Analysing engineering information associated with the problem

GETTING STARTED

Working in a group, discuss why engineers use many different types of information and data as part of their quality control checks.

Engineers use a combination of different types of information to manufacture an engineered product, including specific details of manufacturing processes, to ensure that the product is made to the correct size and from the correct materials.

LINK IT UP

Refer to Component 1: Learning aim B for information on quality requirements and quality control.

Types of engineering information

Engineering information can include work instructions, production data/plans, job cards, test reports and engineering drawings.

Work instructions

Work instructions describe how a part or component should be manufactured. They provide information on how to complete a task one step at a time.

Some manufacturer's manuals include information similar to work instructions, such as describing how to repair, assemble and test an engineered product by following step-by-step instructions.

Production data/plans

When manufacturing a component in a workshop, it is likely that you will use a production plan to guide you through the various stages that need to be completed. This ensures that you do not miss out any stages or complete them in the wrong order.

The complete process is broken down into stages, known as operations. Descriptions are given for each stage or operation of the process and will include information about:

- the required materials and components
- the tools and equipment to be used
- **speeds** and **feeds** to be used on machines, such as drills, lathes or milling machines
- quality control checks to be completed
- timings for each operation.

KEY TERMS

Speeds and **feeds** refer, respectively, to the 'spindle speed' (the speed at which a machine spindle rotates) and the 'feed rate' (the rate at which a machine tool moves across a 'workpiece', i.e. the material being machined).

Job cards

A job card is a form of work instruction (see Figure 3.23), as is an operations sheet. Engineering organisations use job cards as a way of showing all the requirements that need to be carried out for an activity. This may include the tools, materials and components needed, the amount of time that the activity should take, staffing details, and other details about the tasks to be completed.

Works Order No:			
Part no: Description:		Sales order no:	
Customer name:		Customer standards apply:	
Customer acc no:		Certificate of conformity required:	
Customer ref:		Check issue:	
Quantity:		Check drawing:	
Required by:			
Scheduled for:		Issued by:	
Scheduled completion:		Signature:	
Materials: Req qty	Item code	Product description	
Mat spec	Issued qty	Batch no	Initials

Figure 3.23: An engineering job card

When using production documentation, you should make sure that:

- you read and understand the information fully and use it to select the correct materials, tools and equipment
- you follow the instructions in the correct order
- you ask for further guidance if you are not sure about anything.

ACTIVITY

Following the details on an instruction sheet you are given, such as a job card, produce a small engineered component by doing the following:

1. List all the materials, tools and equipment needed.
2. Obtain the materials needed.
3. Access the tools and equipment needed.
4. Follow the instructions to manufacture the component.

Test reports

A test report must be completed when an engineered product or component needs to meet specific performance requirements. You can use test reports to help identify patterns and trends within production activities.

CHECK MY LEARNING

You have looked at some types of engineering information that can be used when carrying out an engineering activity.

With a partner, discuss how you would use work instructions, production plans, job cards and test reports.

Types of engineering working drawing

GETTING STARTED

Working with a partner, make a list of the types of drawing that would need to be used to provide full details of an electronic games console design.

We have looked at how engineering drawings can be used to present ideas and communicate information to other engineers and customers. In most cases, you will need to use a combination of drawing types to be able to communicate a design clearly.

In addition to the different formats of drawing, there are specific types of working drawing that can be used to provide particular details of a design.

Component drawings

A component drawing includes the information needed to make that particular component, including the materials to be used, dimensions of the component, any surface finishes that are required, and information about specific processes, such as producing threaded holes or counterbores. Examples of components that component drawings are generally used for include nuts, bolts, screws, integrated circuits, rivets and mechanical components such as bearings and gears.

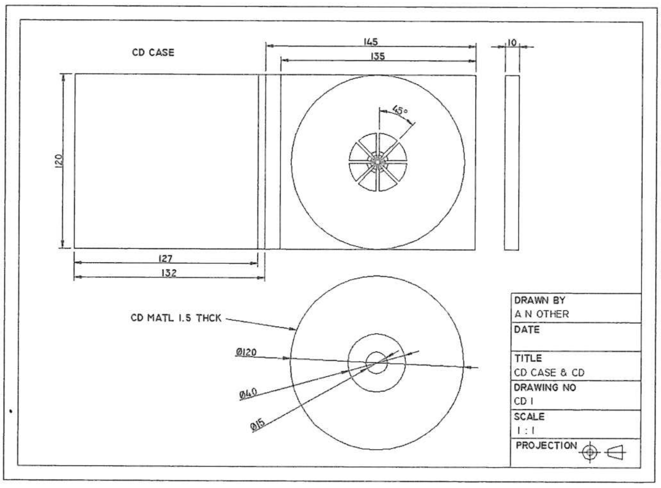


Figure 3.24: Example of an engineering component drawing

Component drawings, such as the one shown in Figure 3.24, must be sufficiently clear for an engineer other than the designer to be able to follow. These drawings contain the minimum information needed to produce the part. They do not show how individual components interact or combine with each other. For this, you need an assembly drawing.

