Activity

Using the formula V = IR, complete Table 3.8 by working out the values of each resistance.

Voltage (volts)	Resistance (ohms)	Current
10	2	5
20		5
30		5
40		5
50		5
60		5
70		5
80		5
90		5

Table 3.8 Voltage, resistance and current

Now produce a graph plotting the voltage (y axis) and the resistance (x axis).

The gradient of the line y / x at any point will provide you with the current. When this happens, the voltage and resistance are said to be 'proportional'.

2. Be able to use mensuration and trigonometry to solve engineering problems

Simple area and volume

P4 P5

Estimating area and volume is one of the most fundamental aspects of engineering mathematics and it is carried out for a number of reasons. Engineers often need to estimate the material required to make a product or component – examples include the sheet steel to process automotive body work, the volume of polymer used to make electrical casings, the area and volume of pipes used in the estimating flow in petrochemical operations, and the volume of ingredients used in food processing or pharmaceutical manufacturing.

Other examples include the design of a new factory layout or the estimation of an area potentially used for engineering office space in a new plant.

You are highly likely to have covered this material at school, so Tables 3.9 and 3.10 should provide useful revision.

Make the grade 8

The next activity will help you in achieving the following grading criteria:

- **P4** determine the area of two regular shapes from given data;
- **P5** determine the volume of two regular solid bodies from given data.

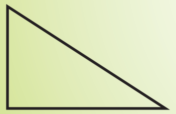
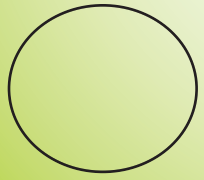
Shape	Formula for calculating area
	Rectangle: Area = base × height
	Parallelogram: Area = base × height
	Triangle: Area = ½ × base × height
	Right-angled triangle: Area = ½ × base × height
	Circle: Area = π × radius^2 Area = πr^2 Or: Area = πDiameter^2 / 4 Area = πD^2 / 4

Table 3.9 Calculating basic area

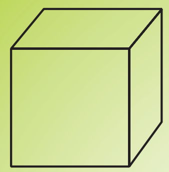
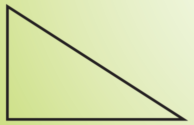
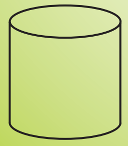
Shape	Formula for calculating volume
	Cube: Volume = base × height × length
	Parallelogram: Volume = base × height × length
	Triangle: Volume = ½ × base × height × length
	Right-angled triangle: Volume = ½ × base × height × length
	Cylinder: Volume = πr^2 × length

Table 3.10 Calculating basic volume

Activity

Once you have worked out the adjacent side, it is possible to work out the opposite using the tangent function (Toa). Have a go at using 'Toa' to see if you get the same answer for the opposite side as we did previously using the sine function (Soh).

Make the grade 10A

The next activity will help you in achieving the following grading criterion:

P6 solve right-angled triangles for angles and lengths of sides using basic Pythagoras' theorem, sine, cosine and tangent functions.

Activity

1. **Using Pythagoras' theorem, determine the length of the opposite side in Figure 3.26 if the adjacent side is 15 metres and the hypotenuse is 22 metres.**
2. **Using trigonometry, determine the angle θ in Figure 3.27 if the adjacent side is 15 metres and the hypotenuse is 22 metres.**

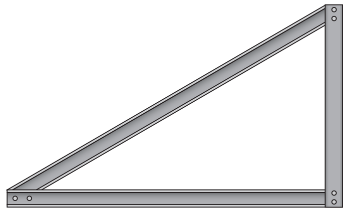


Figure 3.26

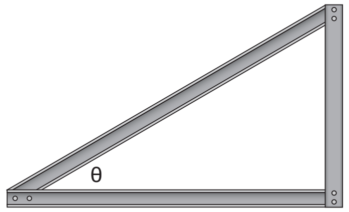


Figure 3.27

Make the grade 10B

The next activity will help you in achieving the following grading criterion:

