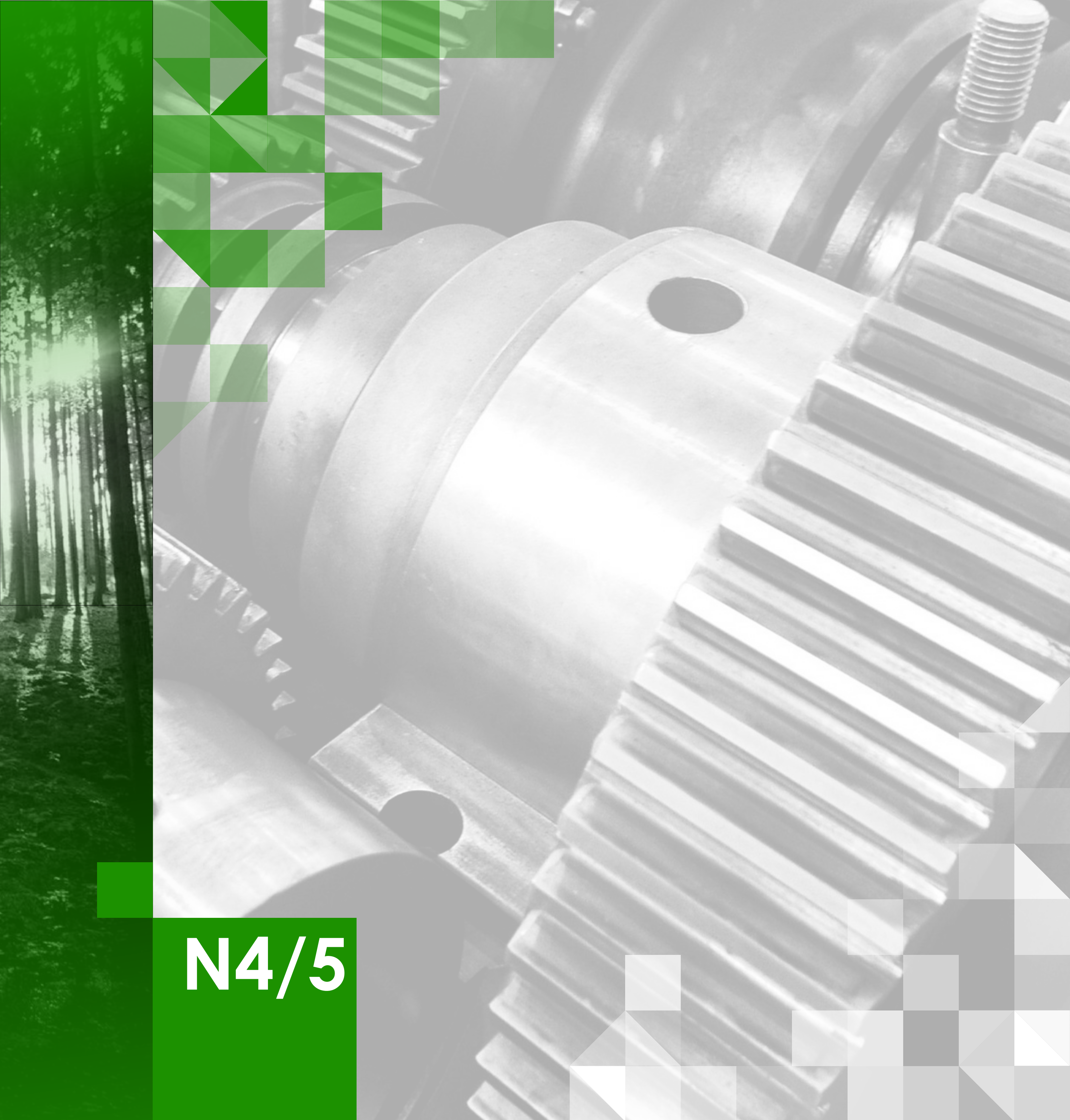


N4/5

MATERIALS & MANUFACTURE

Contents

Classifying Wood

Hardwoods:
Hardwoods come from broad leafed trees and have a wide colour range and grain marking. Hardwoods have very close grain making them less likely to twist/warp and are more aesthetically pleasing than softwoods. Hardwoods can be **deciduous or evergreen**.

Deciduous hardwoods lose their leaves in the winter and are **slow to grow**. They grow mainly in places with cool summers and cold winters.
e.g. oak, ash, elm, birch, beech, walnut and sycamore.

Evergreen hardwoods keep their leaves all year meaning they **grow faster and larger**. These trees grow in warm climates. e.g. teak, mahogany, balsa and ebony.

Hardwoods are **expensive** to buy because they are slow growing. We must be careful not to cut down more than we can grow as this leads to deforestation which can have a severe impact on our climate and environment.

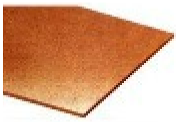
Softwoods:
Softwood trees have needle shaped leaves, are mainly **evergreen (coniferous)** and grow quickly, e.g. pine, cedar, spruce and larch. Softwoods grow in cool or cold areas.

Softwoods are **less expensive than hardwoods** because they **grow fast** and **tend** not to be as strong (though there are exceptions - e.g. balsa is a weak hardwood). They are light coloured with an open grain

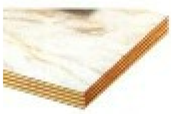
Many softwoods come from **managed forests**; this means that for every tree cut down, at least one more is planted. This is good practice because it means that a constant supply of wood can be maintained making it a **sustainable** material.

Manufactured Boards:
Manufactured boards are supplied in **large sheets**, normally 1200mm by 2400mm and are often a **cheaper** alternative to natural grown timber. They are **stable** and are most commonly used in **mass production** of furniture because of the large economical sizes. They are **eco-friendly** because they use up the waste products from sawmills.

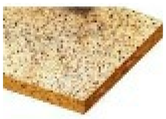
Hardboard is a thin material made from wood fibres. It is often used in places it can't be seen, like the back of a wardrobe/ base of drawers. It is weak and brittle but is very low cost.



Plywood is made from thin sheets of timber called veneers. Each layer is glued with the grain running 90° to the grain of the previous layer. This creates uniform strength across the board.

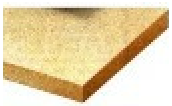


Chipboard is made from wood chips. It is lightweight and only suitable for indoor use. It has unsightly edges which need to be dressed. Chipboard is often covered with a plastic (Melamine) face, for use in furniture and work tops.



Block board is a sandwich of plywood and wood strips. It can be faced with a veneer to give it a decorative finish. It is very strong and is often used in work surfaces

MDF (medium density fibre board) is made from fine wood fibres. This board has a smooth finish on all sides and is the best choice when a good paint finish is required.



Wood Properties & Defects

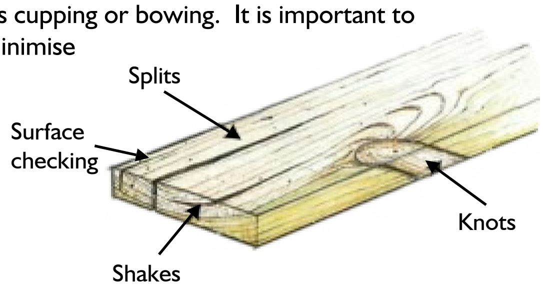
For many projects, the grain pattern, texture and colour are vastly important when deciding on which woods to use. The relative strength and working characteristics are also important but these are usually secondary to the desired aesthetic. Durability is also important - perishable wood will last less than 5 years whereas very durable wood will last 25 years or more; the durability of a species can vary depending on the level of exposure and the climate.

Name of Wood	Properties	Uses	Appearance	Hardwood	Softwood	Source
Beech	Not durable, strong, hard, tough, easily worked	Furniture, veneers, plywood, turnery, steam bending	White/yellow brown, fine texture, straight grain	✓		Euro.
European Oak	Tough, durable, works well with sharp tools, strong, splits, heavy, acidic (corrodes steel)	Joinery, exterior woodwork, furniture, floors, boat building	Light brown, straight grain, coarse texture, broad rays	✓		Euro.
Walnut	Moderately durable, tough, easily worked, heavy	Furniture, interior joinery, turnery, veneer, carving	Grey-brown, coarse even texture, straight or wavy grain	✓		Euro.
European Ash	Works well, flexible, split & shock resistant, perishable	Sport equipment, steam bending, boat building, plywood, veneer	White/pale brown, coarse texture, straight grain	✓		Euro.
Iroko*	Strong, very durable, resistant to fire, moisture, acids & alkalis, difficult to glue, heavy, dulls cutting edges.	Int./ext. Joinery, boat building, turnery, cladding, veneers	Golden to medium brown colour, coarse texture with an oily feel, grain can be straight or wavy (like teak)	✓		S. Asia Africa
Mahogany**	Easy to work with sharp tools, fairly strong, medium weight, durable, warps easily, finishes well	Interior panelling, furniture, joinery, veneer, floors, plywood	Deep reddish-brown, grain can be either straight & even or interlocked, medium textured wood	✓		S. Amer. Africa
Douglas Fir	Works well, fairly durable, tough, splits easily	Building construction, joinery, plywood	Reddish-brown, straight grained and knot free		✓	UK N. Amer.
Parana Pine	Easily worked, not durable, fairly strong, hard	Joinery, furniture, turnery and plywood	Pale brown with streaks of red, straight grain, mostly knot free		✓	S. Amer.
Scots Pine	Works well, resinous, stable, strong, cheap	Building construction, joinery, turnery, plywood, furniture	Cream/pale reddish-brown, can be riddled with knots		✓	Euro.
Red Cedar	Resistant to weather & insects, strong, v. durable	Exterior boarding, furniture, cladding, decking, shingles	Reddish-brown fades to grey, straight grain, coarse texture		✓	UK N. Amer.
Whitewood	Easily worked, not durable, fairly strong, split resistant	Building construction, joinery, plywood, boxes and crates	Pale cream colour with straight grain, fine texture & small knots		✓	Euro. Amer.

*Iroko is commonly used in place of Teak - it has the same appearance and properties but costs half as much - it is oily so requires no preservative and can be used outside.

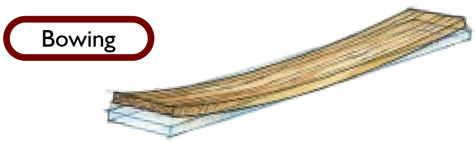
**Mahogany is a term that is used to describe a wide range of timbers including Sapele and Utile - this means that the colour and properties of the wood can vary slightly. Meranti is sometimes used in place of mahogany because it looks similar but is much cheaper. Brazilian mahogany is very expensive and increasingly rare.

Freshly felled and cut trees have to be "seasoned" before being used. This involves removing the moisture from the tree cells to stabilise the wood. Wood can either be naturally air-dried or kiln dried - this is faster but can change the colour of the wood e.g. kiln dried beech turns a pale pink colour. Wood shrinks as it dries and this can lead to distortions (or warping) such as cupping or bowing. It is important to check your wood is sound before working with it to minimise problems and potential product failure.

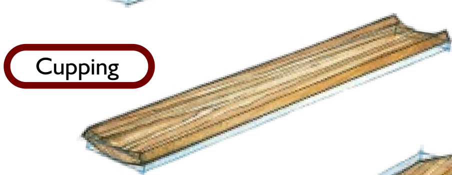


Splits
Caused by exposed end grain drying too rapidly. Sealing the end grain with wax or waterproof paint prevents this.

Surface checking
Similar to a split except the wood opens up on a face rather than an end.



Shakes
These are caused by growth defects or shrinkage stresses that cause the growth rings to open up.



Knots
The remains of cut branches; the wood surrounding a knot has irregular grain and is difficult to work.

Warping
Twisting, cupping & bowing caused by poor seasoning, especially when boards have been stacked incorrectly.

Marking Out

There are specialist tools for marking out wood. You should be able to recognise and name each of

Steel rule

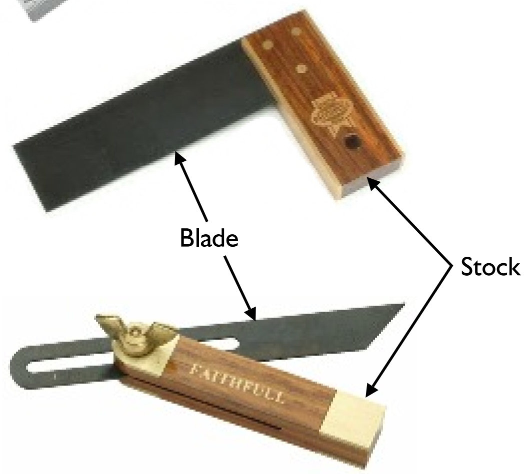
Used for general measuring and marking out. Sizes used should always be mm.

Try square

Used when marking lines across wood at 90° to an edge. The stock should be pressed firmly against the wood to ensure accuracy.

Sliding bevel

Similar to a try square but can be adjusted to draw lines at any angle to an edge. Again the stock must be pressed firmly against the wood when marking out.



Marking knife

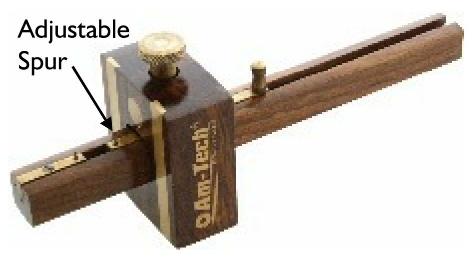
The marking knife cuts across the grain of the timber. It should be used before sawing as it creates a groove which improves accuracy.

Marking gauge

Used to mark lines parallel to an edge. To give a clear line it must be held firmly against an edge and scored lightly across the surface.

Mortise gauge

This has an extra adjustable spur and is used to mark two lines parallel to an edge. E.g. In preparation for cutting a mortise and tenon joint.



Cutting gauge

This can be used instead of a marking knife, to mark a line near to an accurately prepared end. A cutting gauge is similar to a marking gauge but has a blade in place of a

Cutting Tools

There are various types of chisel and saw used in woodwork. They are the most widely used of all woodworking tools and each type has a different use for different tasks.

Safety...

Chisel blades are extremely sharp so great care should be taken when using them:

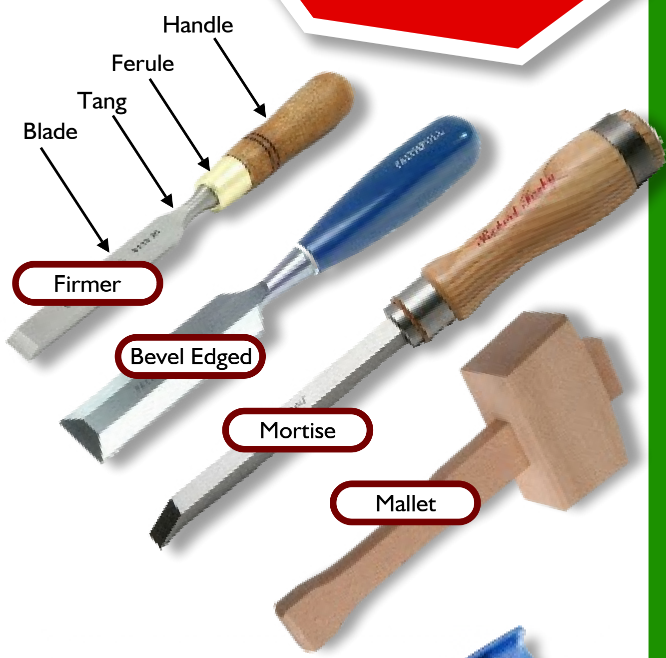
- Any work should be secured in the vice or cramped to the bench.
- Both hands should be behind the blade at all times to ensure the users safety.

Firmer Chisel

This has a rectangular blade and is used for general workshop purposes. The purpose of the metal ferule is to stop the wood handle splitting when struck by a mallet

Bevel Edged Chisel

This chisel has tapered edges to allow it to cut angles less than a right angle for dovetails. It is not as strong as a firmer chisel so is more suitable for use with light work.



Mortise Chisel

This has a square blade to provide extra strength to cope with the leverage needed when cutting a mortise. It should only be used when cutting mortises.

Carpenters Mallet

Not a cutting tool but used for driving wood chisels and for assembling or dismantling joints - because it is made from Beech it won't damage work as a hammer would.

Tenon Saw (back saw)

This is used for accurate, straight cuts in small pieces of wood e.g., When cutting joints. It has a brass back which keeps the blade straight and adds weight to the saw making accurate cutting easier. The back limits the depth of the cut. A tenon saw is an example of a cross-cut saw - it has lots of small alternating teeth, a wide kerf, and is designed to cut across the grain of the wood.

Coping Saw (frame saw)

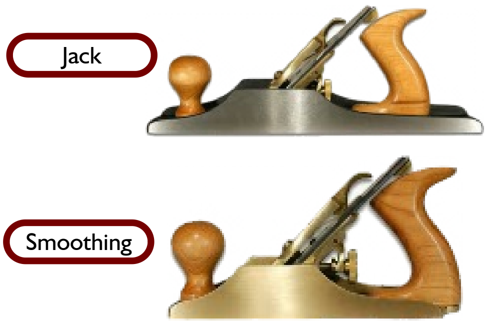
This is used to cut curved shapes in thin timber. The blade usually has the teeth pointing back towards the handle. This type of saw cuts when it is pulled back because the frame is put into tension. The blade can be turned to aid the cutting of irregular shapes. A coping saw can be used to cut out shapes from the middle of a piece of material by inserting the blade through a pre drilled hole before attaching to the frame.

Rip Saw

These saws are designed to cut along the length of the wood, parallel to the grain. The cutting edge of each tooth has a flat front edge and it is not angled forward or backward. This design allows each tooth to act like a chisel (rather than being knife-like, as with a crosscut saw), preventing the saw from following grain lines, which could curve the path of the saw and prevent a straight cut from being achieved.

Planes

Planes are used to shape and clean up wood. You should learn the parts of the plane and know how to use and adjust the blade.



Jack Plane
The most common of all the planes. The jack plane is suitable for achieving a flat surface on larger pieces of timber. It is very versatile plane hence the saying "jack of all trades".

Smoothing Plane
This is shorter and lighter than the Jack plane. It is used for cleaning up work to remove any pencil marks and planing and removing end grain.

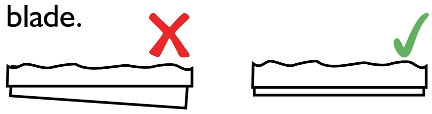
The blade of any plane must be maintained and kept sharp. Since the blade protrudes from the sole of the plane, care must be taken to protect the cutting edge when not in use. This can be achieved by storing the plane on its side.

When planing timber, try to plane in the direction of the grain. Planing against the grain results in a very rough broken surface.

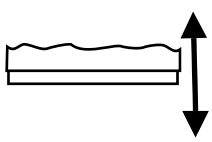
When planing end grain it is necessary to plane the timber from both sides or to cramp a piece of scrap wood to the back edge to prevent the wood splitting.

The plane must be suitably adjusted before use:

Step 1: Moving the **lateral adjustment lever** straightens the blade.



Step 2: Turn the **depth adjustment nut** to set the depth of the blade.



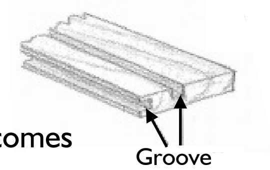
Blade moves up and down. There should be just under 1 mm projecting past the sole

Planes

Specialist planes are available for shaping wood and each has its own particular use.

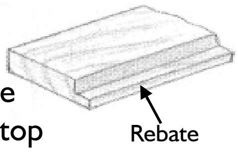
Combination Plane

This is used for running grooves in timber, to accommodate drawer bases, frame panels, etc. It comes supplied with varying shapes of blades which allow a combination of square and curved mouldings.



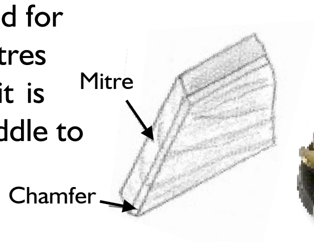
Rebate Plane

This is designed to run rebates for box bases, carcase back panels etc. It is fitted with an adjustable depth stop and side fence; with the blade held in the front mounting, stopped rebates can be run.



Block Plane

The block plane is a small smoothing plane intended for light work. It is suitable for trimming end grain, mitres and running chamfers. When planing end grain it is important to plane from both ends toward the middle to avoid splitting the workpiece.



