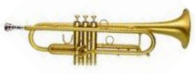
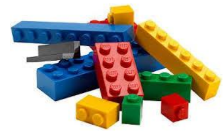
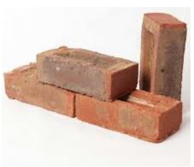
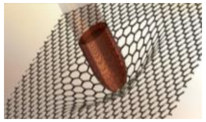
Knowledge organiser: Topic Area 1: Engineering materials

Types of materials

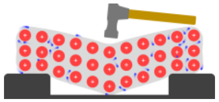
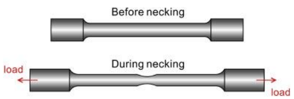
Metals		
Ferrous Metals 	Ferrous metals contain iron. They may have small amounts of other metals or other elements added, to give the required properties. The are also magnetic. They will *rust* if unprotected.	Iron, carbon steels, high speed steels
Non-ferrous metals 	Non-ferrous metals do not contain iron. Pure metals (have no other metal or element). They are not magnetic.	Copper, brass, bronze, aluminium, zinc, tin, lead, titanium
Alloys 	Metal alloys involve mixing two or more metals and other elements to improve their properties.	Brass, aluminium and titanium alloys.

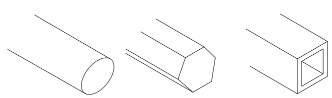
Polymers		
Thermoplastics (thermoforms) 	Thermoplastics - a polymer which becomes soft when heated and hard when cooled. Thermoplastics can be cooled and heated several times without any change in their chemistry or mechanical properties.	ABS, polyethylene, HIPS, PVC, polycarbonate, polypropylene, nylon, polymethylmethacrylate (PMMA/Acrylic).
Thermosetting- plastics (thermosets) 	Polymer that irreversibly becomes rigid when heated. Cannot be reheated and reshaped, making them harder to recycle.	Polyester resin, urea – formaldehyde, epoxy resin, phenol-formaldehyde.

Other engineering materials		
Ceramics 	A ceramic is an inorganic non-metallic solid made up of either metal or non-metal compounds that have been shaped and then permanently hardened by heating to high temperatures.	Tungsten carbide, Glass, ceramic bearing material
Composites 	Composite material is made from two or more materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the original components.	Glass reinforced plastic, Carbon fibre, Concrete
Smart materials 	Smart materials are material that respond or adapt to changes in their environment dur to stimuli such as: external stress, moisture, electric or magnetic fields, light, temperature, or chemical compounds	Shape memory alloys, thermochromic pigments, photochromic materials, phosphorescent pigment, Quantum Tunnelling Composite.

New and emerging materials		
Nano technology 	Developing and engineering materials at an atomic level. Allowing for nano particles to be added to fabric or glass.	Self-cleaning glass, stain-proof fabrics, graphene.
Metal foams 	Think AERO chocolate but in metals. Common in aluminium alloys, allowing for strength but reducing the weight.	Metal Foams
Self-healing materials 	As the name suggests, these materials 'heal' themselves when they become damaged. They usually contain some from of bacterial which then 'seals' the damage.	Self-healing concrete
Aramid fibres 	A type of aramid fibre that is woven into a textile material and is extremely strong and light weight.	Kevlar

Knowledge organiser: Topic Area 1: Engineering materials

Material properties			
Malleability 	The ability of a material to permanently deform in all directions without fracturing.	**Corrosion Resistance** 	How well a material (especially a metal) can withstand damage caused by oxidization or other chemical reactions
Ductility 	The ability of a material to deform without fracturing, usually by stretching along its length.	**Brittleness** 	The opposite of malleability - Brittle materials are often those which can also be described as 'hard'. They don't cope well with impacts and tend to shatter.
Conductivity/Resistivity 	The ability of a material to conduct heat or electrical energy. Resistivity – the ability to resit conducting heat or electrical energy.	**Machinability** 	How easily the materials can be cut by means of turning, drilling, milling, filing etc.
Hardness 	Resistance of a material to deformation, indentation, or penetration by means such as abrasion, drilling, impact, scratching.	**Elasticity** 	The ability of a material to return to its original shape after a force has been applied.

