece of the engine or controls is relatively simple to make. This is because machines assemble and shape the raw materials or assist people in assembling them.

Imagine how difficult it would be for one or two very skilled people to make these cars without the assistance of machines, computers, robots and diagnostic systems.

It is easy to imagine how a craftsman, equipped with hand tools, can manipulate hardwood into a well- made table or use metals to create some fine jewellery. In these cases, human touch and sensitivity toward the aesthetics of the pieces is easy to appreciate. However, computers are needed when manufacturing to consistently satisfy high demand and reproducible quality.

Sophisticated computer systems can be integrated together to monitor every aspect of a manufacturing process. Designs can be modified time and again without the need to repeat all the drawings and computers can hold vast amounts of technical data with great accuracy. This information can be fed into a manufacturing cell where several robots or machines can carry out the precise tasks time and again precisely and with accuracy.

Computer Numerical Control (CNC)
This is the control of machines using numbers or digital information. This can be provided manually or through a computer. Generally this is used for milling and drilling procedures. CNC makes use of the machine axes and the tools move along these axes according the programme.

Flexible Manufacturing Systems (FMS)
A flexible manufacturing system involves the use of pre-programmed machines and computers to carry out a series of tasks and operations. They can be programmed so that a different set of operations can be carried out as the designs change.

Automatic Guided Vehicles (AGVs)
This is an unmanned vehicle that follows a pre-programmed route around a factory floor or warehouse.

Modular/Cell Production
See the use of computer systems

Just In Time (JIT)
See the use of computer systems

Master Production Schedule (MPS)
A master production schedule (MPS) is a plan for individual commodities to be produced in each time period such as production, staffing, inventory, etc. It is usually linked to manufacturing where the plan indicates when and how much of each product will be demanded.

You should also be familiar with the use of standardised and bought-in components made by specialists.

Examples of Modern Manufacturing Systems

Computer Aided Design (CAD)

- 2D Design
- OnShape
- Solidworks
- Autodesk Inventor

Many modern CAD systems allow users to complete analyses, including CFD and FEA.

Computer Aided Manufacture (CAM)

- Laser Cutting
- CNC Milling
- CNC Routing

Flexible Manufacturing System (FMS)

Robots are often used in FMS, this is due to the fact it can be reprogrammed in response to re-designed products. A good example of this is in the automotive industry. Welding/painting robots can be used to weld parts together; the locations of these can be reprogrammed.

Automatic Guided Vehicles (AGVs)

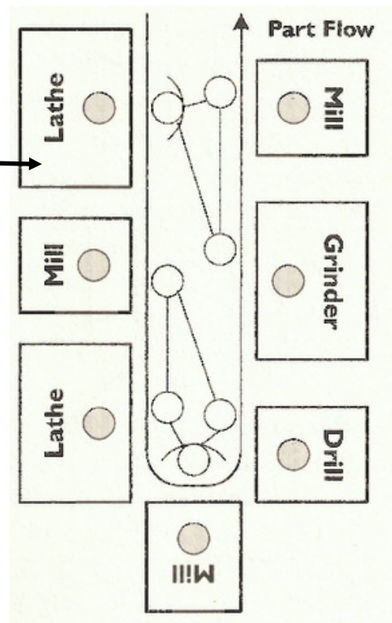
An automated guided vehicle or automatic guided vehicle (AGV) is a portable robot that follows markers or wires in the floor, or uses vision, magnets, or lasers for navigation. They are most often used in industrial applications to move materials around a manufacturing facility or warehouse. Application of the automatic guided vehicle broadened during the late 20th century.

Example: Moving finished goods from manufacturing to storage or shipping is the final movement of materials before they are delivered to customers. These movements often require the gentlest material handling because the products are complete and subject to damage from rough handling. Because AGVs operate with precisely controlled navigation and acceleration and deceleration this minimizes the potential for damage making them an excellent choice for this type of application

Modular/Cell Production

A good example of modular/cell production is in the manufacture of Toyota cars, they often arrange different machines in a U shape to reduce travel times.

The parts travel between each cell, often using AGVs.



Just in Time (JIT)

Fast food restaurants like McDonald's usually have everything they need to assemble and don't do so until the order has been taken, except for a few finished products. This makes the process so standardized that every time a customer goes they get the same experience.

In this case there was a dramatic change after World War II, when after showing a less than efficient process they turned to JIT and by having inventory on hand they lead to shorter lead times and a much more efficient service for customers. After implementing JIT at Harley Davidson the inventory levels declined in 75 percent, but at the same time productivity rose. By doing so, they were able to identify and solve the inefficiencies of the process because it could no longer hide under a large amount of costly inventory.

Master Production Schedule (MPS)

The majority of large manufacturers use a form of MPS, it takes into account a wide range of information in order to produce products quicker and more economically.