



**Specialist Technical  
Principles  
Work booklet**

Name:



Every 2 weeks you will be set a new theory section to read, write revision cards for, respond to questions and mark / give feedback on a previous section.

This work booklet will be a brilliant revision tool for you and should be kept up to date and in good condition.

Section	Due Date	Completed	Marked
Forces and Stresses on materials and objects	Thursday 24th January 2019		
Improving functionality	Thursday 7th February 2019		
Ecological and social footprint	Thursday 28th February 2019		
The 6 R's	Thursday 14th March 2019		
Scales of production	Thursday 28th March 2019		
Timber based materials : sources, origins and properties	Thursday 25th April 2019		
Working with timber	Thursday 25th April 2019		
Commercial Manufacturing, surface treatments and finishes	Thursday 9th May 2019		

If the section tasks are not completed for the due date you will stay after your P3 lesson that day to complete some of the task and then be asked to complete the full task for the following Monday or you will be given an after school detention.



Task 1: Use the information provided for each section to create a set of your own revision cards. You will have covered how to create revision cards which suit your learning style in your PHSE lessons. You can use the space provided in the booklet which can later be cut out or create your own set of cards.

Remember:

- Add all vital information cut out only unnecessary words e.g. full paragraphs into concise sentences.
- Use key and technical vocabulary
- Highlight or underline key words
- Add sketches and diagrams where necessary
- Use lists, bullet points, tables to make the notes easy to read



Task 2: Use the information, your own additional research and your completed revision cards to answer the exam style questions for each section.

Remember:

- Write in full sentences in order to practise your exam technique.
- Use your revision cards or information as a second option, try to answer the question from memory at first and then add once you have checked your notes.



Task 3: Collect the mark scheme from Mrs Harper on the due date for each section. As part of your next set of homework you need to mark your responses or ask someone at home to mark if for you and give feedback.

Remember:

- Look for the key words from the marks scheme and tick where you see these.
- In the feedback box add any missing information, additional responses or corrections.





**Forces and Stresses  
on materials and objects**

## Forces and stresses

All materials, structures and products have to withstand stress as certain forces are applied to them when they are in use. The ability to withstand the stress is what allows them to perform their functions successfully.

An applied force may be either static or dynamic. A **static load**, such as a book resting on a table top, does not move. A **dynamic load**, for example the same book dropped onto the table from a height, does move. Dynamic loads will produce much greater forces than static loads.

When new products are developed, designers must decide what type of loads they will have to cope with. Whether you sit in a chair, or fall back into it, will have a huge impact on the forces or stresses the chair will need to withstand. Products should be designed to cope easily with the maximum anticipated stress in order to be safe and reliable.

### Tension

**Tension** occurs when a pulling force is applied to either end of a material. The object becomes stretched as it tries to resist being pulled apart. For example, a rope being pulled in a tug-of-war competition, or chains supporting a swing are under tension.

**Tensile strength** is the ability of a material to resist being pulled apart.



### Compression

**Compression** occurs when a pushing force is applied to either end of a material. The object becomes compressed as it tries to resist being squashed. For example, a spring in a suspension system or a clove of garlic in a garlic press are being compressed. Air in a balloon and spray deodorant in a can are also being held under compression.



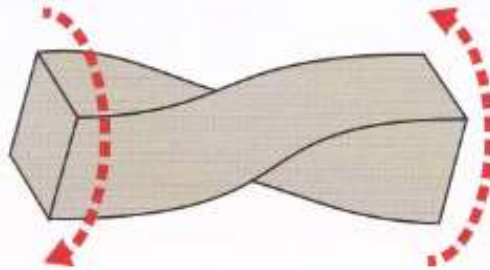
Holding liquids and gasses under compression is an economical way of storing them. They take up less room and their release can be easily controlled through valves and other devices.

**Compressive strength** is the ability of a material to resist being compressed or squashed.

## Torsion

**Torsion** forces occur when a material is being twisted. The two ends of the material rotate in opposite directions creating a twist, like wringing out a wet towel.

Many structures and objects, including cars going over uneven road surfaces and boats riding over waves, are subject to torsion.



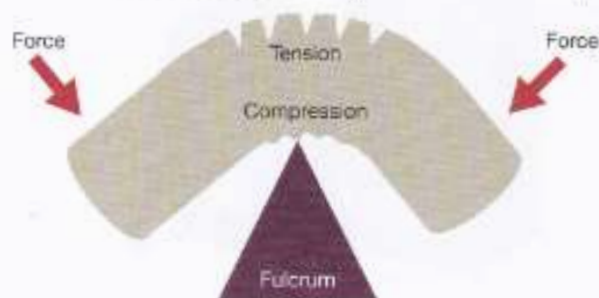
**Torsional strength** is the ability of a material to resist being twisted out of shape.

## Bending

A **bending** force results in both tension and compression either side of its neutral axis. When two people are sitting on opposite ends of a seesaw, the beam will bend over the fulcrum. The top of the beam will be stretched and the underside will be compressed.

The pressure to make a material bend is applied at either end with an upwards or downwards pressure. Pressure could also be applied in the middle whilst it is supported at both ends.

**Stiffness** is the ability of a material to resist being bent out of shape.



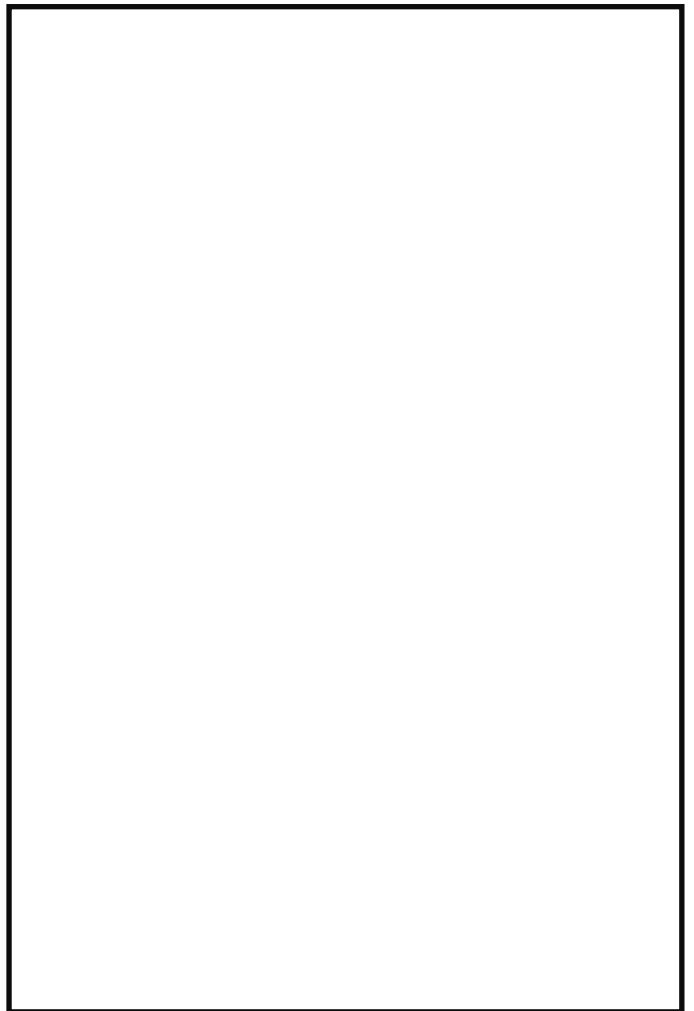
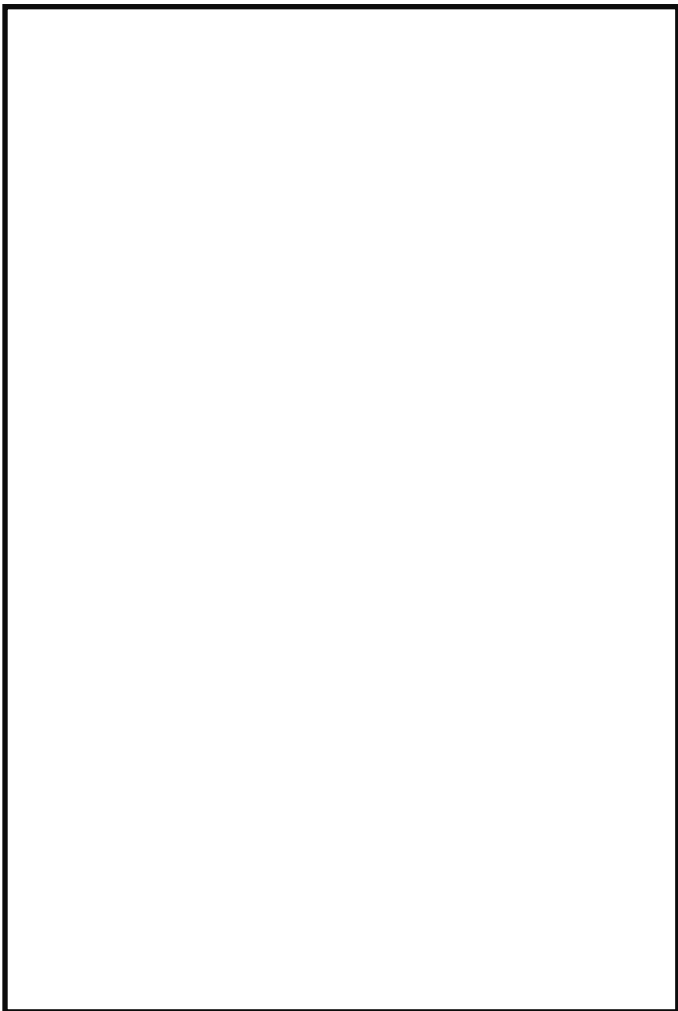
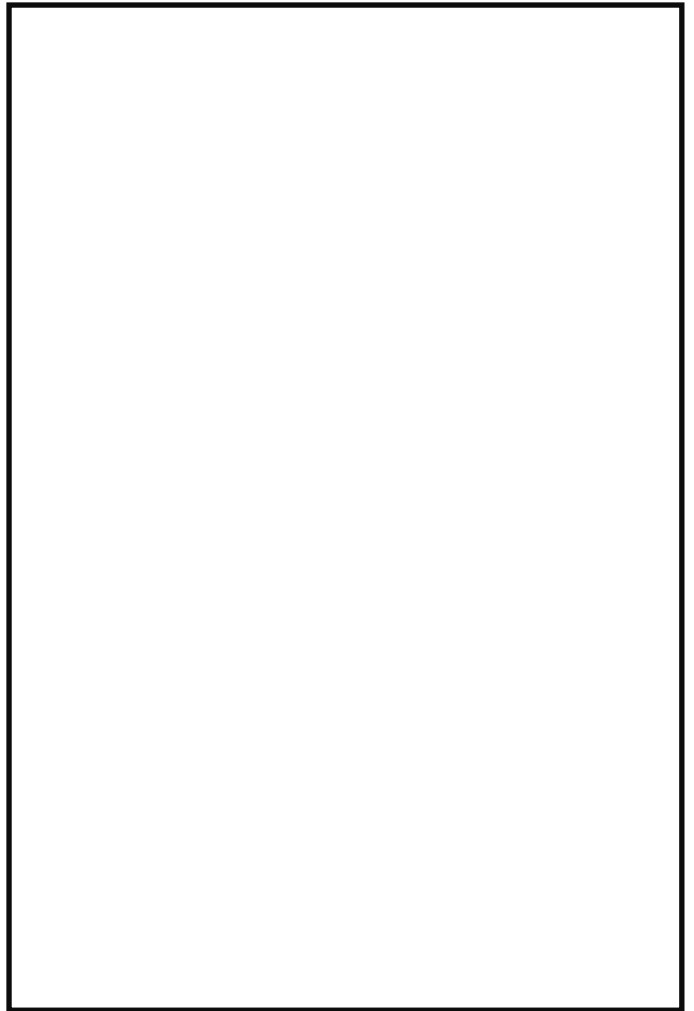
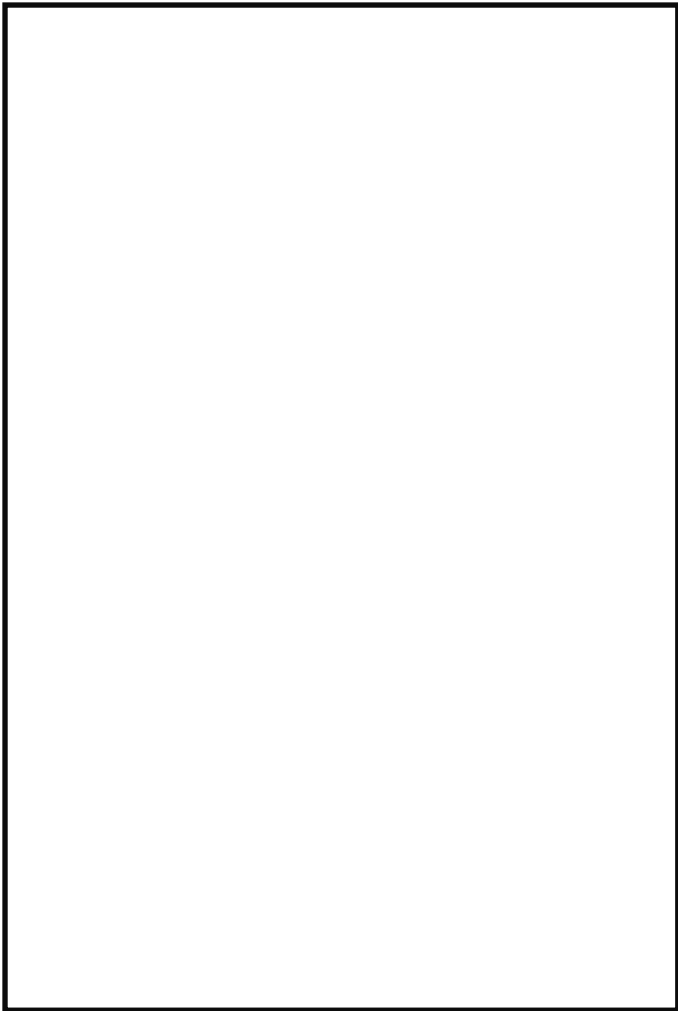
## Shear

**Shear force** is a force that acts on an object in a direction perpendicular to its length. For example, wind pushing against a tree is a shear force. The object experiences shear stress, and may eventually snap or break.