Assembly drawings

To show how component parts fit together, you need an assembly drawing. Assembly drawings, such as the one shown in Figure 3.25, are used by engineers to make sure they do not assemble components in the wrong way. These drawings do not, however, show individual details of components, and therefore assembly and component drawings need to be used together.

There are variations of assembly drawings that may be needed when developing an improved solution to a problem. These include:

- sub-assembly drawings that show how components fit together to form a larger component such as an alternator, which is a sub-assembly of a car engine assembly

- fabrication assembly drawings that show details of joining methods required for structures manufactured from sheet materials, and may also include details of welds or fixings.

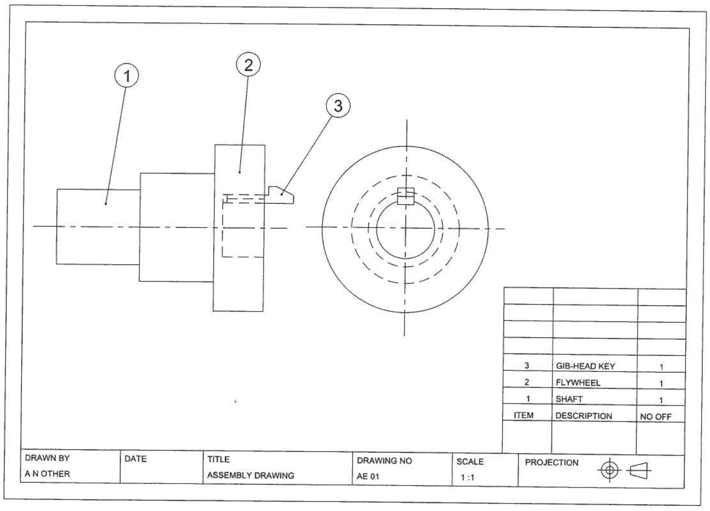


Figure 3.25: Example of an engineering assembly drawing

Repair and modification drawings

Sometimes repairs or modifications need to be made to a component. For example, additional holes may need to be drilled, or part of a component removed, to allow it to fit within an assembly. In these instances, there is only a need to produce a modification or repair drawing with details of the specific changes required.

Installation diagrams

Installation diagrams are used to show how a component should be installed in its final location – for example, how to install a hot water boiler or piece of machinery.

Wiring diagrams

Wiring diagrams are similar to circuit diagrams, except that they show how electrical circuit components, such as switches and other electrical equipment, are actually connected together. You can find examples of these types of diagram for the wiring of the machinery in a workshop.

ACTIVITY

Imagine that you have been tasked with designing a prototype digital camera that is suitable for water sports.

1 Research the types of drawing that you will need to use.
2 Prepare a presentation to show what information each type of drawing will provide.
3 Include an explanation of why each type of drawing is useful.

CHECK MY LEARNING

You are now aware of some of the types of drawing an engineer could use to share information.

In a group, explain what each type of drawing shows and when each type is usually needed.

Drawings and information

GETTING STARTED

Make a list of the types of information you would need to produce an engineered product in a workshop. With a partner, discuss why some engineering drawings may be difficult to interpret.

KEY TERM

Conventions are the rules used to present information such as drawings; for example, BS8888 is the standard set of rules for working drawings. They cover line types, symbols and layouts of drawings.

Engineering drawings can contain lots of information. Often these drawings may appear confusing and difficult to interpret if you are unfamiliar with the different drawing **conventions** used.

Drawings are extremely useful for showing how parts fit together, whether the parts are male or female, and how any specific connections need to be made.

Materials and components

One easy way of remembering whether a part is male or female is to think about a nut and a bolt.

- A bolt has a thread on the outside – an external thread. Parts with an external thread are termed 'male'.
- A bolt is usually assembled with an accompanying nut, which has a thread on the inside – an internal thread. Parts with an internal thread are termed 'female'.