M4 **use trigonometry to solve complex shapes.**

Activity

Use trigonometry to determine the following in Figure 3.28:

- **the height of the trapezoid;**
- **the length of the sloping sides.**

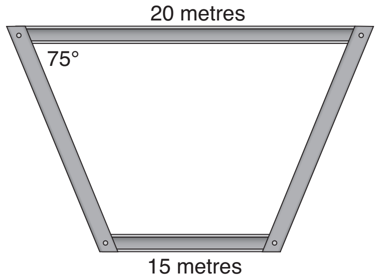


Figure 3.28

Grading criteria recap

To achieve a pass grade you must be able to:

P1 use arithmetic methods to evaluate two engineering problems ensuring answers are reasonable;

P2 use algebraic methods to transpose and evaluate simple formulae;

P3 plot a graph for linear and non-linear relationships from given data;

P4 determine the area of two regular shapes from given data;

P5 determine the volume of two regular solid bodies from given data;

P6 solve right-angled triangles for angles and lengths of sides using basic Pythagoras' theorem, sine, cosine and tangent functions.

To achieve a merit grade you must be able to:

M1 transpose and evaluate complex formulae;

M2 identify the data required and determine the area of two compound shapes;

M3 identify the data required and determine the volume of two compound solid bodies;

M4 use trigonometry to solve complex shapes.

To achieve a distinction grade you must be able to:

D1 transpose and evaluate combined formulae;

D2 carry out chained calculations using an electronic calculator.

Material property	Description
(Tensile) strength	E.g. the ability of a material to withstand tensile (stretching) loads without breaking.
Hardness	
Elasticity	
Toughness	
Ductility	
Electrical conductivity	
Electrical resistivity	
Ferromagnetism	
Environmental degradation	
Thermal conductivity	
Thermal expansion	

Table 8.3 Properties used to define the behaviour of common engineering materials

Common engineering materials

We have discussed some of the different categories of materials at the beginning of the unit. Figure 8.11 shows how different groups of materials can be split up into categories.

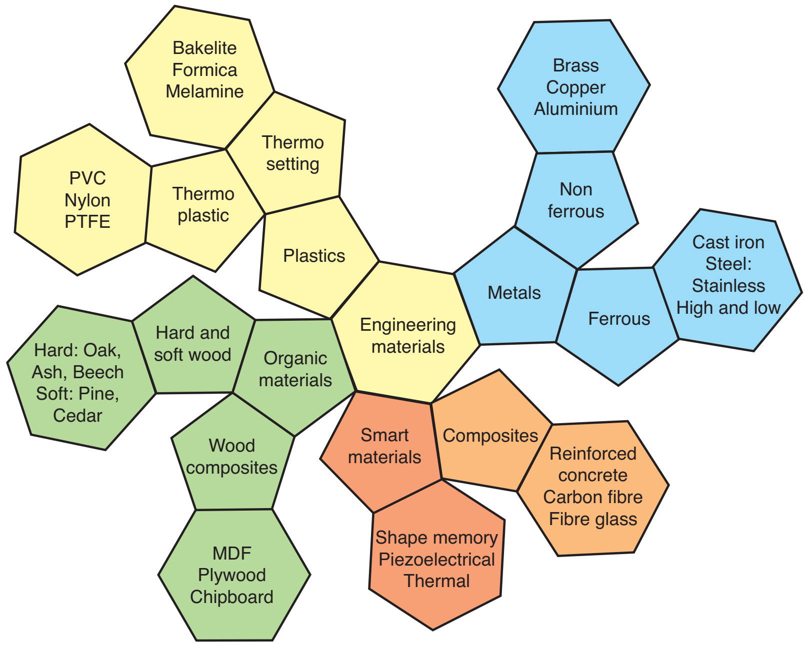


Figure 8.11 Classification of materials

You may be unfamiliar with some words in this unit, so here is a brief explanation at this early stage.