Spokeshave

A spokeshave is a specialised plane for finishing a curved workpiece. It is controlled by two handles mounted either side of a short blade. The depth of the blade is adjusted by two knurled screws

Hand Router/Router Plane:

A specialised type of hand plane with a broad base and a narrow chisel blade projecting well beyond its base plate. It is used after sawing and chiseling to level out the bottom of joints such as the through housing. It is also used for cutting small recesses for locks and hinges

Surface Preparation

Step 1: Before assembly

Solid timber should be levelled off and cleaned using a smoothing plane.
Man made boards are cleaned using a pencil rubber and fine glass paper.

Glass paper should be used with a sanding cork to get the best possible finish. A power sander can be used for larger areas but sanding should always follow the direction of the grain. Different grades of glass paper should be used starting with coarse and finishing with fine paper like wet and dry.

Step 2: Assembly

During assembly take care no adhesives mark or run onto areas out with the joint. This can occur during cramping when glue is squeezed from the joint. Glue should be applied sparingly to reduce this risk. Any unwanted adhesive should be washed and sanded off immediately. Any residue which is not removed will spoil the applied finish.

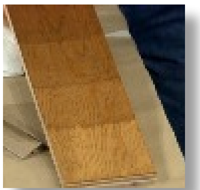
Step 3: Final preparation

After the cramps are removed a final rub down with glass paper is required in preparation for the chosen finish.

Wood Finishes

Stains and Dyes:
These are used to change the colour of wood but like varnish they still allow the grain of the wood to be seen. These should always be tested on scrap wood to test the colour. They can be applied using a brush or rag but should be applied quickly and sparingly to prevent uneven cover. The wood can be waxed to seal the surface. (Any traces of glue will not stain)

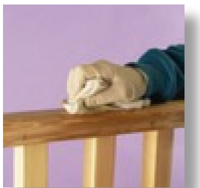
External Wood
- Preservatives such as Creosote are used for external timber.
- They are normally harmful to the skin so great care should be taken when applying them
- Safety goggles and gloves should be used.


Test Stain


Apply Stain


Wipe then Wax

Oil and Wax:
Some woods like teak do not varnish well because they have a high oil content. They would instead be finished using a specialist oil or wax. They should be applied in thin layers using a rag or foam brush (oil) and polished thoroughly between coats using a clean rag. The more work put in the better the finish. Oil and wax seal the wood and allow the grain of the wood to be seen.

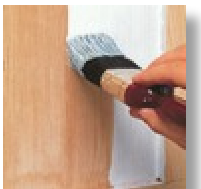

Wipe Down


Apply Finish

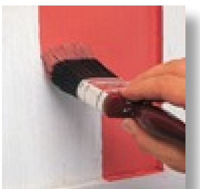

Wipe Excess


Polish

Paint:
There are several advantages to painting wood. It protects the surface, less expensive wood can be used and the colour can be changed to suit any new colour scheme. A primer coat should be applied first to seal and protect the surface of the wood. After lightly rubbing down an undercoat should be applied before a final rub down and the final coat of paint.


Primer


Rub Down


Undercoat

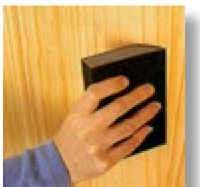

Rubdown


Topcoat

Varnish:
Protects the surface of the wood while allowing the natural colour and grain of the wood to show through. The surface of the wood should be wiped clean before the first coat of varnish is applied to seal the wood. Apply the varnish along the grain, then brush across the grain to make sure the bands have blended. Finish off with light brush strokes along the grain. The surface should be lightly rubbed down then further coats should be applied, dried and rubbed down with fine wire wool until the desired finish is achieved.


Wipe Clean


First Coat


Rub Down


Further Coats


Rub Down

Drilling & Boring

The increased availability of power drills has reduced the need for hand operated drilling apparatus, however quieter, inexpensive manual tools are still used.

Bradawl

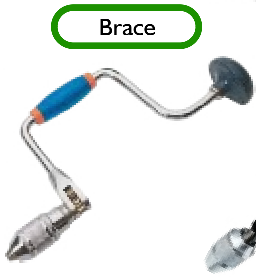
This is used to create a starter hole for either inserting a self tapping screw or for positioning a drill accurately on a mark. It is the simplest tool for boring and is used with a twisting motion.

Power Drills

These are either powered from the mains supply or are cordless with a battery. Most have variable speed selection controlled by how much the trigger is pressed and reverse action to extract wood screws. The torque limiter allows screws to be driven flush without damaging the screw head

Hand Drill

A manually operated tool that is held at right angles to the material and requires no power to operate.



Brace

The brace is another hand tool. It is held at right angles to the material and is generally used with an auger bit. The brace is used to bore and has specially designed square shanked bits.

Twist Drills
Although twist drills are designed for metal they can also be used on wood. Because of the shallow angle of the point it is a good idea to mark the wood with a bradawl to ensure accurate drilling.

Spade Bits
Used for drilling large holes up to 50 mm. The long lead point makes for more accurate drilling even at an angle to the work face.

Forstner Bits
These are used to cut clean flat bottomed holes with a smooth finish. Holes that stop before reaching the far side of the material are known as blind holes.

Rose/Countersink Bits
Used to open the mouth of a hole to allow the head of a countersunk screw to lie flush with the surface of the material.

Dowel Bits
This is like a twist drill except it has a centre point to stop it wandering and two spurs to cut a clean edged hole.

Plug Cutters
This creates a cylindrical plug of wood to match a hole created by boring.

Hole Saws
A hole saw is a cylindrical saw blade on a metal plate with a twist drill that passes through its centre. They range in size from 25-89mm. You should bore slowly and steadily when using a hole saw.

Auger Bits
Used for boring deep holes with a brace, it has a pair of spurs that score the wood ahead of cutting to ensure a crisp edge to the hole.

Machines & Power Tools

Power tools and machines save time and increase accuracy & finish. This will vary depending on the skill of the operator. Power tools are either connected to the mains supply or are cordless with a rechargeable battery. Power tools are useful as the same job can be completed in less time and with reduced physical effort compared to using ordinary hand tools.

Safety...

- Remember to leave tools safe by switching off and unplugging them.
- Always wear safety equipment when using machinery and power tools:
  - A face mask to protect your lungs from dust and fumes
  - Safety goggles to protect your eyes from debris and dust
  - A face screen to protect your full face from debris

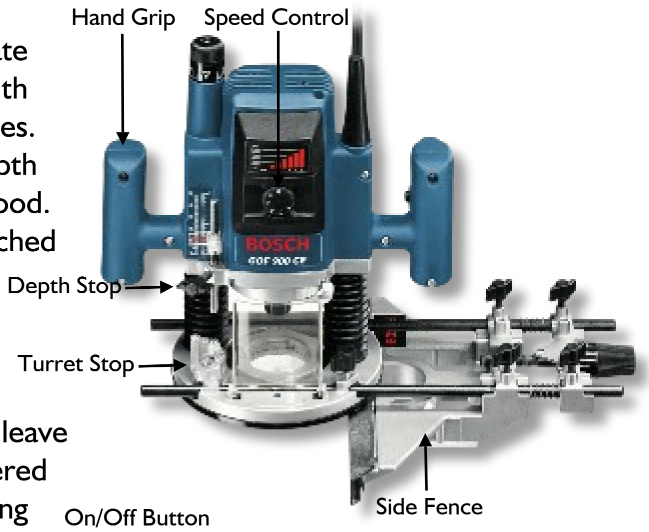
Jigsaw

A jigsaw is used to cut thin to medium material. Different blades can be purchased to allow metal and plastics to be cut. Jigsaws can be used to cut apertures from the centre of sheet material if holes have been pre drilled. When using a jigsaw you should take extra care and:

- *Check that the path of the blade is clear below the work*
- *Make sure the power cord trails behind the tool*
- *Never curl your fingers around the material near the cut*
- *Ease off the trigger when you are about to finish a cut*
- *Switch off and wait until the blade has stopped moving before you put the tool down*

Power Router

A router can be used to cut housing joints and create decorative edgings on wood. Routers can be used with guides and jigs to cut a variety of circles and straight lines. Like a pillar drill they come complete with a built in depth stop to determine how deeply they will cut into the wood. They also have a turret stop to allow a depth to be reached in stages.



Palm Sander

Designed to be operated with one hand, palm sanders leave a smooth, flat surface to work. They have a foam covered base plate which takes sheets of glass paper of varying grades. They are rarely used in the school workshop because of the amount of dust they generate but, given the proper extraction, they are an effective tool. Sanders should be kept moving over the work at all times - stopping or pressing too heavily generates heat which can cause wood dust and resin to block the paper and can also mark your work.

Machines & Power Tools

Machines differ from power tools in that they are usually bolted to the floor. All machines are fitted with an emergency stop button for the user's safety. Because of the potential hazards they present it is important to be extra vigilant, focus on what you are doing, ensure you are wearing all appropriate safety equipment and following safety rules.

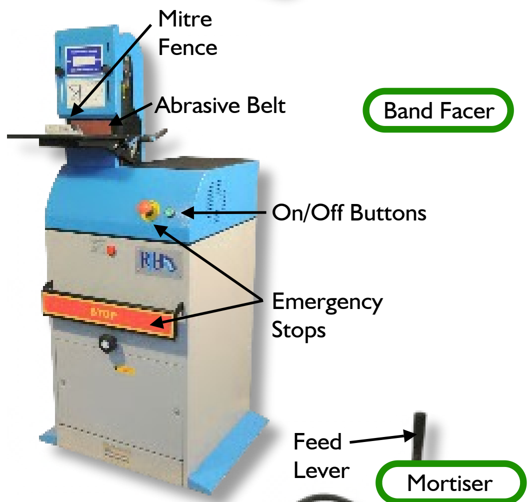
Pillar Drill

A drill, fixed vertically, with an adjustable worktable. Drill bits are held by the chuck whilst the work is clamped to the worktable. Adjust the worktable to bring the work close to the bit, set the depth gauge, centre the bit then switch on. Turn the feed lever to drill the hole then raise it again before turning off. Pillar drills are safe so long as you:

- *Remove the chuck key after fitting a drill bit*
- *Lower the safety guard before switching on*
- *Hold the work securely or clamp it to the worktable*
- *Always clamp metalwork or hold it in a machine vice*

Powered Fret Saw

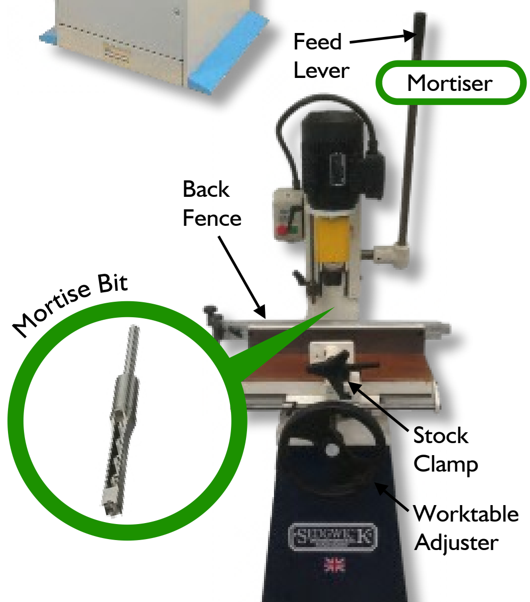
These are generally used for model making and light craft; the fine, thin blades are accurate and allow very tight curves to be cut with ease. Dust extraction is not provided with fret saws so if it is being used for long periods a face mask should be worn. Dust is cleared via a flexible pipe that lightly blows on the material so the cut line remains visible.



Band Facer

Band facers provide a means for quickly shaping components and sanding end grain. An abrasive belt, stretched between two rollers, revolves at a high speed and gradually removes material from a workpiece. A sliding mitre fence allows work to be accurately sanded to an angle. The usual safety rules apply if using a band facer - safety equipment etc. In addition you should:

- *Never sand very small or very thin components as these can easily slip between the belt and worktable exposing your fingertips to the abrasive band*



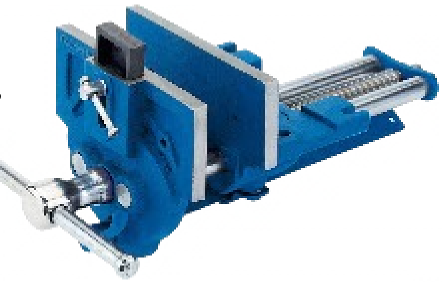
Mortiser

This machine cuts square shaped holes from wood. It has hollow chisels with a drill bit that runs through the centre; the bit removes most of the material whilst the chisel squares up the hole. The machine has a depth stop and a fully adjustable worktable with integrated cramp. Again all the usual safety precautions should be taken when using this machine.

Cramping

Every workshop needs a variety of cramps to hold wood whilst it is worked on or while the glue dries. Before gluing up any project you should select the correct cramp for the size of work and dry cramp before any glue is applied to check for accuracy and fit.

Bench Vice
The bench vice is the most widely used of all holding tools, it should be used to cramp small work while it is marked, cut or glued. Beech is usually used to cover the steel clamping plates (not shown in picture).



Bench Vice

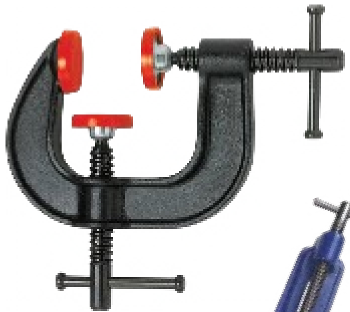
Sash Cramp
Sash cramps are used for holding large assembled work. They consist of a flat steel bar with a screw adjustable jaw at one end and a moveable jaw at the other. The movable jaw is held in the required position by a retaining pin that passes through holes in the steel bar. Sash cramps range in size from 450 - 1200mm.

Sash Cramp

G-cramp
A general purpose cramp that can be used to hold wood down on the bench while it is worked on or to cramp long narrow work (if a series of G-cramps are used). G-cramps are made from cast iron or steel and can damage wood if over tightened, you should therefore use some thin scrap wood to protect your work from the cramp.

G-cramp

Edge Cramp
Similar to a G-cramp these are particularly useful when gluing a veneer on a curved edge. They can also be used to hold thin laminated plywood against a form whilst the glue dries.



Edge Cramp

Mitre Cramp
Mitre cramps hold glued mitre joints at right angles, preventing wood components from moving whilst reinforcing nails are inserted.

Mitre Cramp

Web Cramp
Particularly useful when trying to cramp turned assemblies, this cramp consists of a length of nylon webbing that is wound around a workpiece. The webbing is pulled taut by a ratchet mechanism applying equal force to all corners and surfaces.

Web Cramp

Quick Grip Ratchet Cramp
Quick grips are essential when fast assembly is required. A moveable jaw slides quickly into position then the trigger is used to apply clamping force. Quick grips can also be reversed to pull assemblies apart.

Quick Grip

Adhesives & Fixings

Glue has been used for centuries to join wood to wood; the earliest glues would break down if exposed to moisture but today we have a wide variety of excellent adhesives with different properties - moisture and heat resistant glues; slow or fast setting; even extra long pot life.

PVA Glue

This is the most common workshop adhesive. It is a white ready to use liquid glue which can be supplied in both waterproof and non waterproof forms, it is non-toxic, with a long shelf life. Cramps must be used to hold the work in place until the glue sets. Any excess glue must be wiped off and the area sanded before a finish can be applied.

Contact Adhesive

Supplied as liquids or pastes these are used to attach plastic laminates to flat surfaces. The adhesive must be evenly spread on both surfaces and allowed to 'touch dry' before being aligned and brought into contact. Care must be taken at this stage as it is almost impossible to separate once contact has been made. Contact adhesive is water resistant.

Synthetic Glues

These are made from plastic resins (e.g. epoxy) and provide a very strong bond. They are supplied in two parts which set when mixed. They are all waterproof and widely used for external jobs.

Hot-melt Glues

Cylindrical sticks that are used with electrically heated "guns". The glue sets within seconds making it ideal for constructing models and mock-ups. It's also available in thin sheets for veneering with an iron.

Nails and Hammers

Wire Nails

Used for general purpose joinery work. Wire nails vary in gauge which usually increases with length. Oval wire nails are designed to reduce the risk of splitting wood and their heads can be punched below the surface.

Panel Pins

Used for fixing thin manufactured boards or small joints they are normally short with thin shanks. They have small heads which can be driven below the surface with a nail punch then filled.

Clout Nails

These are galvanised (coated in Zinc) to give a weatherproof coating. They usually have large heads for a larger gripping surface and are most commonly used outdoors e.g. shed roofs

Staples

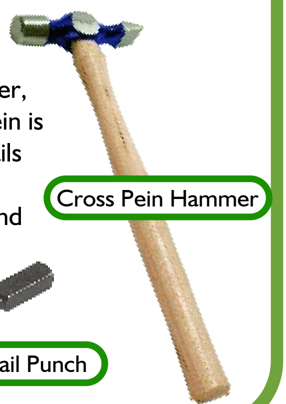
Heavy duty staples can be used for joining thin materials, or securing joints like the mitres on a picture frame.

Claw Hammer

Used for heavy work such as driving large wire nails, the split pein or "claw" is used for levering out bent nails. This version has a rubber sleeve moulded to the shaft for a comfortable non-slip grip.

Cross Pein Hammer

A general purpose woodworking hammer, the wedge shaped pein is used to start small nails or panel pins held between the finger and thumb

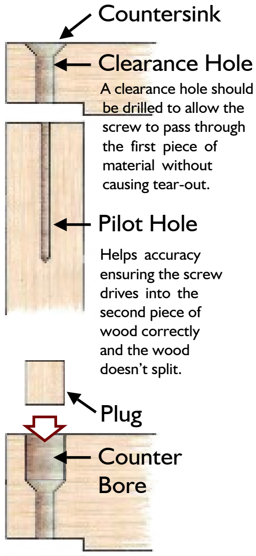


Woodscrews & Fittings

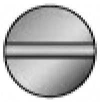
Woodscrews are used for joining wood to wood. They provide good clamping force to create a strong joint that can be easily dismantled if required. They are also used for attaching fittings such as hinges, locks and handles. Most screws are made from stainless steel (resistant to corrosion) and brass (decorative appearance). Steel screws are either chrome plated or "japanned" (black lacquer) to protect them from corrosion and stop them staining the wood.

Screw Slots

The design of the slot(s) that are cut into the head of a screw determines the type of screwdriver that should be used:



Slotted



A single groove is cut across the top to receive a straight-tipped screwdriver.

Crosshead/ Pozidrive

The intersecting slots are designed to receive a Phillips screwdriver which is less likely to slip if pressure is applied.

Clutchhead

A type of thief-proof screw that requires a special screwdriver and is used for fixing locks to finished work.

Torx/Star and Allen

These require special "keys" to operate. They tend to be used in the assembly of flat pack furniture. The six points further reduce the chance of tool slippage.

Design of Screws

The spiral threads on screws bite into the wood to draw two pieces of wood together; this makes it very difficult to pull the pieces apart (unlike nails). Most screws have a "shank" which acts like a dowel but some screws are "shankless". These provide a strong fixing and tend to be used with manufactured boards as they help reinforce the material. Screws also have different heads:

Countersink Head

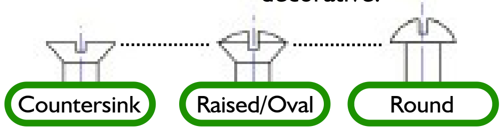
The head of countersunk screws taper inwards towards the shank. Countersunk screws are used when the head of the screw needs to be flush with the surface.

Raised Head

The head is slightly domed and is normally used to attach metal fittings like sliding bolts or handles.

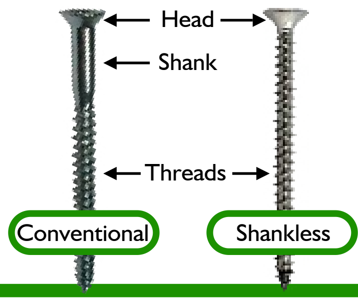
Round Head

These are used where metal is to be joined to wood, and it doesn't matter if the head is not flush. They are quite decorative.



Screw Cups

Used when it is likely the screw will be removed from time to time, to prevent damage to the surface and improve appearance.



Knock Down Fittings

These fittings are designed for use with butt joints and require precisely bored holes for accurate positioning - they are used in flat pack furniture and when it is desirable to take assemblies apart quickly.

Chipboard Insert

Nylon inserts that improve the strength of chipboard joints by expanding when a screw is tightened into them.

Panel Connector

Used to bolt boards edge to edge - a blind hole is drilled on the underside of each panel with a narrow channel linking them, turning a nut draws the panels together.