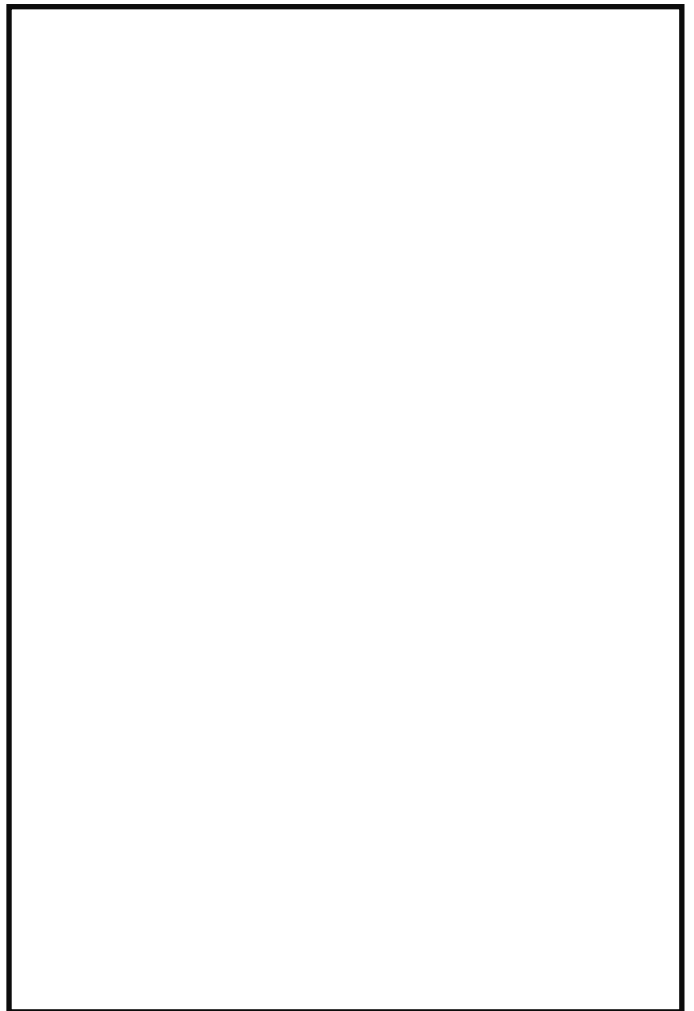
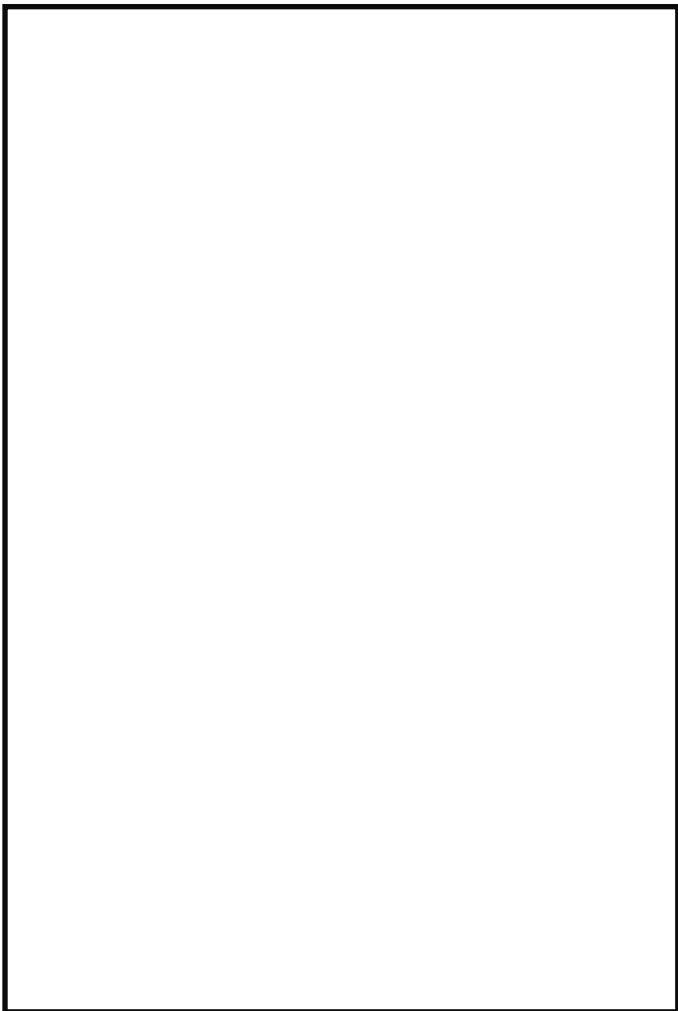
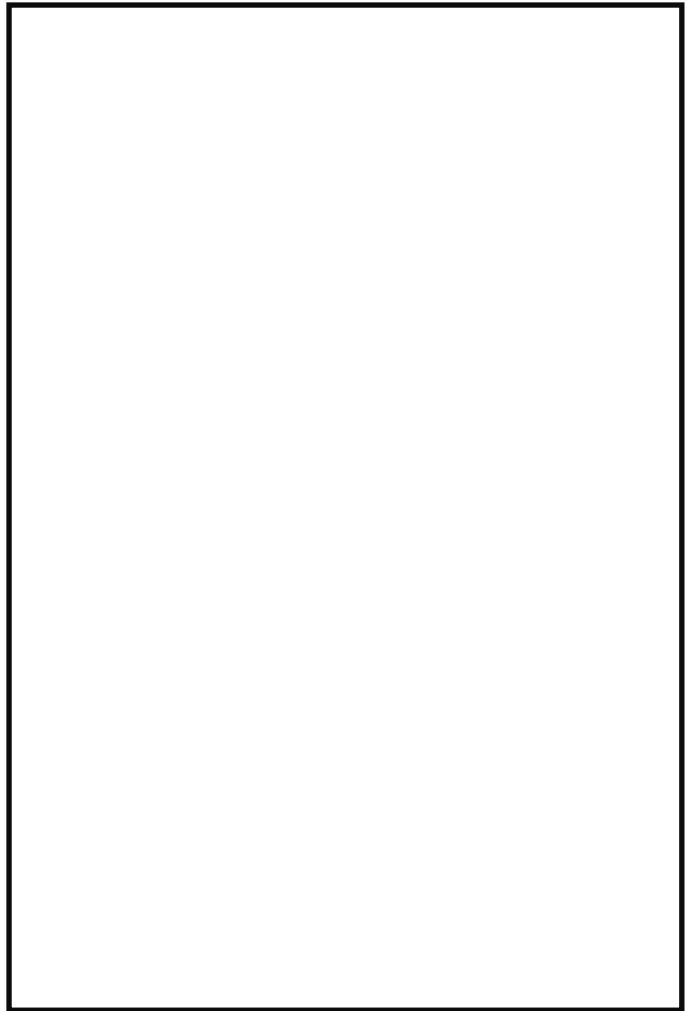
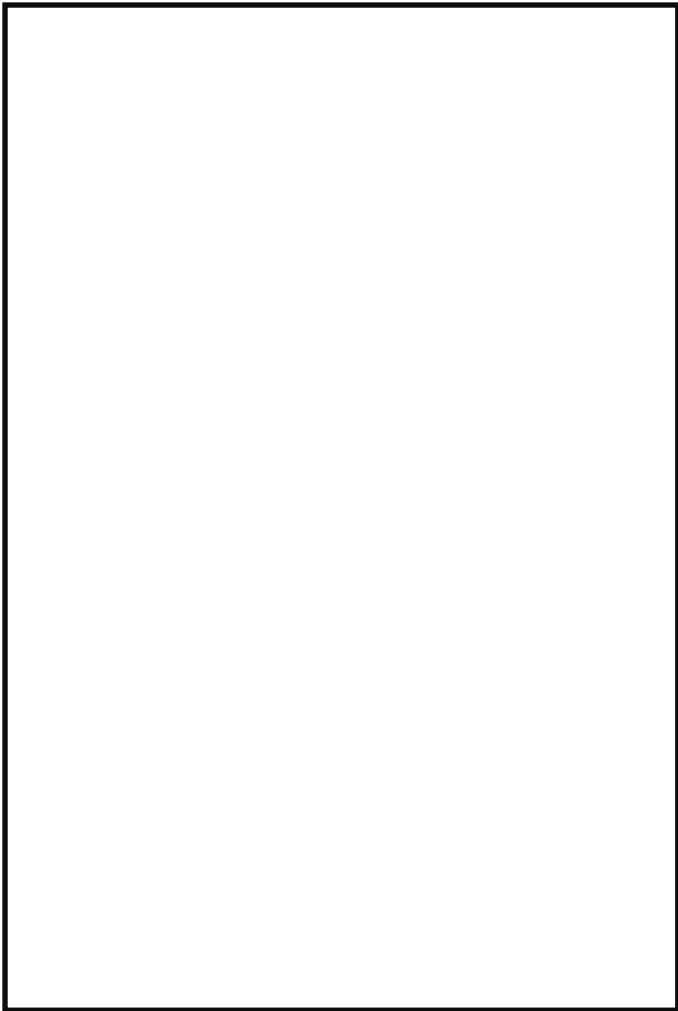
Shear forces also occur when a material or a joint between materials is being pulled apart along different planes or lines (tension is similar but in only one plane i.e. a straight line). The two forces will travel in opposite directions from different planes or lines. Imagine fabric shears cutting a cloth.















## Forces and Stresses on materials and objects: Questions

Q1. Give 3 other examples of materials under tension.  
(3 marks)

Feedback:

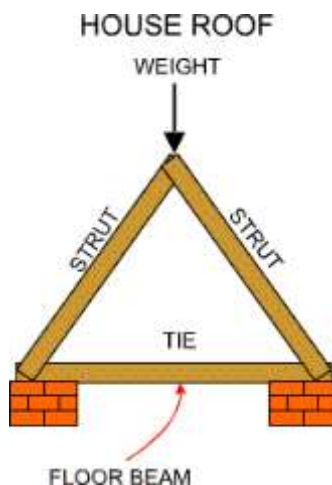
Q2. A Strut performs the opposite function to a tie; it provides outward facing support in its lengthwise direction. These can be found under the roof of a house, bearing the weight of the slates or tiles.

Feedback:

Looking at the diagram, what force is being applied to:

- The tie?
- The struts?

(2 marks)



Q3. In which directions do the forces travel when a material is under torsion? (1 mark)

Feedback:

Q4. What 2 forces are acting when a material is being bent? (2 marks)

Feedback:

Q5. What happens to a material if it is subjected to greater tensile forces than it can withstand? (1 mark)

Feedback:

Q6. Which of the following are examples of shear force?

- a) A pencil lead breaking when being pressed too hard
- b) A fence post snapping in a storm
- c) A vehicle tow rope breaking

(3 marks)

Feedback:

**Total marks : / 12**

**WWW?**

**EBI?**



**Improving functionality**

## Consideration of forces and stresses

Consideration of forces and stresses affects how designers and manufacturers go about creating products. You may not necessarily think it a good idea to make a chair out of cardboard, which you might assume would be too weak to cope with the weight it needs to support; nevertheless, it can be done very successfully.

Many robust items are made from what we consider weak materials; they just need to be strengthened. This can be done in a number of ways and the specific process required depends on the material used and the final strength required.



## Strengthening and enhancing materials

To strengthen or enhance a material you first need to consider the forces and stresses that it will be subjected to when in use. Remember to consider **dynamic forces**, if applicable, as well as **static forces**. This will give you an idea of how much strengthening is required. Designers work out the direction and the magnitude of forces that will potentially be applied to all parts of a product. In this way, they do not waste materials, energy and time strengthening the whole product if only one part of it needs to withstand a certain force.

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## Reinforcing

This is a way of strengthening a material or an object by adding material to it to improve its ability to withstand force and stress.

A car tyre is specifically designed to cope with all of the different forces applied to it during the many thousands of miles it should last. Every element of the mainly rubber tyre has been reinforced. The tread is designed to last for a long time and to expel water so that it grips the road and resists skidding. The side wall is layered to resist being bumped into kerbs and collapsing under the weight of the car. Steel belts are added to resist punctures from sharp objects. Numerous other features help to strengthen the tyre.



Many buildings are made using concrete and steel. Concrete can be brittle and can crack whereas steel bends and flexes. Combining the two results in a very strong construction material called **reinforced concrete**. It has more flex than concrete alone, making it much safer and less prone to failure. The practice of combining materials to improve performance applies to many of the products that we use every day. Duct tape, for example, has a thin adhesive vinyl layer attached to a cloth netting that adds strength and stops it stretching.

Combining two or more materials permanently creates a **composite material**.



Denim jeans and jackets have small metal rivets in specific places such as around the pockets.

These places are where a lot of fabric needs to be stitched together, meaning that more strength is needed to increase the overall tear resistance. The use of mechanical fasteners such as metal rivets allows the material to cope with the added forces of the wearer constantly taking items in and out of the pocket. Rivets have since become a popular design feature. Often additional stitching is added to vulnerable areas such as belt loops and seams.



## Webbing

**Webbing** is a strong fabric woven into strips from yarns, which are often made of synthetic fibres such as nylon or polyester, or very high-strength materials such as Kevlar. Webbing is used for belts of all kinds, including car seat belts, straps for securing loads on vehicles, climbing equipment, furniture manufacture and many other products. It is very light, strong and flexible.



## Stiffening materials

Some forms of reinforcement involve stiffening a material through manipulation. Materials can be **laminated** to improve strength. **Interfacing** may be used to stiffen fabric. **Folding** and **bending** techniques can be used to improve the mechanical and physical properties of a material.

### Laminating materials

Laminating involves bonding two or more materials to improve a product's strength, stability, aesthetics and even its **flexibility**.



When a piece of paper is laminated in a plastic pouch, for example, its properties are changed. It becomes water resistant, more durable and less prone to tearing. It can retain its flexibility, but the thicker the grade of plastic pouch used, the more rigid it will become.



The frame of the classic Ikea® POÄNG chair is made from layers of flexible plywood that are glued together and held under compression in a mould until the adhesive has set. This creates a laminated wood frame that is solid and stable; it has added strength and yet has retained some



*Material bent over a former and held in place with clamps*

This form of lamination is achieved by using a former or mould to shape the material and then applying pressure to hold it in place. The pressure can be applied through a series of clamps.

### Fabric interfacing

Fabric interfacing is used in textile garments as an additional layer in specific areas where extra structure, shape or support is required. Areas that are commonly interfaced include collars, cuffs and waistbands. Interfacing helps ensure a garment sits correctly in position and does not hang limp.

There are two main types of interfacings; fusible or sew-in. Fusible (iron-on) interfacing uses heat to bond it to the surface of the fabric. Sew-in is sandwiched between the layers of the fabric and held in place with stitching. Interfacing comes in different weights or thicknesses depending on the task required.

A baseball cap, for example, uses a heavyweight interfacing to keep the peak rigid, as opposed to a collar which would need greater flexibility and would require a much lighter weight interfacing.

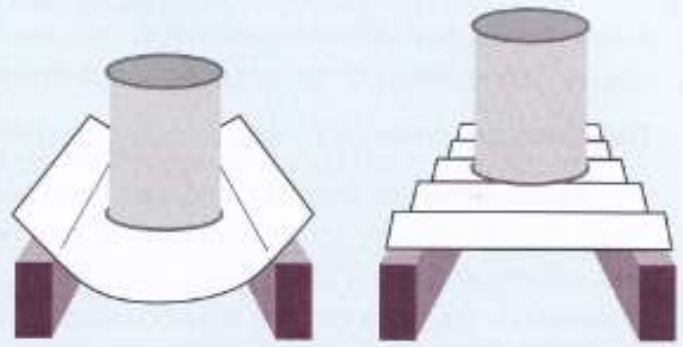


### Folding and bending

Material manipulated through reshaping can gain many physical advantages. If you place a piece of paper across a gap it will not be able to hold much more than its own weight – however, if you put some specific folds in the paper first, it will be able to hold a surprisingly heavy load. This demonstrates that the strength of a product or piece of material is determined, to some extent, by its shape, as well as by its rigidity and flexibility.