Ferrous materials

M1

Ferrous metals

Metals that contain iron are said to be ferrous. The ferrous metal that you will be most familiar with is probably steel. Steel also contains non-metal carbon and it is the amount of carbon present in steel that dictates its inherent properties. The actual content of carbon in steel is very low. Carbon steel is usually split into three categories: low, medium and high carbon steel.

Low carbon steel

Low carbon steel (containing approximately 0.05–0.29 per cent carbon) is also referred to as mild steel. It is the most commonly used plain carbon steel because it has a relatively low cost. Its other main characteristics are that it is a relatively tough, malleable, ductile material with a good tensile strength that can be easily formed. However, it does have a low resistance to chemical attack, which means that it corrodes easily. It is used to make chains, pipe, wire and rivets, and for general engineering purposes. It has a shiny, silver appearance.

Medium carbon steel

Medium carbon steel (containing approximately 0.3–0.79 per cent carbon) has a high tensile strength and is also tough and hard. It manages to balance ductility with strength, so it can be used where both properties are desirable. We discussed a good example earlier in this unit: a wire rope on a crane. Other uses include gears, crankshafts, hammers and screwdrivers. Medium carbon steel also reacts to heat treatment, changing its properties for specific purposes. It has a dark silver appearance.

Team Talk

Peter: **'What metal is used to make springs?'**
Samirah: **'Spring steel.'**
Peter: **'I've never heard of it.'**
Samirah: **'It's just a term used for the production of steel springs. They are usually made from medium carbon steel that has been hardened. This has a very high yield strength which makes them spring back when a load is removed.'**

Key words

Ferrous is commonly used to describe metals that contain iron.
Alloys contain two or more elements that have been mixed together to change or enhance properties. Alloys contain a metallic element mixed together with either another metallic/non-metal element or a chemical compound and are commonly used in engineering today.
Carbon steel refers to steels that contain iron and carbon.
Synthetic is something that is made artificially.
Composition refers to the different elements that make an alloy (similar to ingredients in a cake).

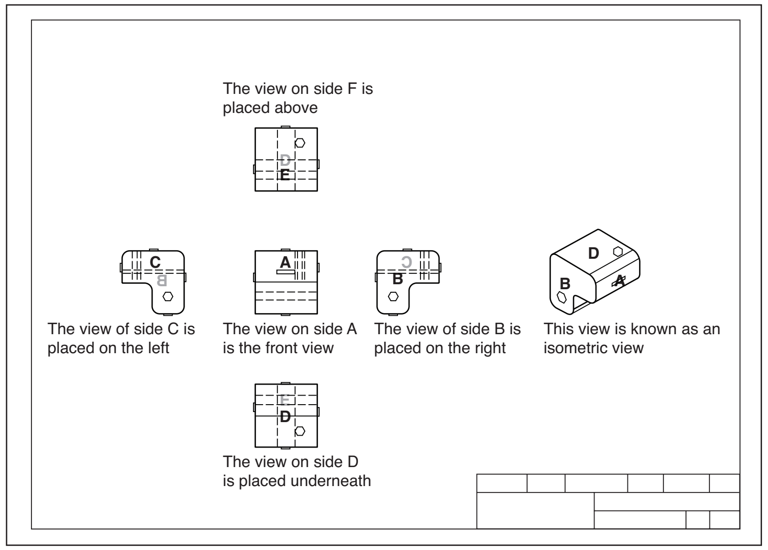


Figure 10.16 First-angle orthographic projection (dashed lines indicate hidden lines)

Figure 10.17 shows the third-angle projection views now positioned as follows:

- View A is the front view.
- View B from the left is placed on the left.
- View C from the right is placed on the right.
- View D from above is placed above.
- View E from below is placed below.