Cam Fitting

Used with manufactured boards - a metal dowel is screwed into one board whist a boss is placed in the other - turning the boss pulls the joint tight.

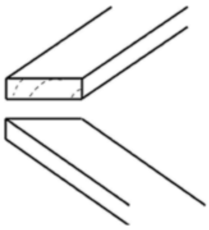
Corner Plates

These form demountable joints between table legs and rails. It is held in place with woodscrews and a tightening nut pulls the assembly together.

Joining Wood

Frame Construction

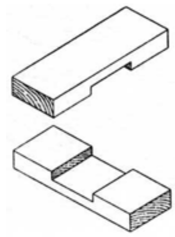
Flat frames are used widely in manufacturing a variety of products including doors, windows, mirror/picture frames, benches and many, many more. Certain joints will be more suited to some projects than others and selecting the right one is important. You have to consider aspects such as **how difficult** the joint is to manufacture (and the **time** required) as well as the **strength** of the joint and the **strains** that will be put upon it. **Aesthetics** are also an important consideration - will the joint be seen?



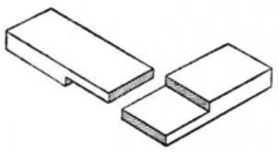
Mitre Joint

Mitre joints are often used to produce the corners of picture frames and boxes. The mitre needs to be cut at a 45 degree angle using either a **mitre saw** or **mitre box**. Though aesthetically pleasing and easy to make this joint is **weak.**

Cross Halving



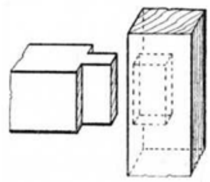
Each piece of timber has half its thickness removed. It may be held together using glue, dowel rod or screws. The joint is **reasonably strong** but marking out and cutting have to be **accurate** to ensure a good aesthetic and fit.



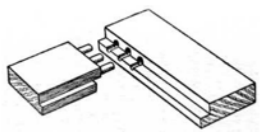
Corner Halving

Similar to the cross halving with half the thickness removed from both pieces. It is much **stronger than the mitre joint but not as attractive** when viewed from the side because end grain is visible.

Mortise & Tenon



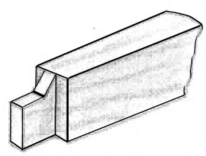
A **very strong** joint popular in the construction of chairs and tables. The thickness of the tenon should be one third the thickness of the rail. The shoulders on the tenon must be cut **accurately** to ensure there are no unsightly joint gaps.



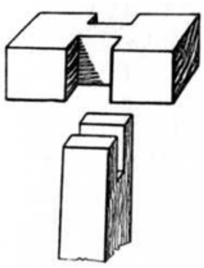
Dowel

Both pieces of wood are drilled to allow the dowel rod to be glued into place and form the corner joint. It is **quite strong** but needs **great accuracy** in marking out and drilling.

Haunched Mortise & Tenon



This variation is used if the joint is at the end of a frame as the tenon will be hidden. It retains the strength and looks better.



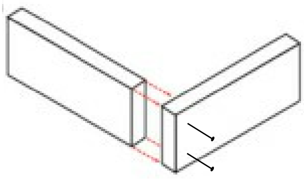
Bridle

The bridle joint is similar to the mortise and tenon except the mortised part is open at one end to allow the other member to be set in place. It is **equally as strong** as the mortise and tenon with a similar gluing area.

Joining Wood

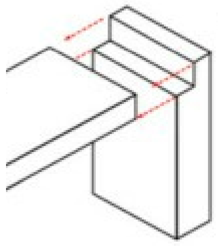
Carcase Construction

Carcase constructions are used in the manufacturing of cabinets, bookcases, benches and a wide variety of furniture. Certain joints will be more suited to some projects than others and selecting the right one is important. You have to consider aspects such as **how difficult** the joint is to manufacture (and the **time** required) as well as the **strength** of the joint and the **strains** that will be put upon it. **Aesthetics** are also an important consideration - will the joint be seen?



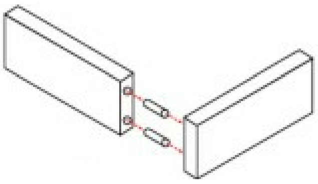
Butt Joint

A very simple joint but it is also **very weak**. Formed by simply gluing the wood together to make a corner; nails are often used to strengthen the joint.



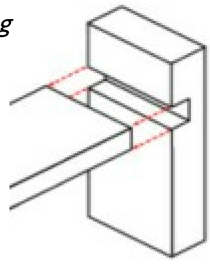
Corner Rebate

This has half the thickness of one piece of timber removed to create a shoulder. This **adds strength** and makes it easier to glue and pin the pieces together at right angles.



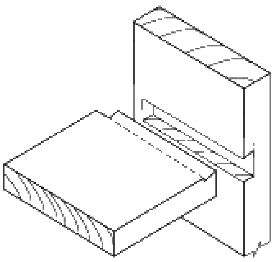
Dowel Joint

Both pieces of wood are drilled to allow the dowel rod to be glued into place and form the corner joint. It is **quite strong** but needs great **accuracy** in marking out and drilling.



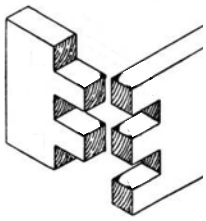
Through Housing

These are used to fit shelves or dividers into furniture. A through housing is simple to cut as it goes across the width of the wood. It is **reasonably strong** though not as aesthetically pleasing as the stopped housing.



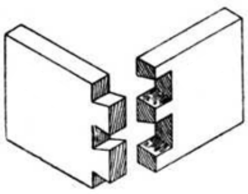
Stopped Housing

The stopped housing is **equally as strong** as the through housing but more **difficult** to cut. Because the cut is hidden it is much **neater** and aesthetically pleasing when viewed from the front.



Finger Joint

This is the second strongest joint on this page, the only joint that is stronger is the dovetail joint. The finger joint can be **difficult to make** but **looks very good**. It has a lot of surface area for gluing which is where the strength comes from.



Dovetail Joint

The **strongest carcase joint** but also the **most difficult to make**. The pins interlock with the tails making it nearly impossible to pull apart. The pins and tails have a trapezoidal shape which, once glued, require no mechanical fixing.

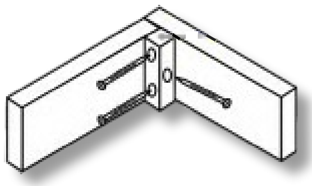
Joining Wood

Manufactured Boards

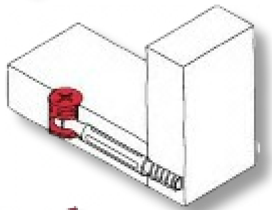
Manufactured boards are not assembled using traditional woodwork joints because the boards don't have the same integral strength as natural wood. Instead they use modern manufacturing methods including specialised fittings.

Manufactured boards have grown in popularity for the manufacture of **mass market furniture**. Stores like Ikea have opted for these cheaper materials as consumers change furniture more often and there is increased demand for low cost items. Companies like Ikea benefit as their products use standard components. Unlike a one off production, these mass produced items are flat packed and do not require skilled workers to cut accurate joints instead they are assembled at home using special knock down fittings.

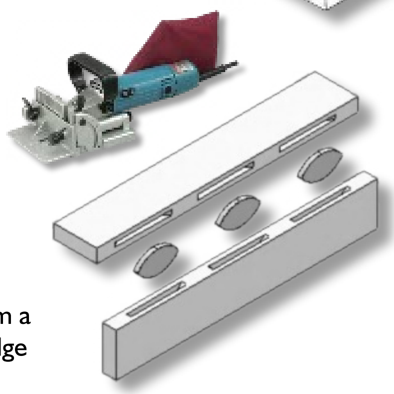
Housing joints could be used for joining boards but are difficult to cut accurately by hand and can weaken the board depending on its type; it may be easier to use a simpler method:



Method 1: Block Joint
Using timber lengths 20 mm x 20 mm in section cut to a length suitable for the width of the manufactured board. This would be drilled, glued and screwed to join pieces at right angles.



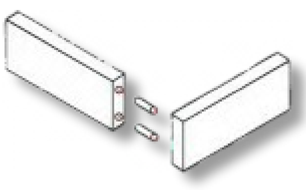
Method 2: Knock Down Fitting
Drill holes in the appropriate places and use knock down fittings including "cam and bolt" shown opposite.



Method 3: Biscuit Joint
This joint requires a specialist piece of equipment - a biscuit jointer* - a small circular saw blade cuts a crescent-shaped hole in the edges of two manufactured boards. An oval-shaped, dried and compressed wooden biscuit (beech or particle wood) is covered with glue, placed in the slot, then the two boards are clamped together. The wet glue expands the biscuit, further improving the bond.

*In the workshop the jointer should only be used by, or under strict supervision of, a teacher.

Method 4: Dowel Joint
Both boards are drilled to allow the dowel rod to be glued into place and form a corner joint. This type of joint can be used to join wood at right angles and edge to edge.



Method 5: Screw Connectors
Regular screws that are driven directly into chipboard and mdf will not hold very well. For mechanically fixing two pieces of particle board specially-designed connectors can be used. These connectors have very shallow countersunk heads which, when driven into a predrilled pilot hole, forms its own countersink (except in melamine faced boards). They have deeper threads than wood screws to "bite" into the material more.

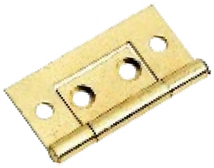
Some manufactured boards have unsightly edges, showing end grain or wood chips. Thin strips of matching timber or wooden veneers can be glued to the edges to improve appearance or boards can be mitred to hide the edges.

Ironmongery

Ironmongery is a generic term for metal fixings and fittings including hinges, handles and locks. Well made hardware is relatively expensive but cheaper alternatives can ruin the appearance of an aesthetically pleasing work piece.

Butt Hinge

A traditional cabinet makers hinge. It is used for hanging doors and attaching lids; these hinges require a recess, they range in size from 20 - 150 mm. They are usually made from steel or brass.



Flush Hinge

These are not recessed so the weight of the door is only supported by screws; this means they are only suitable for lightweight doors and lids. They are usually made from steel or brass and range from 30 - 150 mm.

Concealed Hinge

A modern hinge that allows tiny adjustments so that rows of doors can be accurately aligned. They require a blind hole to be drilled in the door of the work piece which receives a circular boss from the hinge.

Lift-off Hinge

These are used when it is necessary to remove a hinged component quickly e.g. cleaning a mirrored door. They are usually made from brass, steel or aluminium and are available in right or left hand versions.

Piano Hinge

Available in lengths up to 2 metres, this type of hinge is used when an exceptionally strong fitting is required. It spreads the load and has a neat finish; it can also be cut to fit the workpiece. It is usually made from brass or steel.

Fall-flap Lock

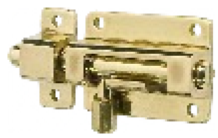
This lock requires a through hole and a counter-bore in the back of the workpiece door so that the lock lies flush. When the key is turned a bolt locks the door against an L-shaped plate.

Magnetic Catch

A small encased magnet is screwed to the inside of a carcase workpiece, this attracts a metal plate which is fixed to the door of the construction. It is important to align the two accurately to ensure good contact.

Ball Catch

This comprises a cylindrical case with a spring loaded steel ball that is inserted into the edge of a door. When closed the ball springs into a recess in a metal plate that is fixed into the carcase; accurate alignment is essential.



Slide Bolt

These tend to be used on gates and external doors but they can also be used for internal applications e.g. bathroom doors. Some varieties come with a fitting for a padlock whilst others can be more decorative.

Knobs

Made in a variety of sizes to suit furniture ranging from small cabinets to large wardrobes. They are attached by passing a screw through the workpiece into the knob.

Sliding-door Handle

These are circular or rectangular recessed inserts that are glued into sliding doors to allow them to pass one another. They are designed to be used with a pushing motion by fingertips.

Drop Handle

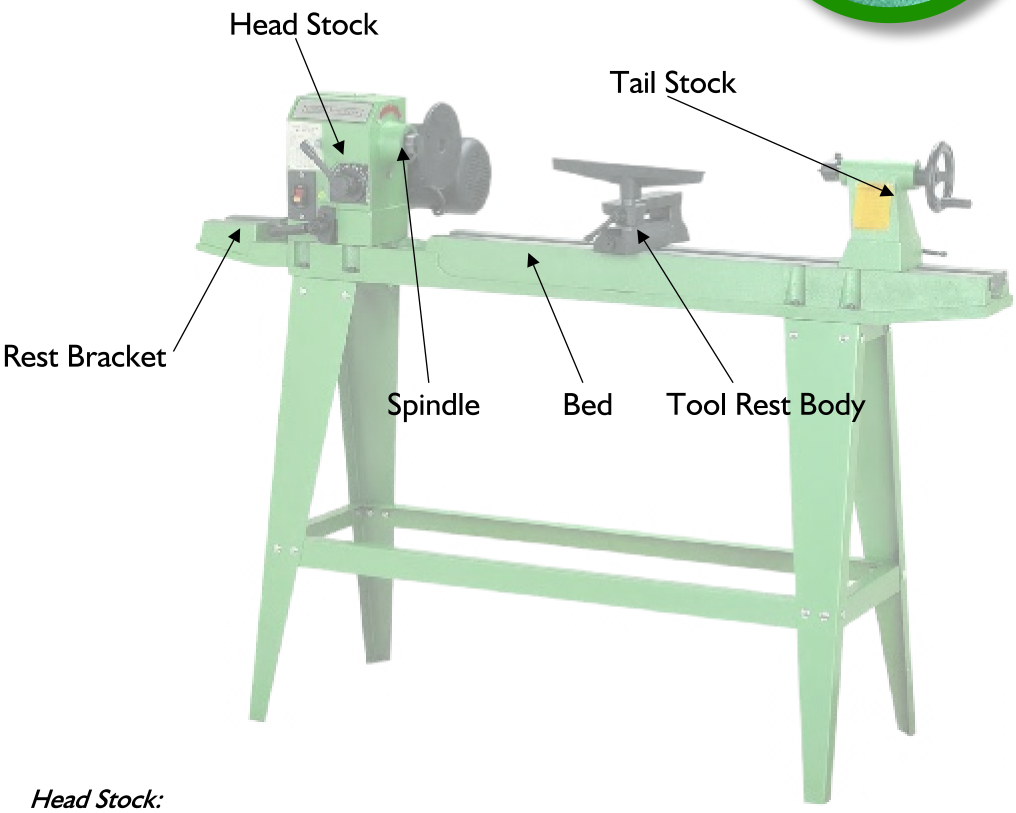
A decorative handle designed to be gripped by fingers and thumb. Since they tend to be small they are only suitable for lightweight doors and lids.

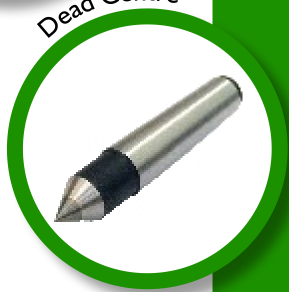
"D" Handle

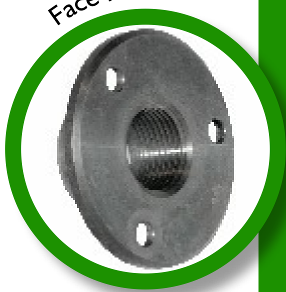
These slim handles suit simple modern furniture and are designed for a full hand grip making them suitable for medium weight applications. They are made with threaded inserts for screwed attachment.

Wood Lathe

Lathes are used to turn square in section into cylindrical spindles. You should be able to name parts of the lathe and accessories and explain their purpose.







Head Stock:
Contains the motor and belts that control the lathes speed and drive the spindle. For large diameter work like plates and bowls, the lathe speed should be slowed down .

Spindle:
Threaded at both ends to allow a face plate to be attached for turning bowls. The right end of the spindle allows a driving centre to be inserted.

Bed:
Supports the tool rest and the tail stock.

Tool Rest Body:
Holds the tool rests and can be adjusted by position and height for safe turning.

Tail Stock:
Used to support timber between centres. It can also hold a drill chuck.

Rest Bracket:
Positioned on the left side of the lathe, it is used when turning bowls and other items with large diameters.

Dead Centre:
Attached to the tail stock, used to support the wood. This centre may need to be lubricated to prevent burning caused by friction. (liquid soap can be used)

Revolving/ Live Centre:
Turns with the wood creating less friction and preventing burning.

Faceplate:
Attached to the outside end of the head stock for holding wood when turning plates or bowls.

Fork Centre:
Used to hold long pieces of timber securely for turning.

Using a Wood Lathe

Detail can be added to turnery using the wide variety of chisels below. You should learn them, how to prepare wood for the lathe and how to operate it safely.

Tools

Gouges are used to remove wood quickly to a rough finish. They come in various shapes and sizes and can be used to turn decorative curves on the blank.

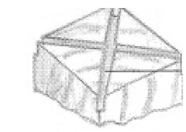
Chisels are used to give fine decorative cuts and a good surface finish.

Scrapers are used to smooth and finish the work before glass papering.

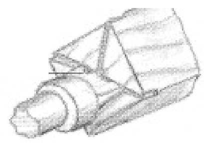
Parting chisels are used to cut the finished article from the work piece. Parting chisels can be used to create flat shoulders between diameters on turnery.

Preparing timber for the lathe

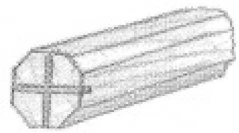
Mark the diagonals on both ends of the wood to identify the centres. Saw down the diagonals on one end (roughly 3-5mm depth) to allow the fork centre to achieve a firm grip.



The **blank** (piece of wood to be turned) should always be longer than the length of the final piece required. This allows the damaged ends which are held by the fork and revolving centres to be removed.



The edges of the blank can be planed off to make the blank closer to a cylinder shape. This makes the initial turning easier.



When turning, the **outside callipers** shown are used to measure and check the outside diameter of the work. **Inside callipers** check internal sizes.

Designing Turnery

By using the range of lathe tools we can create interesting features on our turnery:

- **Coves** are U-shaped features created by gouges.
- **Beads** are projecting features created by V-groove and skew chisels along with a small gouge.
- A **Parting** is a flat feature on the piece that is used either for decoration or to separate the finished turnery from the blank .

Metal Properties

When designing a product made from metal it is important to select one with the **correct properties:**

- How will the product be used?
- Where will the product be used?
- What conditions will the product be used under?

Asking these questions will help you to determine whether the metal used should be lightweight…or resistant to rust…or heavy and strong.

The natural properties of pure metals can be improved by **alloying** them with other elements e.g. iron is quite weak but when alloyed with carbon to make steel the result is a much harder and stronger metal. The properties of metals can also be improved by **heat treatment** to make them harder or easier to work.

Ferrous Metals…

- Contain iron
- Are magnetic
- Need protection against corrosion

Type of Metal	Properties	Uses	Appearance	Ferrous	Non Ferrous	Alloy	Pure Metal
Aluminium	Lightweight and easily formed.	Drinks cans, cooking utensils, vehicle bodies, window frames.	Bright Silver		✓		✓
Copper	Conducts electricity and heat. Easily formed.	Electrical wire, circuitry, water pipes and boilers.	Red-Orange		✓		✓
Tin	Soft and easily formed.	Plating steel and soldering.	Silvery-White		✓		✓
Brass	Casts well and is easily joined by soldering/brazing.	Screws, hinges, door handles and other decorative uses.	Gold coloured		✓	✓	
Duralumin	Lightweight and strong.	Aircraft parts.	Silver coloured		✓	✓	
Mild Steel	Easily welded/formed but needs surface protection.	Bridges, car bodies, screws, nuts & bolts.	Blue-Grey	✓		✓	
Stainless Steel	Forms well and is resistant to rust.	Garden tools, sinks, cutlery.	Shiny silver	✓		✓	
Tool Steel	Hard wearing but brittle.	Drills, files, chisels and screwdrivers.	Black	✓		✓	

Properties of Metal

Brittleness: Easily broken, when struck, with little or no bending at the breaking point. A metal can be very hard but brittle.

Ductility: May be drawn out - pulled into shape like **copper wire**.

Elasticity: Any bending, or stretching, produced by a force disappears when the force is removed. Similar in action to an elastic band.

Hardness: Material offers resistance to penetration or to scratching. **Tool steel** is very hard.

Malleability: Able to be hammered out into thin sheets or small bars without cracking. Can be pressed or rolled.