**Task:**

Using a sheet of A4 paper, try to support the weight of a pencil case or similar item between a gap of at least 150mm. You could use books to create a gap, or the gap between two desks. Try different folds and judge their efficiency. If you have access to weights you could conduct some destructive testing to find the winning design.



The chair is a product that often acquires increased strength through intricate folding and bending. In the example of Harry Thaler's Pressed chair shown below, a single flat sheet of 2.5mm thick aluminium has been pressed using a relief before being folded into its final form. As a flat sheet it displays very little strength and would certainly not support the weight of an adult, but when folded or bent, its strength is increased. Curves and 'V' folds have been utilised to offer support and structure.



Curves, arches and tubes can add considerable strength to products while using a minimum amount of material. Some materials bend easily and can be manipulated by hand and others need specialist equipment to create the curves. This equipment and the corresponding processes are covered in the specific material sections of this book.

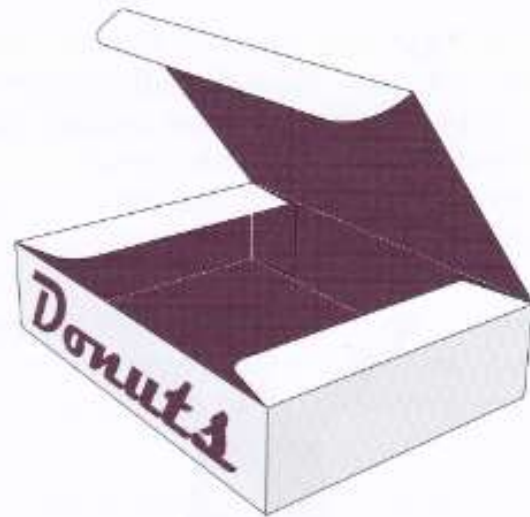
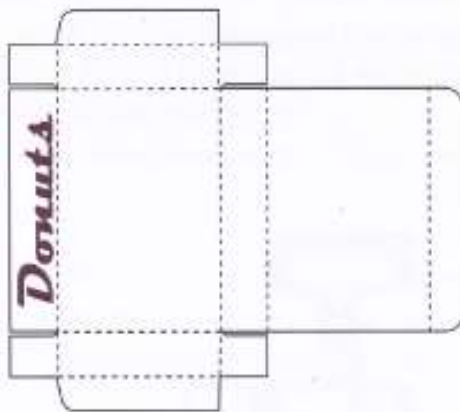


## Nets

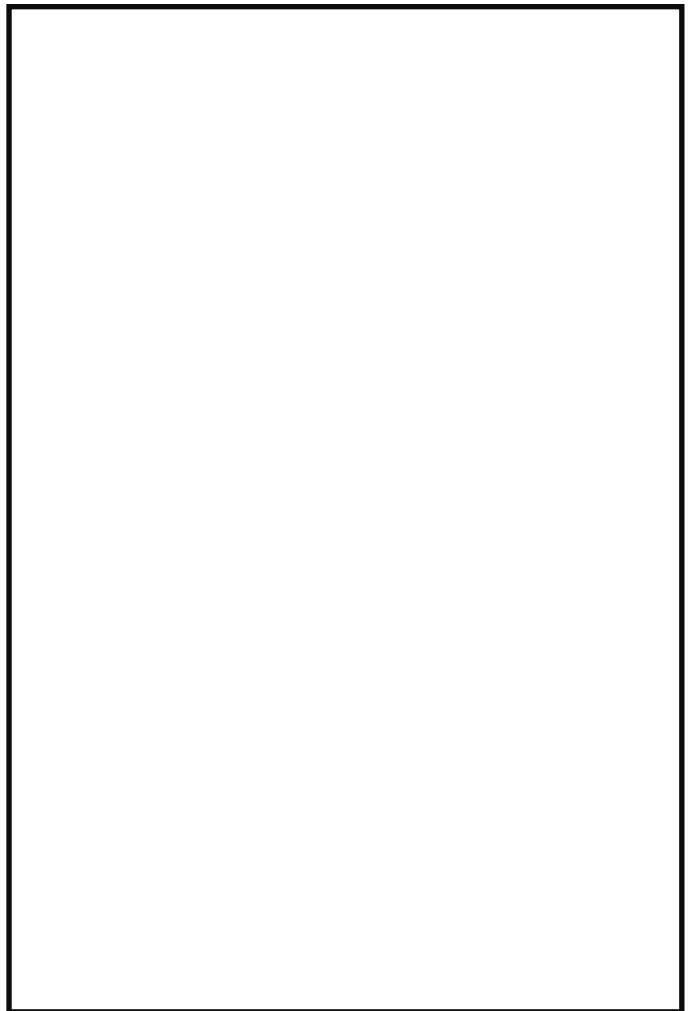
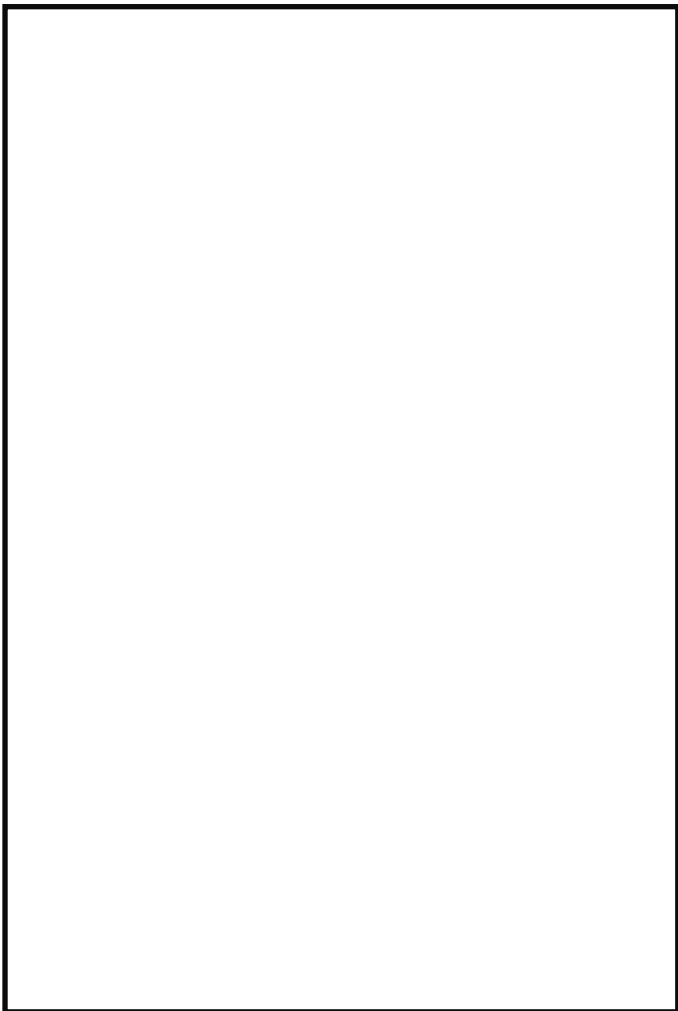
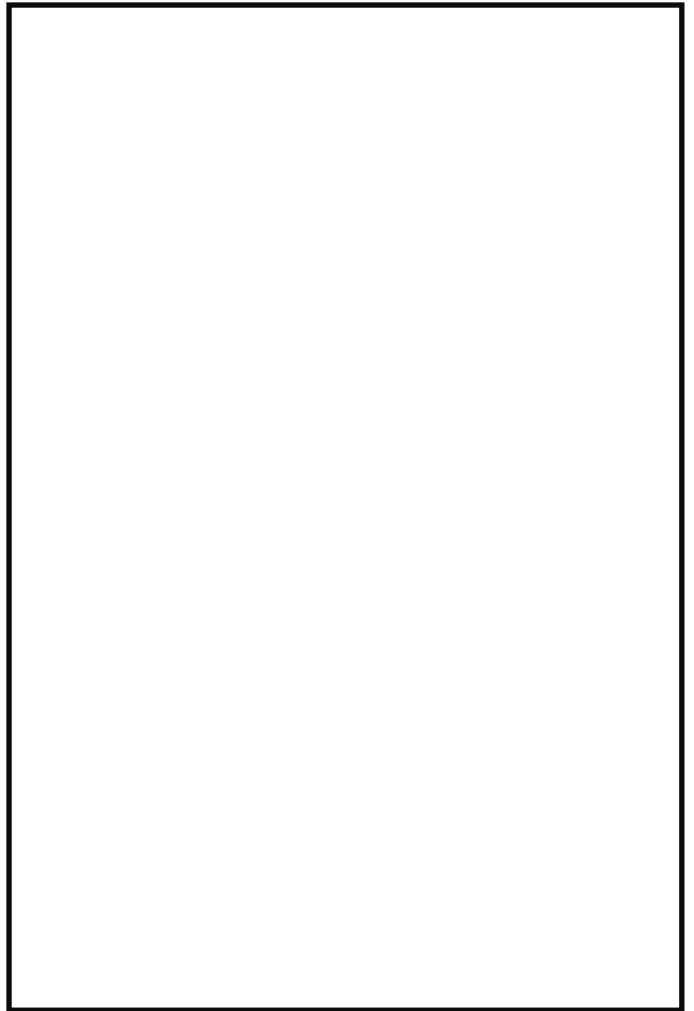
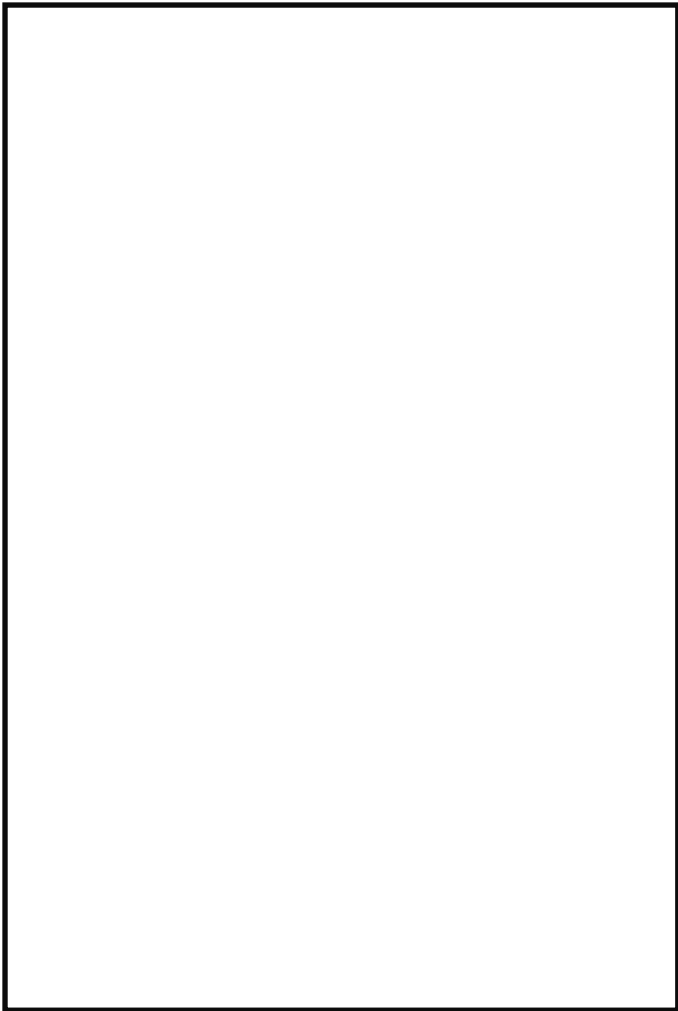
A **net** is a flat two-dimensional shape that can be folded and glued to form a three-dimensional object. The drawing of the net shows **cut-lines**, **score-lines** and **tabs**.