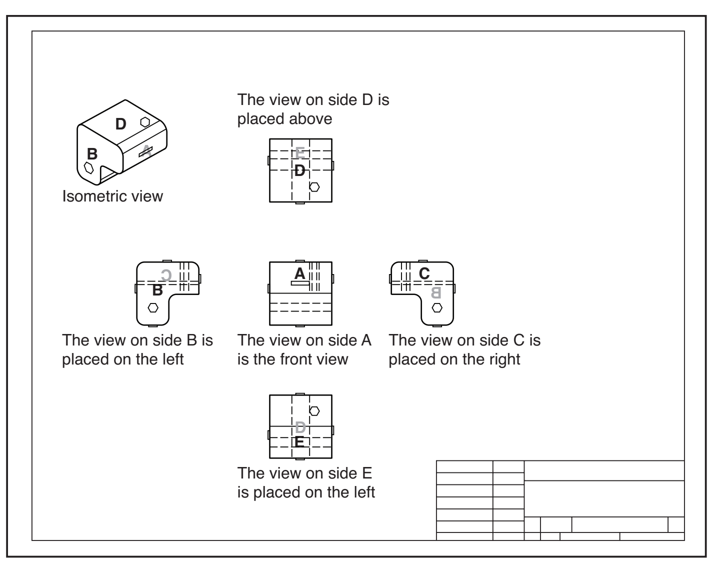


Figure 10.17 Third-angle orthographic projection (dashed lines indicate hidden lines)

Traditionally, front views are known as front elevations, side views are often termed side or end elevations and plan views are used to describe views from above or beneath. To portray a simple engineering component

or object, it is not always necessary to include all five views on the drawing. The CAD designer must decide the minimum number of views required to illustrate the maximum visual information.

Make the grade 2A

P1 The next activity will help you in achieving the following grading criteria:
start up a CAD system, produce and save a standard drawing template and close down CAD hardware and software in the approved manner;

P2 produce a CAD drawing using an orthographic projection method;

P7 set up an electronic folder for the storage and retrieval of information;

D2 (in part) – demonstrate an ability to produce detailed and accurate drawings independently and within agreed timescales.

Activity

Produce a CAD drawing using an orthographic projection method.

1. **Start up a CAD system and set up a drawing template.**
2. **Produce a CAD drawing using an orthographic projection method.**
3. **Save the template and orthographic projection drawing in an electronic folder.**
4. **Complete all work in a reasonable time period and to agreed and appropriate standards.**

This task is a practical activity but you will need to keep a record of the steps you used to complete it. You can use screen dumps by pressing the print screen (PrtScn) key and pasting the captured images into a Word document. Make a detailed list of the main steps you took to complete this activity. For example, how you completed the following:

- **switching the computer on and starting the CAD hardware and software;**
- **procedure to log in to a network;**
- **producing the template and orthographic drawing;**
- **saving the template and orthographic drawing to an electronic folder;**
- **closing the CAD software and shutting down the CAD hardware.**

Obtain a witness statement from your instructor to show you have completed this activity competently and achieved the criteria.

Down-cut milling: this method is called down-cutting because the cutting tool rotates anti-clockwise onto the workpiece. In order to use this method, a device known as a backlash eliminator is required. CNC machines do not have lead screws and so this method is used because it gives a better surface finish and is a more efficient method of cutting.

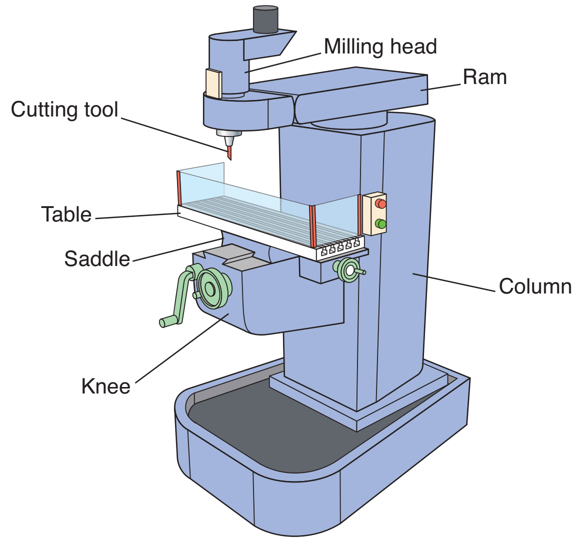


Figure 14.4

Vertical milling

In the case of a vertical milling machine, the cutter spins in the vertical position.