Strength: Ability to resist a force without breaking. Forces may be in tension, compression, shear, torsion, or a combination of these.

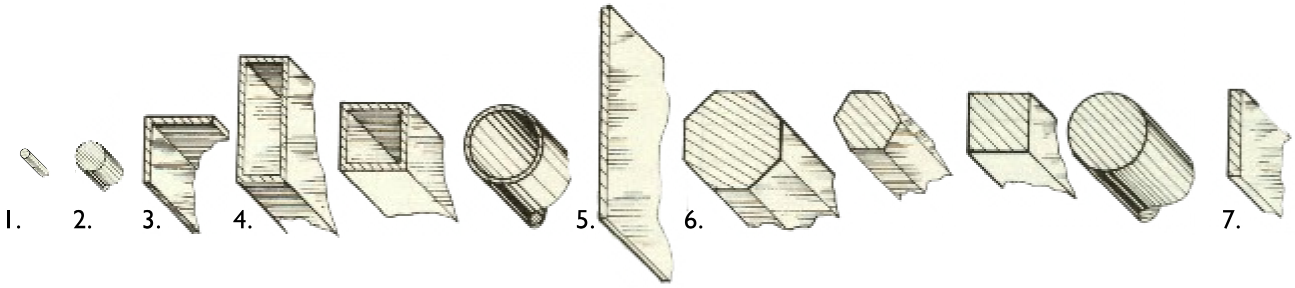
Toughness: Considerable energy required to break. Ability to resist sudden blows, bends or twists.

Conductivity: Heat and electricity are easily transmitted through the material. All metals are conductive but some are better conductors than others.

Working with Metal

Metals are available in a wide range of **standard** shapes and sizes; this makes designing and manufacturing easier because the **same material** can be bought from different suppliers and we can **plan to minimise the amount of waste** material. The most common forms that metal is supplied in are:

1. **Wire**	Thin, pliable round rod.	5. **Sheet**	Large sheets of metal - quite thin.
2. **Rod**	Small section round bar.	6. **Bar**	Square, round, hex and octagonal
3. **Angle**	L - shaped sections	7. **Flats**	Long strips up to 6 mm thick.
4. **Tube**	Hollow bar - square, rectangular and round.		



Marking Out Tools

Steel rule

Used for general measuring and marking out. Sizes used should always be mm.

Centre Punch

Used to mark the position of holes before drilling. One gentle tap from a hammer is all that is needed to create a small pit in the metal to improve accuracy

Scriber

Used to mark out metal by etching slightly into the surface of the material similar to using a pencil on wood

Engineer's Square

Similar to a try square this tool is used when marking lines across metal at 90° to an edge. The stock should be held firm to the edge to ensure accuracy

Odd-Leg Calipers

Used to scribe a line parallel to an edge of a piece of metal. The toe should be held firm to the edge to ensure accuracy

Spring Dividers

Used like a pair of compasses to scribe a circle or arc around a centre point

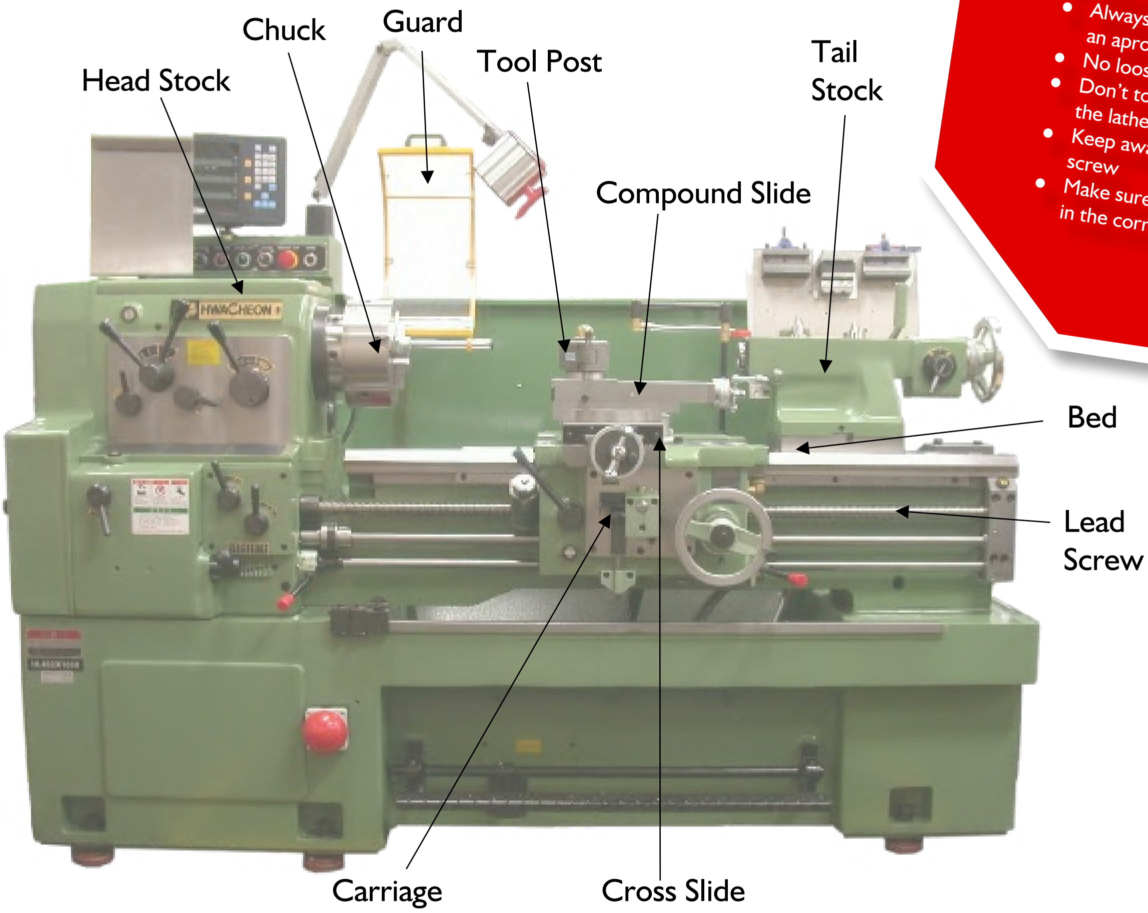
Traditional Technology

The tools opposite are tried and tested marking out instruments that are appropriate for small scale manufacturing.

If multiple objects fashioned from metal are required then CAD CAM technology should be used. This is faster, more cost effective and quality can be assured; however there is a higher initial cost to buy machinery and train people to use it.

See Industrial Manufacture for more info.

Metal Lathe



Safety…

- Ensure the guard is down
- Always wear eye protection and an apron
- No loose clothing or long hair
- Don't touch swarf, or job, when the lathe is moving
- Keep away from a moving lead screw
- Make sure the machine is moving in the correct direction

Compound Slide
Can be set easily at any angle cutting parallel or angled (tapered). Holds the tool post.Finer cutting motion.

Cross Slide
Used to move the cutting tool across the bed of the lathe. Positioned on top of the carriage and under the compound slide. Fine cutting motion.

Bed
Part of the lathe which every other part is connected to. Must be cared for and kept clean.

Carriage
Part of the lathe that carries all the cutting tools mechanisms along the bed of the lathe. Often also called the saddle.

Chuck
The part of the lathe that holds the job. There are 3 and 4 jaw varieties, both designed to hold the job securely.

Headstock
Part of the lathe where all the gears and power train are kept. Holds the on/off switches and the speed controls.

Lead Screw
A long threaded bar attached, when required, to the carriage or cross slide giving automated movement. This has the advantage of giving a better finish. Also used to cut large threads semiautomatically.

Tail Stock
Sits securely on the lathe bed to allow a dead or live centre to hold long pieces of material. Can also be used to hold a Jacob's chuck for drilling parallel to the centre line of the lathe.

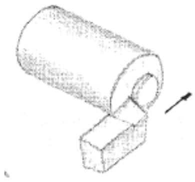
Toolpost
Block which holds the lathe tool in place. Easily set for both angle and height to allow the quick adjustment of the cutting tool.

Using a Metal Lathe

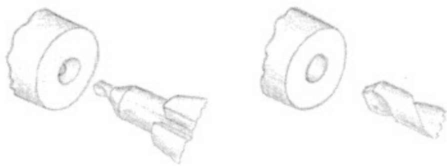
This large machine is used to turn lengths of metal bar, cutting with special tools designed specifically for use with metal working lathes.
The resulting part will be circular in shape. Multiple speeds help to ensure a good finish.

Lathe Processes

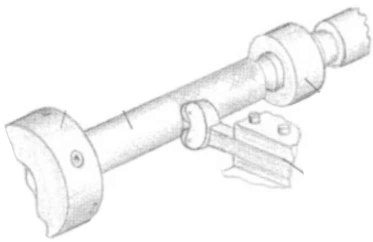
Facing
Cutting across the job, at right angles to the bed of the lathe. This will remove any saw marks.



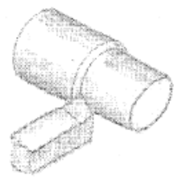
Drilling
Using standard twist drills, parallel to the bed of the lathe on a previously faced surface. Should be prepared using a slocomb drill.



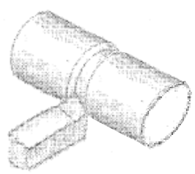
Knurlling
Cutting a rough surface onto the job.
Tool has two cutting wheels.
Must be done at a very slow machine speed while moving parallel to the bed.
Automatic feed must also be slow.



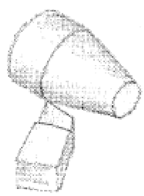
Parallel Turning
Cutting along the length of the job, parallel to the lathe bed. This will make the metal thinner.



Parting Off
Cutting a completed job from a larger bar of metal. Must be done at a much slower machine speed.



Taper Turning
Cutting at a different angle from the lathe bed. Used to make sloped surfaces.



Forging

Forging is an age old manufacturing process which, though technology has changed, is still used today for producing metal components and products. Parts produced at a forge are stronger than those that are cast, this is because as the part is beaten into shape the internal structure changes to follow the shape of the part. You need to know the various parts of the hearth and what/how they are used:

Safety…

When working at the forge it is important that you protect yourself; you should therefore ensure you wear:

- Heat resistant / leather gloves to protect your hands
- A leather apron which is heat and fire resistant to protect your body and clothes
- Safety goggles or a face screen to protect your eyes
- Sensible shoes i.e. no sandals or open top plimsoles.

Hearth
The machine that is used to heat the metal before it is worked. It uses gas as a fuel to provide enough heat. Alumina chips are heated to a high temperature in the forge area to allow metal to be worked. It has built in extraction which must be turned on before you begin forge-work.

Torch
The gas operated tool used to supply directional heat on the metal that is to be worked. There are two feed hoses - one for the gas and one for air - adjusting the mix increases the size and heat of the flame.

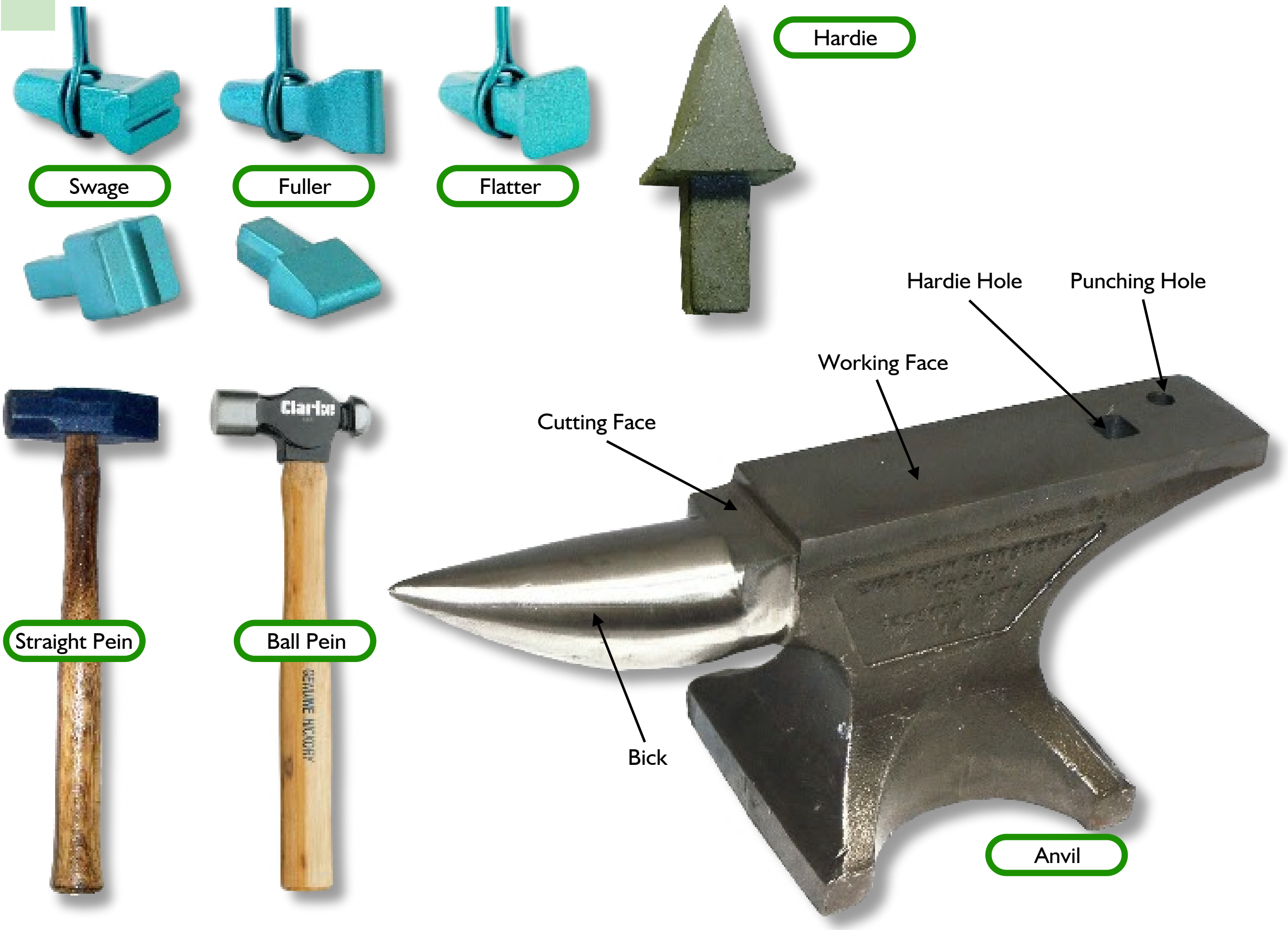
Fire Bricks
These are special bricks that are used in the hearth to retain and direct heat. They are often used in a semi-circle to focus the heat around an object.

Brazing station
This area is dedicated to the joining of two metals by using the brazing process (similar to soldering). Fire bricks are used to contain the heat around the metals being joined.

Tongs
Tongs are used for holding hot metals securely. The mouths are custom made by the smith in various shapes to suit the gripping of various shapes of metal. They are used for holding at the forge and for holding whilst shaping at the anvil.

Forging Tools

Once heated to the optimum working temperature the metal can then be shaped. This is done using an anvil and various specialised tools that are specific to the metal working process.



Anvil
The anvil acts like a work bench for forged metal to be worked and shaped. Anvils are cast or forged from tool steel. The flat top has two holes; the square hole is called the hardie hole, this takes specialised tools for shaping metal. The smaller hole is called the punch hole, as the name suggests, it is for punching holes in hot metal. The bick tapers to a point and is used for bending metal to a radius.

Hardie
The hardie is a cutting tool similar to a chisel. It is used for cutting both hot and cold metals. It has a square shank that fits into the hardie hole in the anvil, with the cutting edge facing upwards. The metal to be cut is placed on the cutting edge and struck with a hammer.

Swage, Fuller and Flatter
These are shaping tools designed to be used with the hardie hole (swage & fuller) or with the working face (flatter). The swage has semi-circular grooves for finishing metal to a rounded shape; it comes in a variety of sizes with different radii. Fullers have a smooth rounded shape and are used for rounding corners and for thinning and spreading (drawing) the metal. Flatters are used on the workface to smooth the surface of the metal after being worked with a fuller. All of these tools are used in conjunction with a hammer.

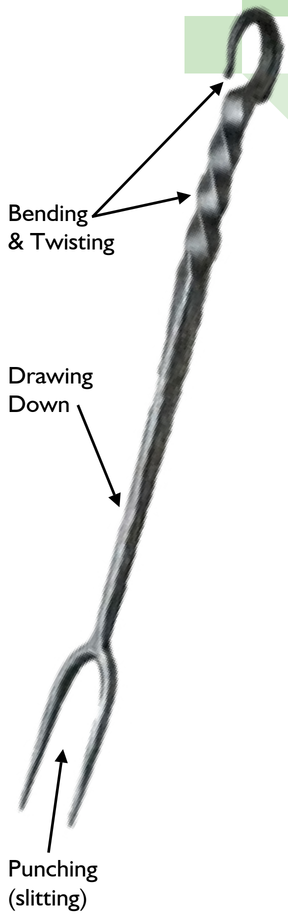
Straight and Ball Pein Hammers
These are both designed for use with metal. The straight pein (or blacksmith's hammer) looks like a cross pein but differs because the pein runs parallel to the handle; this makes it easier to see where a strike will land. The pein is used similar to a fuller and occasionally like a chisel. The ball pein hammer is the most commonly used in metalwork. The striking face is used for hitting punches and chisels whilst the ball pein is used to shape the metal without marking it during the forging process and also to roll off the edges of rivets when joining metal.

Forging Processes

There are various shaping processes that can be used to get the desired outcome for the finished product. Metals can also be treated to make them easier to work or perform in a certain way:

Drawing Down

This involves tapering the metal to a round or square point, the metal should be heated only at the end and rotated during working. Drawing down increases the length of the metal by decreasing the thickness or width.



Bending

Bending can be done with the hammer over the bick or edge of the anvil. Bends can be adjusted by hammering them over the appropriately shaped part of the anvil. Twists can be made be heating an area of square bar, locking it in an engineer's vice and completing a turn with a twisting wrench.

Upsetting

Upsetting is the process of making metal thicker in one dimension through shortening in the other. By heating an area of a rod or bar and then hammering the end it, like you would a nail, the rod gets shorter and the hot part widens.

Punching

Punching may be done to create a decorative pattern, or to make a hole. The process is not limited to depressions and holes. It also includes cutting, slitting, and drifting—all done with a chisel. The punch hole of the anvil is used with this process - the metal to be punched is placed over the hole then, with the metal being turned over periodically, a punch is used until the hole is formed.

Heat Treatments

Heat treatment is a way of making metals more suitable for the tasks they have to carry out. There are 3 stages in the heat treatment process:

1. Heat the metal to the correct temperature
2. Keep it at that temperature for the correct length of time
3. Cool it in the correct way to achieve the desired properties

Annealing

Makes the metal as soft as possible so it is easier to shape and to relieve any stresses. With this treatment the metal is heated to bright red, kept there for a short length of time then allowed to cool naturally in the air.

Hardening

Increases the hardness and strength of steel (hardening and tempering can only be carried out on ferrous alloys). The steel is heated to cherry red, kept there for a short time then quenched vertically in lukewarm water (cold water causes cracking).

Tempering

Removes the extreme hardness and brittleness from hardened steel, making it tougher and less brittle. The steel is heated to a specific temperature (between 230 - 300°C depending on if you want a harder or tougher steel), then immediately quenched in water.

Work Hardening

If a metal has been worked over a period of time the metal will be harden, become brittle and break easily. The metal can be annealed to sort this.

Cutting Tools

A variety of hand tools are available in the workshop for cutting metal, you should familiarise yourself with them and be able to identify which tools are suitable for which forms of metal.

After Cutting…

After metal has been cut sharp edges are created; these need to be removed by filing.

Hacksaw

This is used for cutting medium sized sections of metal and can be adjusted to fit different sizes of blade. The blades are fitted in the frame then tensioned with the thumbscrew. The blades are made from various kinds of steel and their teeth range from coarse to fine - the thinner the metal to be cut, the finer the teeth on the blade. The hacksaw can be used with one or two hands. A **junior hacksaw** is approximately half size; it is used for cutting smaller sections and lighter weight metals. Like the hacksaw it can take various blades but is designed to be operated one handed.

Abrafile

Sometimes called a tension file, this cutting device has a thin, round file blade which is held in a frame. Because the blade has teeth all around it can cut in any direction; this makes it useful for cutting curves and shapes from sheet metal. A hole is first drilled in the material, the file blade is fed through it, then locked in the frame ready for cutting.