**Cut-lines** are drawn solid and show where the material is cut from the sheet.

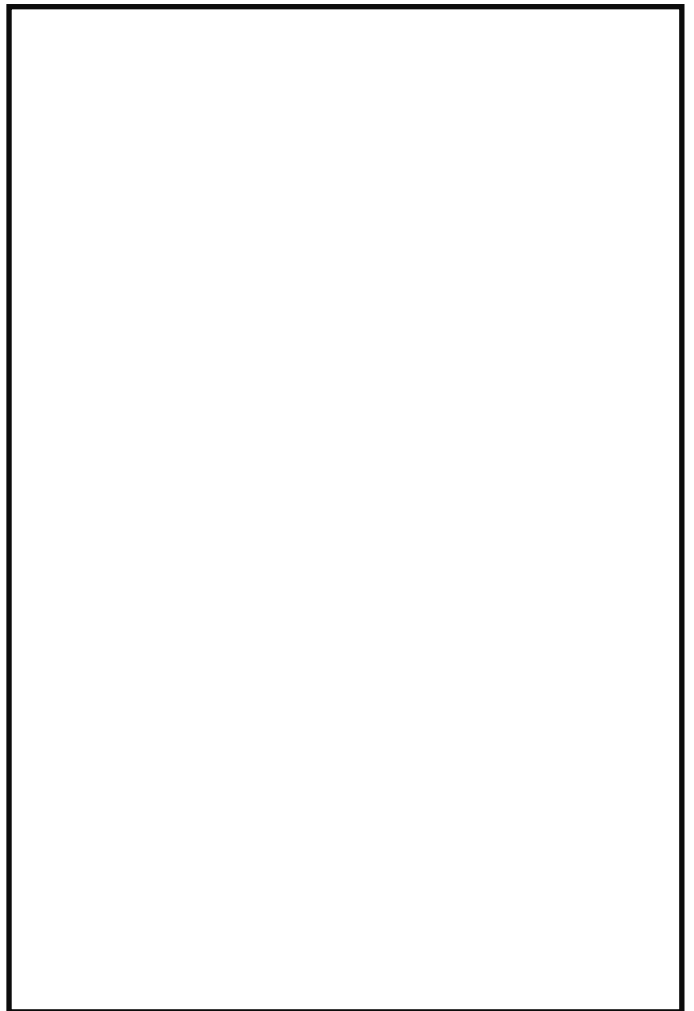
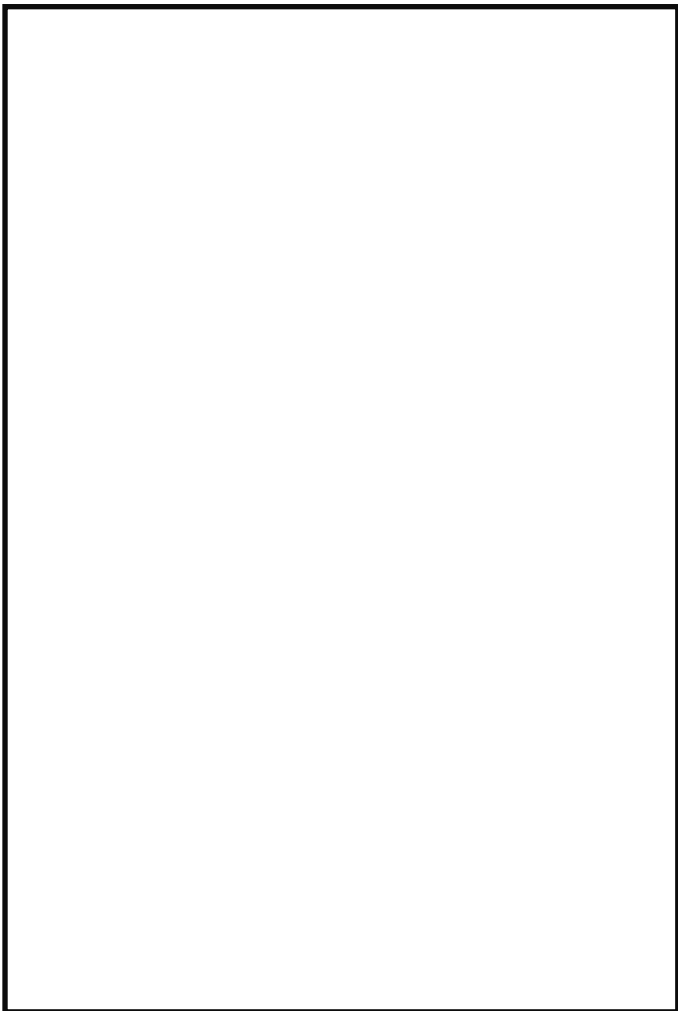
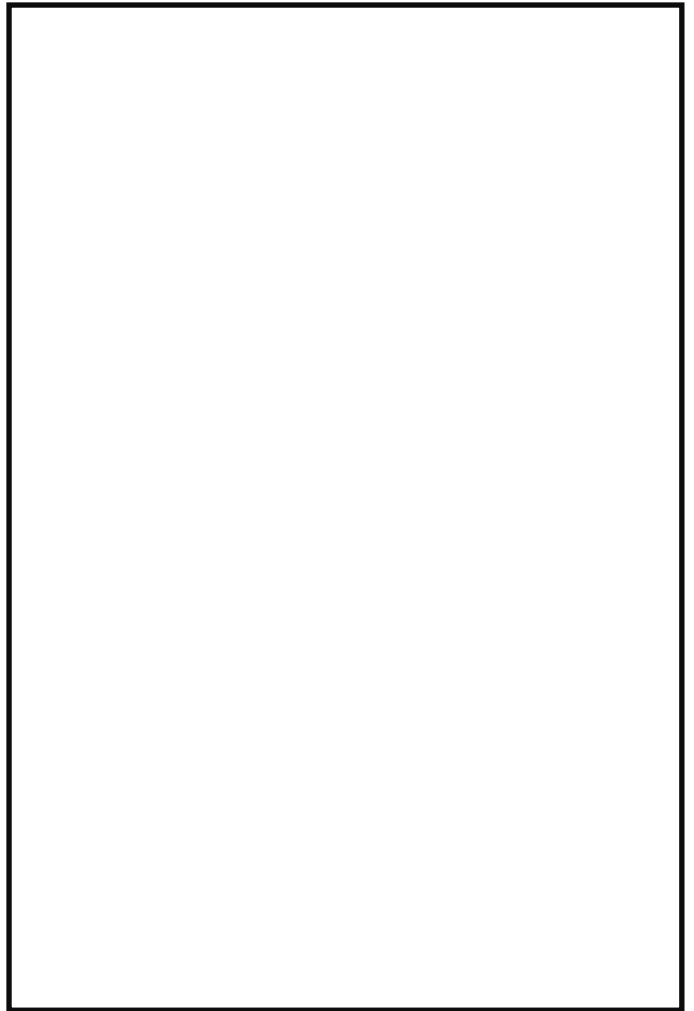
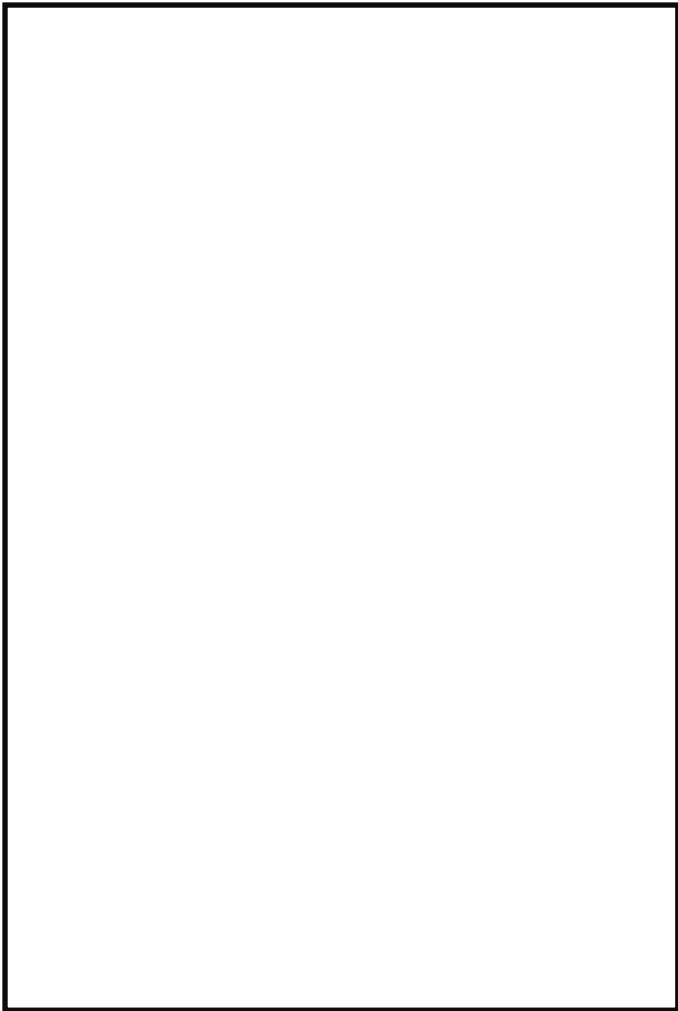
The **score-lines** are usually dotted and indicate where the product is folded. Some materials need to be physically scored along the line in order for the material to fold or bend correctly. This usually involves a blade being pressed into or run along the material to create a shallow indentation. Pressure or heat may be used on some materials to create a fold line. When material is scored, it is important to go to the correct depth or the fold could be weakened.















## Improving functionality: Questions

Q1. How could you determine whether a material needs strengthening for the manufacture of a particular product, and the amount of strengthening that might be required? (2 marks)

Feedback:

Q2. What type of strengthening, apart from rivets, can be applied to the seams of a pair of jeans? (1 marks)

Feedback:

Q3. What are the advantages of a webbing strap compared to a strap made of leather or rubber (2 marks)

Feedback:

Q4. Plywood sheets are made by laminated several layers of wood veneer and glue. The wood grain of adjacent layers is rotated by 90 degrees. What are the benefit of rotating the layers in this way? (1 mark)

Feedback:

Q5. Interfacing is used only in specific areas of a shirt. Apart from the collar and cuffs, where might it be used and what is its purpose? (1 mark)

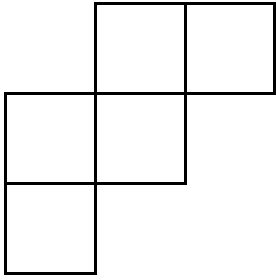
Feedback:

Q6. With relation to timbers, give a specific example of how bending or folding a material can add strength or functionality to a product. Add diagrams to illustrate your answer if necessary. (2 marks)

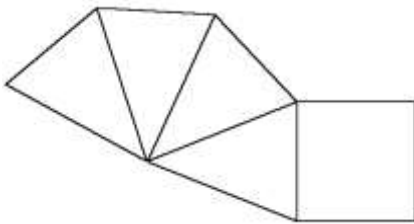
Feedback:

Q7. What 3 dimensional shapes can be made from the following nets? (2 marks)

a)



b)



Feedback:

Total marks : / 11

WWW?

EBI?





**Ecological and social footprint**

## Carbon footprint

Carbon is produced during the manufacture of products. The amount of carbon-dioxide ( $\text{CO}_2$ ) emitted during a process (for example, designing and making a product) is known as its **carbon footprint**. In fact, there are six so-called "greenhouse gases" which are damaging to the atmosphere to various degrees, and each of them can be measured in terms of the damage they cause, and quantified in terms of a single measure, kilogrammes of carbon dioxide equivalent ( $\text{CO}_2\text{e}$ ). Calculating a **carbon footprint** is a way of estimating greenhouse gas emissions caused by a product, process, person, event or organisation.

### Activity: What is your carbon footprint?

There are many carbon footprint calculators available online and take only a few minutes to complete. They give you a detailed analysis of particular human activities and lifestyles. Try <http://footprint.wwf.org.uk> The calculation takes into consideration such factors as:

- how you heat your home
- the temperature that your thermostat is set to at home
- how much you recycle
- whether you are a meat eater, vegetarian or vegan
- what type of transport you usually take



Most western lifestyles result in too much  $\text{CO}_2$  being produced, and are considered to be unsustainable. It is widely believed that changes to the way we produce and use energy are essential to ensure the planet will cope with a growing population.

## Ecological and social footprint

Each person on the planet has an obligation to help protect the environment for future generations. Being aware of your own **ecological** and **social footprint** is a good starting point. An ecological footprint measures the impact of a person's life on the natural environment by quantifying the amount of the earth's natural resources they use. This is usually measured by the amount of CO<sub>2</sub> that is released into the atmosphere in order to sustain their lifestyle. Therefore, measuring your own carbon footprint gives you a fair measure of your ecological footprint.

An ecological footprint may also be measured in terms of the area of land and sea needed to supply a person's needs and dispose of their waste. It can be calculated for an activity, individual, city, country or the entire globe, and can be used as a measure of environmental sustainability. In 2007 it was calculated that globally, we are using up the earth's resources 1.6 times faster than they are being renewed. The size of each nation's ecological footprint shows that there is a huge inequality between nations.

### Social footprint

A **social footprint** is a measure of the impact that a company's social policies have on its employees, partners or subcontractors and on society as a whole. Companies have an obligation to protect the environment by reducing their ecological footprint wherever possible, but they also have a duty to consider the effect that company policies have on all those affected. For example:

- Is there a flexible hours policy for parents who need to pick up children from school?
- Is the company understanding when a parent has to stay at home because a child is sick?
- Is the health and safety of all employees a primary concern?
- Are employees being paid a fair wage?
- Are there appropriate training schemes for employees?
- Are promising employees sponsored through University?
- Does the company contribute anything to the local community?

## Social issues in the design and manufacture of products

There is a growing desire among consumers to know the provenance of the products that they are buying. This means that designers and manufacturers need to know not only where all of the materials and components to make the products come from, but also where they were originally sourced, what the conditions were like for the workforce there and whether they were paid a fair wage. Only then can they be sold as ethically sourced and produced goods.

## Safe working conditions

Most developed societies have a set of rules that govern working conditions for employees, but many countries do not protect their workers to the same extent as the UK. Much of the planet's workforce has little or no protection against their employers; they can be paid very low wages and have to work excessively long hours in poor conditions. The biggest worry for many workers is the lack of health and safety provision to protect them from danger whilst at work.

In Britain, we have employment laws that protect workers' rights and ensure that contracts are issued between the employer and the employee. Both parties know what is expected of them and can be held accountable in a court of law.

The **Health and Safety Executive** (HSE) is an organisation which looks after the welfare of employees and enforces the Health and Safety at Work Act (1974). Under this legally binding agreement, employers are obliged to provide a safe working environment for all employees and protection for visitors, if appropriate. In April 1999 the national minimum wage was brought into effect to protect the income of low paid workers, often in low-skilled jobs. The amount is regularly reviewed to ensure the minimum wage allows workers to have a certain standard of living.



In many countries, workers' rights, wages and working conditions fall below the standards that we would deem to be fair or safe. Therefore, as designers, manufacturers and consumers we should try, where possible, to find out what conditions are like where an item is produced. A growing number of consumers choose to purchase goods from companies that offer decent working conditions and wages to their employees, even if the goods cost a little extra. **Fairtrade** is an organisation that promotes this idea across the world, specialising in farming, clothing, food production and even gold mining. Their philosophy is to give workers and farmers a fair price for their services and products and to facilitate sustainable trade with other countries. The Fairtrade Foundation is covered in Chapter 1.

## Ecological issues in the design and manufacture of products

When products are made, natural resources are used, so designers and manufacturers have to make decisions which have a direct impact on the consumption of the earth's resources. By designing products efficiently and, where possible, reducing the burden on finite resources, products can be made more sustainable. The impact can be further reduced with clever thinking and planning around how the product will be distributed and what will happen to it once it is no longer needed.

## Harvesting raw materials

When raw materials are harvested from the earth, it is inevitable that some disruption will occur. The amount of environmental damage caused very much depends on the mineral being extracted or plant material being harvested and the methods being used in harvesting it. Once the raw material has been obtained, it normally needs to be processed into a usable form. This process of refining can also be very detrimental to the environment if it is not done responsibly. Modern processing techniques are becoming more energy efficient, and sourcing materials from sustainable and trustworthy sources helps to ensure that poor practice is not encouraged.

## Deforestation

The devastation caused to many of the planet's forests is caused by the need to provide timber for housing, infrastructure, cooking and warmth as well as to clear areas on which to grow food for an increasing population. It is estimated that about 80% of the world's forests have been destroyed since 1900. The reasons for **deforestation** are complex and depend on which country you look at.

As a consumer, timber should be obtained from approved sources where the forests are managed. This means that for each tree harvested, at least one other is planted. Rare and very slow growing wood should be totally avoided. Lists of endangered woods can easily be found online.

The term **slash and burn** describes a technique of converting virgin forest into farmland. The trees are felled and then set alight. The resulting ash gives the soil nutrients for a short period of time and crops are grown or cattle are grazed. The main issues with this practice is that once the forest is gone it does not grow back. Much of the wildlife that the forest supported loses its home permanently. Many species are becoming extinct due to shrinking habitats, and the rate of extinction continues to increase as more forest is destroyed.



*Stumps on the valley caused by deforestation and slash and burn agriculture in Madagascar*

A major problem is that developing countries, where many of the remaining forests exist, view the forest as a commodity and sell harvesting rights to wealthier nations. This means that the timber is exported, as well as most of the food grown and animals raised on the newly cleared land.



*The Gobi Desert is the fifth largest in the world and is rapidly desertifying parts of China*

An additional threat in many dry areas, is that a huge amount of water is needed to grow crops and to sustain livestock, but because the rain forests are so diminished, the climate has become dryer and rainfall is lower. Eventually the water table drops and water becomes scarce. This then leads to **desertification** where the land dries out and is no longer able to support vegetation.

## Mining

**Mining** is essential in order to gather the primary materials, minerals and metals required to supply our manufacturing needs. There are two main types of mining; surface mining and underground mining. Both methods have negative effects on the landscape and the environment. These include soil erosion, sinkholes, air pollution and water contamination.



*Diavik Diamond Mine, Northwest Territories, Canada*

Underground mining has less of an impact visually. However, it is dangerous work for the miners and it can lead to instability on the surface, causing subsidence and even sinkholes. Surface mining tends to scar the landscape and create an increased loss of habitat for wildlife. Both methods produce large amounts of CO<sub>2</sub> as the buried materials are mined, transported and processed into usable materials and products.