A working drawing, or assembly drawing, will show, where applicable, details of how male and female parts fit together. Similarly, an electronic circuit diagram will show the typical values of the components within it. These could include current, voltage and resistance values. You will need to think about these details when selecting components to use.

Dimensions

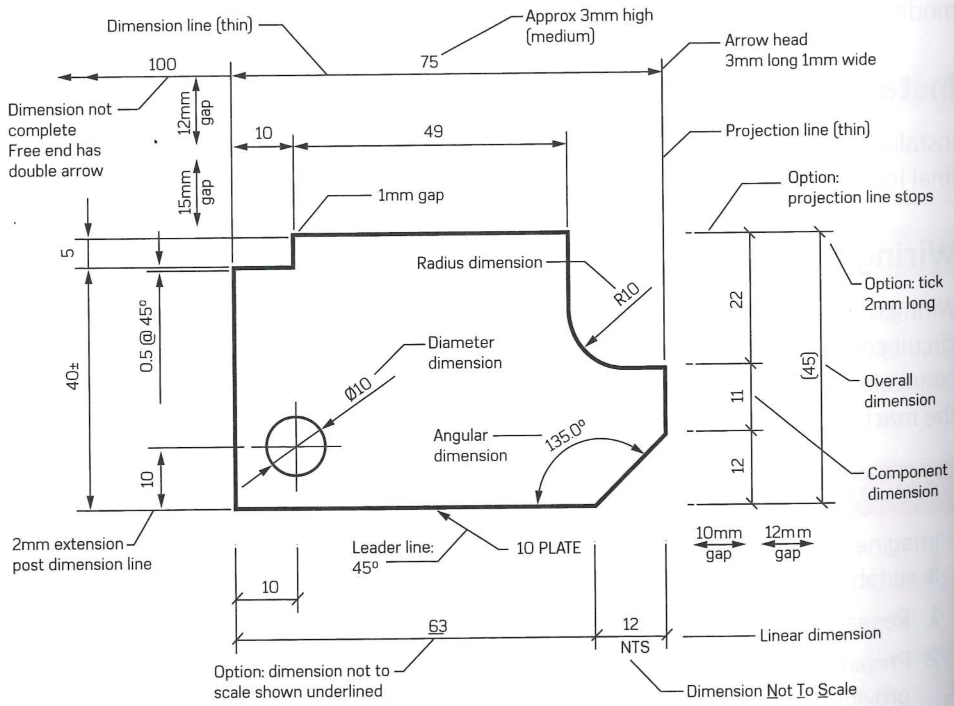


Figure 3.26: Engineering drawings often include information about radii, diameters and tolerances among other manufacturing information

Look at the example of an engineering component drawing shown in Figure 3.26. There are a range of features on the drawing that you need to understand in order to interpret correctly the information being shown.

One of the most important features of any engineering drawing is the dimensions marked on it. To interpret these, you must be able to understand the abbreviations and conventions used.

Some of the more common abbreviations and symbols are shown in Table 3.17.

Table 3.17: Abbreviations used in drawings

Abbreviation or symbol	Meaning
∅ or dia	Diameter
R	Radius
NTS	Not to scale

You also need to remember the following points about dimensions.

- Dimensions always show the true size of a component, although sometimes components are drawn to a different scale.
- Dimensions are usually shown only once on a drawing – this means that you may need to transfer dimensions from one side of a component to the other.
- Different line types are used for dimensioning on a component drawing – these are shown as dimension lines, extension lines and leader lines.
- Short dimensions should be labelled closest to the component – this prevents lines overlapping.
- Dimensions should never appear on top of a drawn object; they should always be to the side, away from the object.
- Try to group dimensions together wherever this is possible.
- Horizontal dimensions should appear above the dimension line.
- Vertical dimensions should be to the left or right of the line and preferably orientated so that they are written along the dimension line.

ACTIVITY

Assemble an engineered product using only engineering drawings. Make a note of any problems that you have with interpreting the drawing information and any parts of the assembly that you found easy to complete.

Take photographs, annotating them to highlight the problem areas. Discuss with a partner.

CHECK MY LEARNING

The ways in which information such as drawing dimensions and abbreviations can be added to a drawing have been covered in this lesson.

In a small group, think about and discuss the reasons why drawing conventions are important and must always be followed.

Identifying issues and causes associated with a problem

GETTING STARTED

Working in a small group, think about the types of problem that could be encountered with the design and manufacture of an engineered product such as a mobile phone or a bicycle.