Snips

Snips are designed to cut thin sheet material and are operated similar to scissors. When cutting one handle can be held in an engineer's vice; this leaves one hand to operate the snips and the other to hold and manoeuvre the sheet material. The snips shown are **straight snips** and are used t cut straight lines and outside curves; you also get **curved snips** for cutting inside curves and **jeweller's snips** for intricate work.

Cold Chisel

The cold chisel is designed to cut thin sheet metal by a process called **shearing**. Thin sheet material is clamped in an engineer's vice with the waste material facing up and the cutting line barely visible. The cold chisel is held at an angle on the edge of the material and tapped gently with a ball pein hammer to begin cutting. The colours on the chisel show where it has been tempered (blue) and hardened (orange/yellow).

Combination Pliers / Wire-cutters

These are designed for cutting wire; both have sharp cuttin edges but the combination pliers are also used for gripping objects and material.

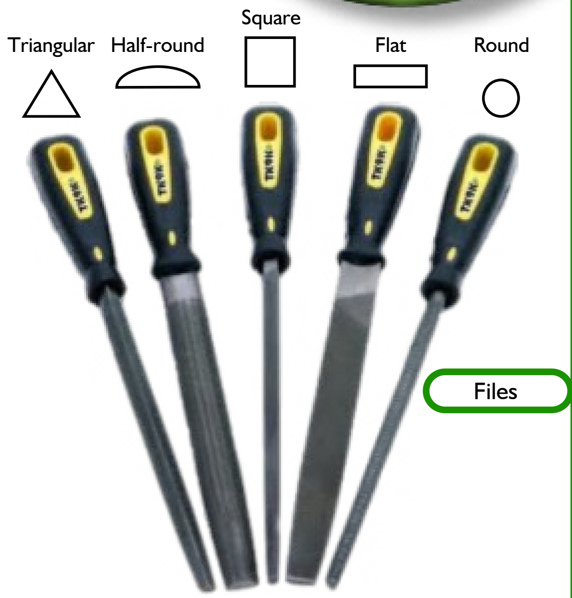
Metal

Finishing Metal

A variety of tools and materials are available in the workshop for finishing metal, you should familiarise yourself with them and be able to identify them.

The processes for finishing metal follows the same order as for plastics with the addition of emery cloth (used after filing but before wet & dry)
See "Finishing Plastic" for more information

Files
Files are used for metalworking, woodworking and plastic working to cut fine amounts of material from a workpiece after the main cutting process. Files have forward-facing cutting teeth, and cut most effectively when pushed over work. Pulling a file will cause the teeth to bend, permanently damaging the file. **Needle files** are small files which also come in a range of shapes. They are used for intricate spaces and detail. Files can become clogged up during use. To maintain the life and performance of files, a file card should be used to clean the teeth. The file card is used like a brush, dragging it across at the angle of the cut on the file. There are many kinds of files; the ones you should be familiar with are shown on the right.



Emery Cloth
This is a natural abrasive that has been glued onto a cloth backing. It is quite coarse so is limited to metalwork. The cloth backing makes it easy to tear strips off, but when held in tension it is stronger than paper backed abrasives which wear and tear quickly on metal. Emery cloth is therefore used before wet & dry to take away most of the roughness.

Wet & Dry Paper
Wet & Dry is an abrasive paper that can be used dry or wet because of a special waterproof backing. The water acts as a lubricant that carries away the particles of metal that would otherwise stay on the surface and block the paper. Wet & dry is available in grits right up to P2500 to get work to the smoothest possible finish.

Metal Polish
Metal polish is a final stage in the finishing process. The polish is an abrasive with millions of tiny particles suspended in a liquid. Using the polish gets rid of <u>very minor</u> imperfections on the surface and removes any tarnishing (oxidisation) from the metal. To ensure the metal stays shiny, waxes and lacquers can be use on the surface but this is only suitable if the function and safety design factors of the product allow it. (E.g. silver cutlery used for eating wouldn't be suitable for lacquer)

Painting and Galvanising
These are two further ways of protecting a **ferrous alloy** once it has been finished. Paint can be applied and has the advantage of being colourful as well as protective (e.g. Forth Rail Bridge). Galvanising involves dipping the finished metal in molten zinc to give a shiny protective coating.

Holding Tools

A variety of tools and materials are available in the workshop for finishing metal, you should familiarise yourself with them and be able to identify them.

Soft Jaws

Engineer's Vice

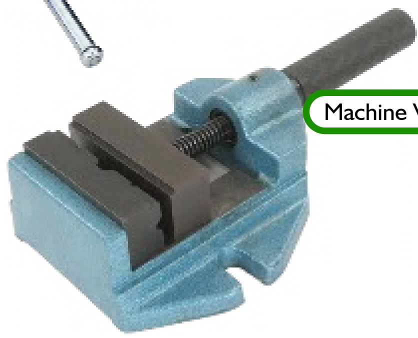
Normally held in the bench vice or bolted to the bench, this vice is used for holding metal and plastic (when used with **soft jaws** to protect from the diamond pattern grip plates). It overhangs the bench which allows long pieces of metal to touch the floor whilst still being held securely. A number of engineer's vices can be used in a row for holding extra long lengths

Engineer's Vice

Machine Vice

Used for holding small metal workpieces that are to be drilled. V-shaped grooves in the jaws allow square and circular cross-sections to be held securely both vertically and horizontally.

Machine Vice



Hand Vice

Used for holding small and irregularly shaped parts (both metal and plastic) whilst drilling, riveting etc.

Hand Vice

Folding Bars

Used to hold sheet metal whilst it is bent. They are normally held in the engineer's vice and are used when a straight, neat bend is required.

Folding Bars

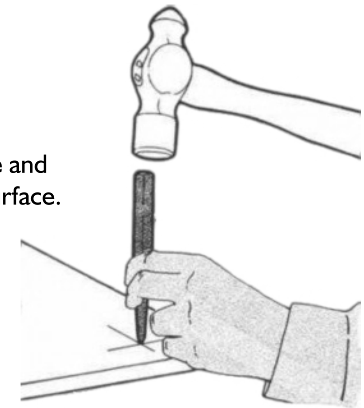
Mole Wrench

Used to firmly clamp pieces of work together, or to hold them whilst drilling, grinding or welding. The jaws can be adjusted for any size of work using the knurled screw, locked into place by squeezing with your hands and released by raising the yellow handle.

Mole Wrench

Drilling Metal

Before drilling any metal it must be marked out and prepared:



1. The position of any holes must be accurately measured with a **steel rule** and marked with a **scriber** and **engineer's square** to create a cross on the surface.

2. Using a **centre punch** and **ball pein hammer** a small **pit is made** on the centre of the cross. This is used to help **locate the drill bit** and stop it wandering over the surface of the metal (the bit is hardened and can easily break with any sideways movement).

3. The metal is **held** using an appropriate holding tool and is **drilled slowly** using a **twist bit**. Metal filings called **swarf** are produced; these are razor sharp and **should not be touched**. Swarf still attached to the material can be removed by drilling on the reverse side using a slightly larger drill bit.

Metal

Notching, Bending & Shaping

Forging is not always necessary when bending metal; sheet material and softer metals are easily bent without the need for heat.

Notching

This is **primarily a sheet metal shearing process** that involves punching the edge of a sheet to **remove a piece of metal of a particular shape**. In industry special punch presses are used but the same effect can be achieved using snips in the workshop. The tabs that are created are often used for joining two metals together by **welding**. Notching is commonly carried out before bending or folding metal to achieve a **more accurate bend**.

Notching can also be used on **tubular sections**; by removing a v-shaped section from the metal, almost all the way through, it can be bent and welded to create an angled piece without having to worry about lining and holding two separate parts. **Annealing** can be used to make thicker sections easier to bend.

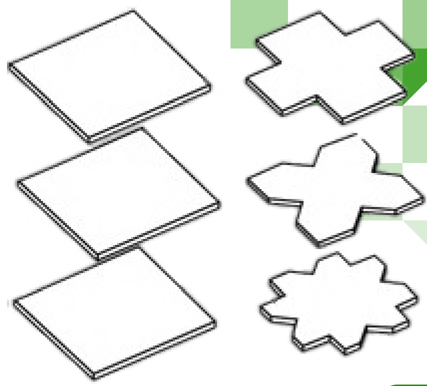
Folding & Bending

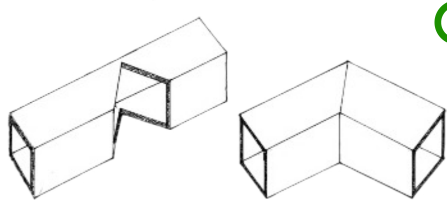
Most sheet material can be bent without annealing but for very sharp bends on thick material this heat treatment could be used. Folding or bending is usually carried out **using an engineer's vice and folding bars**. A hide mallet is used to prevent the surface of soft metal from being damaged or a piece of wood can be used for protection. To stop the metal stretching and deforming it is best to start bending in the middle of the sheet and work outwards, repeating this gradually until the desired angle is achieved.

Mild steel bar will bend quite easily but for **stronger or thick sections forging should be used** to bend the metal. For a curved bend a piece of circular steel bar with the correct radius can be locked in the vice and the metal formed around it.

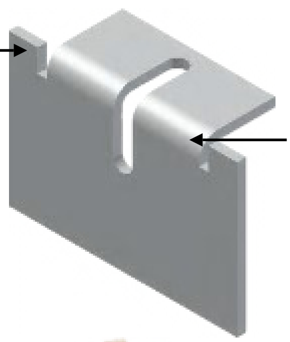
Shaping Sheet Metal

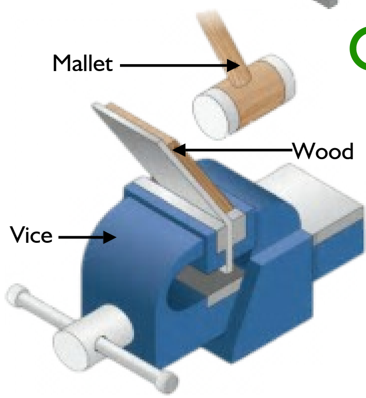
Sheet metal is shaped using a variety of mallets and hammers. Metal can be **beaten into a wooden former** to take on its shape or worked freehand with a leather sandbag and mallet. When shaping metal the striking tools have heads softer than the metal so they don't mark it. The metal has to be annealed before shaping.





Notching





Bending

Shaping Metal

Hide/Copper Mallet

Nylon Hammer

Bossing Mallet

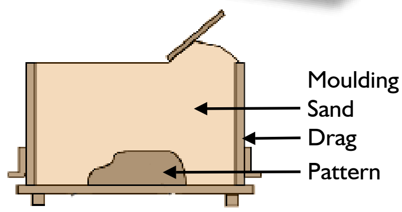
Sand Casting

Casting involves pouring molten (liquid) metal into a mould and leaving it to solidify. Sand casting is a centuries old process and even today it is still used to produce around 40% of all cast products. It is a relatively **cheap process** however once set the product requires further work to remove the excess material in the gates, runner and riser.

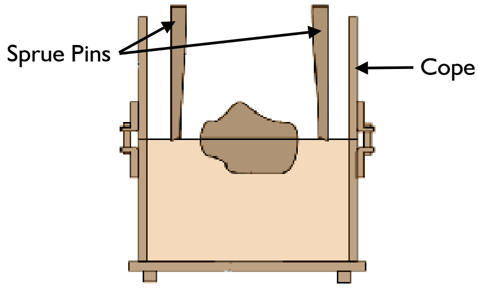
Safety...

- Never carry the crucible alone.
- Pre-heat all tools and metal before adding to crucible.
- Always wear solid shoes and leather safety equipment.
- Never touch the hot metal with your hands.

In schools aluminium is used for casting - a crucible (ceramic pot) is preheated and filled with small amounts of aluminium. When the aluminium turns molten a de-gassing tablet is added to remove impurities before it is poured into the mould.

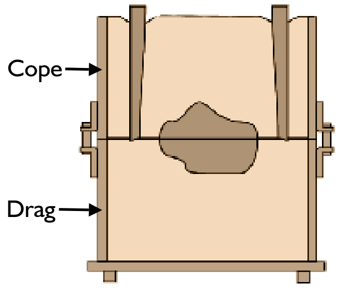


The box used for casting comes in two parts - the cope and the drag which fit together. Special moulding sand is used together with parting powder to help separate the surfaces of the sand and pattern. The pattern has to have a high quality surface finish, be polished and have slightly sloped edges to allow it to be easily removed from the sand. The casting process is as follows:

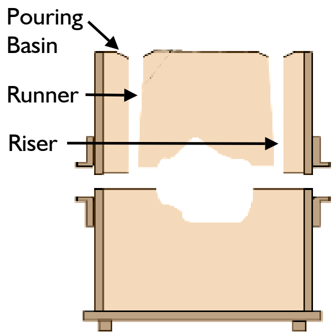


1. Put the drag upside down on a flat board. Place the pattern inside the drag. Shake parting powder over the pattern so that the sand doesn't stick to it.

2. Fill up the drag with sand, ramming it down. Level off the top with a straight edge to give a flat surface.

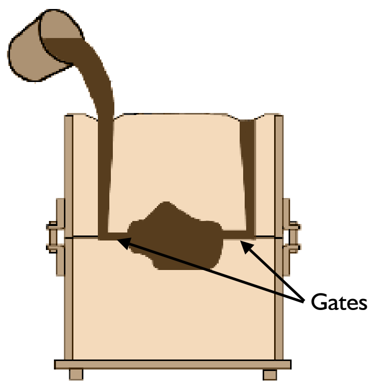


3. The drag and board are flipped over and the cope is fitted. Sprue pins are inserted to allow the metal to be poured in then more sand is rammed in.



4. A small hollow is created around one sprue pin to help when pouring in the metal, both pins are then removed.

5. Remove the cope and place it aside. Small channels called "gates"are cut in the sand to allow the liquid metal to run to the pattern.

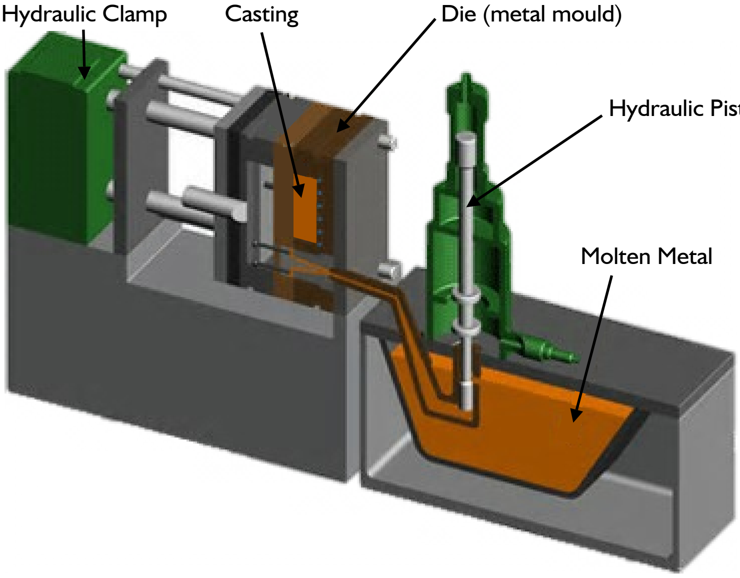


6. Replace the cope and pour the molten metal from the crucible down the runner. Keep pouring until the molten metal appears at the top of the riser.

Die Casting

When **large numbers** of cast parts are needed, die casting becomes the most **economical** process. The process is similar to injection moulding except molten metal is used. The casting **equipment is expensive** so high volumes must be produced to **offset the initial cost**.

The mould is created using two hardened tool steel dies which have been machined into shape. Most die castings are made from non-ferrous metals, specifically zinc, copper and aluminium based alloys. The **process is simple** which keeps the **cost per item low**. It is especially suited for small to medium sized castings. Die castings are **characterized by a very good surface finish** (by casting standards) and **fine detail** and **accuracy**



The Process

Die Preparation
The surface of the dies are sprayed with lubricant to help with the removal of the casting. The lubricant also helps control the temperature of the die.

Injection
The dies are then closed and molten metal is injected into the dies under high pressure. Once the mould is full, the pressure is maintained until the casting solidifies.

Ejection
The dies are then opened and the casting is ejected by ejector pins.

Shakeout
Like sand casting this involves separating the scrap, which includes the gate, runners, sprues and flash, from the casting. This is often done using a special trim die in a hydraulic press. Other methods of shaking out include sawing and grinding. The scrap is recycled by re-melting it and feeding it back into the system.

Advantages of die casting
- Excellent accuracy & fine surface detail
- Thinner walls can be cast compared to sand casting
- Inserts can be cast-in e.g. threaded parts
- Rapid production rates.
- Produces stronger components than sand casting

Disadvantages of die casting
- Equipment and dies are expensive
- Limited to high fluidity metals
- Castings can be porous so cannot be heat treated (heat treating expands trapped gasses and cracks the component)

Dip Coating

Dip coating is a process that involves coating a metal with plastic. This is usually done to ferrous alloys to provide the metal with some **protection against corrosion**. It also provides some **electrical and heat insulation** and can **improve the appearance** of the metal because of the bright colours of plastic powder that are available.

A machine called a fluidiser is used when dip coating. The fluidiser acts as a container for the plastic powder (usually **polythene** because it's cheap). Low pressure air is blown into the fluidiser, from below, to make the powder move around; this is so that when a part is dipped it is coated evenly. Dip coating involves working with heat and small particles so it is important that you wear **heat resistant gloves, safety goggles, a face mask and an apron**. You must also ensure that the area is **well ventilated with extraction running**.

The Process

1. Clean the metal and make sure it is free from dust and any grease. Then find a suitable method to suspend the metal whilst heating and dipping (usually a hook fashioned from wire)

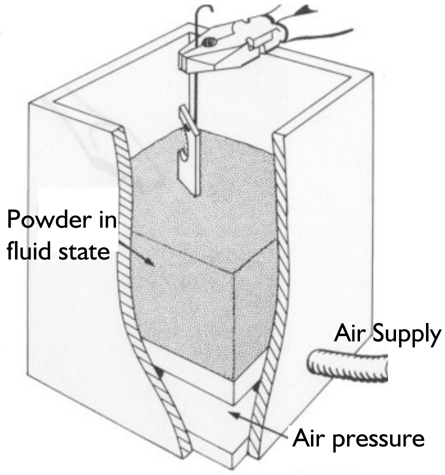
2. Using an oven heat the metal component to 180°C (thin metal or wire may need to be hotter)

3. Remove from the oven and dip the metal component in the fluidised plastic powder for a few seconds until coated

4. Return it to the oven to fuse the coating to the metal and give a smooth finish. Be careful not to overheat as this can damage and discolour the plastic.

5. Hang the finished component up to cool and set, then trim any imperfect edges with a sharp knife.

Dipping work into the fluidiser



Coating Metal

Metal may be coated for many of reasons by a number of methods - below are some of the most common:

• *Painting*	Painting **protects against corrosion** and can **add colour** to a piece of work, however it is **time consuming** as many coats are needed. **Brush marks are usually seen.**
• *Spray Painting*	Spray painting is **quicker than painting** and also **adds colour**. It **protects against corrosion** and leaves a **uniform surface finish.**
• *Lacquering*	**Protects against corrosion**, can be **coloured or clear**, applied with a brush but, when dry, can be **polished to a smooth sheen.** Clear lacquer allows the natural metal to be seen.
• *Dip Coating*	Dip coating **protects against corrosion**, offers **electrical and heat insulation** and can improve the appearance through **colour** and **glossy finish** of some plastics
• *Galvanising*	Galvanising **protects against corrosion** but because it is coated in another metal (zinc) it **tarnishes over time**. Galvanising is commonly used for **outdoor metal products** where the **aesthetic is a secondary consideration**
• *Bluing*	This process involves dipping heated metal in a bath of oil, leaving it to cool and wiping dry with a cloth. It's **cheap** and **provides some protection against corrosion** but **isn't aesthetically pleasing**

Metal

Joining Metal

There are five methods to join metal - adhesives, mechanical fixing, soldering, brazing & welding. The only suitable adhesives are epoxy and contact adhesive. Rooms should be well ventilated and care should be taken not to get any of the chemicals on your skin. Brazing and welding involve heat so it is important to wear the appropriate safety equipment.