The workpieces and table move in exactly the same way as for horizontal milling, but the cutting tool is vertical, or perpendicular, to the table. It looks a little like a pedestal drill or bench drill but with a moveable table.

Team Talk

Neil: **'What types of shapes can vertical milling machines produce?'**
Tony: **'A vertical milling machine can cut along edges or surfaces of material. It is great for making straight edges or a flat surface on the top of a workpiece. It can also produce slots, holes and keyways.'**

Secondary machining techniques: drilling and grinding

P1 D1

In this Learning Pod, you will learn about two secondary machining techniques and how they are used:

- drilling;
- grinding.

Drilling machines

Drilling is the simplest type of secondary machining technique. Figure 14.5 shows a pedestal drill.

Drilling machines have a worktable that can move to locate the workpiece, but it does not move during drilling.

The drilling machine is mainly used to drill holes. In an engineering workshop, holes from 1 mm to around 25 mm can be drilled. These machines are also used for reaming, which is an accurate way of producing a hole.

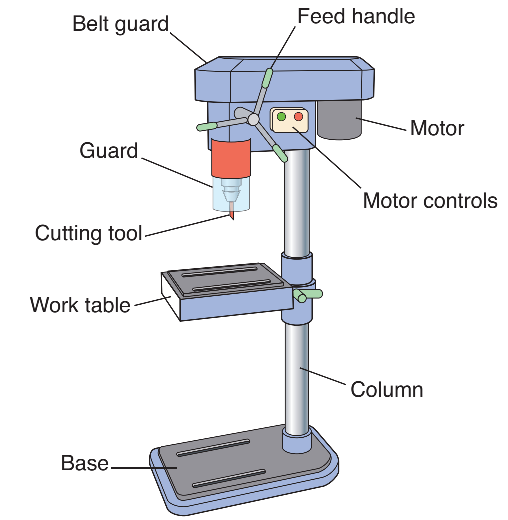


Figure 14.5 Pedestal drill

Grinding machines

Grinding machines are used when extreme accuracy is required. .

Grinders generally fall into two main types:

- surface grinders;
- cylindrical grinders:
  1. centreless grinding;
  2. profile grinding;
  3. thread grinding.

Surface grinders

Surface grinders are used for very accurate or precision machining. They use a spinning ceramic grinding wheel that rotates at a very high speed. A component that has been machined using a milling process can then be finished to a more accurate size using a surface grinder. Grinders have the advantage of being able to remove material that is very hard, which milling processes cannot do. They do not generally remove lots of material.

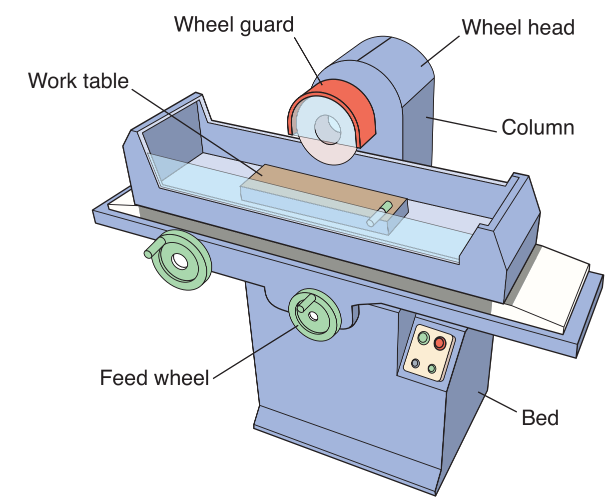


Figure 14.6

Cylindrical grinders

A cylindrical grinder uses a high-speed, spinning ceramic grinding wheel to produce highly accurate components. The products produced are cylindrical. Where products have been machined using a lathe, a cylindrical grinding machine will finish these to a very accurate size. These machines can also finish boreholes to high precision.