As an engineer, it is important that the products and components you design and make perform as expected. It would be inconvenient if a hook designed to hold tools in a garden shed was not able to support the weight of a spade; it could be dangerous if the tyres on a car could not cope with travelling at motorway speeds.

Identifying problems

Engineers use data from tests to identify potential problems or faults and then find solutions to these problems.

We have seen the scatter graph in Figure 3.27 previously, but what if the circled test values are accurate and not the result of measurement errors or false readings?

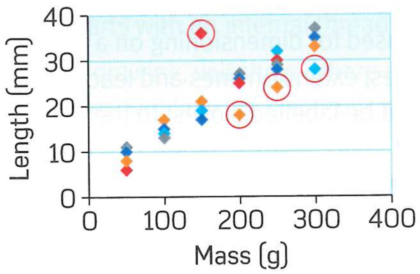


Figure 3.27: Results from a load–extension test for springs

Looking at the graph, one of the springs extended to nearly twice the length of the others with a load of 150 g. This could lead an engineer to think that the material used is of a different quality, or perhaps of a thinner gauge than specified. By noting these anomalies in results, engineers can investigate the causes of a problem.

ACTIVITY

Look at the results for the load–extension test in Figure 3.27.

1. Think of reasons why some of the springs did not perform as expected.
2. Identify possible stages in the production of the springs where mistakes could have led to the differences in performance.
3. Suggest ways to prevent the same problems happening in the future.

Typical causes of faults

Faults can be divided into two types:

- random faults
- systematic faults.

Random faults

Random faults are often associated with the materials or the equipment used to make a component. Causes of random faults include the following:

- poor-quality materials that do not meet the specification
- flaws in materials that cause the materials to fail
- blunt or damaged tools and work-holding devices
- damaged gauges and measuring equipment.

The analysis of data can help to trace random faults; for example, if a number of faulty components were produced on one machine and none on other machines, then inspections could be carried out to check for damage to that individual machine.

Systematic faults

Systematic faults are usually the result of human errors at some stage in the production process. These include:

- incorrect materials being selected for a component
- incorrect cutting speeds and feeds being used
- marking-out errors
- inaccurate use of tools and equipment.

In most cases, systematic faults will not be noticed through the interpretation of data, other than perhaps to notice trends for individual machine operators.

Interpreting patterns and trends related to engineering information

You need to be able to look at engineering information and identify whether there are patterns or trends. We have looked at the use of scatter graphs earlier, but sometimes you need more information to help identify and solve problems. For example, think about other factors such as when a component was manufactured or where it was made.

CHECK MY LEARNING

We have looked at ways of identifying problems and faults that can occur within engineering processes.

Write down as many random and systematic faults as you can think of that can impact on an engineering process.

Selecting a solution

GETTING STARTED

Imagine that you have been asked to redesign a torch that has already been prototyped using metallic materials. With a partner, make a list of all the factors that need to be considered when redesigning for manufacture.

There are many ways in which the design of a product can be improved, such as by changing the materials and/or reducing the weight or volume. However, whichever changes are made to a design, you must ensure that it will still be possible to manufacture the product.

A range of approaches can be used to make a product easier to manufacture. We have looked at some of the approaches in the lesson on using alternative components, and in many ways the approaches are similar.

Prototype of an LED torch

With a product prototype, the materials and processes are often chosen because they are suitable for one-off production methods. This means that if the product is going to be manufactured on a larger scale, decisions will need to be made about the materials and processes to be used for the increased scale of production.

Approaches that can be taken

There are a number of aspects that you will need to consider when redesigning a product for an increased scale of production.

- Consider using standardised components.
- Design components so that they can be manufactured using as few processes as possible.
- Reduce the number of different materials in the product.
- Reduce the number of different components in the product.
- Avoid unnecessary features that do not improve the product.
- Consider the use of automated processes when selecting manufacturing methods.

Components

There are two ways in which you can redesign the componentry to make a product more efficient for manufacture.

Use of standardised components

This means using the same component in a range of products or in different combinations within the same product. In some cases, the same component can be used both in different combinations within one product and in other products.

Limit the number of different types of part in a product by standardising their design. For example, if brackets are included as part of the design, avoid having four or five different types. It is good practice to have only one design for each type of component as this reduces the time needed for processing and manufacturing and allows for ease of maintenance in the future. If there are fewer designs of a part to make, fewer tool set-ups are required, and the associated number of jigs, templates and formers can also be reduced.

Reducing the number of components

You could also reduce the overall number of components in a product. Instead of joining several parts together, consider using different processes and/or materials. For example a fabricated metal container could be replaced by a container made from injection-moulded polymers. The product can then be manufactured more quickly as fewer processes will be involved.