Adhesives - Permanent Bond

Metals can only be joined by reactive adhesives. Epoxy is the most commonly used adhesive but contact adhesive is also used. Before using either the metal must be cleaned, degreased (solvents are used in industry but washing up liquid works too), dried and abraded with emery cloth to remove any oxides.

Mechanical Fixing

Metals can be mechanically fastened in two ways - **rivets, which are permanent fasteners** or nuts, bolts, machine screws etc. which are non permanent.

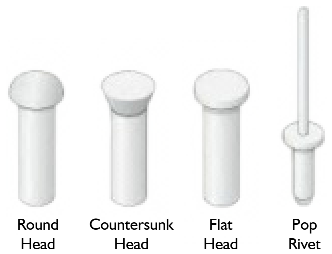
Riveting

Rivets are available in two basic forms - solid rivets and pop rivets. Solid rivets are stronger and have various shapes of head:

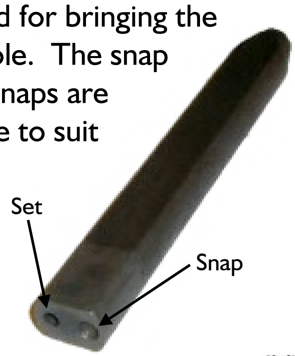
Round Heads
A general purpose rivet used when a flush finish isn't important and countersinking would weaken the work.

Countersunk Heads
The most commonly used rivet it's used to give a flush surface to the work.

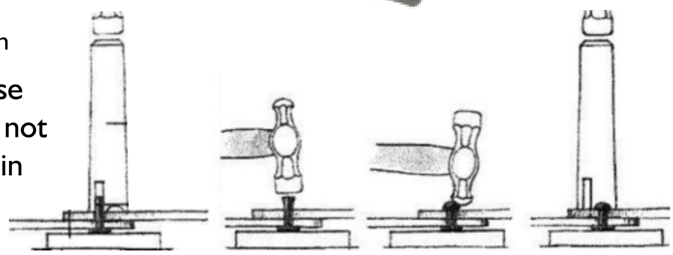
Flat Heads
These are used to join thin metal sheets that cannot be countersunk.



Specialist tools are used in riveting - a rivet set and snap. The set is used for bringing the sheet metal together and making sure the rivet is all the way into the hole. The snap is used to support the head of a round rivet and to shape its tail - two snaps are needed for round head riveting. Various sizes of set & snap are available to suit different sizes of rivet.



1. Drill both pieces of metal, file of any burrs and "set" the rivet, a countersink is needed on the back piece of metal for a flush finish
2. Support the rivet head with the snap held in the vice (round head only)
3. Upset the rivet tail with the flat face of a hammer to fill the holes
4. Use the ball pein to shape the head of the rivet
5. Finish the head with the snap to make it smooth



Pop rivets are much quicker to use but, because they are hollow and made from a softer metal, not as strong. They are used mainly for joining thin sheet material.
Special riveting guns are used with this kind of rivet:

1. The long mandrel is pulled through the rivet by the gun.
2. The ball on the end of the mandrel expands and collapses the rivet head drawing the two pieces of sheet material together.
3. The mandrel then breaks off leaving the rivet in place.

Joining Metal

Mechanical Fixing

Metals can be mechanically fastened in two ways - rivets, which are permanent fasteners or **nuts, bolts, screws etc. which are non permanent**.

Nuts, Bolts & Machine Screws

Nuts
These are the counterparts to bolts and machine screws. Like bolts they can have either hexagonal or square heads. Some special nuts exist - locking nuts for example are designed to prevent vibrations from loosening them. Wing nuts are used to adjust moveable parts and for quick removal without the need for tools.

Bolts
Like screws, bolts can be threaded for all or part of their length. They can have either hexagonal or square heads and come in a range of diameters. Bolts require a spanner or socket to tighten them.

Machine Screws
These are designed to be used with nuts but have heads that can be tightened/loosened by screwdrivers. Like screws they are available in a range of lengths, diameters, head shapes and head types.

Washers
Washers are designed to spread the load over the surface of a material and to protect that surface as the nut/bolt is tightened.

Self-tapping Screws
These are used to join metal to wood. A hole that is equal to the core diameter of the screw is drilled in both materials; the screws are made of hardened steel so they cut their own threads as they are screwed into the holes. They are available in a range of lengths, diameters, head shapes and head types.

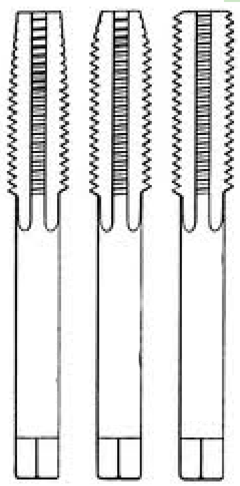
Driving Tools

Joining Metal

Threading

Threading is a process that involves using taps and dies to cut threads onto either the outside of a rod or inside a hole; this allows manufactured metal work to be joined and deconstructed easily.

Taps
The tapping operation is used for cutting internal threads in drilled holes. A tap wrench is used to grip the square corners of 3 different types of tap that are used in sequence. The taps are made from hardened and tempered steel for the best cutting action. For the best results when using a tap complete one full turn clockwise then take half a turn anticlockwise to clear any metal from the hole.



Taps

Taper Tap: This is the first tap that is used to start the thread; it tapers from no thread to full thread about two thirds of the way up the cutting section. It is used, as are all taps, with cutting compound - a type of lubricant that makes threading easier.

Second Tap: This is used to deepen the threads started by the taper tap. Only the first few threads are tapered making it perfect for use on thicker material.

Plug Tap: This tap is fully threaded with only a slight chamfer to locate the tap in the hole. It is used for threading to the bottom of blind holes and for thicker material.

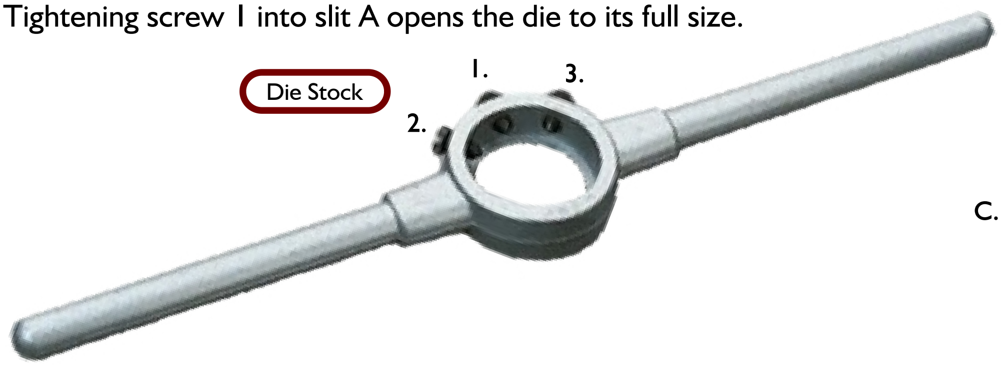
Tap Wrench

Dies
These are used for cutting external threads on metal rods. A die stock is used to hold a die; like taps they are also made from hardened and tempered steel. They need cutting compound the same as taps.

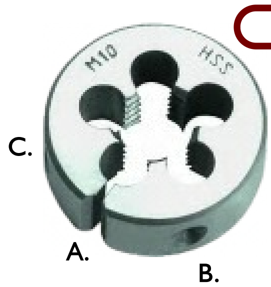
The first few threads of the die are tapered to help in cutting. Dies are split to enable it to be opened slightly for the first cut by tightening screw 1, then closed for the second to deepen the threads if the rod is too tight to be screwed - this is done by loosening screw 1 and tightening screws 2 & 3. The die is fitted in the stock with the tapered side facing up as it is inserted.

The die stock has three screws: screws 2 & 3 hold the die in place and when tightened into holes B & C reduce the size of the die. Tightening screw 1 into slit A opens the die to its full size.

Die Stock



Die



Joining Metal

Soldering, Brazing & Welding

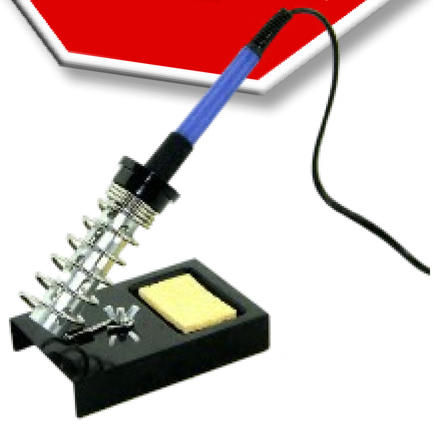
These permanent joining methods all involve heating the metal, introducing a filler (another metal) and, for soldering and brazing, using flux. Flux is used to stop oxidisation during heating (this creates a weak join) and to help the filler material run into the joints.

Safety...

- Don't use damaged welding equipment - report any damage to your teacher
- Wear heat resistant gloves, welding mask and non flammable clothing
- Clamp the current return cable close to where you are welding
- Use an insulating mat or rubber sole shoes so you are not in contact with

Soldering

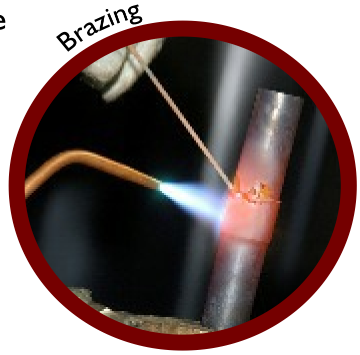
This involves using a soldering iron to melt an alloy of lead and tin (solder) to join two pieces of metal. The solder acts like a glue bonding the surfaces. The two metals must be cleaned and have flux paste applied to the joining areas. Solder is melted over the fluxed areas on both pieces, allowed to solidify, then more flux is applied. The two soldered surfaces are brought together, the solder is re-melted with a soldering iron and the surfaces bond.



Brazing

Brazing is carried out using a torch at the hearth so the appropriate safety equipment should be worn. A filler rod of brass is used in the joining process. The joining metals must be cleaned before a proprietary flux (flux powder mixed with water to a creamy consistency) is applied to the joint and filler rod. Using the torch the two metals are heated at the joint then, when the metals are hot enough, the brass rod is introduced to the joining area - it will melt and flow into the joint. The finished piece is then removed from the heat and quenched in water. Any excess brass around the join can be filed off quite easily.

Brazing



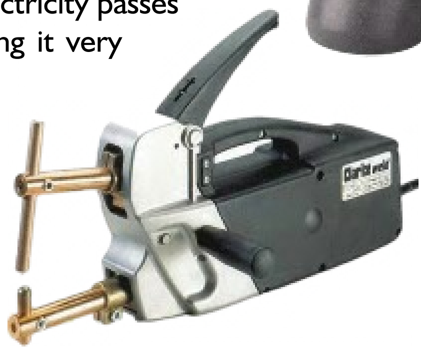
Welding

Welding involves melting two pieces of metal and joining them with a filler rod of the same metal. When the two are welded together correctly, they should be as strong as though they were made from one piece.

Arc Welding: This method uses the flow of a high current of electricity to melt and fuse the metal together. The electricity flows down the welding rod and arcs at the point of contact. This causes both the metal and the rod to melt, run together and form the weld.

Spot Welding: This method also involves electricity but this time the metals are clamped together between two electrodes. Electricity passes between the electrodes for a fraction of a second (making it very energy efficient), this melts the metal creating the weld.

For both methods it is essential that the current is set to the correct level otherwise either a hole will be burned through the metal or the metal will not melt properly resulting in a poor weld.



Metal

Plastic Properties

Thermoplastics:

Thermoplastics go soft when heated, harden when cooled and are then easily shaped. A thermoplastic is like ice frozen in a teacup (a mould) - when heated it returns to a liquid state, it can then be poured into a glass and refrozen (reshaped); this can be repeated over and over again

When a thermoplastic is reheated it will attempt to return to its original shape once the heat has been removed. This is called a **plastic memory.**

Thermosetting Plastics

These plastics need to be heated and then pressurised into formers (mould) to give them the required shape. When cool they become permanently solid and cannot be reshaped, even by reheating. (similar to boiling an egg. Once it is hard boiled it will not soften and reshape again)

Thermoset plastics are used when the product will be exposed to heat or electricity as it has good thermal and electrical insulation properties.

General Properties of Plastic:

Plastics may be obtained in powder, fibres, granules, liquid, film, clear or coloured sheet, rod and tube. They have various advantages over wood or metal:

- Colour — various pigments can be added, textures can be simulated.
- Water resistant — does not need a protective finish.
- Forms easily — can be easily shaped.
- Mass production — lends itself to high speed/high volume production.
- Insulator — useful where heat or electricity is present.
- Weight — can offer weight savings in various applications.

Table of Common Plastics:

* - High Density Polyethylene (HDPE)

Name of Plastic	Properties	Uses	Common Processes	Thermosetting Plastic	Thermoplastic
Acrylic	Hard, durable, scratches easily. Easily cut & polished	Reflectors/lenses, signs, lighting, lightweight screens	Line Bending, Vacuum Forming		✓
ABS	Rigid, opaque, tough, impact resistant, strong	Protective headgear, household goods, rigid luggage, car bumpers	Line Bending, Injection Moulding, Vacuum Forming		✓
Polypropylene	Hard, lightweight, chemical and fatigue resistant	Chairs, medical equipment, containers with integral hinges	Injection Moulding, Rotational Moulding, Vacuum Forming		✓
Nylon	Tough, chemical, fatigue, wear & friction resistant	Gears, equipment parts, combs, brush bristles, clothing, casings	Injection Moulding		✓
Polystyrene	Light & floats, absorbs shocks, tasteless, stiff	Food containers, cups, toys, sound & heat insulation	Injection Moulding, Vacuum Forming		✓
PVC	can be rigid or flexible, weatherproof, durable	Window frames, drainage pipe, medical devices, bags, packaging	Line Bending, Rotational Moulding, Vacuum Forming		✓
Polyethylene	Weatherproof, chemical resistant, low cost, tough	Bottles, kitchenware*, carrier bags, packaging, chemical drums*	Rotational Moulding, Vacuum Forming		✓
Polyester	Rigid, chemical & impact resistant, strong, low cost.	Boat hulls, building panels, lorry cabs, coatings, housings	Only used in Thermoset processes covered at Higher	✓	
Epoxy	Rigid, clear, tough, chemical resistant, good adhesion	Adhesive, electrical components, pacemakers, aerospace parts	Only used in Thermoset processes covered at Higher	✓	
Melamine	Hard, tough, scratch resistant, taste/odourless	Electrical equipment, surface coatings, bottle caps, toilet seats	Only used in Thermoset processes covered at Higher	✓	
Polyurethane	Elastic, abrasion/chemical resistant, impervious (gases)	Printing rollers, solid tyres, wheels, shoe heels, car bumpers	Only used in Thermoset processes covered at Higher	✓	

Marking and Cutting Plastics

Marking Out:

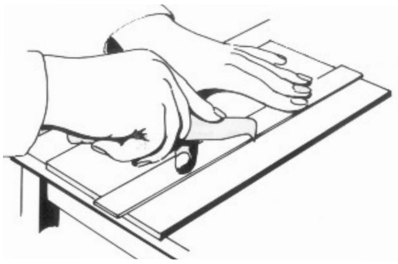
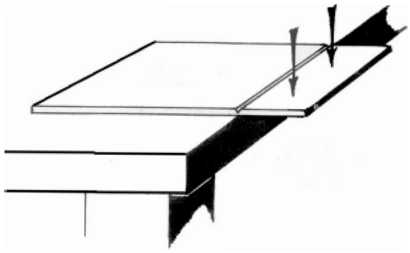
Keep the protective paper or film in place to draw the required outlines. The plastic cover should remain on until all cutting and finishing has been complete to prevent damage to the materials surface.

Most marking out tools can be used when marking out plastic.




Felt pens/permanent marker can be used to mark out acrylic. A scriber can also be used but this will damage the surface.

Sheet acrylic can be cut similar to glass. A plastic cutter is used to score a line along the sheet. The sheet is supported while it is snapped along the line. A long strip can be clamped above while the break is being made.

Templates are often used when marking out sheet plastic. Templates make is easier to create multiple copies of the same design, they are quicker to mark out accurately and in some cases can be glued onto the protective cover and used as a guide.

Cutting:

To cut curves or remove material from the middle of sheet material, a Coping saw or Abra file should be used. A junior hacksaw or tenon saw should be used for short straight cuts. Files can be used to finish off shaping and remove the saw marks.



Plastics like acrylic are brittle and can snap. To avoid this always ensure they are held low in the vice during cutting or filing.

Drilling:

To prevent plastic cracking when drilling you should support the plastic underneath with scrap wood and drill slowly. For a clean hole the plastic should be taped on both sides. A step drill is a specialist plastic tool for drilling. When larger holes are required a multi hole saw should be used.


Finishing Plastic

It is essential to polish the edges before drilling any holes or folding of the acrylic takes place. Leave the protective paper or film in place while these tasks are being carried out. The plastic will get damaged, be difficult to hold in the vice and could also snap if you try to finish the edges after bending.

Safety…

- Beware of sharp edges when working with acrylic.
- When machining plastics wear goggles, and drill at a slow, steady rate.
- Do not inhale the dust created by filing or drilling plastics.
- When using resins, wear protective gloves and apron.
- Wash hands immediately if any chemical comes in contact with your skin.
- Beware of heating elements on the strip heater, hot air gun or vacuum former when heating plastics.

Stage 1: CROSSFILE

File to the required outline by first ***crossfiling***. This should remove all of the saw marks. It will leave scratch lines across the material. With metalwork a burr is created with this process; this is removed by working the file in an upwards motion along the edge of the material.

Stage 2: DRAWFILE

Remove these marks by ***drawfiling***. Drawfiling should remove all the crossfile marks. (in the workshop you may finish this by scraping) ***Scrape*** the edge to remove marks made by drawfiling.The edge of a steel rule or blade of a scissor can be used to do this. A plane can be used to level out long lengths.

Stage 3: WET & DRY

Rub the edge with Wet and Dry abrasive paper. Start with a medium grade and finish with a fine grade, using plenty of water to lubricate the cutting action. Any imperfections in the surface will be highlighted as the fine powder created settles into the scratches/chips.

Stage 4: POLISH

Apply liquid polish with a clean cloth and rub each edge thoroughly. Buff the edges with a clean cloth.

Joining Plastic

There are three methods to join plastics - adhesives, mechanical fixing & welding. Sheet plastic is not porous and the adhesives required to join plastic to plastic are specialised. Rooms should be well ventilated and care should be taken not to get any of the chemicals on your skin - if any does get on your skin you should tell your teacher and wash your hands immediately.

Safety...

When using adhesives to join plastic to itself or any other material it is important that you:

- Wear gloves and an apron to prevent any adhesive getting on your skin
- Do not inhale the fumes - they can be toxic
- Protect your bench from spillages and report any to your teacher

Adhesives - Permanent Bond

Plastics can be joined by both reactive and non-reactive adhesives. Reactive adhesives, like epoxy, require the mixing of a resin and a catalyst (hardner) - a chemical reaction takes place turning the resin into a tough thermoset plastic, forming a permanent bond. Depending on the materials being glued the surfaces must be prepared - cleaned, degreased, dried, or abraded (roughened). Epoxy is used to join plastic to wood or metal.

Non reactive adhesives such as Tensol and other solvent based cements work on their own by fusing two plastics together. The two plastics are coated with a solvent, then clamped or pressed together. The plastic molecules mix together, and the parts bond when the solvent evaporates. This process is limited to thermoplastics (except polythene and polypropylene). It is good practice to use masking tape to protect the plastic around the bond area to ensure a good finished aesthetic.

Welding - Permanent Bond

Plastic welding is achieved with a heat gun fitted with a special nozzle. Thermoplastic rod is fed through the nozzle and is softened by the heated air, it is then used to join two plastics together; the plastics must be the same type as each other and the rod for the process to work.

The edges of the plastic must be prepared - cleaned and chamfered to receive the weld material and create a good bond. The advantage of this method is it is quick with a good solid join, however the disadvantage is the weld is quite visible and could ruin the appearance of a project.

Mechanical Fixing - Non-Permanent

It is not always suitable to have a permanent bond. Some designs may require the parts to separate for access or maintenance. Mechanical fastening is used when precision bonding is not required. This is the simplest way of joining plastics.
Only stronger plastics are suitable for this method since the joint must survive the strain of assembly, the weight of the product, and possible repeated use.