Centreless grinding: this process is similar to cylindrical grinding but it does not use a spindle. It is used in mass production. The workpiece goes between the grinding wheel that cuts it and the regulating wheel that positions it.

Profile grinding: sometimes a more complex shape needs to be ground onto the surface of the workpiece. This to prevent the wheel pushing it over. This is known as blocking. For non-magnetic materials, a vice can be held onto the magnetic table. Vee blocks and angle plates can also be used; these are clamped by magnetism to the magnetic block.

Team Talk

Matt: **'How does the grinder table know how far to go backwards and forwards?'**
Parminder: **'The distance that the table moves left to right is set by the use of control stops. These are small levers that are adjusted to make the table go from left to right, then right to left, and so on.'**

Work-holding devices for cylindrical grinders

A cylindrical grinder operates in a similar way to a centre lathe; the workpiece revolves around a centre. Therefore, chucks and face plates can be used in the same way as discussed in Learning Pod 3.

A very common method of holding on a cylindrical grinder is to use a magnetic chuck. These are flat discs that are used like chucks but they do not have any jaws. A chuck key is turned, causing the flat surface to be magnetised. This can only be used when the workpiece has a very flat, wide diameter surface to slide on the surface of the vice. Of course, the workpiece needs to be a magnetic material such as steel.

Make the grade 4

The next activity will help you in achieving the following grading criterion:

P2 describe the appropriate use of three different work-holding devices for these different techniques.

Activity

Explain how the following work-holding devices are used:

- **three-jaw chuck (used on a centre lathe);**
- **machine vice (used on a vertical milling machine);**
- **magnetic table (used on a surface grinder).**

You should give a brief explanation of how each work-holding device is used and the types of shapes or materials that can be held in these devices.

Use the example below for a four-jaw chuck (used on a centre lathe) to help you.

'A four-jaw chuck is used on a centre lathe. There are four separate jaws that move independently. This means that a four-jaw chuck can hold square bar and octagonal bar easily. It can also hold round bar, but because the jaws move separately, the round bar can be set on the centre line or eccentrically. When using round bar, the workpiece does not automatically sit on the centre line of the lathe. This means it is not used for speed. It is used to set workpieces accurately. Where accurately finished workpieces are used, this type of chuck may damage the surface. A collet chuck would be a better alternative.'

Tools for turning and milling

P3

Turning tools

Centre lathes use a number of specialist tools, as well as tools that are used in other processes. We will look at these in two groups:

- turning tools – specifically used on lathes;
- drilling, reaming and tapping – used in other processes (these will be covered in detail in Learning Pod 6).

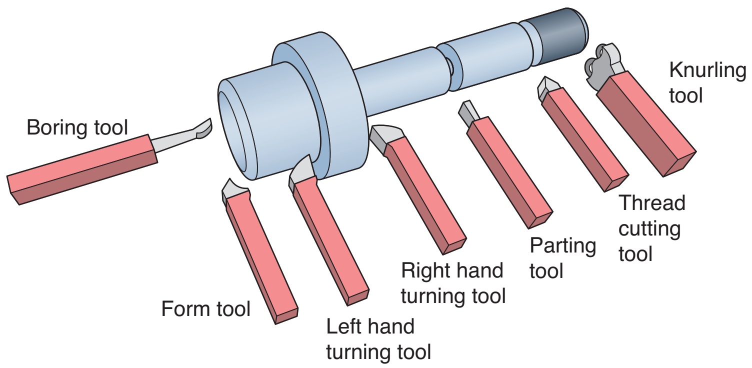


Figure 14.11

Turning tools come in a number of basic types and are as follows:

- left-hand cutting tool;
- right-hand cutting tool;
- facing tool;
- form tool;
- parting off tool;
- thread cutting tool;
- boring tool;
- knurling tool.

