



Turnbull High School



**Practical Metalwork
National 4/5
Course Notes**

Introduction & the exam.

N4 Practical Metalworking.

The National 4 Practical Metalworking course consists of:

- 3 Unit assessment tasks
 - Machine Processes
 - Fabrication and thermal Joining
 - Bench Skills
- Added Value Unit - Garden Lantern **100%**

The following information contained within this booklet contains all the information required to fulfil certain outcomes for the units of the course. It is therefore imperative that candidates are fully conversant with the information contained within this booklet.

N5 Practical Metalworking.

The National 5 course consists of:

- External assessment by examination paper **30%**
- Internal assessment by Course Assessment Task - Garden Lantern **70%**

The examination paper is 1 hour long and consists of one part:-
Metalwork knowledge (*Content of this booklet*)

The graphics knowledge consists of a total of **60** marks.
The Course Assessment Task consists of **70** marks

The following information contained within this booklet contains all the information required to fulfil this aspect of the examination paper. It is therefore imperative that candidates are fully conversant with the information contained within this booklet.

National 5 Exam Question Topics.

The following topics will be assessed in the exam paper:

Measuring and marking out:

A knowledge and understanding of the use of the tools and equipment listed below:
Scriber; scribing block; steel rule; combination set; engineer's square; centre finder; spring dividers; calipers: oddleg, inside, outside; micrometer: analogue and digital; Vernier calipers: analogue and digital; centre punch; witness marks; surface table; angle block; v-block; engineer's blue; units of measurement; datum lines; functional dimensions; the need to make allowances for expansion, bending, stretching, forming, trimming, welding, brazing and soldering.

Reading and interpreting drawings and documents:

working drawings, pictorial drawings, diagrams, cutting lists
orthographic projection

Scale

basic drawing conventions: line types — outlines, centre lines, fold lines, hidden detail and dimension lines

reading and extracting information from working drawings: linear, radial, angular and diametric dimensions

Materials:

Properties of the metalworking materials listed below:

ferrous metals: steel, high carbon steel, iron

non-ferrous metals: aluminium, copper, nickel

alloys: bronze, brass, stainless steel

common sections: square bar, round bar, hexagonal bar, angle iron, tube

sheet materials: tin plate, copper, brass, steel, aluminium

Bench work:

the safe use of the following bench tools and their component parts:

engineer's vice, ball-pein hammer cold chisels, file types: flat, square, round, needle and 3 square, file parts: tang, safe-edge, handle, ferrule, file cut: smooth, 2nd cut and rough, filing

methods: cross filing and draw filing, saws: hacksaw and junior hacksaw, taps: taper, intermediate and plug, tap wrench, drill sizes for tapping, dies: adjustment of split die, die stock, rivet set and snap.

Sheet metal tools and machines:

The safe use of tools, machines and equipment used in sheet metalwork listed below:

folding bars, folding machine, notchers, guillotine, hide and rubber mallets, tin snips (straight, curved, right and left hand), pop riveter, spot welder.

Machine Processes:

The actions carried out on the machines/processes listed below:

pedestal/pillar drill: drilling and countersinking, bench grinders, centre lathe processes: facing off, parallel turning, taper turning, chamfering, drilling and use of compound slide, milling machines: vertical, horizontal and CNC, industrial cutting processes: laser and plasma cutters.

Machine tools:

The safe use of the equipment and machinery parts listed below:

parts of centre lathe: headstock, tailstock, tool post, compound slide, cross slide and saddle, lathe cutting tools: left-hand knife tool, right-hand knife tool, knurling tool, parting tool, 3-jaw chuck, 4-jaw chuck, Jacob's chuck, chuck keys, revolving centre, machine vice.

Finishing:

The finishing processes listed below:

Planishing, polishing, bluing, machine finishing (ground, milled), preparation and application of paint and powder-dip coating.

Safe working practices:

Good practices and safe systems for general workshop and individual activities as appropriate.

Personal protective equipment: apron, gloves, safety goggles, safety specs, visors, welding masks.



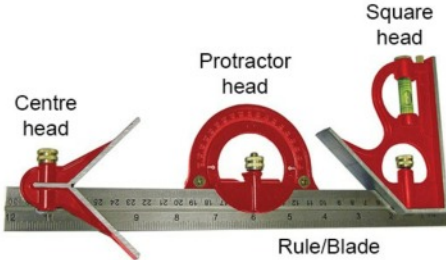



Fabrication and thermal joining:



The processes and techniques listed below:


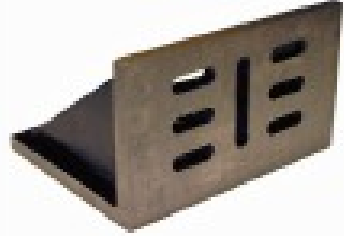
thermal joining: welding (mig, spot and electric arc), soldering, brazing; mechanical fixing: riveting (snaphead, countersink and pop), screw-fixing; metalwork adhesives; heat-treatment methods: annealing, hardening and tempering.

Measuring and marking out.

Tools and equipment

Tool	Description	Image
Scriber	The scriber is a tool which is used to "SCRIBE" or mark lines on metal.	
Scribing Block	A scribing block is used to lay out lines at a set height from the base, thus its second name surface height gauge or just surface gauge.	
Combination Set	A combination square is a tool used for multiple purposes in metalworking. It is composed of a ruled blade and one or more interchangeable heads that may be affixed to it. The most common head is the standard or square head which is used to lay out or check right and 45° angles.	
Engineer's Square	An Engineers Square is similar to the Try Square except it is smaller and made of metal. It is used to check that the edges of the plastic or metal are square or to scribe lines at Right Angles to an edge.	
Centre Finder	The centre square is probably one of the simplest tools ever designed as it is composed of only two pieces of material. When placed up against a round piece of material such as a round section of steel it can be used to find the centre accurately.	
Spring Dividers	These are used to mark out circles and arcs and to step out equal lengths along a line.	

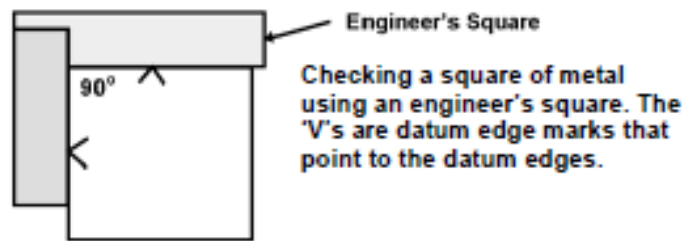
Tool	Description	Image
Oddleg Callipers	These are used to mark out lines on metal Parallel to an edge.	
Inside Callipers	Inside callipers are used to test the diameters of holes or the distances between two surfaces where it would be difficult to use a steel rule.	
Outside Calipers	Outside callipers are used for testing the outside diameters of round bars and thickness of sheet metal where it is difficult to use a steel rule.	
Micrometer	This tool is used to measure sizes with great accuracy. The most commonly used micrometers can measure to one hundredth of a mm. The micrometer is generally used for measuring external sizes.	
Digital micrometer	Same as a micrometer but offers a digital reading.	
Vernier calipers	The vernier calipers are also used for measuring very accurate sizes. The vernier caliper can measure internal sizes, depths and external sizes.	
Digital calipers	Same as a Vernier calipers but offers a digital reading.	

Tool	Description	Image
Centre punch	<p>Before metal can be drilled with a twist drill the surface must be firstly punched using the Centre Punch. The reason for this is to ensure the drill does not slip on the surface.</p>	
Surface table	<p>A surface table is a solid, flat plate used as the main horizontal reference plane for precision inspection, marking out (layout), and tooling setup. The surface plate is often used as the baseline for all measurements to the workpiece.</p>	
Angle block	<p>Slotted holes or "T" bolt slots are machined into the surfaces to enable the secure attachment or clamping of workpieces to the plate, and also of the plate to the worktable. Angle plates also may be used to hold the workpiece square to the table during marking-out operations.</p>	
V-block	<p>V-Blocks are precision metalworking jigs typically used to hold round metal rods or pipes for performing drilling or milling operations.</p>	
Steel Rule	<p>The steel rule is a basic measuring tool. When used correctly, a good steel rule is a surprisingly accurate measuring device.</p>	

Marking out Tips and hints

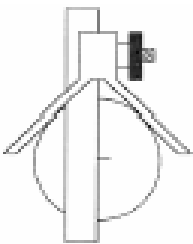
Pens and pencils do not work well on metal, they rub off easily and don't show up well. Marking out is shown by scratched lines. To help the scratches to show up, before marking out, the surface of the metal can be covered with a thin layer of a quick drying ink called **Engineer's Blue**. Marking out tools scratch away the blue layer to show the contrasting metal colour underneath.

Before marking out, the metal should be prepared by filing two **datum edges**, from which all measurements are made. These edges should be perfectly straight and be at 90° to each other.



Combination Square

The photo shows all three heads on the rule. In use, only one head at a time would be on the rule.

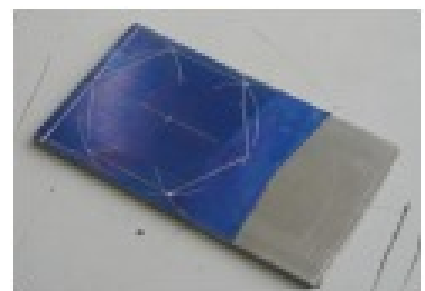


Centre square being used to find the centre of a disc. With the disc edges touching the arms, draw two lines at different angles, where they cross is the centre.

The angle head being used to draw a line at a set angle.

Engineer's Blue

Engineer's blue is a dye used in metalworking to aid in marking out rough parts for further machining. It is used to stain or paint a metal object with a very thin layer of dye that can be scratched off using a scriber reveal a bright, yet very narrow line in the metal underneath. The advantages are that any existing scratches are covered with the dye and the new lines have a contrasting background.

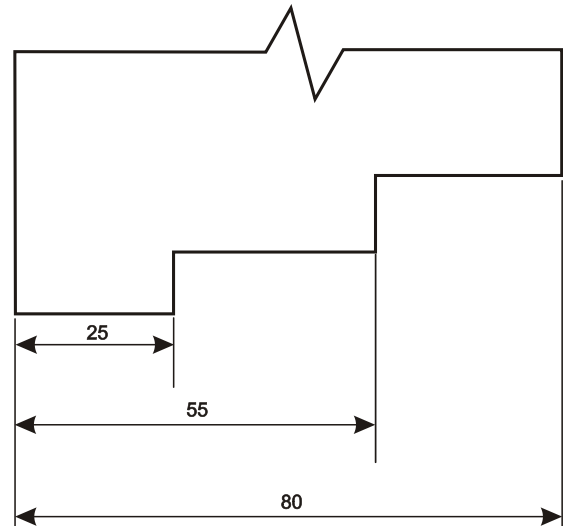


Witness marks

In order that lines can be seen more clearly faint dots, called witness marks, can be lightly punched around the entire shape (that will be cut-out). A centre punch is used, along with a hammer: to create witness marks. Rest the work on a block of metal to do this, not in a vice.

Datum lines

Using the same point every time when marking out your component will reduce the chance of accumulating a tolerance error.



Using datum lines

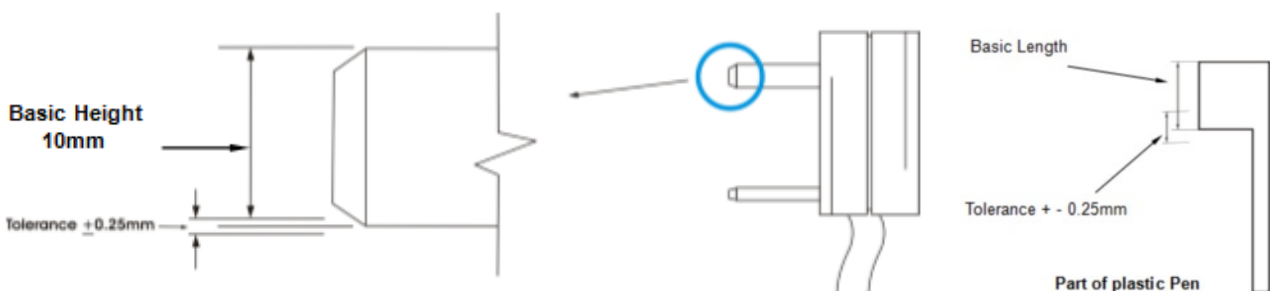
Dimensional Tolerances

When products are manufactured, they, in many cases have to be able to be assembled to other components which make up the complete product. It is very difficult to ensure that the components are the exact size every time, therefore to allow for slight mistakes in manufacturing we use a system called Tolerance. This allows the components to be made within certain sizes which in turn allows for slight mistakes allowing the components to still fit.