*Sinkhole of an abandoned salt mine in Solotvyno, Ukraine*

## Drilling

Some resources such as gas, oil and shale gas are best harvested through drilling. A **borehole** is drilled into the earth's crust to reach pockets of a resource. Boreholes can be drilled as deep as 12,000 metres, although the average depth is around 2,000 metres. The surface impact is usually less dramatic than mining, but large storage areas or **pipelines** are needed to store or transport the fuel to where it will be refined.



## Farming

A huge proportion of the earth's surface is used as farmland. In 2016, it was estimated that 11% was used for agriculture. However, this represents around 36% of the land considered to be suitable for growing crops. **Farming** creates about 15% of the world's greenhouse gas emissions, some from crops but mainly from livestock. We need to produce food efficiently for a growing population and our dependence on a meat-based diet may not be sustainable. It requires 2.5 times more land to sustain a meat-based diet compared to a vegetarian diet; five times more than a vegan diet.

Increasingly large areas are being farmed to grow plants that are used to make modern materials and biofuels. These are considered to be carbon neutral as they absorb  $\text{CO}_2$  while they grow, converting it to carbohydrates and water by the process of photosynthesis. The  $\text{CO}_2$  is released when biofuels are burned for fuel or composted as biodegradable products when disposed of.

## Product miles

A product is normally a collection of materials and components. Each element may have taken a very different journey on its way to being part of a product. For example, a garden bench may have steel legs that came from China, teak wood slats from Africa, nuts and bolts from Italy and might be assembled in the UK. By adding up all the miles that individual parts have travelled and considering the weight of each component, you can work out the CO<sub>2</sub> emissions that have been produced in transportation alone to obtain the materials for the product.

The next part of the journey is the distribution to the specific country or the location of the wholesaler or shop. Then the product travels to the consumer. Eventually it will be disposed of, and the product makes its final journey to a tip or recycling plant, which may also be several thousand miles away.



By adding up all the separate journeys you can find the total product miles. This calculation is all part of a **life cycle assessment** that most responsible companies will undertake in order to estimate their CO<sub>2</sub> emissions for a product from 'cradle to grave'. It also helps them work out how to reduce the total distance travelled.



There is a growing movement among British consumers to buy local and British products whenever possible. This helps to reduce product miles and CO<sub>2</sub> emissions. When ordering products, it is worth finding out where they will be dispatched from so as to avoid excessive miles. The transportation of products overland or by sea is much better for the environment than by air. Buying locally also helps to support jobs and increases investment in the local economy.

## Oceanic pollution

One of the major issues with a society based around manufacturing and consumerism is the amount of waste that is produced. Poor waste management, along with a lack of education over the last century in the importance of dealing correctly with waste, has meant that pollution has dramatically increased around the world. Both the oceans and the atmosphere have suffered as a result.



Many oceans currently collect huge floating rubbish dumps, which continue to grow and devastate wildlife. Plastic is the main problem, as it does not degrade for such a long time. Many sea creatures and birds ingest plastic pieces, which can cause death from intestinal blockages and poisoning. Both sewage and oil spills continue to pollute the seas. Sewage may come from industry, seaside towns and cities and from shipping. Oil spills are less frequent due to tighter regulations and large fines for companies that pollute, but when they do occur, they can be devastating to the environment and for those who rely on the oceans and coastlines for a living.

### Case study:

In 2010 British Petroleum (BP) experienced an explosion on their Deepwater Horizon rig which resulted in an estimated 900 million litres of crude oil escaping into the Gulf of Mexico over 87 days. 16,000 miles of coastline were affected and it is thought to have cost over £30 billion to clean up and to compensate those affected for loss of livelihood.

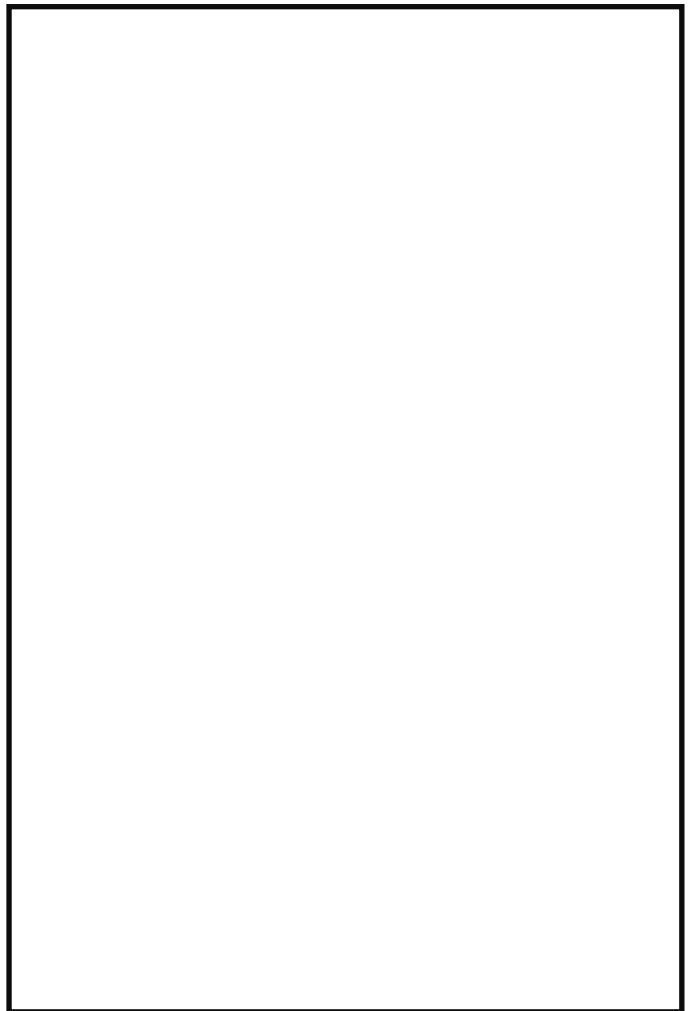
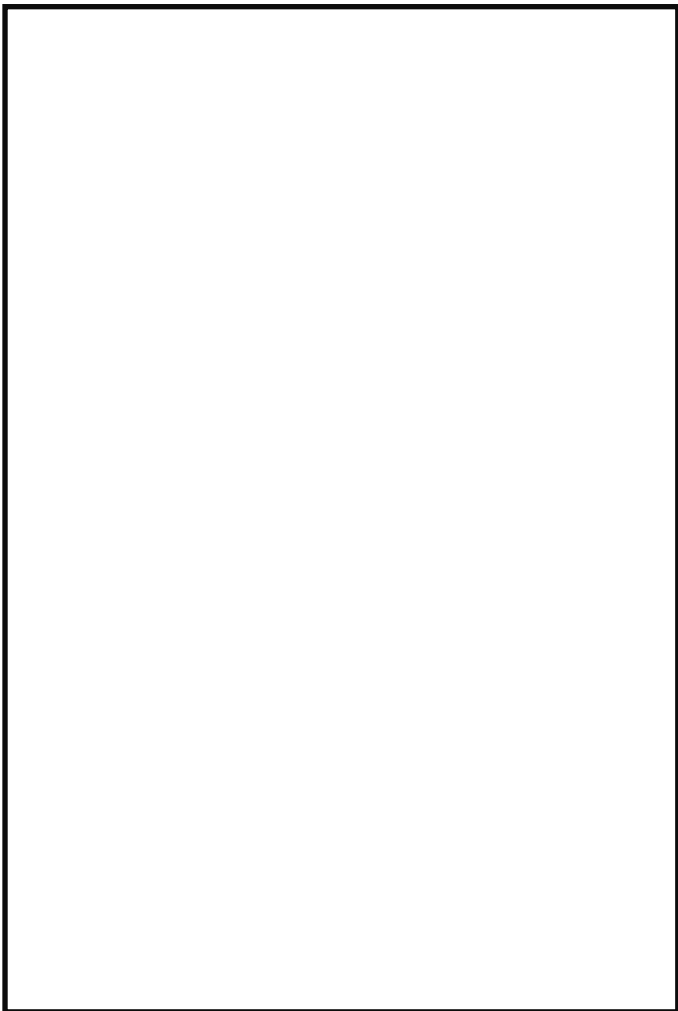
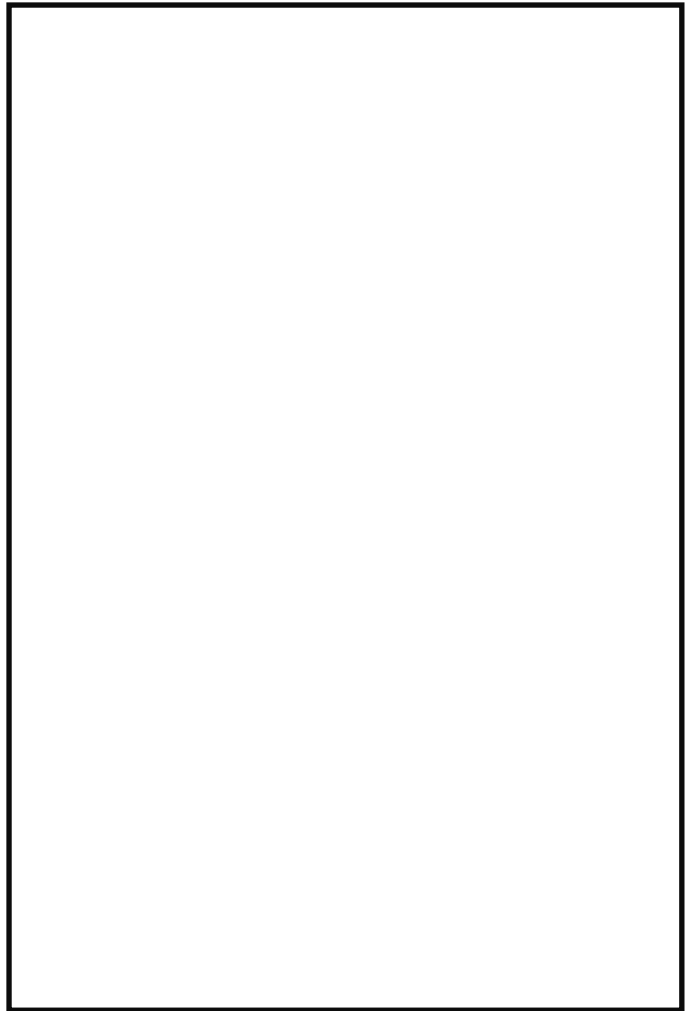
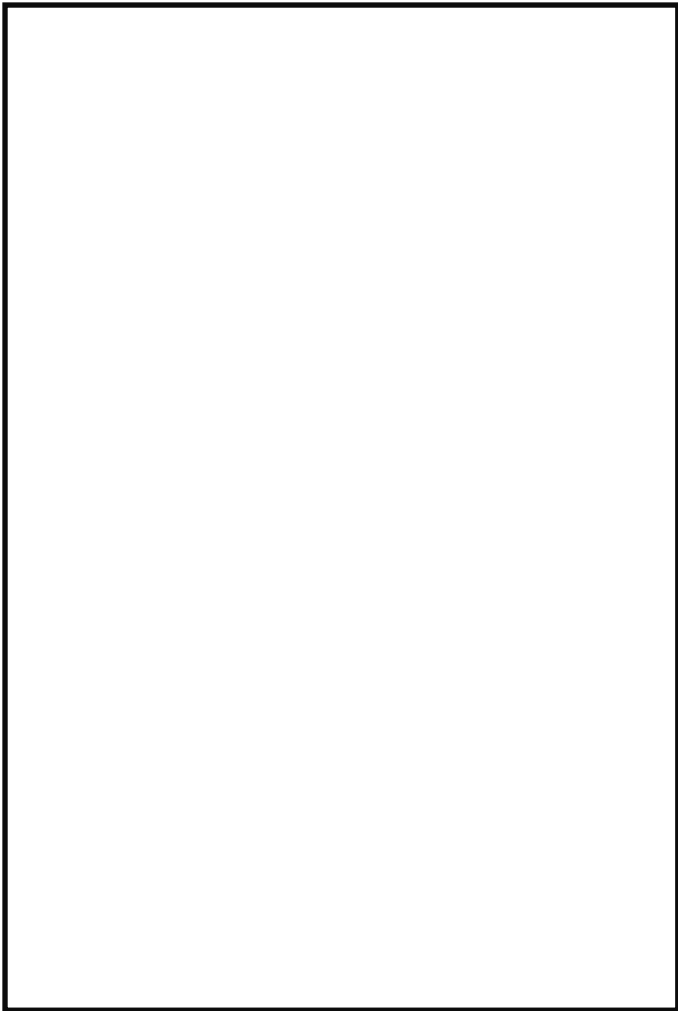
## Atmospheric pollution

Since the industrial revolution, manufacturers have relied on fossil fuels to power the machines that mass produce goods for our consumer society. The ever-increasing rise in population and the increased wealth of many countries means that there is a growing need for food, transportation, housing, new products and energy. Each of these create emissions which results in atmospheric pollution.