Number	Process
11	Metal arc welding without gas protection
111	MMA welding with covered electrode
114	Flux cored metal arc welding
121	Submerged arc welding, with wire electrode
131	MIG welding
135	MAGS welding
141	TIG welding
15	Plasma arc welding
21	Spot welding
22	Seam welding
221	Lap seam welding
23	Projection welding
25	Resistance butt – welding
31	Oxy – fuel gas welding
311	Oxy – acetylene welding

Table 2.6 Identifying numbers for different welding processes

Make the grade 1

The next activity will help you in achieving the following grading criterion:

P1 extract information from engineering drawings and related documentation to enable a given task to be carried out.

Activity

In this activity, you need to interpret information from a drawing and use additional information to enable a task to be carried out. The task in this case is to machine and assemble the mallet shown in Figure 2.13. The answers for this activity appear on the engineering drawing (Figure 2.12). To help you, you will find all the information you need somewhere in this unit; additional documentation could also be of help.

You are given an engineering drawing of a mallet (Figure 2.12) that you will machine using a lathe. Study the drawing and answer the following questions.

1. **What should the overall surface finish of the mallet be?**
2. **Name four machining instructions indicated on the drawing. In what units are the dimensions measured?**
3. **What is the symbol used to denote the diameters on the drawing?**
4. **If the raw material were a casting, what would the tolerance allowance be?**
5. **Name the three different sized threads on the drawing (including the pitch).**
6. **If only imperial bar stock were available, what sized bar would be required for the mallet shaft (part number 3)?**

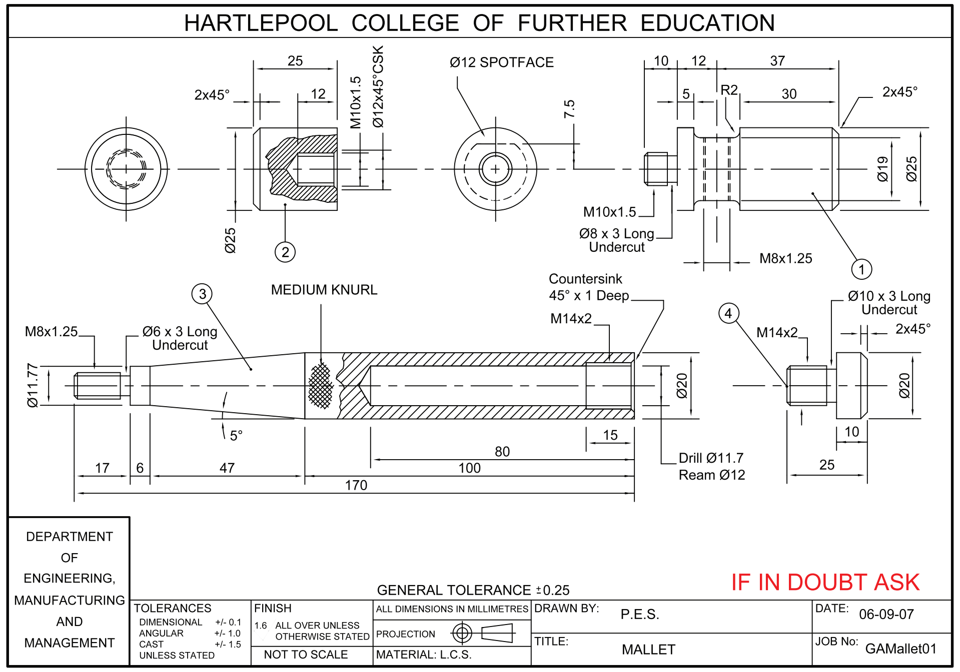


Figure 2.12 Engineering drawing of a mallet

Types of engineering drawings

P2

General assembly drawings

General assembly drawings and sub-assembly drawings are used to show how a product is assembled. They can be fully assembled or they can be laid out to show how a product fits together. The different parts of the product are sometimes listed in a separate table and are represented on the drawing with a number.