In the first example given overleaf the component has a tolerance of 0.25mm either way. This means the component can be made within the sizes 19.75mm to 20.25mm. The tolerances vary depending on what is being made.

In the example shown opposite (*button for TV remote*) the button has been made with a tolerance of 0.5mm. This means that in the manufacturing process it will have a full 1mm allowance. This does not seem a lot but in manufacturing terms is a substantial allowance.

For example, the height of a pin of an electrical plug, as shown on the next page, is 10mm. The company has determined that the size could vary between 9.75mm and 10.25mm and still be able to fit in the slots in the socket. In this case a tolerance of 0.5mm could be applied to this dimension without affecting the function of the part. This size is normally stated as 0.25mm.



When manufacturing or constructing an item it is virtually impossible to achieve precisely the required size of the item. The error permissible in manufacture is called tolerance - this is normally given on the drawing of the item. Tolerances which affect the size of an object or feature on it are referred to as dimensional tolerances. They are also used to tolerance the size of locating features on an item in relation to another. For example, the required length (or basic length) of part of a plastic pen clip shown below is 10mm. This size could vary, between 9.5mm and 10.5mm and still fit in the slot provided for it on the pen. tolerance of 1mm, normally stated as $\pm 0.5\text{mm}$ could therefore be applied to the dimension without affecting the function of the part. The length of the part of the clip could then be manufactured to any size between 9.5mm and 10.5mm and still be acceptable.

Types of Tolerance

Functional & non functional dimensions

The remote button and the electrical pin of the plug shown on the previous page are examples of a **functional dimension** as they are directly affected by the size of both components. If either was out with the tolerance allowed they would not fit.



Whereas a **non functional dimension** would be the height of the inside button or the length of the pin would not affect the fit of the two components.



Due to a number of different processes involved in the manufacture of products in metalwork we need to make allowances for expansion, bending, stretching, forming, trimming, welding, brazing and soldering etc.

The tolerances that you need to work to in your Course Assessment Task are:

Operation	Tolerance
Individual Components	
Marking out	$\pm 0.5\text{mm}$
Fitting work	$\pm 0.5\text{mm}$
Sheet metal work (cutting)	$\pm 1\text{mm}$
Bending work — sheet metal	$\pm 2\text{mm}$
Bending work — metal strip/ bar	$\pm 5\text{mm}$
Forge processes (twisting, drawing down and flattening)	$\pm 3\text{mm}$
Assembly, joining and fitting	
Functional sizes	$\pm 0.5\text{mm}$ linear
Thermal joining	Minimum length of 20mm consistent in width
Drilling and countersinking	$\pm 0.5\text{mm}$
Parallel turning, facing and chamfering	$\pm 0.5\text{mm}$ linear $\pm 0.2\text{mm}$ diameter

Units of Measurement

Most countries use the **Metric** System, which uses the measuring units such as meters and grams and adds prefixes like kilo, milli and centi to count orders of magnitude. The United States uses the older **Imperial** system, where things are measured in feet, inches and pounds.

1 meter = 100 centimetres = 1000 millimetres

Reading and interpreting drawings and documents.

Development of ideas: working drawings

Working drawings contain all the information needed to make the design, including:

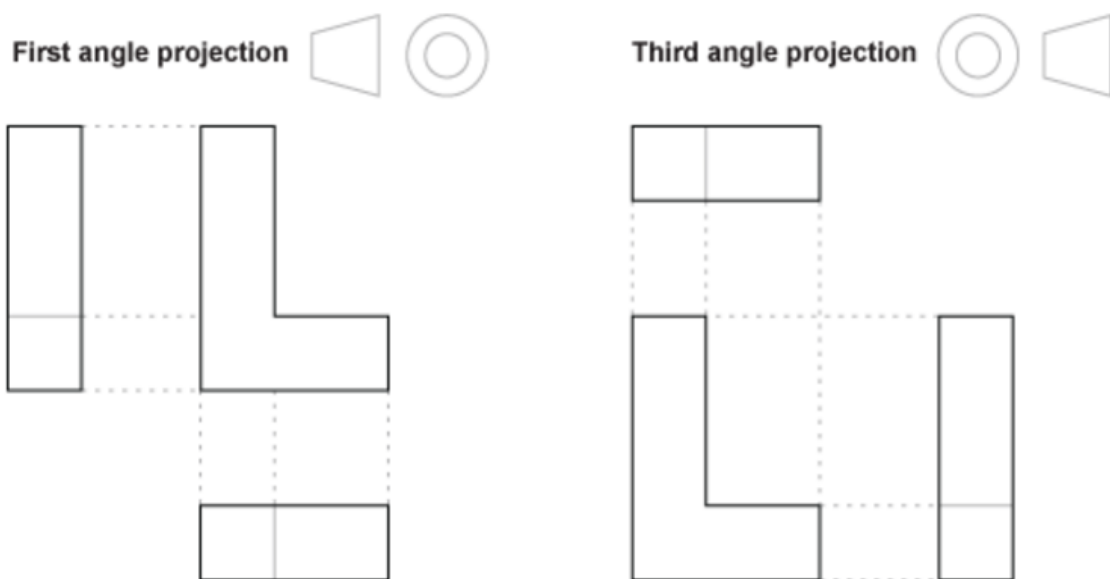
- dimensions
- details of components
- materials
- assembly instructions

Working drawings are normally done as orthographic projections.

Orthographic projection

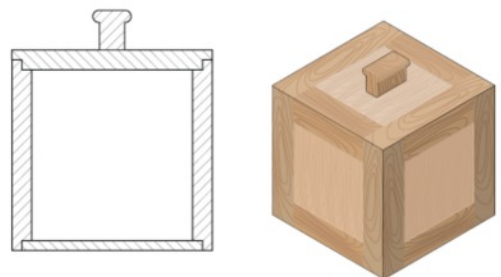
Orthographic drawings usually consist of a front view, a side view and a plan, but more views may be shown for complex objects with lots of detail. A drawing board and parallel motion or T-square is used to project one view from another. Orthographic drawings can be produced from Computer Aided Design software for example Autodesk Inventor.

Orthographic drawing may be done using first angle projection or third angle projection. We use the third angle projection method in the UK.



Sectional and assembly drawings

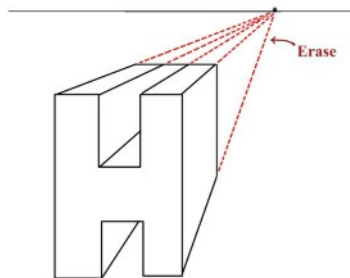
Some products may need a section drawing to give extra structural information, or an assembly drawing to show how parts fit together.



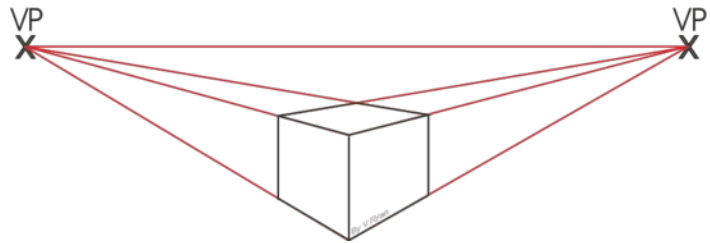
Pictorial Drawings

Perspective:

There are two types of perspective views. They give a 'realistic view of an object or building. Often used to promote or advertise an item.



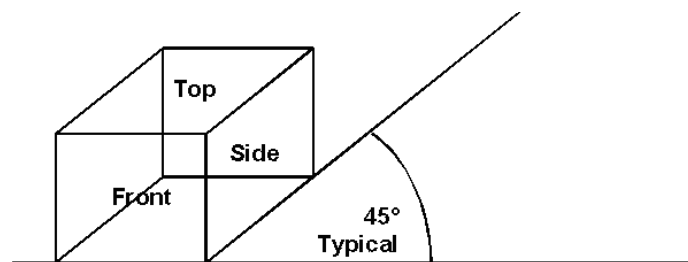
One point perspective



Two point perspective

Oblique:

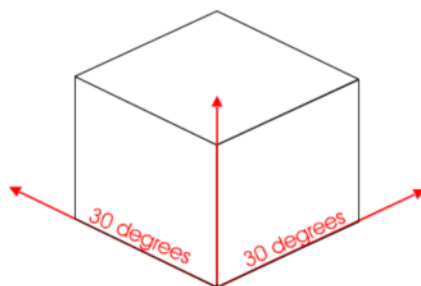
The main advantage of an oblique view is that the initial drawing is 2D. This allows us to easily draw circles before extending the shape back to give a depth. All depth sizes are drawn half size to ensure the drawing looks more realistic.



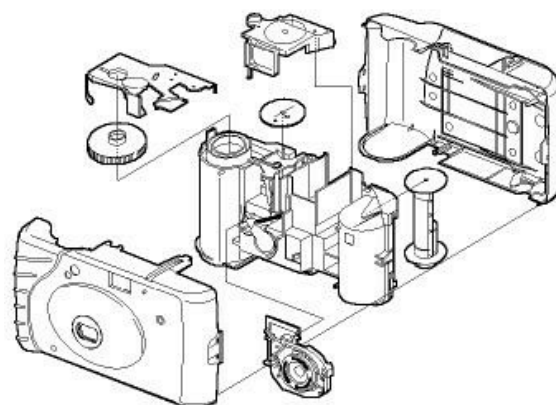
Oblique

Isometric:

Isometric views are often used in engineering as they can give a very clear view of how a component or object will look. This is especially so with exploded views which help show how several components are assembled together.



Isometric View



Exploded Isometric View

Scales

Scaling drawings allow us to draw exceptionally large objects such as houses on any size of paper available to us. To enable this to happen we have to scale every size (dimension) by the same factor. i.e. taking the example of the house, every dimension would have to be divided by say 100. By doing this we are scaling **DOWN** the size of the house. We can also draw exceptionally small objects larger, examples of which are, the minute electronic chips which are now part of our every day life. They are so small we could not draw them as they are we have to **SCALE UP** the drawing to be able to draw them.

When we carryout a drawing using the actual dimensions, this is called '**full size**', or the drawing has been drawn to a scale of **1:1**. For every 1mm drawn, 1mm is represented. When we carryout a drawing and reduce all the sizes by a factor of 2, i.e. all dimensions are divided by 2, this is scaling down the drawing. This makes the drawing half its original size. What the 1 & 2 represent are, for every 1mm drawn on paper the actual size of the real object is 2mm.

We can also increase the size of an object by any factor. In the example shown opposite the sizes have been increased by a factor of 2. This will make the drawing twice its original size. The 2 is stating that for every 1mm actual size of the object, 2mm have been drawn. If we increased the object by **10** the scale would be **10:1**. If we reduced the objects dimensions by twenty the scale would be **1:20**.

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With respect to Engineering drawings, there are recommended scales for reduction and enlargement. These are as follows:-

Reduction:- 1:2, 1:5, 1:10, 1:20, 1:50, 1:100, 1:500, and 1:1000






Enlargement:- 2:1, 5:1, 10:1, 20:1, and 50:1.