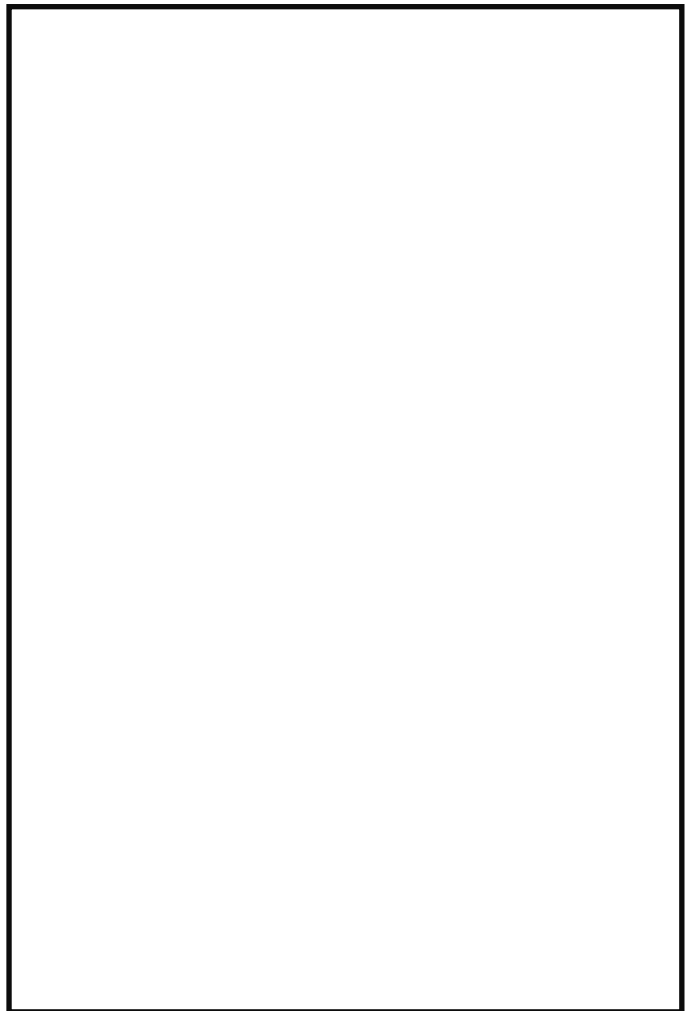
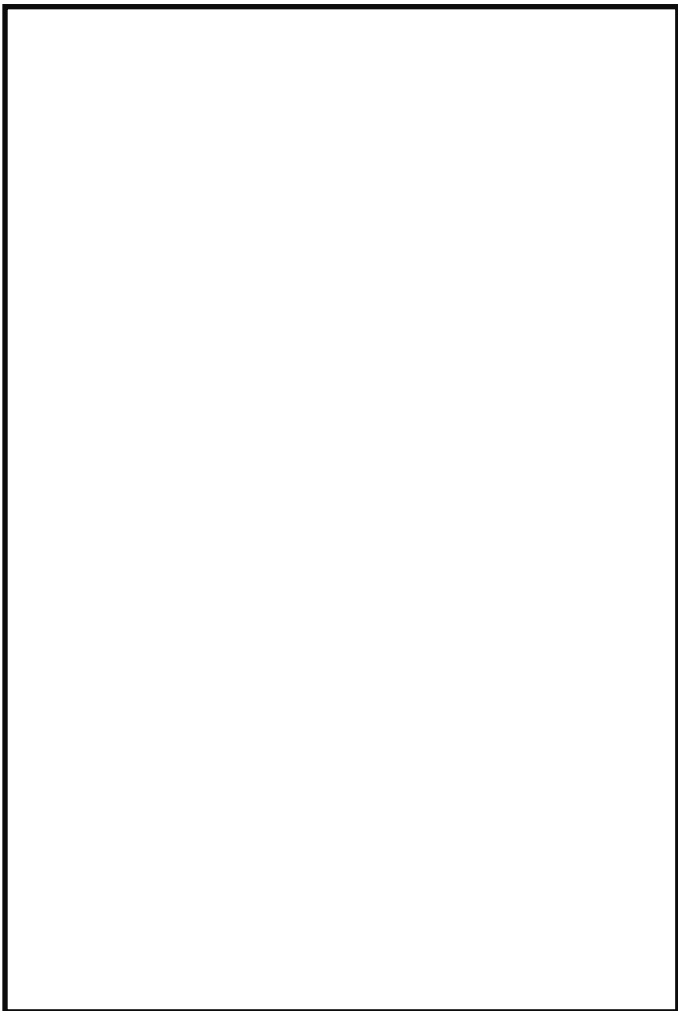
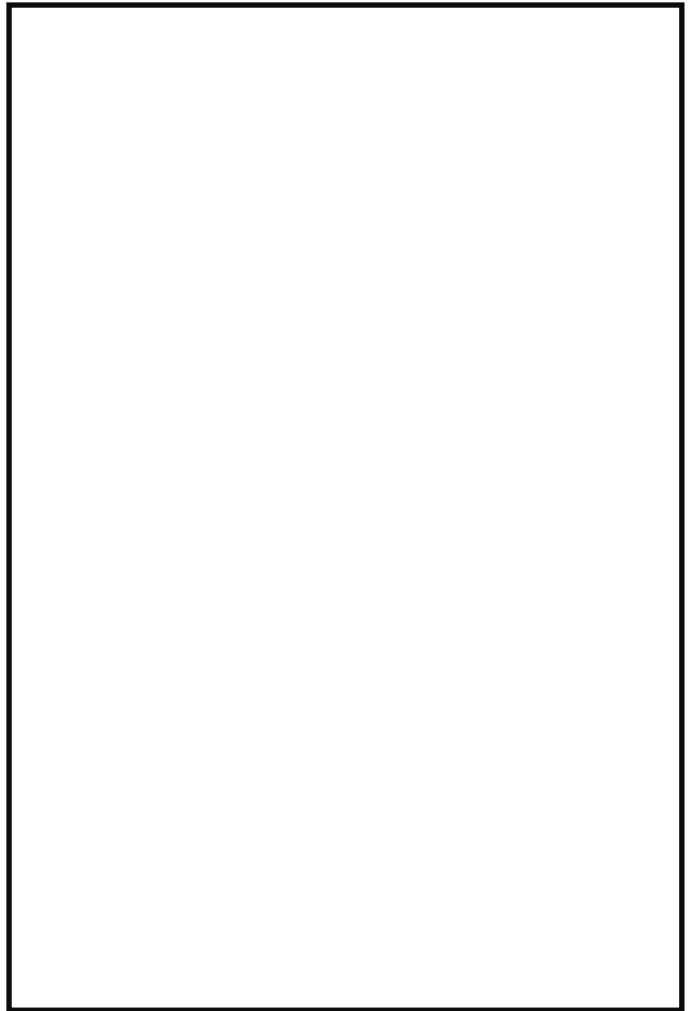
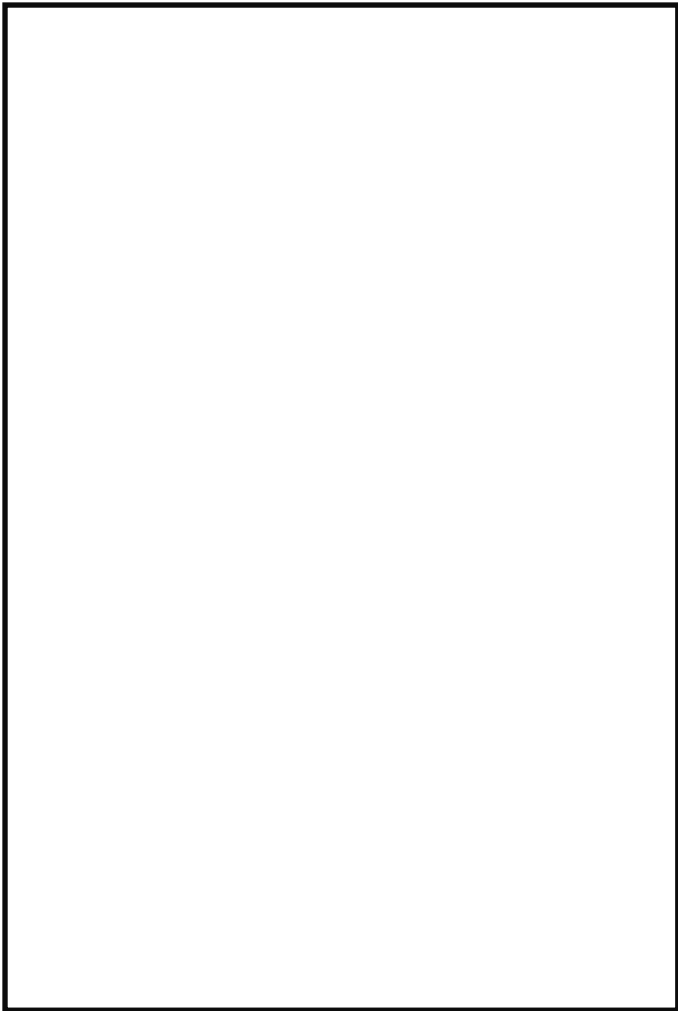
An increasing number of cities around the world have very poor air quality owing to the high levels of pollution produced by human activity. Much of the pollution is caused by transportation, heating and energy production, which is still mainly fossil fuel based. Cleaner energies need to be adopted in order to reduce atmospheric pollution levels.

The Paris agreement, which was signed by 174 countries and the European Union in April 2016 under the United Nations Framework Convention on Climate Change (UNFCCC), states that they intend to hold the increase in average global temperature to well below 2°C (above pre-industrial levels) in order to reduce the risk of climate change.













## Ecological and social footprint: Questions

Q1. In 2012, the average biologically productive area per person worldwide was around 1.7 global hectares (gha) per capita. The following ecological footprints were measured;

- US: 8.2 gha
- UK: 4.9 gha
- China: 3.4 gha
- India: 1.2 gha

Discuss why the US and UK have such highy gha? Why does India have such a low gha? What measures could the US, the UK and China take to reduce their ecological footprint? (6 marks)

Feedback:

Q2. Discuss 2 other factors that you consider may contribute to:

- a) A manufacturing company's social footprint (6 marks)
- b) A school's social footprint (4 marks)

Feedback:

Q3. Give 3 health and safety risks for designers who use a computer at work all day. (3 marks)

Feedback:

Q4. Explain how designers and manufacturers can help to reduce the impact of raw materials being harvested. (2 marks)

Feedback:

Q5. Other than loss of habitat, state another problem caused by deforestation and explain its implications. (2 mark)

Feedback:

Q6. Describe 2 negative impacts of surface mining.  
(2 marks)

Feedback:

Q7. Use you own research to answer this question:  
Shale gas is extracted through a process called 'fracking'.  
This involves drilling down and then sideways into the shale, setting off small explosions in the walls of the boreholes and pumping down large volumes of water and chemicals at high pressure to open up fissures in the rock. The gas is then driven out and pumped to the surface. Discuss the environmental concerns raised by this process. (4 marks)

Feedback:

Q8. Biofuels are generally considered to be sustainable energy sources from crops. Farmers often use chemical fertilisers to increase crop yields and mechanical equipment to harvest and process them. Discuss whether biofuels are carbon neutral. (2 marks)

Feedback:

Q9. What is the purpose of a product life cycle assessment and what impact can such an assessment have on the production methods and materials. (2 marks)

Feedback:

Q10. Explain why buying local produce is considered worthwhile for the environment (3 marks)

Feedback:

Q11. Name 3 clean energy sources. (3 marks)

Feedback:

**Total marks : / 39**

**WWW?**

**EBI?**



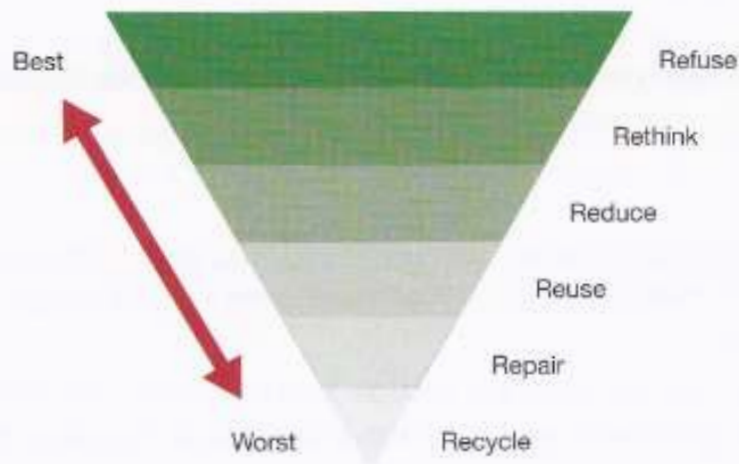
**The 6 R's**

## The six Rs

Responsible designers and manufacturers have to create products that are as sustainable as possible. This reduces the burden on the earth's natural resources. To do this they need to go through a detailed process of analysis in order to devise sustainable solutions. Following the guidance of the six Rs helps them to see where savings in the carbon footprint of the product can be made.

Consumers also have a responsibility to consider their impact on the planet through the choices they make and the products they buy. Following the same six Rs enables them to take on social responsibility for their lifestyle choices.

The **hierarchy of sustainability** places the strategies that are best for the planet above those that have a greater negative impact on the environment. By systematically working through them for each element of a proposed product or purchase, the best possible option will eventually be chosen. This will potentially save resources, reduce energy consumption and minimise CO<sub>2</sub> emissions.



### Refuse

The first stage in the process is to ask whether the proposed product, part, purchase or even journey is required at all. Asking the question 'is it really necessary?' can play a major role in reducing demand on materials. Simply not using something saves 100% of what you have chosen not to use. Examples include using your own carrier bag instead of getting a new disposable plastic one, walking or cycling to school instead of being driven, not using products such as some pesticides that are known to be harmful to the environment, or not eating (or using) products that are over-farmed, over-fished or on the endangered list.

## Rethink

Consumers have a growing number of choices to make about where and on what they spend their income. Greener and more sustainable options are not always the cheapest or the best, but making informed decisions and rethinking one's spending power can play a huge part in conserving resources.

A growing number of passengers refuse to travel by air due to the massive carbon footprint that it creates. Taking different forms of transport to get to their destination has differing levels of impact. Consider the following in relation to CO<sub>2</sub> emissions compared to the time of the journey and the practicality; car on your own, sharing a car, coach, train, motorbike, cycling, walking. There may only be one or two realistic options, but the process of considering the impact is the important part in the decision making.

Deciding on the design of a product, for example the materials used in its production, will directly affect its sustainability. The types of questions designers need to ask are:

- Are the materials locally sourced?
- Are they sustainably produced?
- Is it essential to use this material, of which there is a finite supply?

By rethinking how the product is likely to be made, the product can often be redesigned in a more responsible way. Logistics companies use computers to work out the shortest routes when delivering parcels, saving time and reducing CO<sub>2</sub> emissions. A company may rethink how they communicate information to their customers, and the result may be a paperless system, saving paper and postage costs. These are examples of rethinking products and services to create a positive impact.

## Reduce

Reduction is often the result of having rethought a design or action. Materials and energy are saved due to efficient manufacturing practices and the use of clever design, incorporating sustainable materials.

- Modern materials that are lighter and stronger than traditional ones have contributed to the **miniaturisation** of products, saving material and energy in manufacture and in use
- Reducing the complexity or number of parts a product uses and reducing the number of different materials in a product makes recycling easier
- In factories, schools and hotels, fitting motion sensitive lighting and smart heating systems can significantly reduce energy usage
- Many large companies employ staff to conduct 'energy walks' to turn off unused appliances and lights and to ensure windows and doors are shut to conserve heat



Switch off  
after use

## REUSE

Reusing products multiple times for the same purpose is also known as **primary recycling**. Reusing a product in a different way from the one it was designed for is known as **secondary recycling**.

The classic glass milk bottle is reused many times before it reaches the end of its useful life, at which point it is recycled. A plastic milk bottle, however, is intended to be used only once, although it can have many different subsequent uses.



Donating to and buying from charity shops extends the life of products and in recent years there has been a resurgence in products having second lives. Websites such as eBay, Freecycle and Gumtree are designed to allow users to sell or give away used or unwanted items.

It is becoming popular for furniture and other household items to be '**upcycled**' with a coat of paint and some minor repairs or adaptations, extending their useful life by many years.

## Repair

Being able to repair a product when it is broken or worn is a way of extending its life and delaying the purchase of a new one. Repairing is a positive option over replacement as it means that only some parts of the product are replaced. This creates jobs for skilled people who conduct repairs and stimulates a spare parts market. A number of products can often be bought reconditioned rather than new, and these are usually a cheaper and more sustainable option.

Unfortunately, repairing products has become harder over the years. Growing numbers of products are not designed to be repaired. Some are sold as sealed units and when they break, they need to be replaced in their entirety. There are a number of reasons why items may be designed this way, but it is usually because they are cheaper to replace than repair. Modern manufacturing techniques combined with global competition means that products are made with low profit margins so it is best for companies to maximise sales.

Many products contain complex integrated electronic circuits and require specialist knowledge, equipment and tools to repair them, often making it uneconomic to do so.

Some products, especially modern electronic products, are designed to last only a few years as the technology dates quickly and older products will be superseded by newer, faster, more efficient models.



## Recycle

**Tertiary recycling**, although a very important stage, is lower down the hierarchy of preferred options because most materials that are recycled this way tend to be of lower quality than the original material. It takes a lot of energy to recycle materials – although not as much as creating new ones.