Mechanical fasteners (screws, rivets, nuts and bolts) are the most common joining method. Conventional machine screws are rarely used except with extremely strong plastic. If a fastener has to be removed a number of times, metal inserts are recommended. It is also possible to join sheets of plastic to other materials if done with care. Clearance holes and countersinks can be drilled in plastic to allow it to be screwed onto wood.

Injection Moulding

The injection moulding process is used for **mass manufacture** of plastic products. It allows a great number of identical objects to be produced very **quickly**. It works by softening plastic pellets and forcing them into a mould of the product being manufactured. These **moulds are expensive** to make so large quantities of the product must be sold to recover the initial start-up cost.

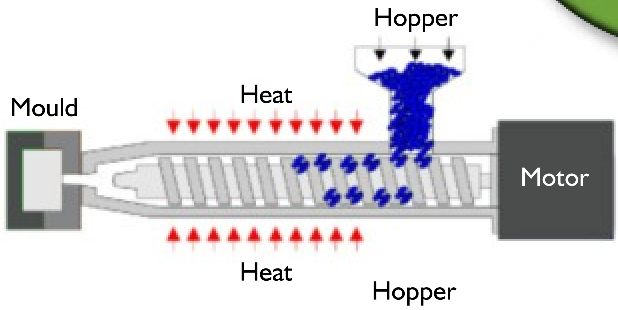
Which Plastic?

- ABS
- Polypropylene
- Polystyrene

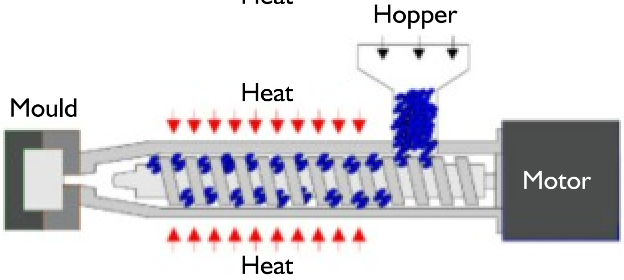
Are used to manufacture products such as casings, wash basins, chairs and many others.

The Process

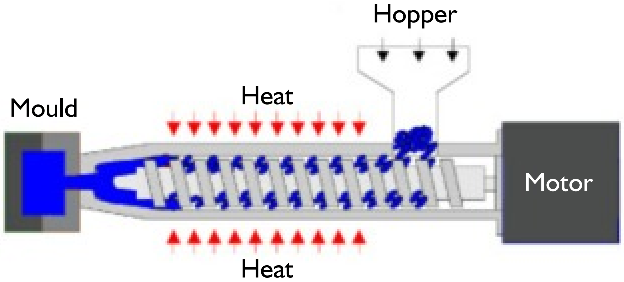
1. The hopper is filled with **thermoplastic** pellets and fed into the machine.



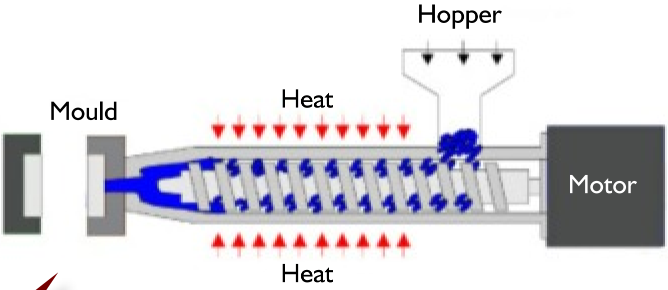
2. A rotating screw mechanism feeds the pellets through a heater causing them to plasticise (soften).

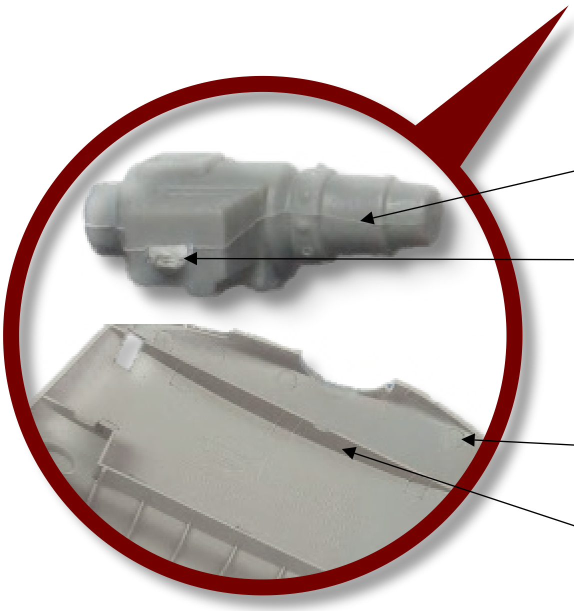


3. The plastic is injected, under pressure, into a mould of a product where it is cooled.



4. The mould is opened and the finished product is ejected requiring no additional finishing.





Identifying Features

Split Line	The visible line where the two parts of the mould meet.
Sprue Mark	These are areas where the plastic was injected into the mould.
Draw Angle	Angle that allows components to be released easily from the mould.
Ejection Mark	Circular indent showing where the product was pushed out of the mould.
Webs	Pieces of plastic that improve the strength of plastic products.

Rotational Moulding

The rotational moulding process is used for **small production runs** of plastic products. It is used to produce **hollow and seam free** components. It works by melting plastic granules to coat the inside of the **relatively low cost mould**. This process is used to produce **large products economically** and, because no outside pressure is used in production, products are **stress free** with **no split lines**.

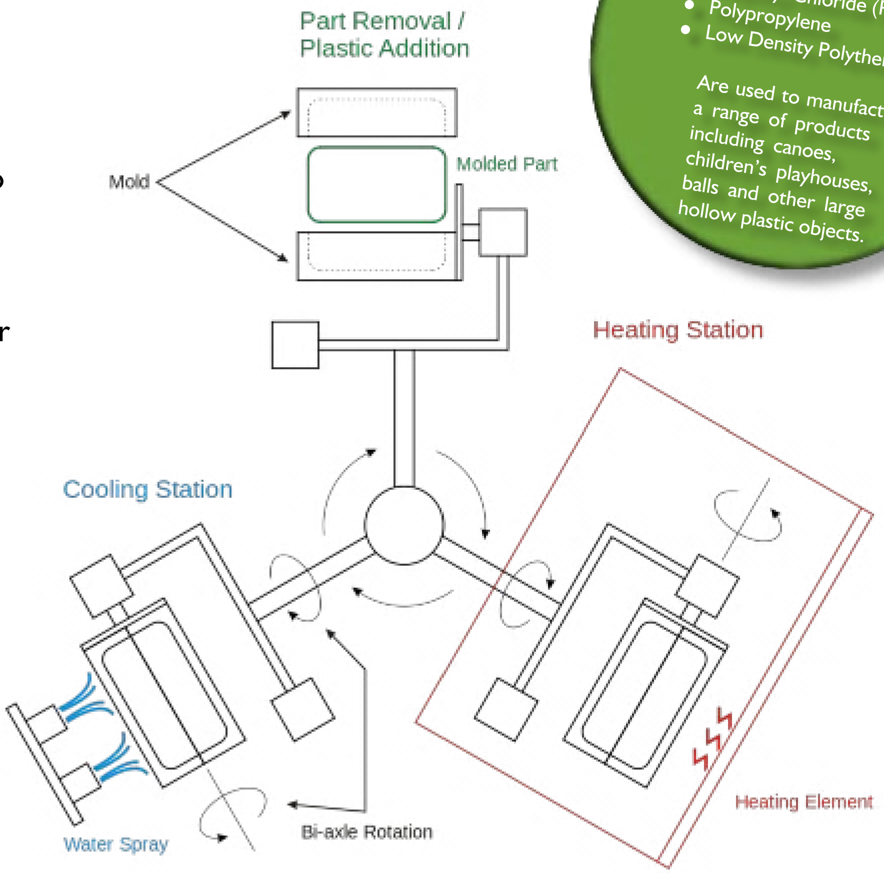
Which Plastic?

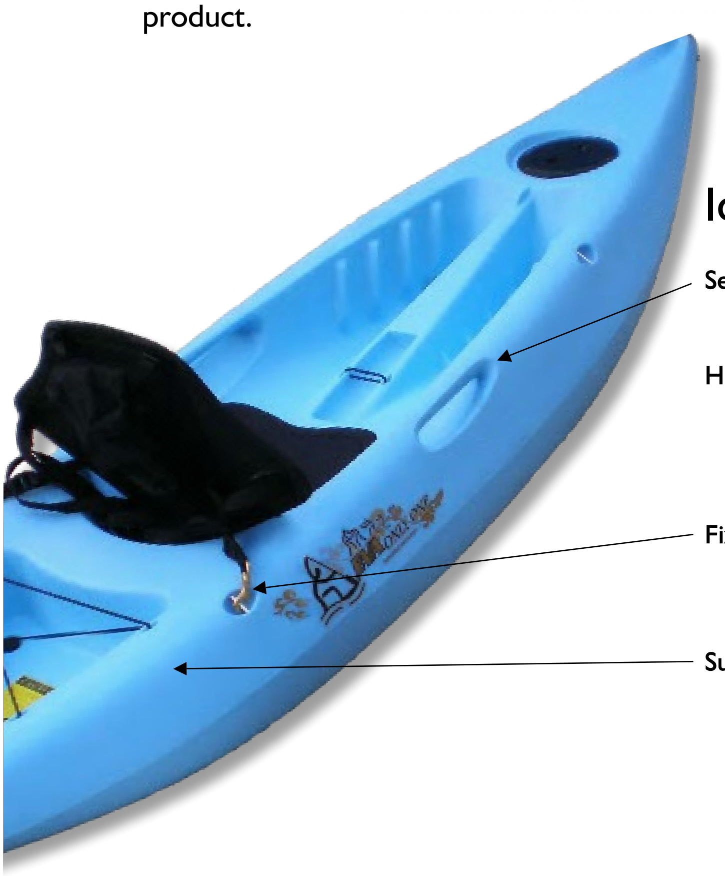
- Polyvinyl Chloride (PVC)
- Polypropylene
- Low Density Polythene

Are used to manufacture a range of products including canoes, children's playhouses, balls and other large hollow plastic objects.

The Process

1. The correct amount of thermoplastic granules are added to the mould.
2. The mould is rotated slowly around two or three axes whilst a heating element melts the plastic.
3. The melted plastic builds up an even coating on the inside of the mould and is then cooled so that the plastic will keep its new shape.
4. The mould is opened revealing the finished product.





Identifying Features

Seamless No visible lines where the two parts of the mould meet.

Hollow A single piece constructed product with a thin uniform wall thickness - therefore products tend to be fairly lightweight.

Fixings In rigid constructions these can be anchor points or, in inflatable constructions, valves.

Surface Finish Excellent quality - either really smooth or can be textured to simulate a variety of materials.

Vacuum Forming

The vacuum forming process is used for **medium/large scale production runs** of plastic products, usually packaging, or other **low cost** components. It uses **plastic sheets** and often requires a **secondary process to trim** the formed sheet to leave the finished part. Any waste can be ground and **recycled**.

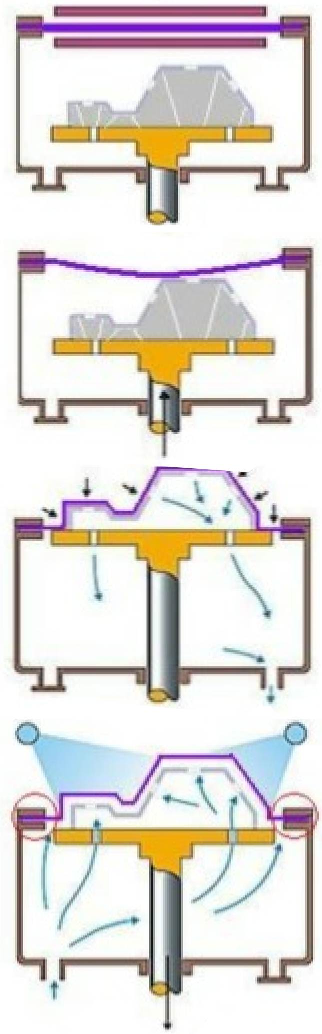
Which Plastic?

Almost any Thermoplastic can be used in vacuum forming so long as it is in sheet form. The most common are:

- ABS
- Polystyrene
- Polypropylene
- Polyethylene

The Process

1. A plastic sheet is clamped in the vacuum former, above a mould, then heated.
2. The plastic becomes soft, flexible and will begin to sag. The bed is raised to allow the plastic to drape over the mould.
3. A vacuum is used to suck the air out and ensure that the plastic fits exactly to the mould
4. The plastic is cooled and air is blown back in to help release the formed product from the mould. The bed is lowered, the plastic is unclamped then trimmed to size.



Identifying Features

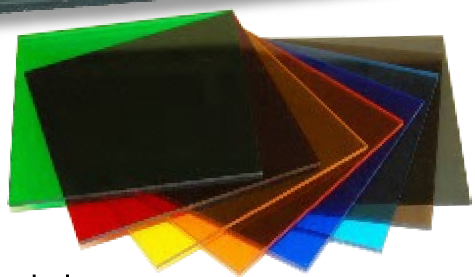
Sheet Material	Thin sheets of thermoplastic are used in this process
Pips	These are small bumps on the surface of the product where venting holes were created on the mould. They help the plastic conform to the mould
Thinning	As the plastic conforms to the surface of the mould some areas will stretch more than others; these areas will have a thinner wall thickness
Draft	A draft is the name given to the angle or taper that allows the product to be easily removed from the mould; corners are also radiused for the same reason

Line Bending & Thermoforming

These processes are widely used in workshops for **single curvature bending**. They use **plastic sheets** of varying thickness to create **bends or curves** either along the length of plastic or across its width.

Line Bending

Line bending involves heating a thermoplastic sheet material over a strip heater or hot-wire heater until it becomes soft and pliable, then bending it to an angle.



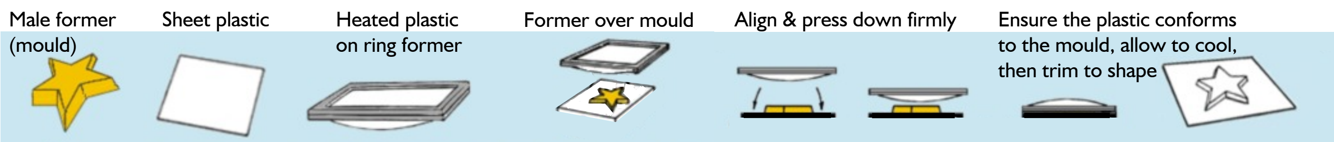
Thermoplastics may be bent to any angle, using a jig or a former, or if the angle is not critical, simply by bending the thermoplastic sheet by hand and then holding it until it has cooled. All protective film should be removed before heating.

Sharp bends are achievable but the edges of the plastic will bow out at the line of the bend. This can be minimised by drilling holes right on the edge of the sheet to allow for the distortion. Thicker sheets need to be turned over to ensure even distribution of heat along the line of the bend and prevent the plastic from bubbling. There are advantages to this process - it is **basic with low set up costs**, straight **bends are produced very efficiently** and once shaped **no additional processes** are required.

Thermoforming

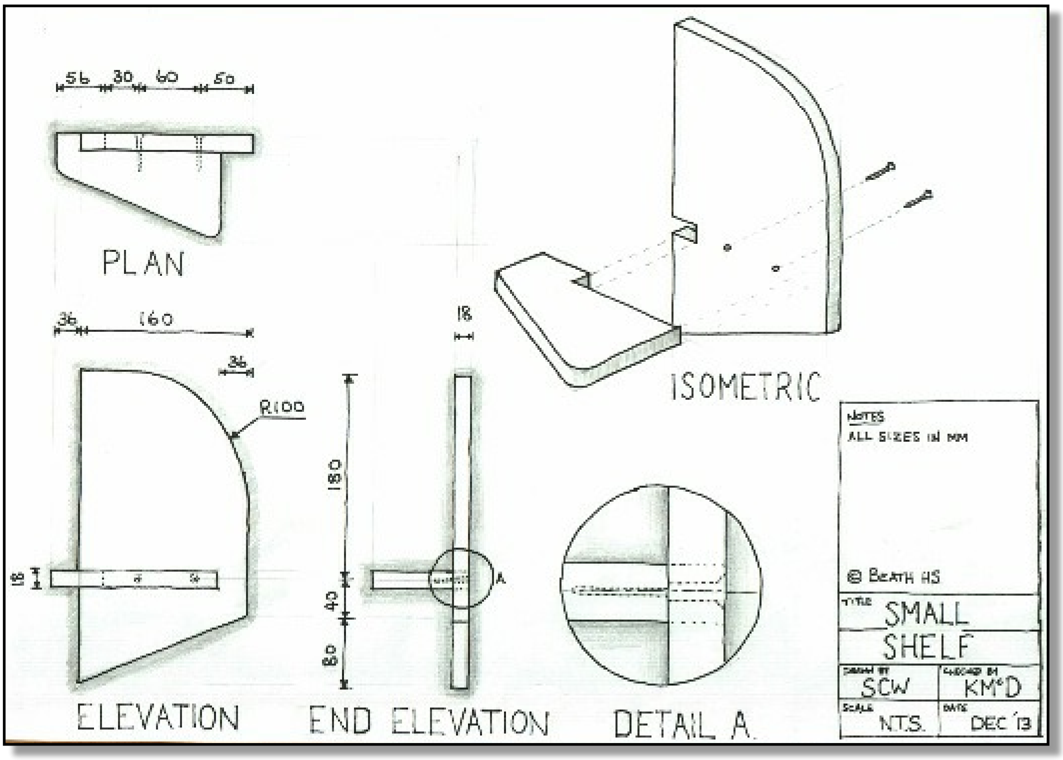
Thermoforming is a term used to describe the heating of plastic to a temperature that makes it pliable. The plastic is heated in an oven, like the one opposite, to allow it to be stretched into or onto a mould and cooled to a finished shape. Unlike line bending the entire sheet is heated so you can form gradual curves as opposed to angled bends; again all protective film should be removed before heating.

The process of stretching the plastic onto a mould is called "**press forming**" this is usually only done with thicker sheets of plastic since vacuum forming is most suitable for thin plastic sheets. Moulds can be made from a variety of materials - aluminium, ceramic, but in schools they are commonly made from wood, though for curves, paint cans can be used for example. The plastic is very hot so you should **wear heat resistant gloves** when handling it.



Planning for Manufacture

Planning in preparation for manufacture requires the production of a working drawing, procedure and cutting list (see Design booklet). As part of this unit you need to be able to read and understand a working drawing as well as create one.

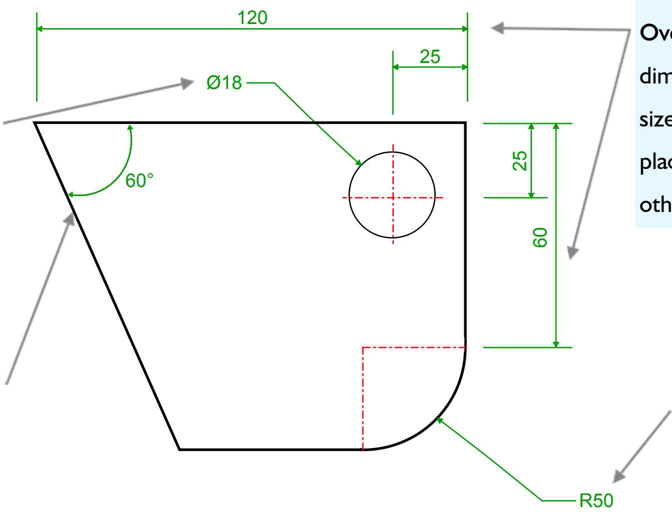


1. The Title Block
The title block is the first place to look - it gives you the project title, the scale, any notes, tolerances and other useful information.

2. Dimensioned Orthographic Views
These are 2D views of the final assembled product - they provide detail on what the finished product will look like and are dimensioned to provide enough information to allow manufacture:

Diameters - Where a compelte circle is shown in a drawing, the diamater symbol Ø is placed before the figure.

Overall dimensions - Overall dimensions give the maximum sizes of objects. They are placed on the outside of all other dimensions.



Angles - Figures are placed so they can read from the bottom or right-hand side.

Radii - Always show the radius on arcs, curves and filleted corners. The letter symbol R is always shown before the figure.

3. Isometric View
These show what the product looks like in 3D - the one shown is an exploded isometric - it is useful in showing how a product is assembled.

4. Detail
A detail is a zoomed in view of a part of the design that brings attention important information that is often too small to be seen in the orthographic views.