Materials and manufacturing processes

You should aim to reduce the number of different materials and manufacturing processes used. By limiting the range of raw materials, they can be used more efficiently and processes can be completed faster. If component parts need to be joined together using thermal processes such as welding, using the same material for all components will make assembly easier because it can be difficult to weld different metals together.

Using the same types of polymer for different components would also allow the same processes to be used to manufacture them. For example, high-density polyethylene (HDPE) could be used for various injection-moulded parts.

It is also more efficient to reduce the number of different pieces of equipment needed. The use of CNC or automated machinery should be encouraged wherever possible. These various considerations can be summarised as follows.

- Limit the number of different materials that you specify.
- Think of processes that are more efficient for manufacturing.
- Avoid using lots of different sizes and thicknesses of material.
- Think about ways in which you can include CNC processes.

ACTIVITY

Use the internet to find an image of a prototype engineered product.

1 Sketch the existing design and annotate your sketch with details about the materials used in the prototype.

2 Produce a range of 2D and 3D sketches to show how the product would be made in quantity.

3 Annotate your sketches to explain how the product would be made.

CHECK MY LEARNING

You have learned about the approaches an engineer can use to improve the design of a product by using different materials, components or processes.

With a partner, discuss the factors you need to consider when replacing a polymer material used for a prototype design with a metallic material for the actual product.

Possible engineering solutions

GETTING STARTED

Think of a simple everyday product that you are familiar with. Write down any flaws or problems with the design that you can think of.

Most existing products and components, no matter how small or simple, can be improved in some way. However, producing the ideal solution is often not economic: it would cost more to redesign some components than the money an engineering company would save as a result of the design changes.

When you investigate products to identify potential improvements, you need to think about the following factors:

- the design of the product or component
- the tooling used for manufacturing the product or component
- the manufacturing processes used to make the product or component.

In most cases, improvements to one aspect of the product will have a knock-on effect on other aspects. If you change the design of a product, there are likely to be changes needed to the tooling used and potentially also to the manufacturing processes.

Example of a component that has been redesigned using computer-aided design (CAD) and then produced in titanium using 3D printing

The component shown in the photograph, part of an axle assembly for a go-kart, was originally manufactured from stainless steel plate and then stamped out and deformed in one process.

The manufacturing company that makes this component has identified a number of faults with the existing design, including large quantities of waste material being produced and offcuts of materials that are hard to recycle.

The company decided to make some small changes to the design of the component to allow it to be manufactured using a different process. The new process chosen is 3D printing and the material has been changed to titanium. This reduces the amount of material wasted because, with an additive process, no waste materials are produced.

When you are redesigning a product, think about the concepts we have covered before and remember the acronym KISS – 'Keep It Simple, Stupid'.

Do not overcomplicate things – a simple design will probably perform better than a complex one.

- Design components so that they can be manufactured using as few processes as possible.
- Reduce the number of different materials in the product.
- Reduce the number of different components in the product.
- Avoid unnecessary features that do not improve the product.
- Consider the use of automated processes when selecting manufacturing methods.

All these factors link up with the concept of keeping the design simple.

DID YOU KNOW?

Albert Einstein once said: 'Everything should be made as simple as possible, but not simpler' (*Yale Book of Quotations*). He meant that you should make the design of a product as simple as possible while meeting the specifications, and success will be achieved when the product is as simple as it can be.

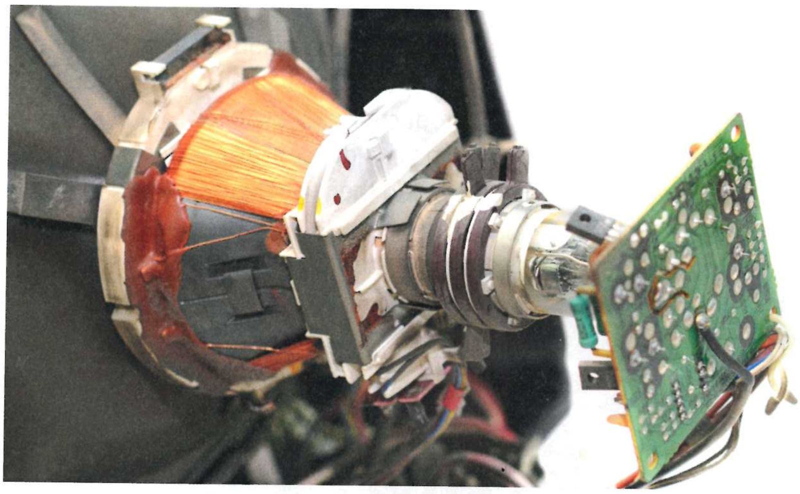
ACTIVITY

Examine an engineered product, either a physical example or an image of one.