This form of recycling requires the reprocessing of the material and in many cases involves chemicals and/or heat to recover the recycled materials. Metals are melted and can be very high quality if separated correctly before processing. Plastics are separated into their different forms and reprocessed separately. The same applies to different colours of glass, although much recycled glass has a pale tint, usually green. Paper is graded and made into different paper products.

All councils in Britain operate recycling centres and will recycle nearly all household waste. More complex items are sent to specialist centres for processing. Batteries and electrical appliances are particularly difficult as they may contain toxic metals and chemicals that need careful processing, as these may leach into the environment if incorrectly disposed of.

The WEEE directive (Waste Electrical and Electronics Equipment recycling) came into force in 2006 and was updated in 2013. It governs the recycling of the estimated two million tonnes of electrical items that UK companies and households dispose of each year.



*The WEEE symbol*

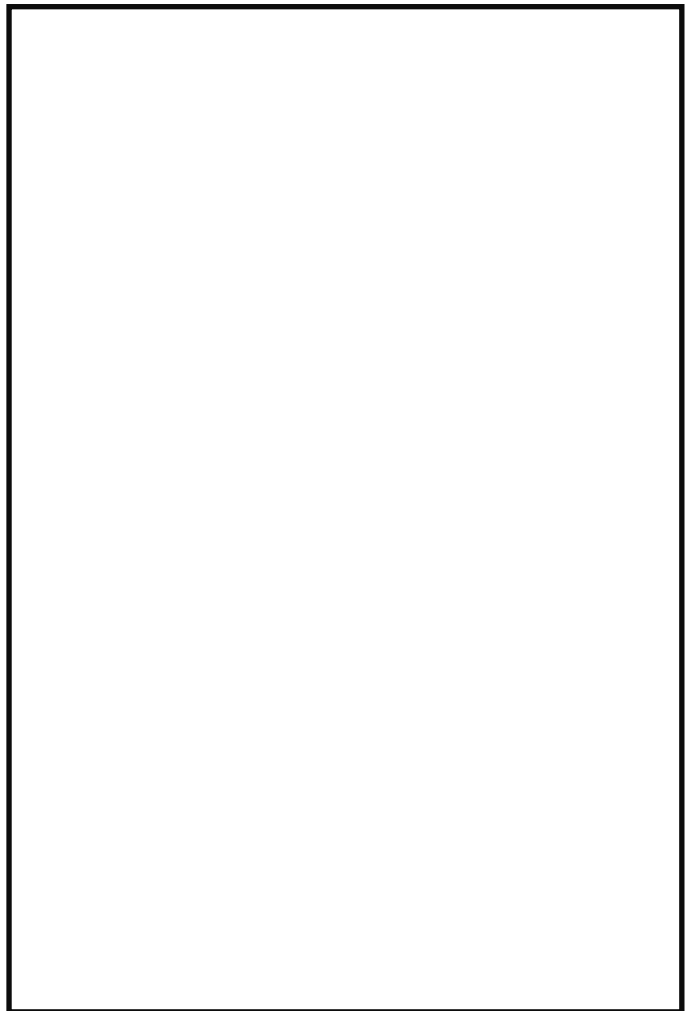
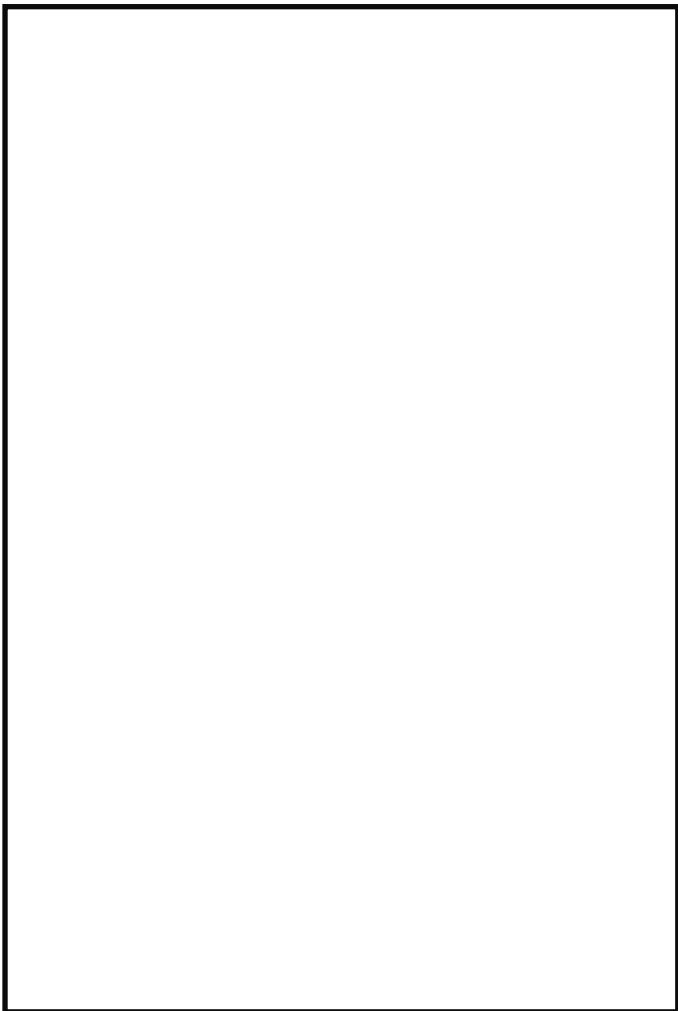
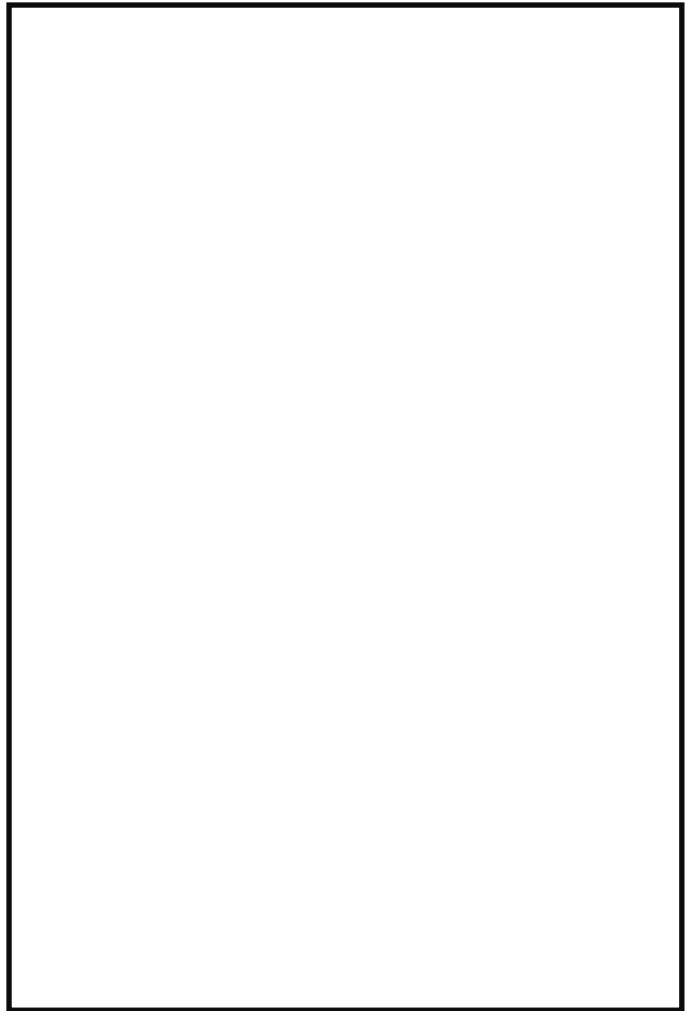
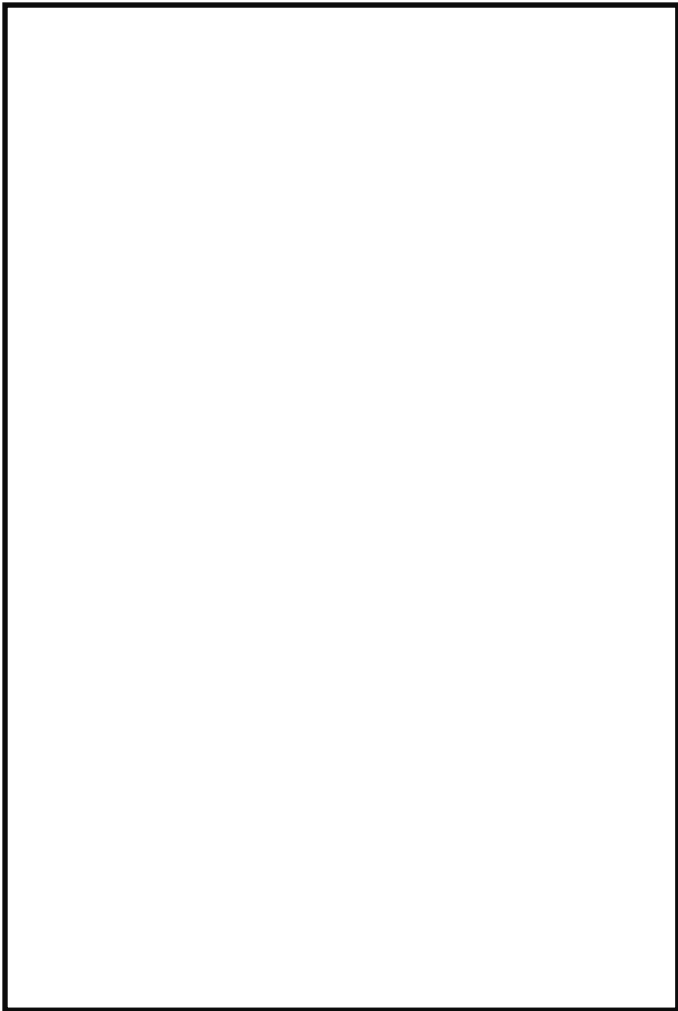
In an ideal world, tertiary recycling would remove all recyclable materials from our household waste so that only biodegradable materials would be left. Only very few parts of the world are set up to cope with this level of processing. The percentage of waste materials being recycled continues to grow however, and as the supply of finite materials becomes more limited, the demand for recycled materials will increase further, forcing countries to become even better at dealing with their waste.

#### **Case study:**

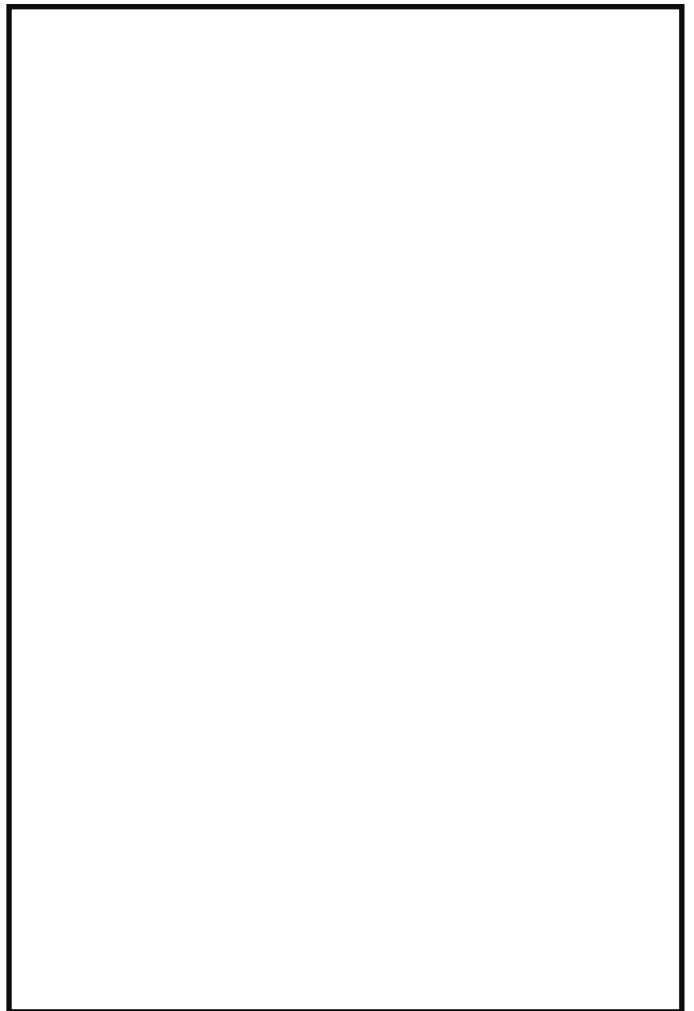
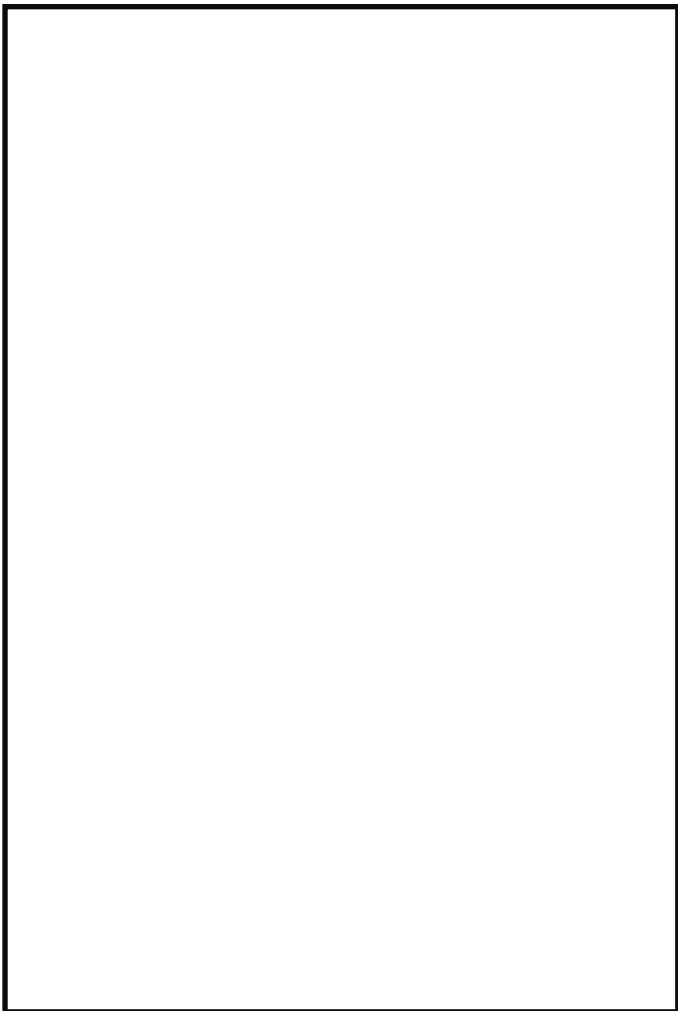
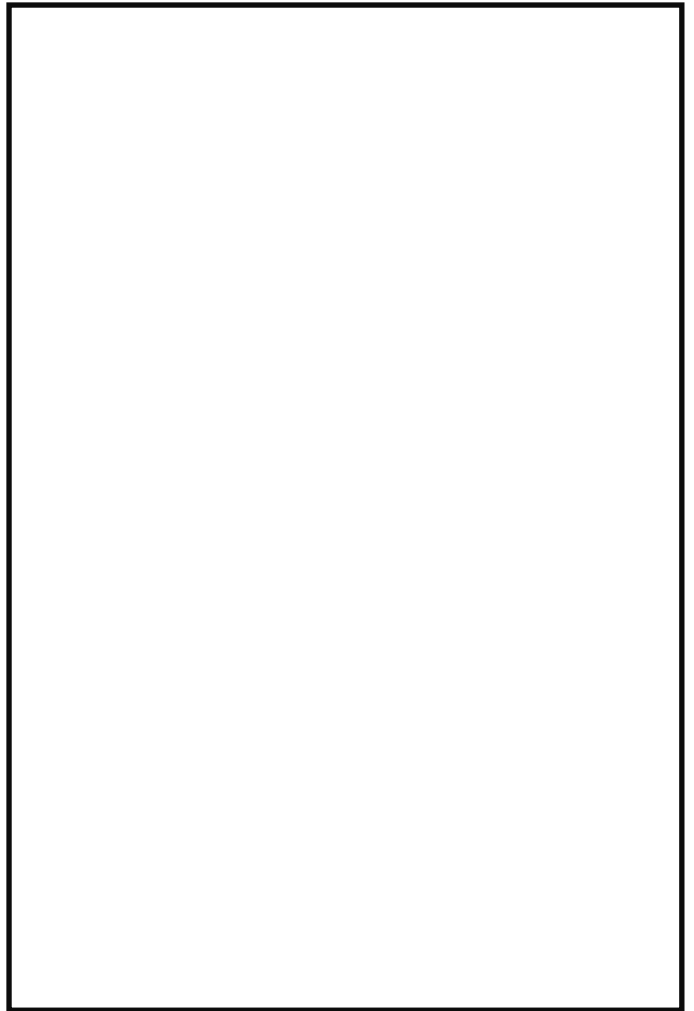
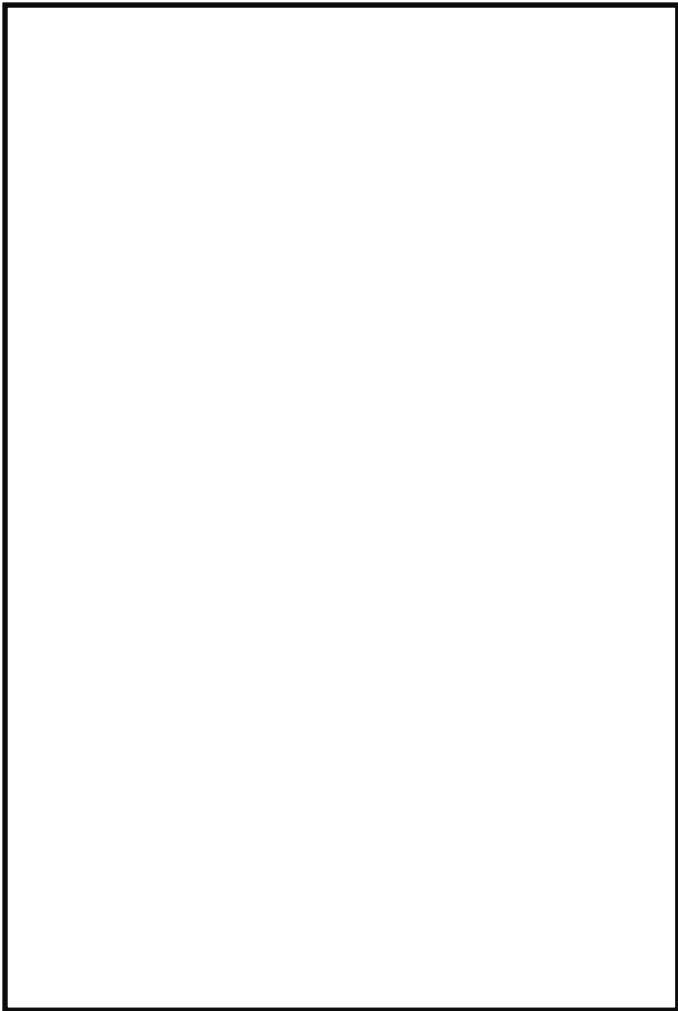
In the town of Kamikatsu in Japan the 1700 residents separate their waste into 34 different categories and have a 'zero waste' ethos. They work together to reduce the impact that the town has on the environment. They hope to recycle 100% of their waste by 2020.