CAD / CAM

CAD/CAM stands for Computer Aided Design / Computer Aided Manufacture. This system involves a product being drawn or modelled using a computer, then manufactured with machinery controlled by a computer. With this system no paper copies of drawings are required as **everything is done digitally**.

Computer Aided Design

Sophisticated computer programs such as Inventor are used to draw **accurate**, full size models of a design of a product. Colour, texture and lighting can be added to the model to give a **realistic impression** of what the finished product will look like. Standard components such as nuts, bolts and screws can be added from a **library of parts**, thus **saving time**. Models with moving parts can be animated and **analysed to calculate the stresses** the product will have to withstand so it does not break when used. This can save time carrying out tests on expensive prototypes and **changes to the design can be made easily** to resolve any problems that are discovered. 2D orthographic drawings can be produced from the model if desired; these can be easily dimensioned and drawn to any appropriate scale.

Computer Aided Manufacture

Computers are used to control a range of machinery to manufacture a variety of products. The laser cutter in Craft 01 is just one example - the movement of the laser is **controlled very accurately** to produce intricate work in a much **shorter period of time** compared to cutting manually and the **results are repeatable**. In any CAM system, the data from the CAD software is saved in a suitable format and imported into the CAM program used to control the machine. CAM machinery can include CNC routers & lathes, rapid prototyping hardware, injection moulding, die casting and vacuum formers in addition to others; **these machines are expensive**. The machines can also be used in sequence in a **production line**. Complex **products can be assembled or joined** (welded, riveted, screwed etc.) with speed and ease. **Vast numbers** can be produced in a single day using a CAM system; the machines sometimes running 24/7 with no break in the production run - this is known as **mass manufacturing**.

Unit Costs
The unit cost is what it costs a company to **produce**, **store** and **sell** one unit of a particular product. With **mass manufacture,** although a large amount of money is spend on materials and energy (required to run the factory), the **cost of producing a single product is very low** because of the overall amount that is made - this is known as **economy of scale**.

Quality Assurance
This is a way of checking and ensuring the product is manufactured with **no faults or defects**. With a CAM system it is important to **"get it right" at the CAD stage**. Once an accurate file is uploaded the machinery will run numerous **identical items** with the same **good quality**. Only a fault with the machine (or sometimes the material) will affect the quality of a finished product. **Properly maintained and fully functional equipment will always assure quality.**

CAM Advantages
- Low unit costs
- Quality assurance (accuracy)
- Fast method of production
- Fewer labour costs
- Machines can run continuously

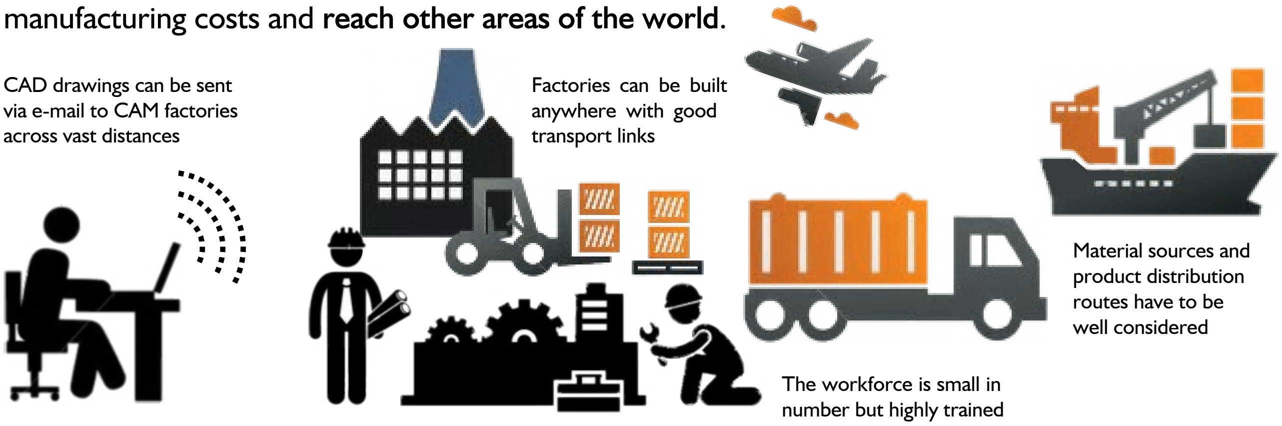
CAM Disadvantages
- Initial high cost of machinery
- Cost of machine maintenance
- If a machine breaks, production is shut down, costing time and money
- Loss of jobs

Industrial Manufacture

Manufacturing has changed massively since the Industrial Revolution - a large workforce of unskilled labourers used to be commonplace and factories tended to be built along river courses for power and transport. Nowadays industry can develop anywhere with good infrastructure, and workers tend to be skilled or semi-skilled.

Globalisation

Globalisation relates to the **movement of people, goods and ideas** (or information). It is fuelled by advances in technology that make movement quicker and easier; the advent of **e-mail** and the **Internet** for instance has made **sharing information** and ideas very easy. This means it is possible to have a design office in one location and manufacturing plant in another (previously these had to be localised for effective communication) - the office can send CAD drawings to the other side of the world to be manufactured with CAM hardware if necessary. **Infrastructure** (road, rail, air & sea) has made the movement of manufactured products much simpler - once complete, products can be loaded onto a suitable form of transport for **distribution** to anywhere in the world (this has to be considered - see "Issues of Sustainability"). China for example has become a major manufacturing nation - it has **high productivity, very low labour costs and good infrastructure** - this makes it very attractive to firms looking to cut their manufacturing costs and **reach other areas of the world**.



Impact on Workforce

The new advanced manufacturing processes that are used today require **highly trained people** to operate and run them efficiently. CNC and rapid prototyping hardware require skilled workers with **specialist knowledge** - something which old heavy industry did not require (labour was largely physical). This means that **companies have to continually invest in training** their workforce in order for them to keep pace with, and operate, new technological innovations. Globalisation (with accessible, low cost air travel), has allowed workers with specialist skills to move greater distances to find work that suits them. This is often necessary because **fewer workers are required to operate CAM hardware** so jobs that exist are competitively won. The term used to describe this type of manufacturing, that uses advanced technologies/processes and a highly trained workforce, is "**The New Manufacturing Economy**";- an integration of digital information, automated machinery, environmental responsibility and business strategy (e.g. niche marketing).

Globalisation has allowed:

- Geographical freedom
- Remote manufacturing (via the Internet)
- New market opportunities
- Workforce migration

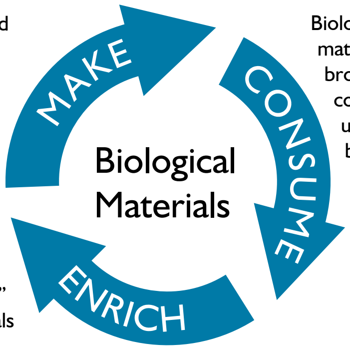
The Modern Workforce is:

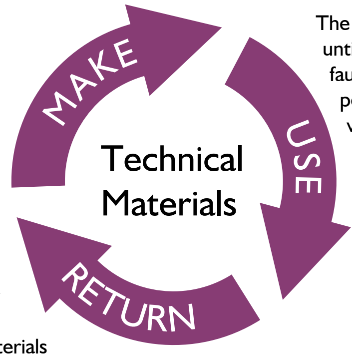
- Highly skilled and trained
- Invested in by their employer
- Reduced in number (compared to heavy industry)
- Environmentally aware

Sustainability

Good designers will always consider sustainability from the beginning of the design process, right through to manufacture. Sustainable design seeks to **minimise, or completely eliminate, negative effects on the environment** through the knowledge and skill of the designer. This can be done through innovative design and the **responsible use of materials**.

The Circular Economy





The circular economy moves away from the present linear system of take-make-dispose and looks to systems found in nature. A **Cradle-to-Cradle** approach is therefore adopted - in the same way plants live, die and provide nutrients for other plants in a closed loop - we can treat products in the same way; materials used are divided into two groups - **Biological** and **Technical**

Biological Materials
These are materials that are grown (e.g. wood) - they can therefore be **returned to the soil**, as nature intended, to **provide nutrients** for other grown materials that can themselves be harvested. They must be returned in a form that will enrich the soil and should therefore be **free from toxins**.

Technical Materials
These are materials that will **not naturally decompose** (e.g. metals & synthetic plastic) - these are **kept at high quality** in a continuous cycle of renewal. This is different to recycling because recycled materials degrade as they are processed and material is lost during every cycle - in a circular economy there is **no degradation** - the re-use of materials is known as **up-cycling**.

The Key Principles

No Waste
The biological and technical materials of a product are intended to fit within the circular economy - this means **designing for disassembly** (non-permanent fixing), so technical materials can continue in the cycle with no degradation and be **re-used**. Biological materials like wood should only ever be **finished with non-toxic substances** so they can be returned to the soil.

Renewable Energy
The energy needed for manufacturing a product should come from renewable resources e.g. biofuel, wind or solar.

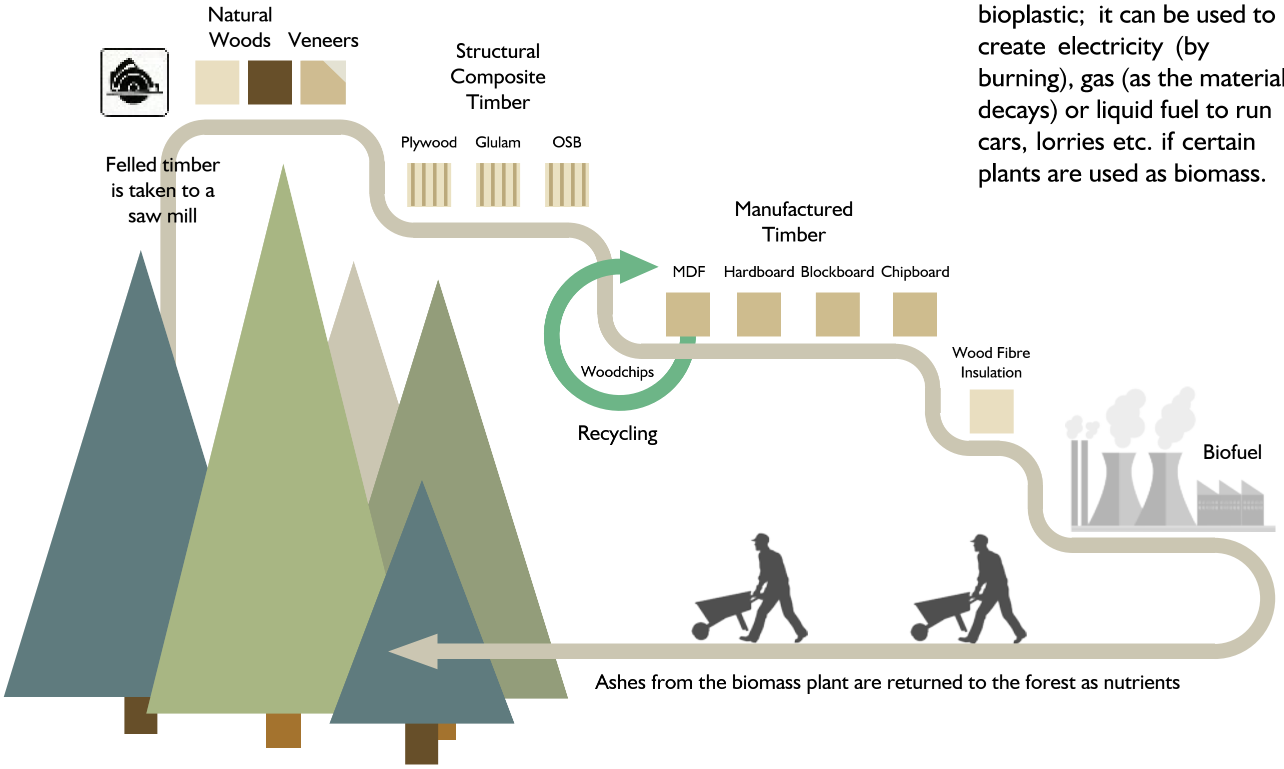
Recovery Systems
The ways in which materials are recovered - this could mean developing **new business models** e.g. a product is rented from a company rather than sold; this creates a **reverse supply chain** with the product going back to the factory for disassembly and re-use.

Sustainability

Forest loss (deforestation) contributes to greenhouse gas build-up as the trees absorb carbon dioxide to produce oxygen. Greenhouse gases contribute significantly to climate change but by choosing wood products from sustainably **managed forests**, where young trees are planted as mature trees are felled, we can help to tackle this problem.

The Wood Cascade

Biomass/Biofuel
Biofuel is made from natural materials like wood and bioplastic; it can be used to create electricity (by burning), gas (as the material decays) or liquid fuel to run cars, lorries etc. if certain plants are used as biomass.



Wood can be sourced sustainably as part of the circular economy - wood is taken from a managed forest with a tree planted for each one taken. The wood is then transported to a sawmill to be cut for use. Veneers are created (thin sheets of wood); hardwood veneers can be used on manufactured boards to give the appearance of a solid section of hardwood - this saves material and improves the aesthetic of the board. Veneers are also used in structural composite timbers, built up in layers with glue to give strength. Further down the cascade manufactured boards are created from waste materials from the saw mill (recycling exists as part of the circular economy). Waste material from the three previous stages are used to create wood fibre insulation for use in houses before the final stage of biomass utilisation to create energy.

The Wood Cascade is one method of using wood sustainably; there are however other methods:

Reclaimed Wood
This is sourced from architectural salvage yards - it can include old floorboards, fireplace surrounds and furniture. Reclaimed wood has a distressed look giving added character.

Managed Forests
Managed softwood forests are common because the trees grow very quickly and used material is easily replaced. Hardwoods cannot be managed in this way so limits are put on how many can be cut down but this is still not sustainable.

Reducing Material Used
By designing products that use the bare minimum of material to still perform and function successfully, we use less, and waste less, during manufacture thereby reducing the number of trees that need to be cut down.

Sustainability

Metals

All metal comes from rock (ore) that is dug out of the ground. This has a negative impact on the surrounding environment - often trees are cleared and vast areas are turned into open cast mines. Animals lose their habitats and the machinery used to dig out, and transport, the ore pollutes the atmosphere. To get the metal out of the ore a great deal of energy is require, this energy is often generated by coal power stations, which again, create pollution.

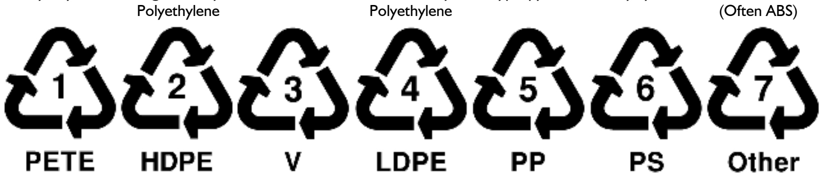
Metal ores will eventually run out so it is therefore important to reduce the amount we dig out of the ground and reuse or recycle the metal we already have. Metal products will have recycling symbols which tell you what kind of metal the product is made from so that when it comes to the end of its life it can be recycled. Depending on the metal, recycling uses between 5% and 20% of the total amount of energy required to harvest the metal from the ore.

Plastics

Some plastics are derived from **natural** renewable substances such as animals (horn), insects (lac) and plants (resin). Normal synthetic plastics are produced from oil which is a finite resource. (eventually oil will run out). These synthetic plastics take years and years to biodegrade, many being toxic to the environment and not all are able to be recycled.

Bio-plastics biodegrade naturally in less time than synthetic plastics, causing less damage and pollution to the environment. Some even dissolve in water.
Commonly used bio-plastics are made from potato and corn starch. These look and act like normal synthetic plastics and can be used to produce products like pens and disposable packaging.

Designers are now expected to design with sustainability in mind. Other than choosing a bio plastic, designers use different materials which can be separated to make recycling or reusing easier. All plastic products that can be recycled display a specific recycling symbol:



Clean Manufacturing

Clean manufacturing is an initiative used by responsible manufacturers who want to protect the environment. It involves minimising and preventing waste during production through:

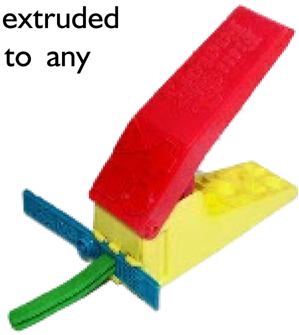
1. Conservation of materials (using less or using recycled materials) and energy (renewables or energy efficient equipment)
2. Re-use of materials
3. Reduction in toxic outputs that affect the environment

Identifying Industrial Processes

In addition to the material processes already discussed in this booklet there are others that you could be asked to identify in an exam - you need to be able to identify them visually:

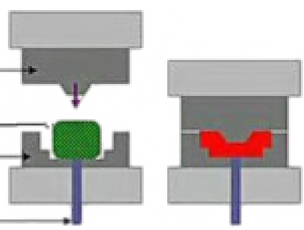
Plastic Processes

Extrusion
An extruded product will have a uniform cross section over its entire length. It's a bit like play-doh being forced through a former. Remember extruded products can be cut to any length.



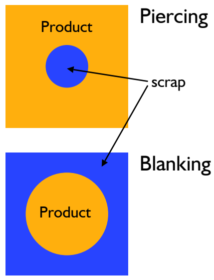
Blow Moulding
Hollow products are created with this process - usually bottles and other containers. The products are inflated inside a mould and will have split lines from where the two parts of the mould meet.

Compression Moulding
This process uses thermoset plastics to make products that have very good heat & electrical insulation properties. The products tend to be strong but brittle and may have areas of flash where the heated plastic pellet was squeezed out the mould. They will also have an ejector pin mark.



Metal Processes

Piercing & Blanking
These processes involve shapes being punched out of sheet metal. Piercing involves a hole being punched in a product; blanking involves a product being punched from a blank. Sometimes the processes are done together e.g. a washer.



Press Forming
This involves sheets of metal being squeezed between two matching metal moulds. Press forming is easy to identify - there will be no sharp bends and it will be fairly obvious that the product has been formed from one sheet of material.

Drop Forging
Drop forging is used to make steel products that are very strong. Think of the function of the product - if it's used to support a lot of weight or hit something hard, then chances are it was drop forged. There may also be some evidence of flash and some surface detail.

Standard Components

Standard components are individual parts, manufactured in thousands or millions, to the same specification (such as size, weight, material etc...). For example steel bolts are available in a vast range of standard sizes / head types. However, each size will be manufactured to an internationally accepted standard.

Benefits to Consumers and Manufacturers

Standard components are used in a great many products that we use on a daily basis. Self assembly products, with standard components, are popular with consumers with low to middle range incomes - this is partly because they are **cheaper** to purchase than products with non-standard parts that come fully assembled. Standard components make **assembly/disassembly of products much easier** for consumers because simple everyday tools can be used. Should a component break it is simple for the consumer to find a **replacement.**

Manufacturers favour standard components because it **saves time** manufacturing one-off components. Standard components are mass produced and are usually **bought-in at low cost**; this means that manufacturers **save money** and the savings can then be passed on to the consumer. The **quality** of the components are assured because of testing, so manufacturers can use them with confidence.

Flat Pack Products

Flat pack or self assembly products have become increasingly popular with stores such as Ikea offering a **wide range of designs, finishes and configurations**. The combination of standard components and **easy to follow instructions** means that the consumer can assemble the product easily. Products are **easy to transport** from the shop to the home and the variety of designs available means that consumers can choose one which best suits the **décor of their house**.
Manufacturers benefit from flat pack designs because the manufactured boards used are **cheap** and **easily machined by CAM hardware**; this also makes them suitable for mass manufacture with **low unit costs**. The fact that the products are designed to be sold unassembled means that they take up less room and are **easier to store and transport** to retailers. **Less packaging** is used and savings are made in the amount of **fuel** needed to transport the products - this is obviously also **good for the environment**.

Rapid Prototyping

Rapid prototyping is a way of producing a 3D model very quickly, much more so than traditional methods. A CAD model must be produced first before being sent to the rapid prototype hardware. There are various types of rapid prototype machines - some use lasers to heat and solidify a resin; others extrude and build up layers of melted plastic on a platform. Whichever method is used the aims and results are very similar:

- Models are very accurate
- Intricate and complex forms can be produced quickly
- The same materials can be used as in the final product
- The functional aspects can be assessed e.g. if parts fit tightly
- The aesthetic qualities can be discussed with the client
- Ergonomic and safety issues can be examined
- Savings are made because skilled model makers do not need to be employed