The size of scale used is mainly dependant on two factors. These factors are the;

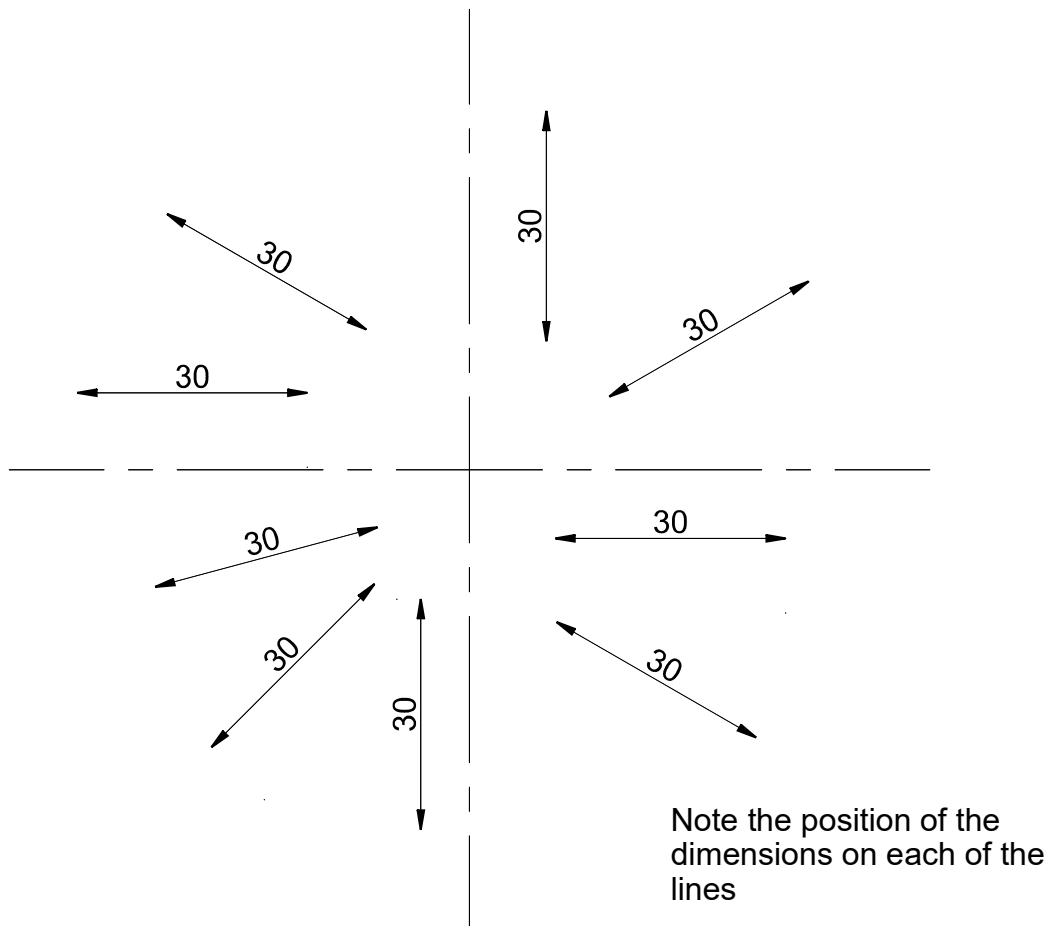
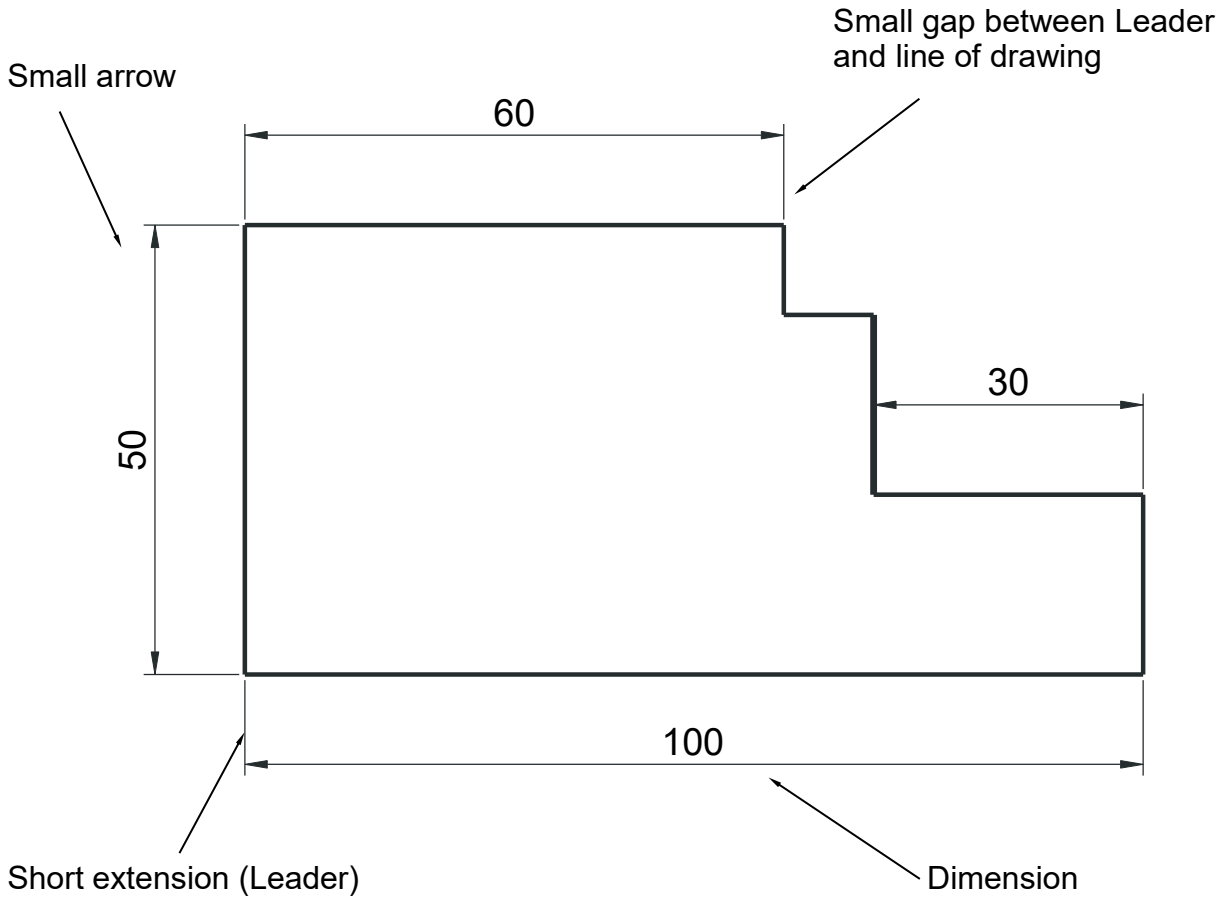
**Size of paper available; And the size of the object being drawn;
The amount of detail required**

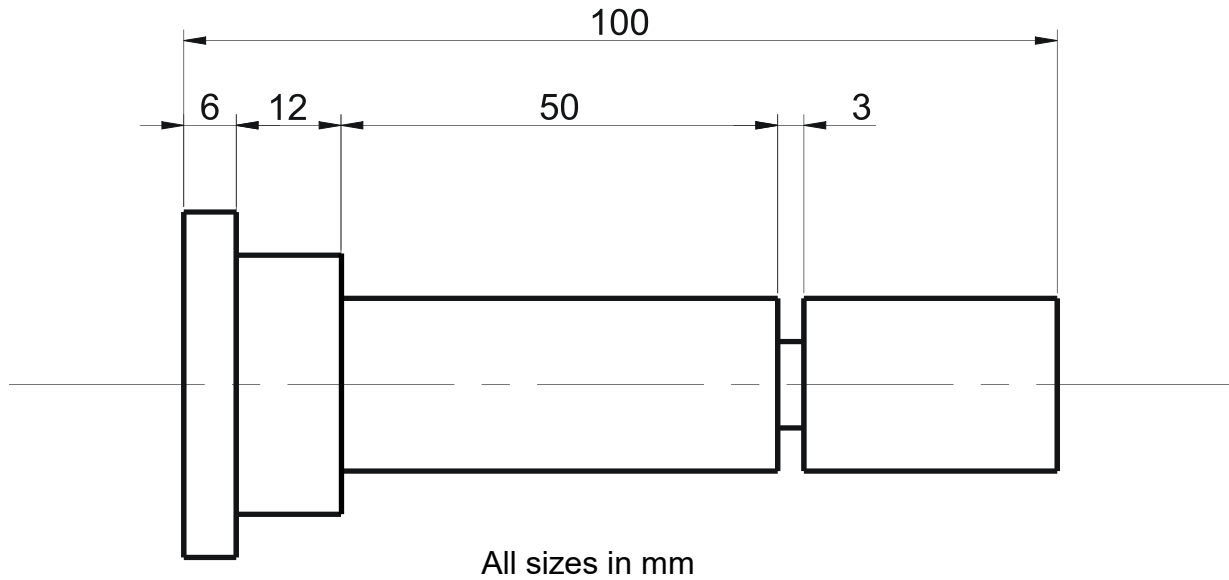
E.g. If house was being drawn on a piece of A4 paper opposed to a sheet of A2 paper, the scale used will obviously have to be different or it won't fit onto the page.

Line Types

Line Type	Image	Description	Use
Outline Solid		Continuous thick	Used for visible outlines and edges.
Projection Line		Continuous thin	Used for projection, dimensioning, leader lines, hatching and short centre lines.
Hidden Detail Line		Dashed thin line.	Used for hidden outlines and edges.
Centre Line		Chain Long dash, dot, Or Chain thin.	Used for centre lines, lines of symmetry.
Fold Line		Chain thin double dash	Used for ghost outlines and bend lines.

Dimensioning



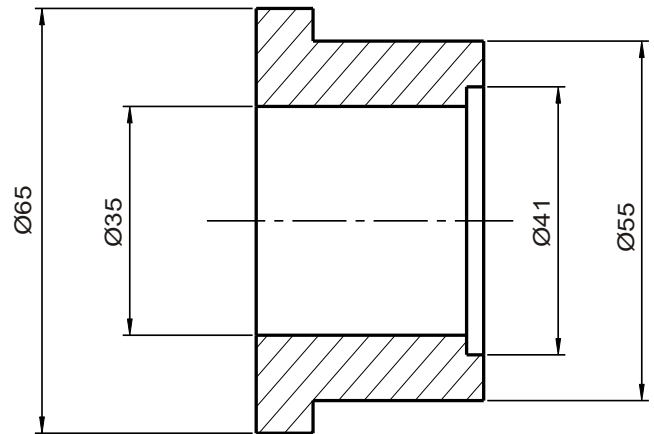


Notice on the above drawing that the largest dimension is placed on the outside of the smaller dimensions. Where there is a limited space for dimensioning, the dimension can be placed above, or in line with, the extension of one of the dimension lines. E.g. the 3mm dimension uses the 50mm dimension leader. It is also important when dimensioning not to include the units of measurement. As can be seen from the drawing above, state on the drawing the unit of measurement. i.e. **(All sizes in mm)**.

The sectioned drawing opposite shows some possibilities for putting a diameter on a drawing. This is by no means the only method.

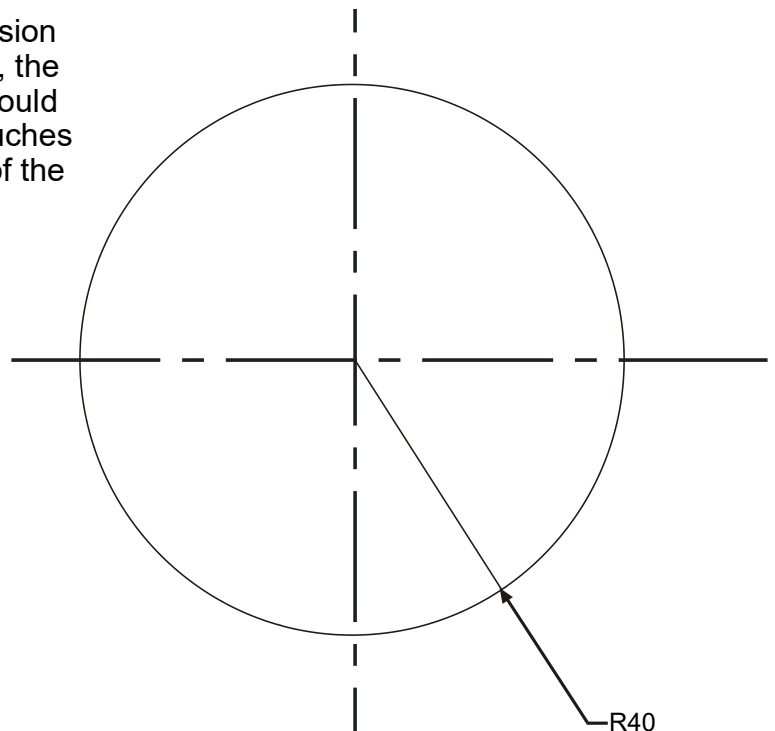
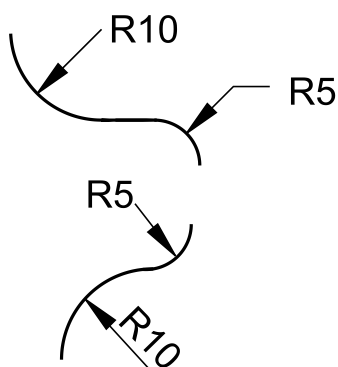
If the section shown was **Square**, then the following symbol would be used.