Material characteristics		
Relative cost 	**Ease of use** 	**Forms of supply** 
Availability 	**Sustainability** 	**Safety in use** 

Testing of materials		
Destructive testing 	This type of testing is uundertaken in order to understand a specimen's performance or material behavior. Those procedures are carried out to the test the specimen to failure.	Tensile testing, hardness testing
Non-destructive Testing 	A testing and analysis technique used by industry to evaluate the properties of a material, component, structure or system for characteristic differences or welding defects and discontinuities without causing damage to the original part.	Conductivity testing, crack testing, ultrasonic testing.

Knowledge organiser: Topic Area 2: Manufacturing processes

Wasting processes

Drilling

Hand tools: Hand drill

Power tools: Cordless drill, pedestal/pillar drill.

A drill bit (consumable) is used to 'carve' through the material. Swarf (cuttings) is ejected via the flutes.

Threading

Hand tools: Tap & tap wrench (holder), die and die stock (holder). Process can also be CNC.

The cutting tools remove material in the shape of screw threads. A cutting or tapping compound (consumable) is used to lubricate the cutting of screw threads.

- Internal threads - Taps come in a various forms such as taper, bottom and plug.
- External threads – Dies come in solid form or split.

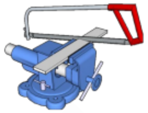
Shearing

Hand tools: Tin snips, aviation snips.

Power tools: Nibblers, bench shears.

A pair of sharpened jaws slice through the material similar to how scissors operate.

Sawing



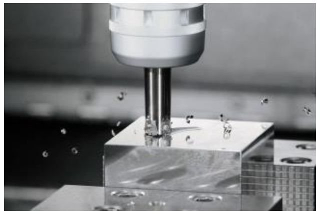
Hand tools: Junior hacksaw, hacksaw.

Power tools: Power hacksaw

A tensioned blade (consumable) with 'teeth' is used to remove material.

Dedicated machines (can be manual or CNC)

Milling



Milling machine: Looks very similar to the pillar drill but instead of the chuck and drill bit moving up and down relative to the bed, the chuck/collet of the milling machine remains fixed and the bed is moved in relation to the cutting tool. The bed can be moved in multiple axis. Products can be very complex shapes.

A coolant (consumable) is often used to keep materials cool. This prolongs the life of the cutting tools.

Turning

Centre lathe: Turning creates cylindrical products/components. Can be used to create holes, grooves and knurls (think grip pattern on barbells/dumbbells). A coolant (consumable) is often used to keep materials cool. This prolongs the life of the cutting tools.

Filing

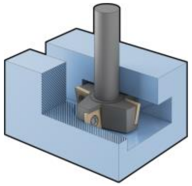
Hand tool: Hand file – many types such as flat, half round, 3 square, round, square.

A hardened

Dedicated CNC processes

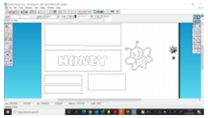
Routing

CNC routing requires a CAD program to operate it. The router follows the program and cuts out two-dimensional shapes from materials such as woods, composites, metals, plastics and foams.



Laser cutting

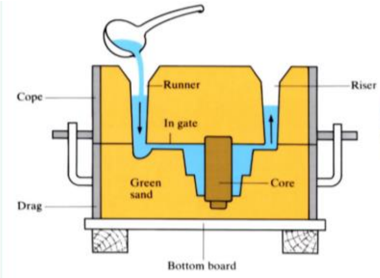
laser cutting also required a CAD program to operate it. A laser beam is used to cut through materials – it essentially burns its way through and is instantly cooled via cold jet of air. Material include woods, composites and polymers.



Knowledge organiser: Topic Area 2: Manufacturing processes

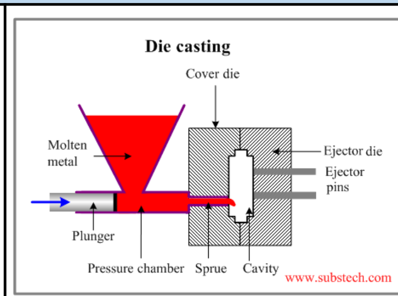
Shaping processes

Sand casting



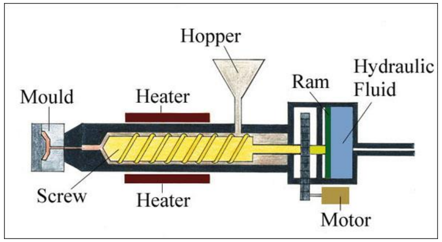
Sand casting uses sand to form a mould. It is split into two halves: the cope (top) and the drag (bottom). Moten metal is poured into the mould and then allowed to cool. The sand must be broken away from the casting. Secondary machining is often required.