Figure 2.13 shows an assembly drawing of a mallet that is made with four different parts and three different types of material (brass, nylon and low carbon steel). It is not possible to identify the different materials from the drawing so they will be listed on the drawing, in a table or on additional documentation.

will include instructions for use and sometimes basic maintenance and repair notes. Detailed manufacturers' manuals for cars are usually bought separately and can be an essential source of information for car enthusiasts who carry out their own repairs.

Activity

A sketch of a two-way electrical lighting circuit is shown in Figure 2.29. Answer the following questions.

1. **Produce a circuit diagram for the two-way lighting circuit shown in Figure 2.29. Research the symbols used for electrical drawings and identify the sources of information used in this task (websites, books, etc.).**
2. **Produce a job card for the installation of the two-way lighting circuit (information on job cards can be found on page xx).**
3. **Produce an appropriate test card for the two-way lighting circuit (information on test cards can be found on page xx).**

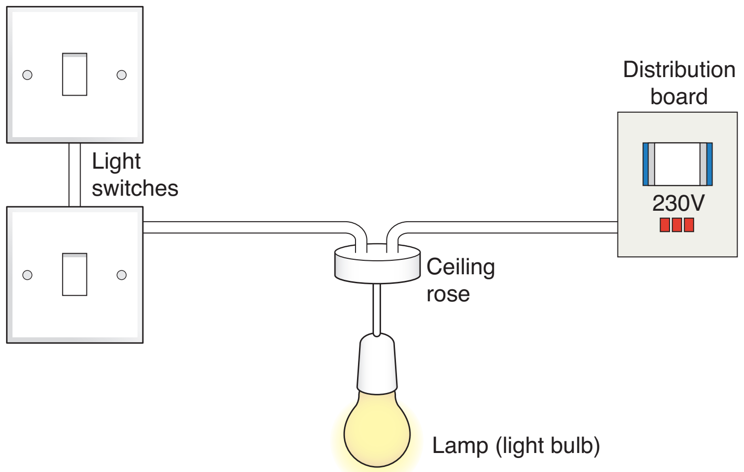


Figure 2.29 Sketch of a two-way lighting circuit

Make the grade 3

The next activity will help you in achieving the following grading criterion:

P3 identify and obtain relevant drawings and related documentation to carry out and check own work output.

2. Be able to use information from drawings and related documentation

Be able to use information from work output drawings

P4 M1 D1

We have previously examined the techniques used to interpret engineering drawings; in the following Learning Pods, we will look at how to use this documentation. When carrying out even the simplest of engineering tasks, having the correct supporting documentation is vital. For example, if we were to attempt to fabricate and assemble a simple mallet without any drawings or instructions, the task would be destined to fail, with numerous mistakes made throughout the process.

Product manufacture/assembly/design drawings

When a product is to be designed or assembled, a product assembly drawing is commonly used to aid the process. As discussed in Learning Pod 2, assembly drawings are used to illustrate how a product or component fits together. The diagram shows a cross-sectional view of the component and the various parts are identified using ballooned numbers. Depending on the amount of component parts, the parts list are shown either on the diagram or on a separate page. Manufacturers' part numbers and quantities may also be identified so that replacement parts may be obtained. An assembly diagram for a simple mallet (as used in Learning Pod 2) is shown in Figure 2.30. The assembly diagram contains no dimensional data for the individual components. This is to prevent the diagram from being swamped with too much information, thus allowing it to be read easily. Dimension details for the mallet will be found in the detailed drawings for each of the individual components. The assembly diagram may also include information that is needed to assemble the product; this could be bolt sizes, torque settings or even a specific assembly order. The overall size and weight of the assembled part may also be given; these details are of particular use when making packaging or transport arrangements.

Product assembly drawings may also give reference to sub-assembly drawings. The sub-assembly diagram details