□45



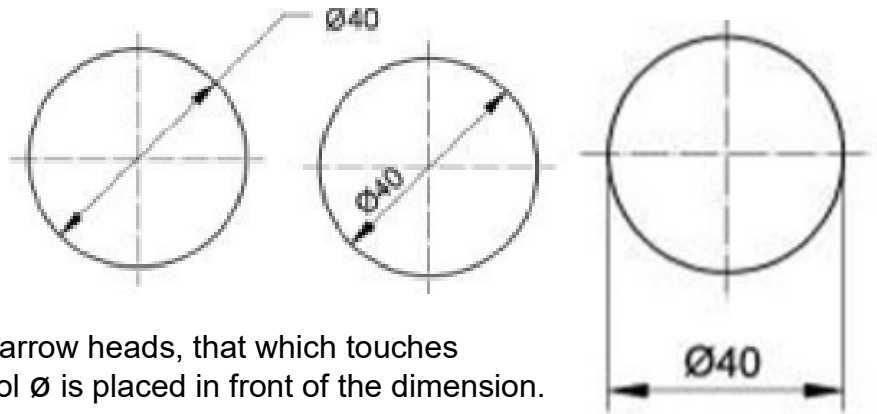
Dimensioning the Radius

Radii should be dimensioned by a dimension line that passes through, or is in line with, the centre of the arc. The dimension lines should have one arrow head only, that which touches the arc. The symbol R is placed in front of the dimension.

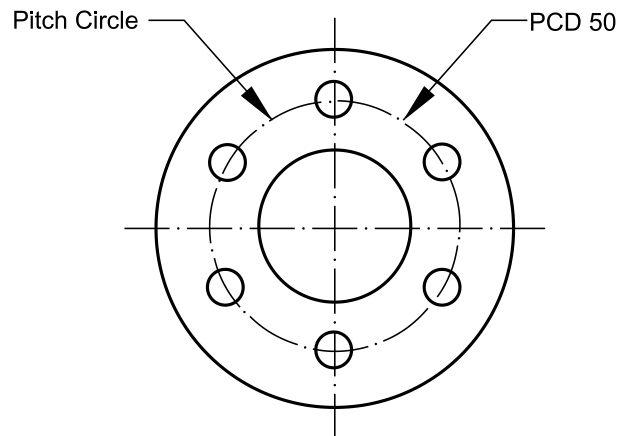


Dimensioning the Diameter

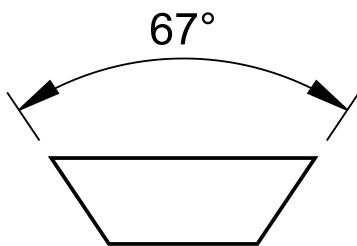
Diameter should be dimensioned by a dimension line that passes through, or is in line with the edges of the circle. The dimension lines should have two arrow heads, that which touches perimeter of the circle. The symbol \varnothing is placed in front of the dimension.



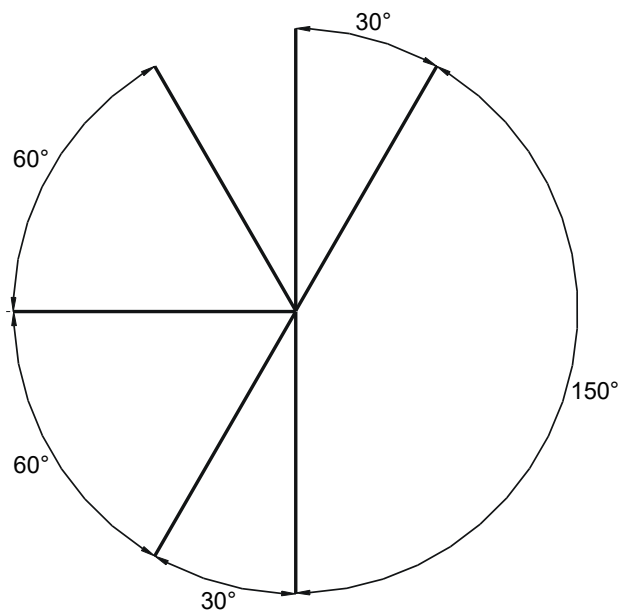
The pitch circle diameter is the diameter of a circular component that is to be manufactured. This circular component often has holes drilled into it. It can also be modified in other ways.



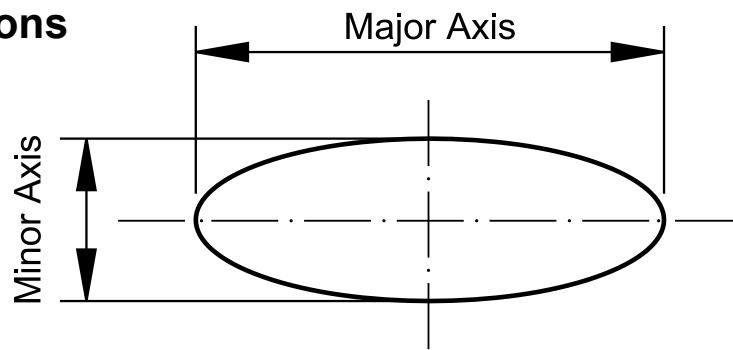
Angular Dimensions



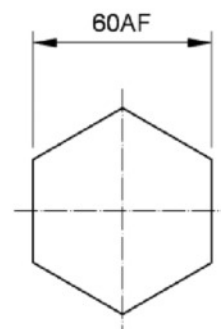
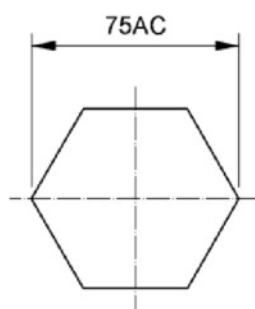
Note the position of the dimensions on each of the lines.



Axis Dimensions



Dimensioning Across Corners/Flats



Cutting List

A cutting list, which can also be known as a material list, bill of materials, or schedule of materials is simply a listing of all the parts that will be required to construct a project. This information can be derived from multiple sources: a measured or scaled drawing, a mocked-up project or an existing piece of furniture. Most cutting lists follow the convention of listing the:-

Part Name, Quantity, Length, Width, thickness and material to be used.

NAME:	NUMBER:	LENGTH:	WIDTH:	THICKNESS:	MATERIALS:
Top	1	1000mm	540mm	20mm	pine
Bread boards	2	540mm	96mm	20mm	" "
Legs	4	470mm	96mm	75mm	" "
Front and back rails	4	1050mm	60mm	20mm	" "
Side rails	4	450mm	60mm	20mm	" "
Slats	20	525mm	40mm	20mm	" "

Materials

Metals are usually classified into two main groups; FERROUS metals and NON-FERROUS metals.

Ferrous Metals

These metals contain iron and are affected by magnetism (apart from stainless steel); examples of such are Cast Iron, Mild Steel, High Carbon Steel, etc.

Non-Ferrous Metals

As the name implies (NON), this category of metal does not contain iron and is usually non-magnetic; examples are, Aluminium, Copper, Brass, Duralumin, Lead, Gold, Silver, etc.

Metals can also be grouped into two categories:

Pure Metals

Pure metals are made up from only one chemical element. Copper, iron, tin, lead, gold and silver are all examples of pure metals which have been mined from the Earth and extracted from the ore using a process called smelting.

Alloys

An ALLOY is a mixture of pure metals or a metal with a substance such as carbon added; examples of alloys are:- **Steel** (Iron & Carbon), **Duralumin** (Aluminium & Copper), **Brass** (Copper & Zinc) & **Bronze** (Copper & Tin).

Alloying

Metals are alloyed to improve the qualities of the individual pure metals e.g. both copper and tin as pure metals are both soft metals that are easily bent and scratched. When alloyed together (90% copper plus 10% tin) they produce bronze which is hard, rigid and resists scratching. Bronze is used for our 'copper' coins.

Corrosion

When choosing metals, resistance to corrosion may be an important factor.

Corrosion is caused by oxygen in the air combining with the atoms of metal, at the surface of the metal, to create a new chemical called oxide, e.g. iron oxide is called rust.

In steel the rust layer is loose and can fall away; this exposes new atoms that will combine with oxygen to form new rust.

In non-ferrous metals the oxide layer is dense and does not fall away; this creates a barrier to the oxygen in the air and new corrosion occurs very slowly. The layer is called tarnish.

Properties

Both physical and mechanical properties vary greatly between different metals and alloys and are an important part of the selection process.

Ferrous Metals

Name	Composition	Properties	Uses
Cast Iron	Iron + 3.5% carbon	Smooth skin with soft core, strong when compressed, self lubricating, cannot be bent or forged.	Vices, lathe beds, garden bench ends, car brake drums, etc.
Mild steel	Iron + 0.15 - 0.35 % carbon	Ductile, malleable & tough, high tensile strength , poor resistance to corrosion, easily welded.	Car Bodies, washing machine bodies, nuts & bolts, screws, nails, girders, etc.
High carbon steel (tool steel)	Iron + 0.8 - 1.5% carbon	Very hard, rather brittle, difficult to cut, poor resistance to corrosion.	Tool blades e.g. saws, chisels, screwdrivers, punches, knives, files etc.
High Speed Steel	Iron Tungsten Chromium Vanadium	Very hard, heat resistant, remains hard when red.	Drills, lathe cutting tools, milling cutters, power hacksaw blades etc.
Stainless steel	Iron Chromium Nickel Magnesium	Tough and hard, corrosion resistant, wears well, difficult to cut, bend and file.	Cutlery, sinks, teapots, dishes, saucepans, etc.

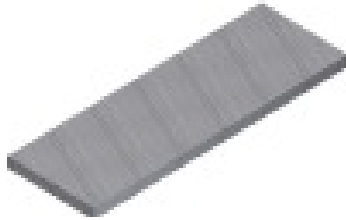
Non Ferrous Metals

Name	Composition	Properties	Uses
Aluminium	Pure metal	Good strength / weight ratio, malleable and ductile, difficult to weld, non-toxic, resists corrosion, conducts heat and electricity well. Polishes well.	Kitchen foil, saucepans, drinks cans, etc.
Copper	Pure metal	Tough, ductile and malleable. Conducts heat and electricity well. Corrosion resistant, solders well. Polishes well	Electrical wire, central heating pipes, circuit boards, saucepan bases.
Brass	Copper Zinc	Quite hard, rigid, solders easily. Good conductor of heat and electricity. Polishes well	Water taps, lamps, boat fittings, ornaments, door knockers.
Bronze	Copper Tin	Tough, strong, wears very well, good corrosion resistance.	Coins, wheel bearings, statues and boat fittings.
Tin	Pure metal	Weak and soft, malleable and ductile, excellent corrosion resistance, low melting point.	Solder (with lead), coating over mild steel (tin can).
Zinc	Pure metal	Poor strength/weight ratio, weak, ductile, and malleable, low melting point. Casts well.	Coating over mild steel (galvanising) die casings used in cars e.g. Carburettor.
Nickel	Pure metal	Corrosion Resistant, ductile and malleable, high melting point	Making alloys like stainless steel, machinery for large scale chemicals, batteries

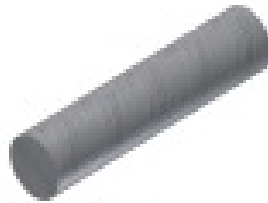
Form of Supply

Most metals are available in a wide variety of shapes and sizes and are usually described by their cross-section. i.e. what they look like when they have been sawn through.