Die casting



Die casting is similar to the process of injection moulding but it uses molten metal rather than molten plastic. Molten metal is fed into a pressure chamber which then forces the molten metal into a die. It is then allowed to cool before it is ejected.

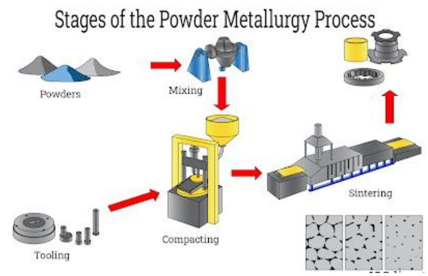
Injection moulding



Injection moulding is the process of heating plastic and forcing it into a mould under high pressure.

Benefits include dimensional accuracy, automation, and both thermoplastics and thermosetting plastics can be used.

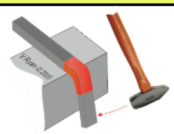
Powder metallurgy for ceramic product

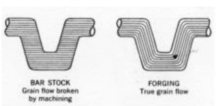


The process of mixing ceramic powder with additives. The mixture is then compacted into the required shape (green state). Heat is then used to solidify the powder.

Forming processes

Forging





Forging is the process of heating metal until it becomes 'cherry red' and then shaping it using a force. Forging improves the strength of metals and does not waste material like machining.

Press forming metal

Press forming metals is achieved by applying a force to sheet metal. The sheet metal is pressed into/onto a die. The process often removes excess material at the same time.

Strip heating polymers

Strip heating involved using a heating element to heat polymers. The polymer can then be shaped and allowed to cool – Thermoplastics only.

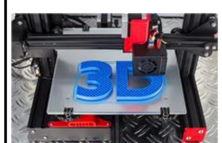
Vacuum forming

Heating a sheet of thermoplastic and then using a vacuum pump to pull the softened polymer over a mould. Moulds must have a draft angle.

Moulding composite materials

Moulding composites mostly consist of building up layers of material and applying a resin to bond the layers together. Moulds in the desired shape are used to form the composite.

Additive manufacturing: 3D Printing (fused deposit modelling)

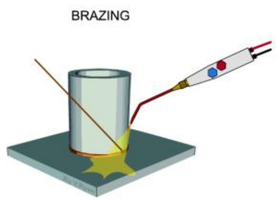


3D Printing requires a CAD model which is then sliced into layers. The 3D printer then prints the layers to build up the product or component. PLA is commonly used.

Knowledge organiser: Topic Area 2: Manufacturing processes

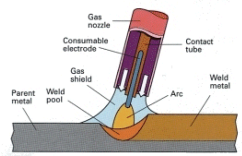
Joining processes

Brazing



Metals must be clean and free from contaminants. The join of the mating metals has a flux applied to it. The two metals are placed together and heated. A filler metal (brass) is melted into the joint. The metals are then allowed to cool.

MIG welding



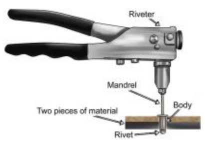
Metal inert gas (MIG) has an electrode (filler metal) contained within the welding torch. Welding actually melts the base materials to help join them together. Argon gas shields the weld from oxidising

MAG welding

Metal active gas (MAG) is much the same as MIG welding but instead of using an inert gas, it uses an active gas (commonly CO2). The active gas helps the weld achieve deeper penetration. CO2 is also much cheaper than argon.

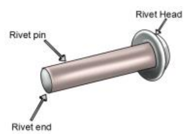
Riveting

Pop rivets



Pop rivets join two pieces of material together by pulling the mandrel through the body of the rivet. The mandrel snaps off and joins the materials. Pop rivets are a good choice when access to the material is limited to one side only.

Cold/hammered rivets



Hammered rivets require the rivet end to be deformed my a form of hammering. They require access to both sides of the materials being joined.