1 Write down any issues that you think there are with the design.

2 Make notes about any problems that you think there could be with tooling or manufacturing processes.

3 With a partner, discuss potential ways to improve the design and improve the product.



Sometimes developments in technology can allow for radical changes in designs

It is possible that there are new technologies that could help simplify the product you are being asked to redesign. It is worth doing a little research to see if any new processes or technologies are being developed that would help improve your design. The image above shows what the inside of a television used to look like – think about how thin and lightweight televisions are now because of the new technologies that have been invented since then.

You also need to think about the extent to which your engineering solutions have fulfilled their primary purpose. In other words, does the solution do what it is supposed to do? For example, while a smartphone has many functions, its primary purpose is to allow people to communicate.

CHECK MY LEARNING

You have learned about methods that you could use to make a design simpler, yet still perform its primary purpose.

Working with the same partner as in the previous activity, think about another product that you are both familiar with, one that has more than one function. Discuss which approaches will lead to the greatest benefit in making the product more effective.

Wider factors that need to be considered

GETTING STARTED

Do you know what batch-produced means? Working with a partner, make a list of engineered products that you think are batch-produced.

You may be asked to redesign a product or component that has been made as a one-off so that it can be produced in larger batches. This means that a different approach will need to be taken for the design and the manufacturing methods.

One-off production

One-off production is used either when you are making a prototype of a product or when a customer wants something that is specially made for them. Often these one-offs are made by just one person, but sometimes small groups of people will work together to produce them. In both cases, the same people work on the complete product from start to finish. One-off products are unique, which makes them expensive to produce because of the amount of time spent on manufacturing them.

Batch production

If a number of products or components are needed that are all from the same design, then they can be made in a batch. Unlike one-off production, batch production offers opportunities to use automation. The production process allows for changes to be made – for example, to make the products in a different size. Often a production line is used to make one type of product, and then the line is adapted to produce a different type of product.

Alloy wheels are an example of a batch-produced product

Table 3.18 gives a summary of the differences between one-off production and batch production.

Table 3.18: Characteristics of one-off and batch production

	One-off production	Batch production
Unit costs	High	Medium
Tools and equipment	General use	**Specialised equipment**
Initial investment	Low	Medium
Production efficiency	Low	Medium/high
Labour type	Skilled	Skilled/semi-skilled
Labour cost	High	Medium

KEY TERMS

Unit costs in this context are the costs associated with the manufacture of an individual product.

Specialised equipment can be used for more than one product or component, but can only be used to carry out a limited range of processes.

ACTIVITY

Imagine you are an engineering designer. You have been asked to analyse an existing batch-produced product.

1 Investigate the materials and processes used to make the product.

2 Produce a short presentation that includes information about:

a) resources needed

b) reasons for batch production

c) safety factors

d) environmental impacts.

Environmental impacts

Environmental impacts of production must be considered when designing an engineered product. These include the following.

Use of energy during production

Energy will always be used during the production of engineered products. However, different sources of energy will have differing impacts on the environment. With fossil fuels, such as coal, oil and gas, there are impacts from the extraction of the fuel source and the burning of these fuels to produce energy. Other sources – renewable energy such as solar and wind power – can be used to generate cleaner energy. The source of the energy and the amount used are important when considering the impact of production on the environment.

Use of resources during production

It is best to avoid non-renewable materials, such as oil-based polymers, or materials that cannot be recycled at the end of their useful life.

Production waste and pollution

Try to avoid wasting materials. This can be achieved by using alternative processes such as 3D printing or casting, or through the recycling of waste materials and offcuts. Sometimes it is unavoidable that waste is produced, for example when turning a workpiece on a lathe or vacuum forming a polymer sheet to produce a moulding. The most effective way of reducing waste, though, is to make sure that production is '**right first time**'.

KEY TERM

Right first time is often quoted in terms of quality control and refers to when something is done without errors so that no time and money are wasted.

CHECK MY LEARNING

You have learned about some of the issues that need to be considered when designing a product for manufacture, such as the requirements of batch production and environmental issues that should be considered.

In small groups, discuss the outcomes of the investigation you carried out in the lesson activity – how would your findings impact on your redesign of the product?