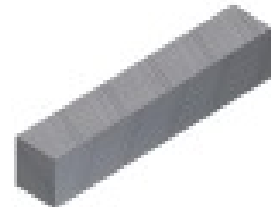
The following cross sections are typical examples of how metals are supplied to the school workshop.



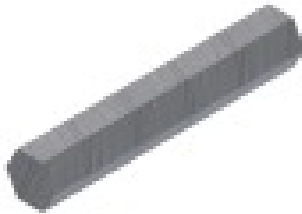
Flat Bar



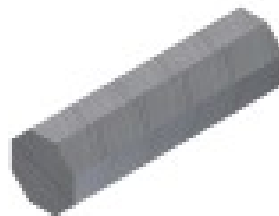
Round Bar



Square Bar



Hexagonal
Bar



Octagonal Bar



Round Tube



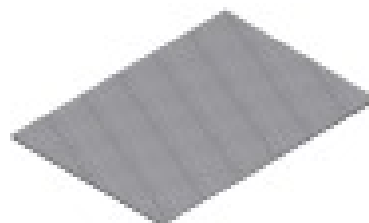
Square Tube



Rectangular
Tube



Angle Iron



Sheet

Tin plate, copper, brass, steel and aluminium are available in sheet form.

Metal Properties

Density:

The amount of matter (mass) in a material.

Density	Material
High	Gold, Lead
Medium	Copper, Steel
Low	Woods, Plastics

Thermal Conductivity:

How fast heat can travel through a material. If a material is known as an insulating material, heat travels very slowly through it.

Thermal Conductivity	Material
High	Copper, Aluminium
Medium	Mild Steel, Tin
Low	Woods, Polystyrene

Electrical Conductivity:

How fast electricity can travel through a material. A poor conductor is an insulator.

Electrical Conductivity	Material
High	Copper, Aluminium
Medium	Mild Steel, Tin
Low	Woods, Polystyrene

Fusibility:

The measure of how easy it is to melt the material. A highly fusible material has a low melting point.

Fusibility	Material
High	Tungsten, Chromium
Medium	Copper, Steel
Low	Zinc, Lead

Thermal Expansion:

The amount of expansion that occurs when the material is heated. A high expansion material will become noticeably larger when heated.

Thermal Expansion	Material
High	Polythene, Nylon
Medium	Aluminium, Tin
Low	Woods, Titanium

Mechanical Properties

Strength:

The measure of how well a material can withstand force without permanently breaking. There are different types of strength measurements.

Tensile Strength

Resists stretching by the pull of forces and is an essential strength for cables, chains and ropes.

Compressive Strength

Withstands pushing forces which try to crush or shorten.

Bending Strength

Has the ability to withstand forces attempting to bend.

Shear Strength

Resists strong sliding forces in opposite directions.

Torsional Strength

Withstands twisting forces under torsion (torque).

Malleability:

The measure of how easily a material can be permanently deformed by compressive forces e.g. hammering without cracking.

Malleability	Material
High	Copper, Aluminium
Medium	Mild Steel, Bronze
Low	Woods, Thermoset Plastics

Ductility:

The measure of how easily a material can be permanently deformed, without breaking, by bending, stretching or twisting.

Ductility	Material
High	Polypropylene, Copper
Medium	Mild Steel, Bronze
Low	Woods, Thermoset Plastics

Hardness:

The measure of how well a material resists scratching and being worn away by other materials.

Hardness	Material
High	Diamond, Chromium
Medium	Mild Steel, Bronze
Low	Woods, Thermoplastics

Toughness:

The measure of how well a material can stand up to sudden forces e.g. a hammer blow, without cracking.

Toughness	Material
High	Polycarbonate, Copper
Medium	Mild Steel, Brass
Low	Glass, Polyester Resin

Brittleness:

The opposite of tough. Brittle materials cannot withstand sudden impact.



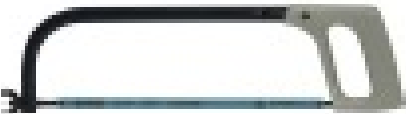



Durability:

The measure of how well a material stands up to weathering (the sun, cold, wind, rain, corrosion and rotting).

Durability	Material
High	Gold, Tin
Medium	Ceramics, Bronze
Low	Mild Steel, Softwoods

Bench Work

Tools and equipment

Tool	Description	Image
Engineer's Vice	The vice is bolted to the bench top so as to ensure the vice does not move whilst working on it. The vice is used primarily to hold metal while cutting, sawing, filing, etc. are carried out. As with the machine vice the body has also been CAST in two separate pieces.	
Ball Pein Hammer	This is a general use hammer although the ball pein end of the hammer is used specifically to round the heads of the snap head rivet.	
Hacksaw	The hacksaw is used for general cutting of metal bar, tubes, etc. The blade is easily removed by slackening or tightening of the front wing nut.	
Junior Hacksaw	This type of saw is also used for cutting metal but is used for light work or where a hacksaw is too clumsy.	
Cold Chisel	Cold chisels are used to cut metal where tin snips or a hacksaw would be unsuitable.	
File	A file is a tool used to remove fine amounts of material from a workpiece	
Tap	A Tap is used for creating internal screw threads.	

Tool

Description

Image

Tap wrench

A **tap wrench** is a hand tool used to turn **taps** for internal threading.



Die

A die is used to cut an external screw thread



Die stock

A double-handled **wrench** for holding and turning the **dies** used in threading operations (cutting the male threads such as on a bolt).



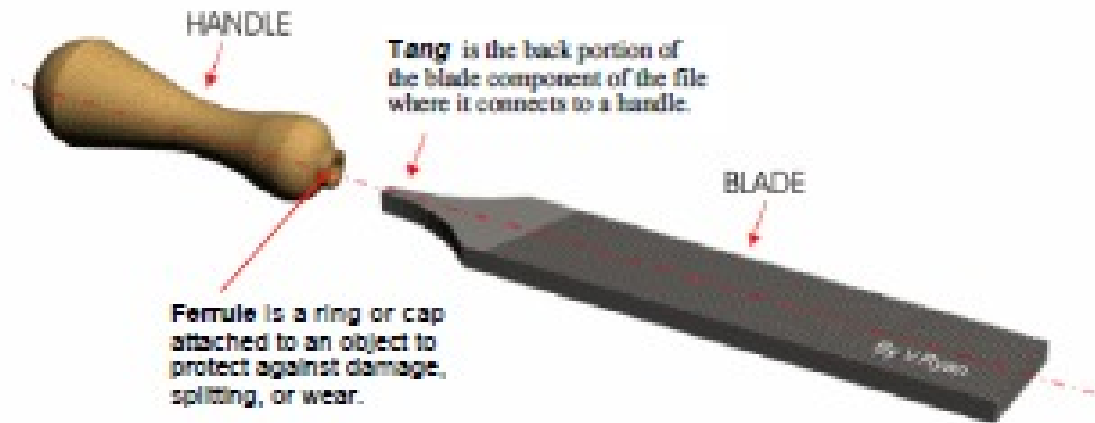
Rivet set and snap

This comes as a pair allowing you to set the rivet up and then from the rivet head. (See pages 31-32 for more detail.)



Files

Files are used to remove small amounts of metal and for smoothing a surface after it has been sawn. They are made from high carbon steel and come in many shapes, sizes and grades of cut.



The most common files are named after their cross section.

Flat file



Round file



3 square file



Square file



Half round file



The roughness of a file is known by its cut.

Rough cut

Used first to get rid of most of the waste quickly. Leaves a rough finish.

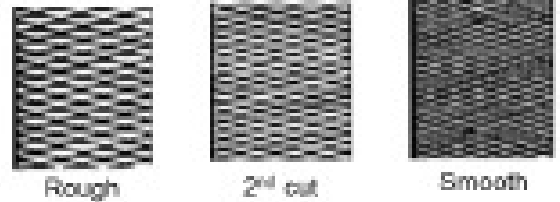
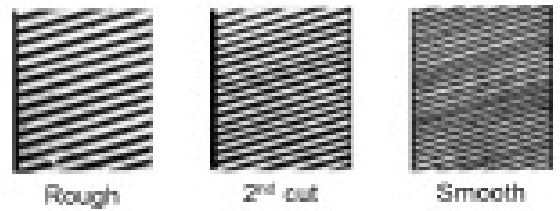
Second cut

Used to file closer to the line and for general work. Leaves a reasonably smooth finish.

Smooth cut

Used to file to the line and to provide a smooth finish.

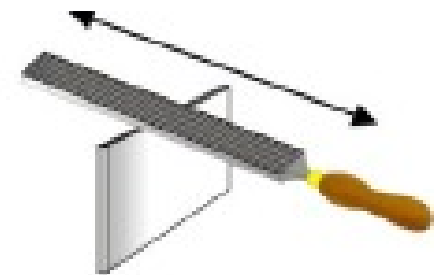
Single Cut



Double Cut

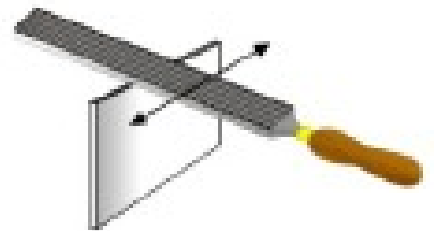
Cross filing

In this type of filing the file is moved across the work piece using the full length of the blade. This method of filing is used for removal of a lot of material with every stroke applied.



Draw filing

In this method of filing, the file is moved sideways along the work piece and is used to obtain a smooth finish after cross filing. This method does not remove much material.



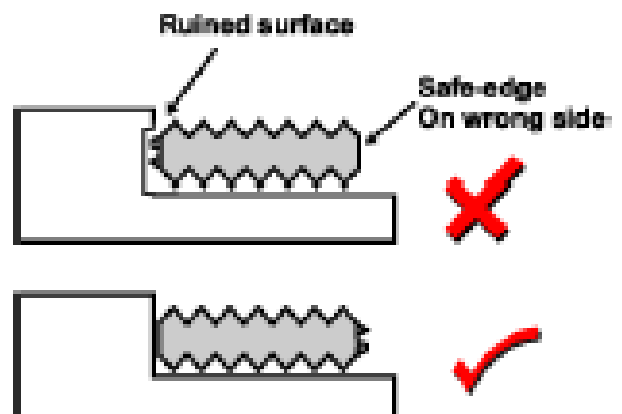
Cleaning the file

Small pieces of aluminium or plastic can be trapped in between the teeth of the file. This is called pinning. A file card can be used to clear the file of the excess material. The file card looks very similar to a wire brush except the teeth are very short.



Safe edge

Some flat files have a safe edge. The safe edge is useful to use when filing into a corner. It stops the file from filing into the other surface.



Standard Screw Threads

The screw thread is a very important detail in engineering. It is used to hold parts together. (e.g. bolt & nut) and to transmit power (e.g. vice screw).



Screw Cutting

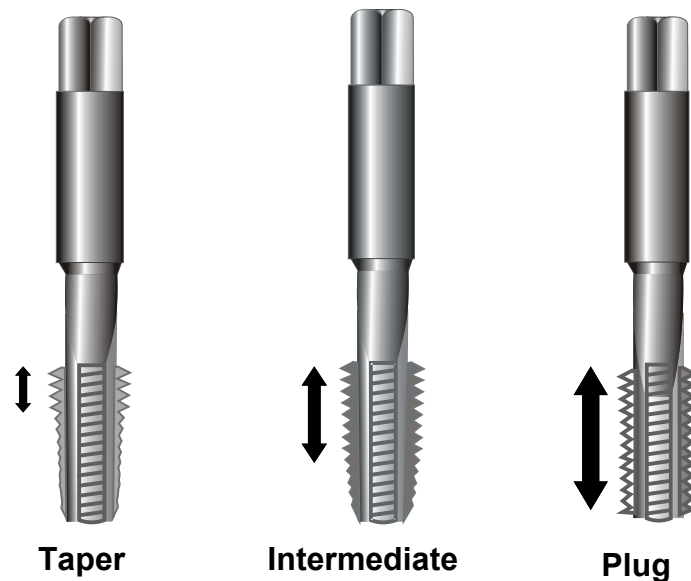
To achieve an internal screw thread, a hole has to be drilled first and then a tool called a tap is used to cut a thread within the hole. Taps are made from high speed steel (HSS). The top of the tap is square which enables the tap to be held securely in a tap wrench, which can be seen opposite.