Mechanical fastener

Nuts, bolts and screws

Nuts bolts and screws rely on a screw thread to join the components. They come in many sizes and different head types such as hex, pozi and flat head.

Self-tapping screws

Self-tapping screws often do not require a pilot hole drilling like bolts do. They create their own screw threads and join materials together.

Finishing processes

Painting

Brush

Using a brush is a very cost-effective way to apply paint. It does not require any specialist equipment such as spray guns, extraction or training of staff. It can however be a slow process. The surface finish is not always perfect.

Spray

Spray painting is a very efficient way of painting materials and leaves a high-quality surface finish. It can be allied via a aerosol can or a professional spray gun. Training is required and specialist extraction for paint fumes.

Powder coating

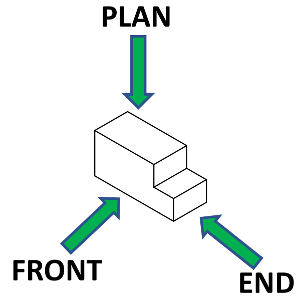
A dry coloured powder is applied to metals and woods by spraying the powder over an electrode. This creates an electrostatic charge which then attracts the powder to the grounded part being coated. Powder coating is very durable and cost effective as there is minimal waste due to the electrostatic process.

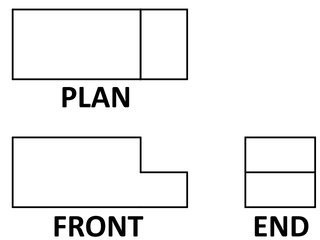
Knowledge organiser: Topic Area 3: Manufacturing requirements

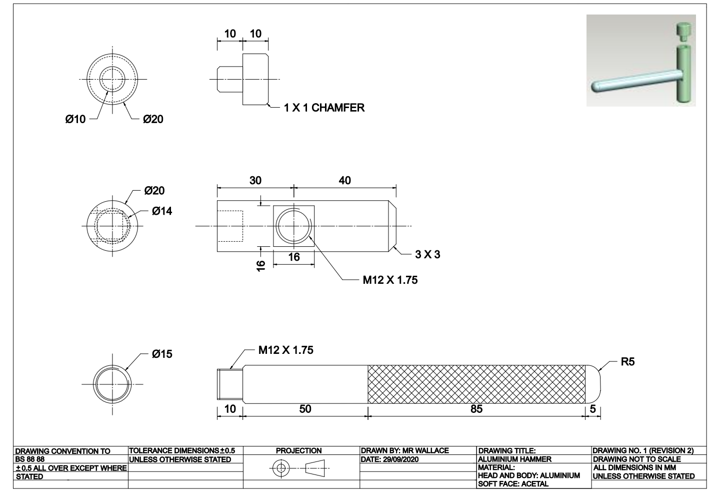
Interpreting orthographic third angle projection drawings

In engineering drawing (sometimes called technical drawings), we are trying to communicate information through a common language than can be understood by all – these are called drawing standards.

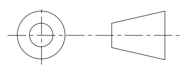
We currently use BS 8888 – 'BS' meaning British Standards developed by the British Standards Institute (BSI). These standards are updated periodically.







Third angle projection explained:

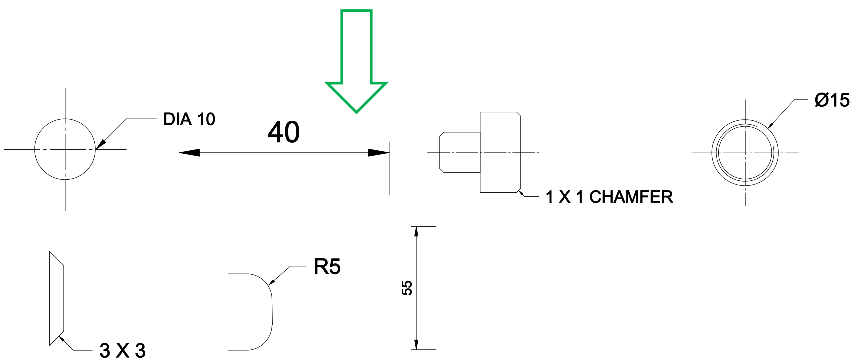


There are two methods of drawing:

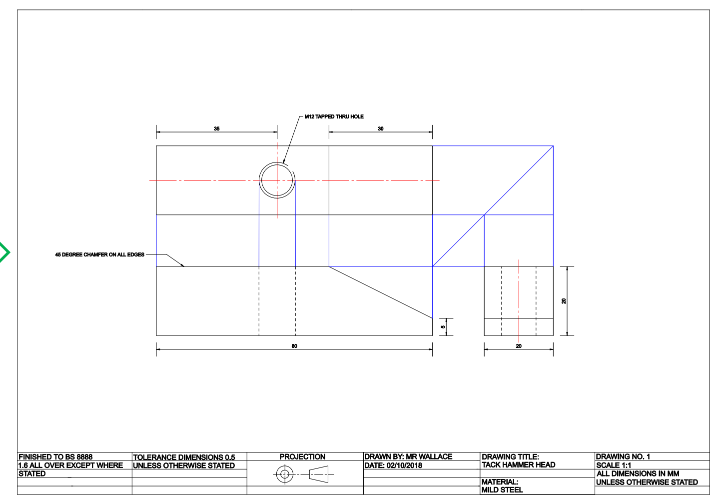
- First angle orthographic projection
- Third angle orthographic projection

In the UK, we use third angle projection. This normally comprises of three views or perspectives (plan, front, end). Specific information is communicated via different line types and abbreviations.

Common line types, symbols, abbreviations and dimension types. Abbreviations are used to help keep drawings from becoming too 'cluttered'.



All lines in engineering drawings are black. The construction lines shown here are in blue to highlight them and demonstrate how they construct the different views of the drawing.



Knowledge organiser: Topic Area 3: Manufacturing requirements

Influence of the scale of manufacture on the production method

Scales of manufacture

One-off (one only) – A bespoke item. Requires highly skilled people. Often a mixture of traditional hand skills and CNC.

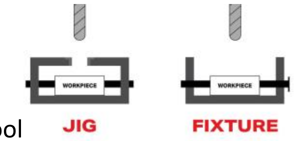
Batch (typically 10s – 1,000s) – Groups of identical items produced simultaneously. Skilled workers and automation are required.

Mass (typically 10,000 – 100,000s) – Often require standardised components and the process is usually highly automated.

Jigs, fixtures, templates and moulds (to speed up the manufacturing process)

A jig both holds the work and guides a tool. A typical example of how a jig might be used is for drilling parts in the same spot continuously and accurately.

A fixture is something that holds work in a given position while a manufacturing process takes place.



Templates can be used to mark out or help guide a cutting tool

Moulds can be positive or negative in shape. They can be used to form material over them or inject/pour molten materials into.

Level of automation

Level of automation can be broken down into three categories, **manual, CAM processes and fully automated robotic control**. CAM processes require fewer humans than manual, fully automated robotic control can be ran with one human overseeing whole engineering plants.

Advantages and limitations of CAM

Computer aided manufacture has many advantages over other methods of production. They include consistency of quality/accuracy, no requirement for breaks (other than scheduled maintenance), and less injuries to staff in hazardous working conditions. Disadvantages include job losses, high set up costs and costly training of staff.

Quality

Reasons for implementing a quality system in engineering

There are many good reasons for implementing quality systems. These include:

Early intercept of problems in production

Reducing waste and associated costs

Consistency of finished products

Conformity to industry standards and regulations

Reduce issues at customer and returns

Quality assurance is a proactive/preventative approach to ensure quality.

Quality control is a reactive approach to check quality.

Knowledge organiser: Topic Area 4: Developments in engineering manufacture

Inventory management

Inventory (often referred to as stock) refers to goods and/or materials held by a business for the purpose of resale or production. Inventory management simply means methods of controlling stock through the manufacturing process or release of materials/products.

Some businesses are manufacturers only, resellers (retailers) only, or can be both – All types of businesses will employ some form of inventory management.

Just in time (JIT) manufacturing

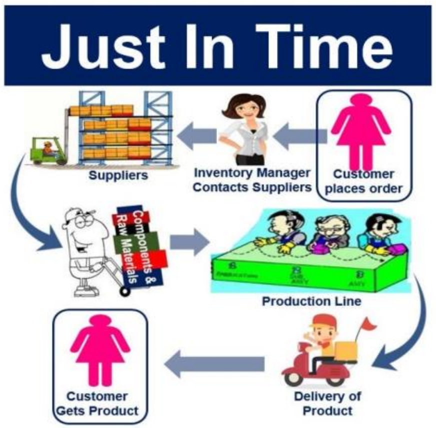
JIT production is a method of organising the manufacture of products so they are made to order – they arrive 'just in time' for the assembly or manufacture of a product.

Benefits include:

- Smaller manufacturing facilities due to no need to store materials/products.
- Products/components never become obsolete
- No risk of unsold stock

Disadvantages:

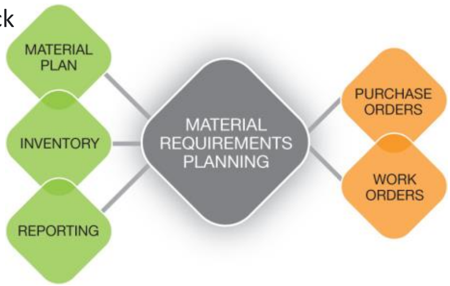
- Reliance on transport networks
- Reliance on reliable suppliers



Material requirements planning (MRP)

Material requirements planning (MRP) is a system for calculating the materials and components needed to manufacture a product. It consists of three primary steps:

1. Taking inventory of the materials and components in stock
2. Identifying which additional ones are needed
3. Scheduling their production or purchase



MRP is done primarily through specialised software.

Benefits include:

- Inventory is available right when it's needed and at the lowest possible cost.
- Improves the efficiency, flexibility and profitability of manufacturing operations.
- It can make factory workers more productive, improve product quality and minimise material and labour costs.
- helps manufacturers respond more quickly to increased demand for their products and avoid production delays.

Disadvantages:

- Software can be expensive
- Cost of training staff
- Still room for human error which can have huge cost implications.

Knowledge organiser: Topic Area 4: Developments in engineering manufacture

Lean manufacturing - The seven categories of waste

Lean manufacturing is a production method which is aimed at reducing times within the production system as well as response times from suppliers and customers.

Transportation Transportation is the process of moving something from one place to another. It does not add any value to the customer, so it should be minimised as much as possible.	**Inventory** This is the waste that is associated with unprocessed inventory. This includes the waste capital tied up in excess stock, wasted transport used moving the inventory, light and heating used to store the excess product.	**Movement** Movement wastage is any movement made that could have been used for another purpose. Anything from staff bending over to pick something up to CNC machines running inefficient programs.
Waiting This is any form of waiting that must be done by either a member of staff or machinery to complete a task.	**Over-processing** Lean manufacturing relies on products delivering value to the customer, but not over-engineering any product.	**Over production** Over-production is perhaps the most obvious form of manufacturing waste. Not only does it unnecessarily use up raw materials, but also wasted storage and excess capital tied up in unused products.

Defects

Not only does it unnecessarily use up raw materials, but also wasted storage and excess capital tied up in unused products.

Globalisation

Globalisation, is the process of interaction and integration among people, companies, and governments worldwide. Globalisation has accelerated since the 18th century due to advances in transportation and communications technology.

Requirement for transportation Selling to as many markets as possible requires materials and products to be transported all over the world via air, sea and land. Globalisation places a huge demand on transportation, and subsequent impact on the environment.	**International standards** Manufacturing to international standards is vital if you hope to sell your products or materials globally. International standards help ensure that materials and products meet a specification which helps keep customers safe.	**Influence on employment opportunities** Manufacturing and selling goods globally has led to many job opportunities around the world, including developing countries.
Differences in employment conditions Terms and conditions of employment relate to the requirements set out in an employee's contract. These outline the rights for both the employee and the business. Employment terms and conditions of businesses can include rights, responsibilities and duties.	**Influence on product cost** Where in the world a product, material or service is sold, can have a huge impact on the cost. This can range from how much the raw materials cost, to how much the product can be sold for based on the economic standing of the country.	**Implications for sustainability** Many manufacturers move their manufacturing facilities to be closer to a source of raw materials. Great care must be taken when doing this so that materials are used in a responsible way such as sourcing timbers from the Forrest Stewardship Council (FSC).

Consideration of economic, social, ethical and environmental implications

We must consider how globalisation can impact the economy of the country we operate from – it can greatly improve developing economies and severely negatively impact others when manufacturing plants move overseas.