Taps are generally available in sets of three and are used in the following order:-

1. Taper Tap
2. Intermediate Tap
3. Plug Tap

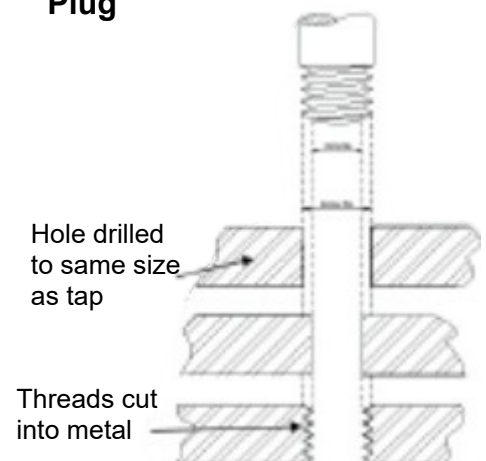
As can be seen in the taps above, the Taper tap has much smaller teeth at the bottom than the Intermediate or the Plug taps. This allows the taper tap to get started by making a shallower thread cut. The taper cut is followed by the second tap which has slightly more teeth. Finally, the Plug tap is used which will make the full thread cut. **Remember to use the correct cutting lubricant.**



Internal Threading

When tapping a thread in an internal hole the actual diameter of the hole to be drilled must be smaller than the actual overall size of the thread to be cut. An explanation of this is shown in the sketch opposite.

The drawing shows that if a hole was drilled which was the same size as the threaded bar, the bar would just fall through. The hole which must be drilled must therefore be smaller in diameter so as to allow the tap to cut the threads.



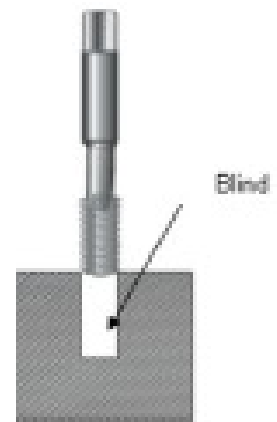
Drilling Data

The table below shows the diameter of hole which would be required to be drilled prior to tapping. E.g. if an M5 (Metric 5mm) thread has to be cut, the size of hole to be drilled will be 4.2mm.

ISO Metric Coarse Pitch Threads		
Diameter	Tapping	Clearance
M2	1.6mm	2.5mm
M2.5	2.1mm	3.0mm
M3	2.5mm	3.5mm
M4	3.3mm	4.5mm
M5	4.2mm	5.5mm
M6	5.0mm	6.5mm
M8	6.8mm	8.5mm
M10	8.5mm	10.5mm
M12	10.2mm	13.0mm

Blind Hole

A blind hole is a hole which **has a bottom to it**. If a blind hole is to be threaded it is very important to ensure that the depth of the hole is established before commencing to thread the hole. If this is not established it would be very easy to break the taps. A piece of tape attached to the tap indicating the depth is an ideal way of avoiding the tap from being broken by being forced into the bottom of the hole.



External Screw Cutting

In the previous few pages internal screw cutting was explored. External screw cutting will now be investigated. To cut an external thread on a metal rod a tool called a **DIE** will be used.

Circular Split Die

The picture opposite shows a split die, this is the most common type of die used in the school workshop. These are used for cutting external threads. The die is made from high speed steel (HSS). To assist in starting the thread cut, the split die has a split which enables the die to be opened slightly thus cutting a shallower cut.



Die Holder or Stock

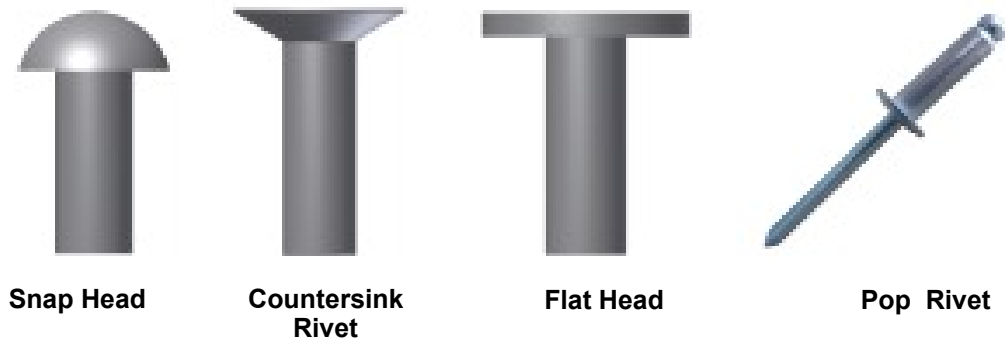
The circular split die fits into the die stock with the tapered side of the thread (shown by the writing on the die). The split in the die fits opposite the centre screw to allow the opening and closing of the die. The two screws at the side hold the die in the stock. To ensure the die can start to create a thread on the rod the rod must firstly be tapered at the end.



Riveting

Riveting is the process of joining two or more pieces of metal together permanently. The process uses metal plugs, more commonly known as rivets. To form the joint, the shank of the rivet is passed through a previously drilled hole in the components to be joined, it is then cut to size and spread or shaped, thus preventing the parts from separating. Sketches of the process are shown overleaf.

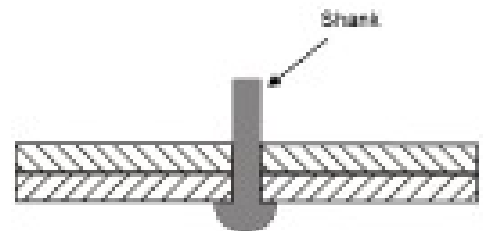
Rivets are classified by the shape of the head, their diameter and length. Common rivet head shapes are round (or snap), countersunk, pan and flat. Other types of rivet found in the workshop are bifurcated and pop rivets. In general the type of work at hand will determine the type of rivet to use.



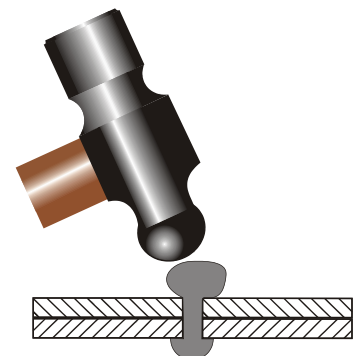
Rivets are made in most types of metal; e.g. mild steel, copper, stainless steel, brass, aluminium. When using a rivet always ensure that the rivet being used is the same material as the metals being joined or it will result in aggravated corrosion at the rivet site.

Snap Head Riveting Process

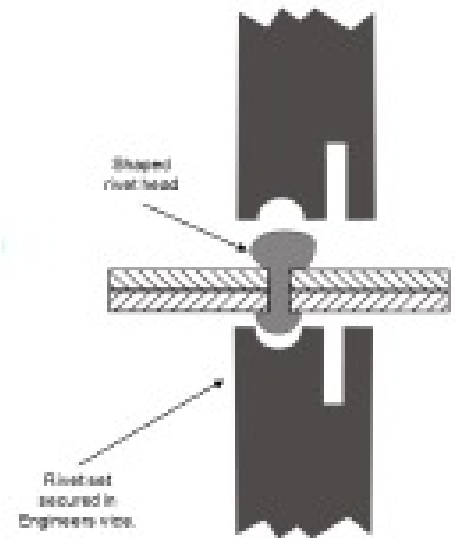
In the sketch shown opposite the rivet is placed through the two sheets of metal. The shank of the rivet is then cut to the desired length. This length is generally 1.5 times the diameter of the rivet. E.g. if the diameter of the rivet is 5mm then the length to be measured above the sheet metal on the shank will be $5\text{mm} \times 1.5 = 7.5\text{mm}$.



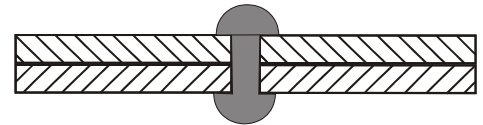
The next stage of the operation is to shape the shank of the rivet to the approximate shape of the final head using the Ball Pien hammer.









The final stage is to place one rivet set into an Engineers vice, place the rounded head of the rivet into the indent in the rivet set as shown. Next place the other half of the rivet set on top of the shaped head and hit it with a hammer until desired shaped has been achieved.



The sketch opposite shows the completed riveting of two sheets of metal using a snap head rivet.



Sheet metal tools and machines

Tool	Description	Image
Folding Bars	The folding bar is used when folding sheet metal in order to obtain a straight, neat bend. They are usually held in a vice for small scale work.	
Folding machine	A folding machine (box folder) is a metalworking machine that allows the bending of sheet metal. Some models only allows for simple bends and creases, while others can have interchangeable blocks which also allows one to form box and pan shapes.	
Notcher	Notching is a metal-cutting process used on sheet metal or thin barstock, sometimes on angle sections or tube. A shearing or punching process is used in a press, so as to cut vertically down and perpendicular to the surface, working from the edge of a workpiece.	
Guillotine	A Guillotine, also known as a bench shear, is bench mounted blade with a long lever making it easy to cut sheet metal. It is usually used for cutting rough shapes out of medium-sized pieces of sheet metal, but cannot do delicate work.	
Raw Hide Mallet	This is used when forming sheet metal. Unlike a hammer, it will not dent the surface of the metal.	
Rubber mallet	Is used to protect the surface from dents when bending metal.	

Tool

Description

Image

Tin snips

Tin snips work like scissors and use a shearing action to cut thin sheet metal. Straight snips are used for cutting along straight lines.



Pop rivet gun

A pop rivet gun is used to secure pop rivets in the piece of work.



Spot welding

Also known as resistance welding. This is suitable for thin sheet steel. It relies upon passing a current through the sheets of metal and heating them up where they touch each other, because this is where there is most resistance. (Electrical resistance produces heat).

Two electrodes squeeze the sheets together and then pass an electric current through for approximately 2 seconds, then hold until the weld sets (2 or 3 seconds)

Resistance welding does not produce a continuous weld. The result is like a line of tack welds 30 to 40 mm apart.



Tin snips:

Curved tin snips

Curved tin snips have rounded blades designed for tasks requiring cutting curves or circles. They are often similar in appearance and design to straight cut tin snips, with long handles for control.



Universal tin snips

Universal tin snips can be used for straight cuts or long, wide curves. They are available in either straight handled, left hand cranked or right hand cranked versions. A fail safe method for remembering the cut orientation of snips is as follows, "the snips will always cut a curve in the direction of the **lower cutting blade**".



Machine processes

Tool

Description

Image

Hand Drill

The hand drill or wheel brace is used to hold and turn twist drills up to 8mm in diameter. The chuck has three self centring jaws which securely grip the shank of the drill.



Portable Electric Drill

These drills are usually available in schools with a maximum chuck capacity of 13mm (i.e. can hold a drill diam. of 13mm maximum).



Pedestal drill

Very similar to a pillar drill but mounted on a worktop or bench



Pillar Drill

The adjustable table which holds the work piece can slide up or down and can be locked at a desirable height. Mounted on the floor.



Twist Drill Bit

Drill bits are manufactured from highspeed steel (H.S.S.) or carbon steel and are used for drilling circular holes in metal, plastic or wood. The most common type of drills used are the twist drills. These drills have three basic parts, a point, a parallel body and a shank which can be either parallel or tapered.



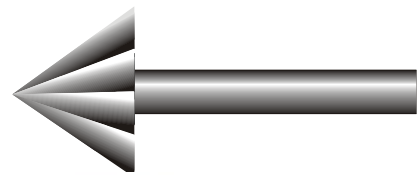
Tool

Description

Image

Countersink Drill/Rose bit

A countersink drill is used to countersink holes in wood, metal and plastics to allow the accommodation of a countersunk screw head. This allows the screw will head sit below the surface of the material.



Bench Grinder

A bench grinder is a benchtop type of grinding machine used to drive abrasive wheels used for sharpening cutting tools such as tool bits, drill bits, chisels, and gouges. Alternatively, it may be used to roughly shape metal prior to welding or fitting.



Centre Lathe

The Centre Lathe is used to manufacture cylindrical shapes from a range of materials including; steels and plastics. Many of the components that go together to make an engine work have been manufactured using lathes. These may be lathes operated directly by people or computer controlled lathes (CNC machines) that have been programmed to carry out a particular task.



CNC Lathe

Computer controlled lathes (CNC machines) that have been programmed by a computer to carry out a particular task.



Milling machine (vertical)

Milling machines are very versatile. They are usually used to machine flat surfaces, but can also produce irregular surfaces. They can also be used to drill, bore, cut gears, and produce slots. Milling machines are very versatile. They are usually used to machine flat surfaces, but can also produce irregular surfaces. They can also be used to drill, bore, cut gears, and produce slots. In the vertical mill the spindle axis is vertically oriented .



Milling machine (horizontal)

This horizontal miller is used when a vertical miller is less suitable.



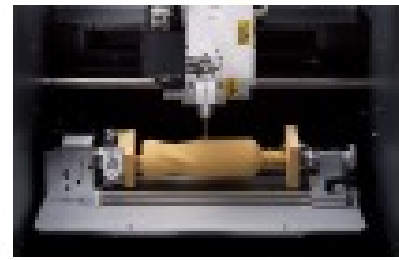
Tool

Description

Image

Milling machine (CNC)

CNC milling is a specific form of computer numerical controlled (CNC) machining. Milling itself is a machining process similar to both drilling and cutting, and able to achieve many of the operations performed by cutting and drilling machines. Like drilling, milling uses a rotating cylindrical cutting tool.



Laser cutter

Laser cutting is a precise method of *cutting* a design from a given material using a CAD file to guide it. There are three main types of *lasers* used in the industry: CO2 *lasers*, Nd and Nd-YAG. This involves firing a *laser* which cuts by melting, burning or vaporizing your material.



Plasma Cutter

Plasma cutting (plasma arc cutting) is a melting process in which a jet of ionised gas at temperatures above 20,000°C is used to melt and expel material from the cut. During the process, an electric arc is struck between an electrode (cathode) and the workpiece (anode).



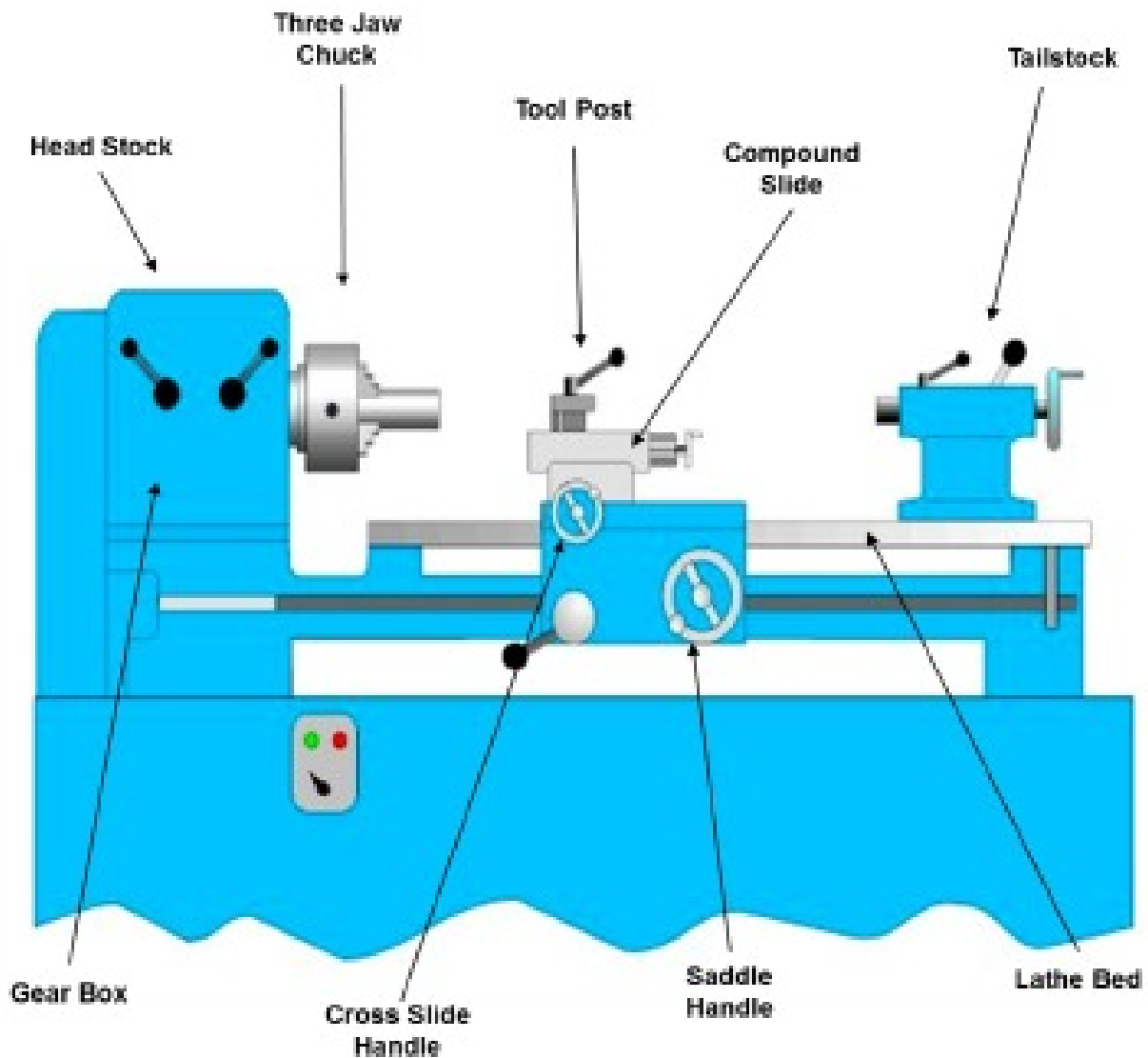
Centre Drill

Often referred to as a combination drill, this is a drill and countersink combined. It is used to drill a hole in one end of a piece of bar so as to accommodate the revolving centre (Page 42). As it is not possible to punch holes in the centre of a round bar prior to drilling the centre drill is used first to stop a drill bit from slipping.



Centre Lathe

The purpose of a centre lathe is to shape metal bar into various desired shapes. A typical example is the nut & bolt assembly seen earlier in this booklet. The work piece (metal bar) is secured to a rotating three jaw chuck. The tools which are made from High Speed Steel (HSS) are secured in the tool post. An electric motor spins the work piece to which the cutting tools are then brought into contact with the metal bar.

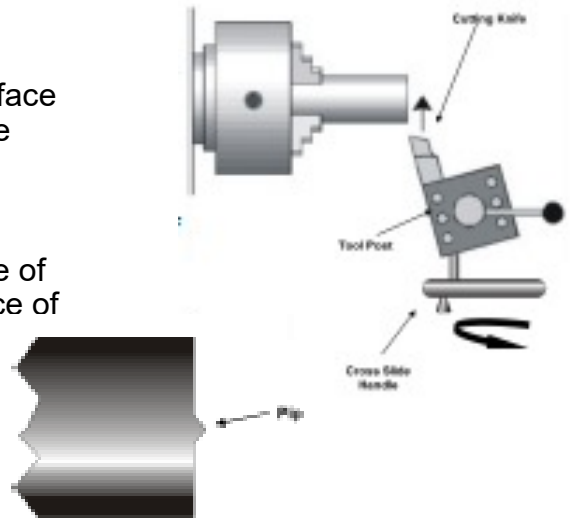


The work, normally rotating towards the operator, can be set up between two centres which engage in countersunk holes at either end, or it can be gripped in a chuck or bolted to a face-plate. The cutting tool, mounted on top of the carriage, can be moved along the machine or square across it and these two motions perform the basic functions in the generation of a true cylinder. The lengthwise traverse of the tool is commonly referred to as 'sliding' which produces a round face and the cross-traverse as 'surfacing' (or 'facing') which produces a flat surface. In addition to sliding and surfacing, the lathe can be used to produce tapered work, to cut screw threads, for boring and recessing, for profiling (shaping to contours), whilst the chucks and face-plates can be used in machining a variety of flat, cylindrical or irregular forms. A further range of operations can be undertaken by reversing the locations of tool and work, the tool rotating whilst the work is held on the carriage and brought up to the tool.

Facing Off

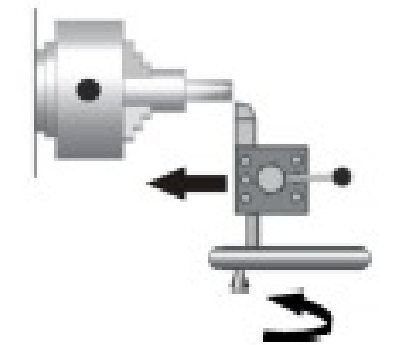
Before starting to shape the metal bar it is essential to face off the end of the bar. This basically means to make the end of the bar perfectly square to the sides of the bar.

When facing off a piece of round bar it is essential to ensure the cutting knife is lined up centrally to the piece of bar. If it is not a “pip” will develop which means the face of the bar will not be truly flat.



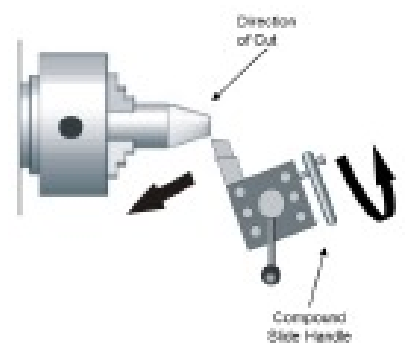
Parallel Turning

This technique moves the tool parallel to the centre axis of the bar as can be seen from the drawing.



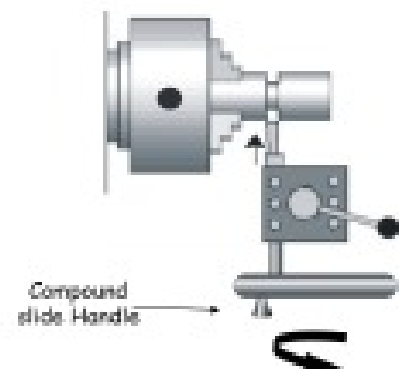
Taper Turning

This is where the tool moves along the bar at an angle moving further away from the centre axis of the bar.



Parting Off

When all turning work has been completed the final task is to “Part Off” (remove the turned piece from the bar secured in the three jaw chuck). A parting tool should be secured in the tool post for this process.



Chamfering

A small taper, called a chamfer can be put onto a piece of metal by sharpening a tool up to the required angle. This is quite useful for finishing the end of a bar off for safety or aesthetic reasons. Instead of a chamfer a small radius could be put onto the bar by sharpening up a suitable tool.

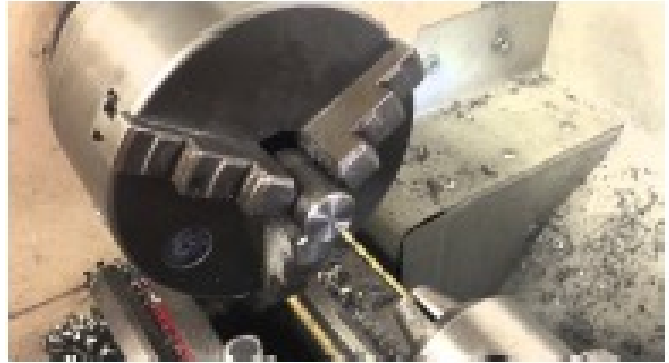


Drilling on Centre Lathe

When drilling on the lathe the drill is stationary and the work revolves. This is the opposite of a pillar drill.

The drill is held in a Jacob's chuck in the tailstock of the lathe. The work rotates and the drill is moved up to the work by turning the wheel on the end of the tailstock.

Before using a twist drill a centre drill should always be used on a slow speed to locate the centre of the bar being drilled. This will stop the drill bit from straying from the centre of the bar.



Machine Tools

Tool

Description

Image

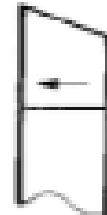
Left Hand Knife Tool

Left-hand knife tools can be used to cut to a left-handed shoulder or cut along the work from left to right.



Right Hand Knife tool

Right-hand knife tools can be used to face off the right-hand end of a bar, to cut to a right-handed shoulder, or to cut along the work from right to left.



Round Nose Tool

Round nosed tools can be used to cut in either direction and to cut to left- or right-handed shoulders where a radiused corner is wanted.



Parting Tool

Parting uses a blade-like cutting tool plunged directly into the workpiece to cut off the workpiece at a specific length.



Form Tool

Form tools can be specially ground to produce any required shape, such as the curved top of a turned screwdriver handle.



Knurling Tool

Knurling is a manufacturing process, typically conducted on a lathe, whereby a pattern of straight, angled or crossed lines is cut or rolled into the material. This is used to add grip or for aesthetic reasons.



Tool

Description

Image

3 Jaw Chuck

A device that holds a workpiece in a lathe or tool in a drill, having 3 adjustable jaws. The jaws are geared to be self centring i.e. they move in unison to centralise the workpiece or tool.



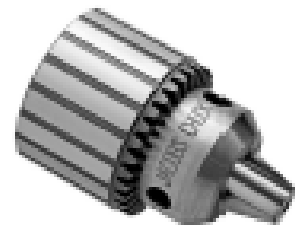
4 Jaw Chuck

Whilst the 4-jaw independent chuck is indispensable for holding work of irregular shape and for off-centre turning, it can also be used for holding squares or rounds. Centring takes a little longer but it can be done very accurately using each individual jaw adjustment.



Jacobs chuck

This tool is placed in the tailstock of the centre lathe and is used to hold twist drills.



Revolving Centre

The revolving centre is secured in the tailstock. The bar to be turned is secured at one end by the chuck and held in place at the other end using the revolving centre. The revolving centre allows the bar to rotate freely allowing turning between centres.



Chuck Key - centre lathe

The tool used to tighten most drill and lathe chucks. A device used to loosen or tighten the bolts or cam locks on the chuck. The chuck key for the centre lathe and the drill should be removed before switching the machine on.

Chuck Key - drill



Tool

Machine Vice

Description

This type of vice is used to hold heavier pieces of metal while drilling. The main body of the vice has been cast in a mould. The handle of the vice has been knurled.



Hand Vice

This is used for holding small and especially irregular shaped parts while drilling, riveting etc.



Toolmaker's clamps

These are used to hold parts together while marking out, shaping and drilling.



Mole Grips

Mole grips, also known as 'locking pliers', are a hand tool with adjustable jaws which can be locked into place around an object to hold it firmly. This tool can be used to secure sheet metal for drilling.



Heat Treatment

When a metal is cold worked, i.e. when it is cut, beaten, hammered, bent, twisted or shaped, etc. at normal room temperature, tremendous internal forces are set up within its grain structure and the metal becomes extremely hard and liable to split. The term 'heat treatment' is applied to metals that undergo some form of heating process in order to change their properties.

Generally, any heating process carried out on a solid metal is referred to as heat treatment. Heat treatments involve processes such as annealing, normalising, forging, hardening, tempering, etc.

Work Hardened

If a material has been bent, hammered or twisted consistently over a period of time the metal will be **Work Hardened**. What is meant by this, is, the tiny molecules which make up the metal have been pushed and twisted out of their original positions thus making the metal very liable to breaking. This can be fixed by **Annealing** the metal.

Annealing

This process makes the metal as soft as possible to relieve the internal stresses, and make it easier to shape. The annealing process generally involves heating up to a certain temperature and allowing to cool, either in the air or in water depending on the material being annealed. If soap is applied to Aluminium prior to heating it will turn **Black** when the correct temperature has been reached.

Tempering

This process involves heating the metal to various temperatures and then immediately quenching it in water. As the metal is being heated it changes colour starting with a pale straw to dark straw to reddish brown to purple then dark blue. Dependant on what properties are required of the steel being tempered will determine what heat it will be heated to e.g. when it reaches a dark blue colour it is at 300° C. These colours are known as TEMPERING COLOURS.

Case Hardening

Mild steel cannot be hardened and tempered as its carbon content is too low. What can be done is to provide it with a hard outer case. In this process the metal is heated to a bright red heat and then rolled in a carbon rich powder. The carbon is absorbed into the skin of the metal thus making it very hard on the outer skin. This type of metal is ideal for components such as gear wheels which require to be hard wearing.

Hardening

To enable carbon steel (i.e. tool steel) to be used for the wide variety of tools and articles that are necessary in the school workshop and in industry it must first be hardened, then tempered.

Taking a high carbon screwdriver blade for example, this is HARDENED by heating it slowly to a dull cherry colour and then quenching it in oil or tepid water. When this part of the process has been carried out, it is unusable. Although it is very hard it is also very brittle (i.e. it can break very easily). To make the hardened steel usable it must now be TEMPERED, i.e. given properties such as toughness, elasticity, strength.

Malleability

This is the ability of a material to withstand being hammered, rolled or bent without the material breaking.

Ductility

This is the ability of a material to withstand being pulled or stretched without the material breaking.

Toughness

This property of the material is the amount of energy it can absorb without breaking and measures its ability to withstand shocks. It is the opposite of brittleness.

Flattening

This involves the heating and re-heating of the metal bar and hammering it until the desired flatness is achieved.



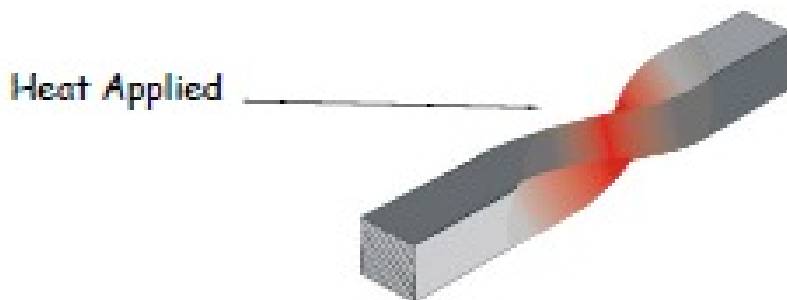
Drawing Down

This involves the heating and re-heating of the metal bar and hammering it until a desired point is achieved.



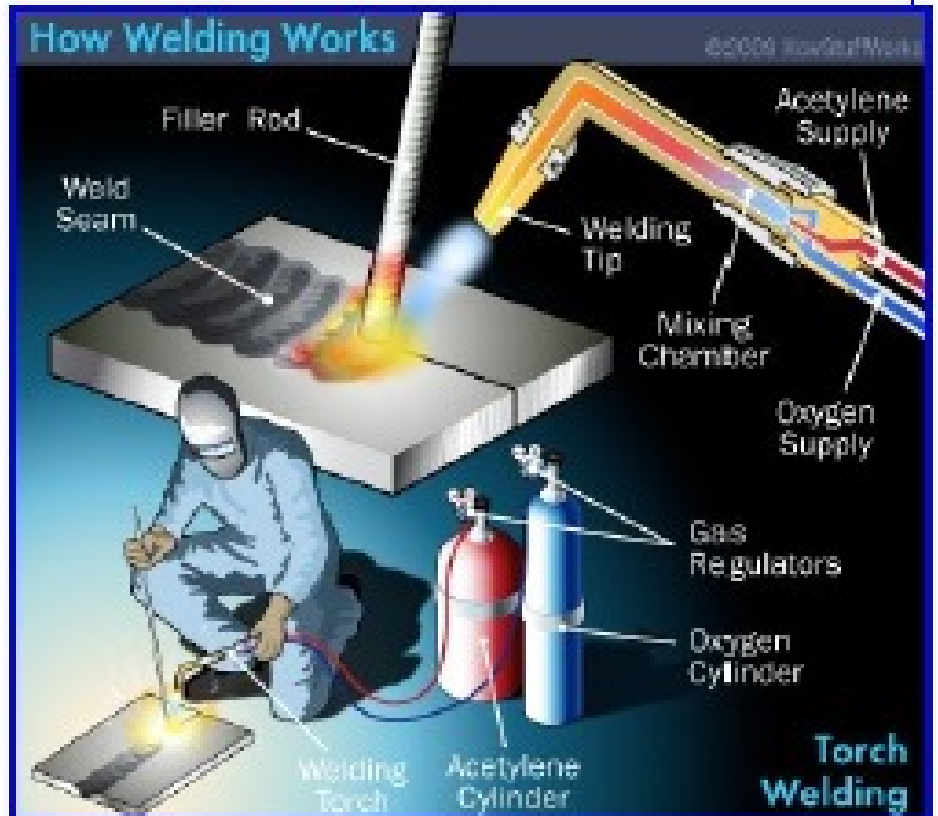
Twisting

As can be seen from the sketch opposite, the metal bar is heated until red hot, it is then twisted to the desired shape.



Welding

Welding is the process of joining two pieces of metal together using very high heat and an additional filler metal. The filler metal used must be the same type of metal being permanently joined.



Soldering

Soldering is the process of permanently joining two pieces of metal together using a mixture of tin and lead. Mixing these two metals reduces the overall melting temperature enough to melt the solder using a soldering iron (a heated piece of metal attached to a handle).



Brazing

This process is very similar to soldering in that it uses an alloy heated to its melting temperature to join two pieces of metal together. When Brazing, the filler metal used is called BRAZING SPELTER, which is an alloy of copper and zinc (BRASS). The heat is generated by the use of a blow torch.



Finishing

Types of finishes

The purpose of applying a finish to a piece of metal is to protect it from tarnishing or corrosion (rusting). Think of a metal artefact (say a bike) was to be constructed and left outside without any protective coating (paint), how long do you think it would take before it rusted? Not very long! Therefore metals have to be protected from rain, snow, etc. There is a number of ways of doing this depending on the type of metal being protected. The following examples are just some methods of protecting metals.

Painting

Paints are applied to bikes, garden gates, bridges, washing machines, etc because these artefacts are generally made from steel. Paints are usually applied this type of metal because they come in various forms and many colours.

Lacquering

This is very similar to varnishing, it can be applied with a brush or can be sprayed on. The purpose of using this type of finish, is, if the base metal has a nice colour to it e.g. copper or brass, it allows this colour to be seen but at the same time protecting it.

Bluing

This process involves heating the metal up and dipping it in a bath of oil, leaving it to cool and wiping dry with a cloth.

Oil Blacking

This traditional and simple process is normally applied to forged steel products. The steel is heated to a dull red and then quenched in a high flash point oil. The oil burns black onto the surface providing a thin protective skin that can be lacquered to provide additional protection.

Enamelling

This process uses powdered glass which is melted to flow over the metal to give a hard, colourful and protective finish.

Vitreous (stove) enamelling is used on steel for equipment such as cookers and provides a finish which is heat, chemical, wear and corrosion resistant. Enamelled jewellery is made using a base metal such as copper or gilding metal. Small enamelling kilns are used for this purpose.

Electroplating

Electroplating is used to give metals such as copper and brass a decorative, protective finish. The product to be coated is immersed in a metallic salt solution called an **electrolyte**. A current is passed between the metal to be used for the coating and the product causing deposits of the coating to be formed on the product. Electroplating is used for chrome-plating taps and silver-plating jewellery.

Anodising

Anodising is a process that is used on aluminium to thicken the oxide layer of the surface. It is an electro process similar to electroplating except that no other metal is introduced. Coloured dyes are added to the process to provide a colourful 'metallic' surface finish.

Plastic Dip Coating

If a ferrous metal is left in the atmosphere for a length of time it will rust. In order to prevent this from occurring a barrier has to be placed between the metal and the atmosphere. One method of doing this is protecting the metal with a plastic coating. This can be applied to most metals and is used on wire metal baskets, racks and handles for tools such as scissors and pliers.

The coating process, **fluidisation**, takes place in a tank called the **fluidiser**. The tank contains powdered plastic with air passing through it, which makes the powder behave like a liquid. When the hot metal is dipped into the powder, it melts onto the surface and bonds to the metal.



Fluidiser

A plastic coating is applied in the following way:-

1. Thoroughly clean and degrease the metal.
2. Heat the metal to 180° degree C in an oven.
3. Dip the metal into the fluidised plastics powder for a few seconds.
4. Return it to the oven to fuse the coating to a smooth glass finish. Leave to cool.

If the surface finish appears gritty, the metal has not been heated to a hot enough temperature before dipping into the plastic.

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