Once all useful and recyclable materials are removed, the majority of the remaining waste is organic matter and can be processed in one of two ways; '**Recover**' or '**Rot**'. Food waste and garden waste can be processed at a high temperature and turned into compost. This is then returned to the earth as a growing medium and used in horticulture. Alternatively, its energy can be recovered. This means that as the waste material is burned, the heat from the combustion is used to heat water, which in turn is used to directly heat homes and businesses. Alternatively, it can be turned into steam and used to propel turbines that generate electricity which is fed into the National Grid. The waste can also be buried in special **landfill** sites where the resulting methane gas from the rotting matter is collected and burned and used to generate heat or electricity in the same way.

The least sustainable option is burying unsorted waste directly in a landfill site. Unfortunately, this currently happens on a large scale and is the cause of environmental concerns about toxic chemicals and heavy metals leaching into the ground. These harmful elements can eventually find their way into the water table and into river courses, resulting in potential poisoning of wildlife and the natural environment.











## The 6 R's: Questions

Q1. What journeys or new products have you undertaken or purchased in the last week that were not absolutely necessary?

Q2. Why does refusing to use air travel help reduce your carbon footprint, even if you still plan to get to your destination by other means? (1 marks)

Feedback:

Q3. Discuss the positive impact on the environment of making the wheels of a car from a very lightweight metal alloy opposed to regular steel. (2 marks)

Feedback:

Q4. How does the second hand market play an important role in reducing demand for new products? (1 mark)

Feedback:

Q5. Name 3 products which are routinely replaced rather than repaired. For each product, explain why this is the case. (6 marks)

Feedback:

Q6. What might constitute WEEE waste from a company and from a household? (4 marks)

Feedback:

Q7. Explain why you should never throw used batteries in the bin. (2 marks)

Feedback:

**Total marks : / 17**

**WWW?**

**EBI?**





**Scales of production**

## One-off production and prototypes

**Bespoke** items that are designed for, or commissioned by, individual clients are classed as one-off products. They might be made to perform a specific task and cannot be bought off the shelf. The name suggests that only one item is made and this is generally true, although if a dining room table and set of six chairs were made, this would still be classified as **one-off** production.



*Bespoke elliptical Pippy Oak dining table with steam bent legs*

When products are being developed, designers will make a prototype. These are one-off versions and are used to test out ideas and to receive feedback from user groups and potential clients.

Many products made for theatre and television are one-off products, as are personalised and hand-made wedding dresses and wedding cakes, pieces of art and some jewellery. A GCSE project will be a prototype and hence a one-off product.

With the introduction of digital techniques such as 3D and digital printing, a number of products that are customised and personalised for consumers blur the lines between one-off and other levels of production. Having your name engraved on something does not make the product a one-off. One-off products are not available for anyone other than the original client or purchaser.

One-off production is very labour intensive and products are frequently handmade by a specialist. Designers and manufacturers may work closely with their clients to deliver the desired outcome. This process means the products can be very expensive and can take a long time to create.

## Batch production

This method of production is used when a certain number of identical products are required. This is known as a **batch**, as they will all have been produced together. One batch could contain a large or small number of products.



Batch production methods tend to use a higher level of automation than one-off production. Machines may be specifically set up to perform certain tasks and templates, jigs, patterns, moulds and formers are used to save time and ensure parts are identical. Usually, once a batch has been produced some or all of the processes will be altered to produce the next batch. This may be as simple as changing the colour or size of a product for the next batch, or it may involve making a totally different product.

Batch production still uses some highly skilled labour. However, as some of the tasks are more repetitive, small production lines and semi-skilled workers may be employed. Expensive specialist tools and equipment are frequently needed to produce batches of products, and initial set-up costs can be high. The more products being made, the cheaper the overall unit cost of each item.



With batch production, there is often quite a short **lead time** to get products to market, meaning that manufacturers can respond quickly to changes in market trends and fluctuations in order levels. The short lead time is made possible by using adaptable machinery and staff. Typical batch produced goods include surfboards and kayaks, some furniture, clothing and food items.

## Mass production

Mass-produced products tend to be items that are in constant use and where the design does not change significantly. Drinks and food containers, electronic products such as mobile phones and even large assembled products such as cars and motorbikes are typical examples.

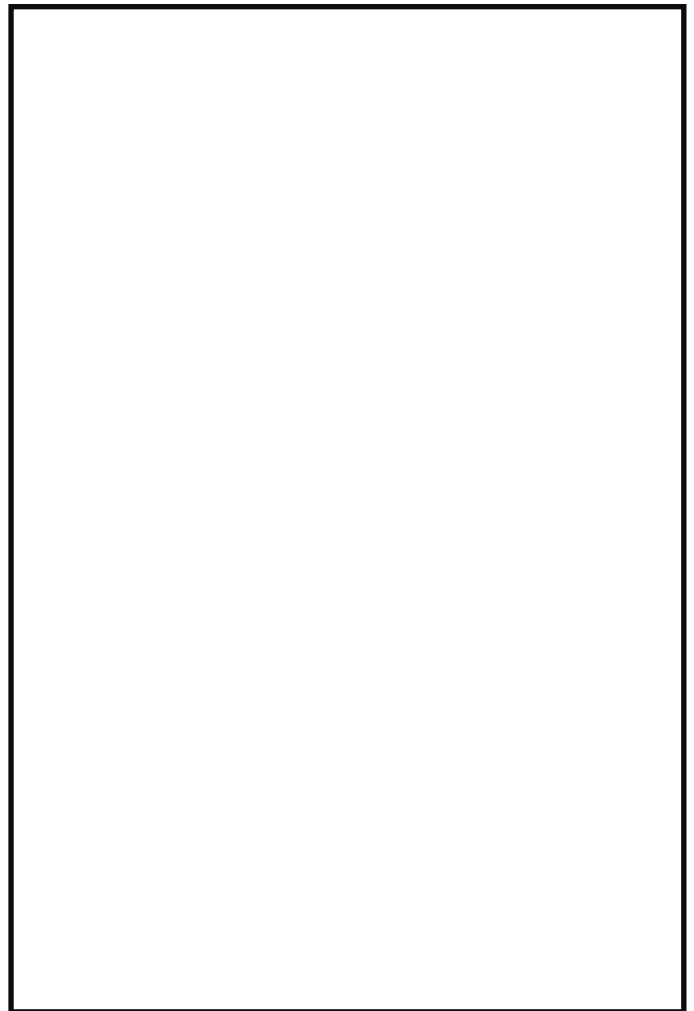
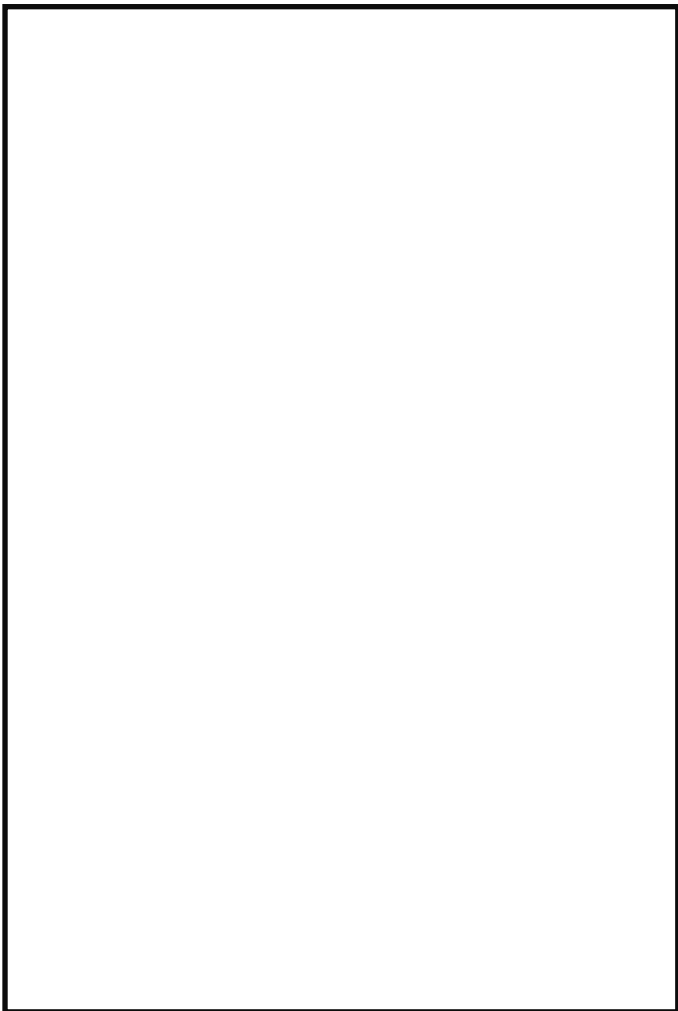
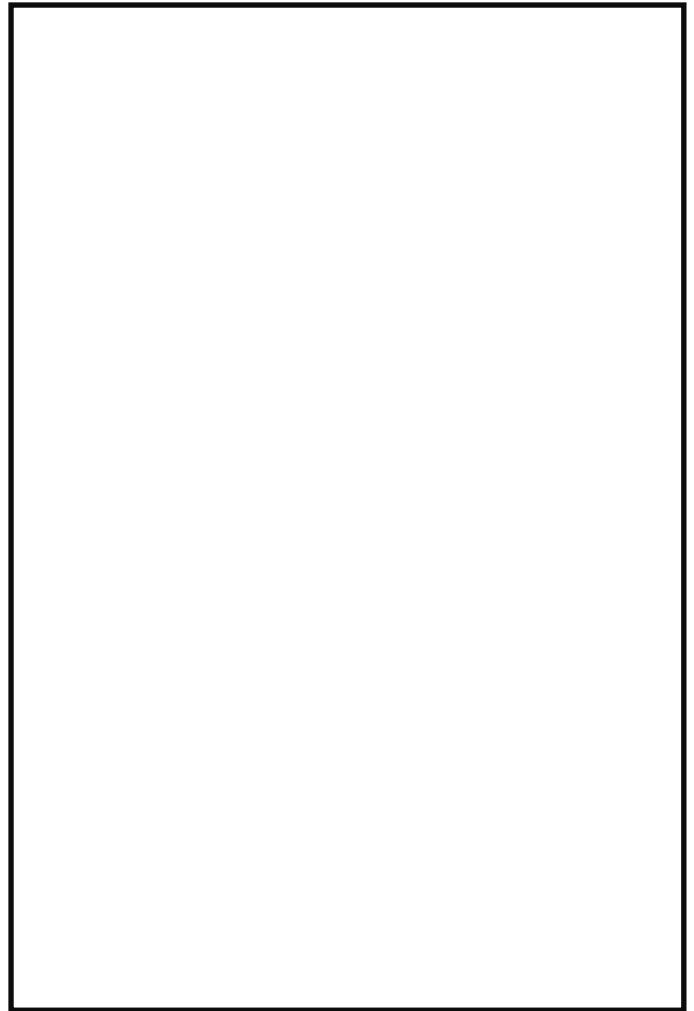
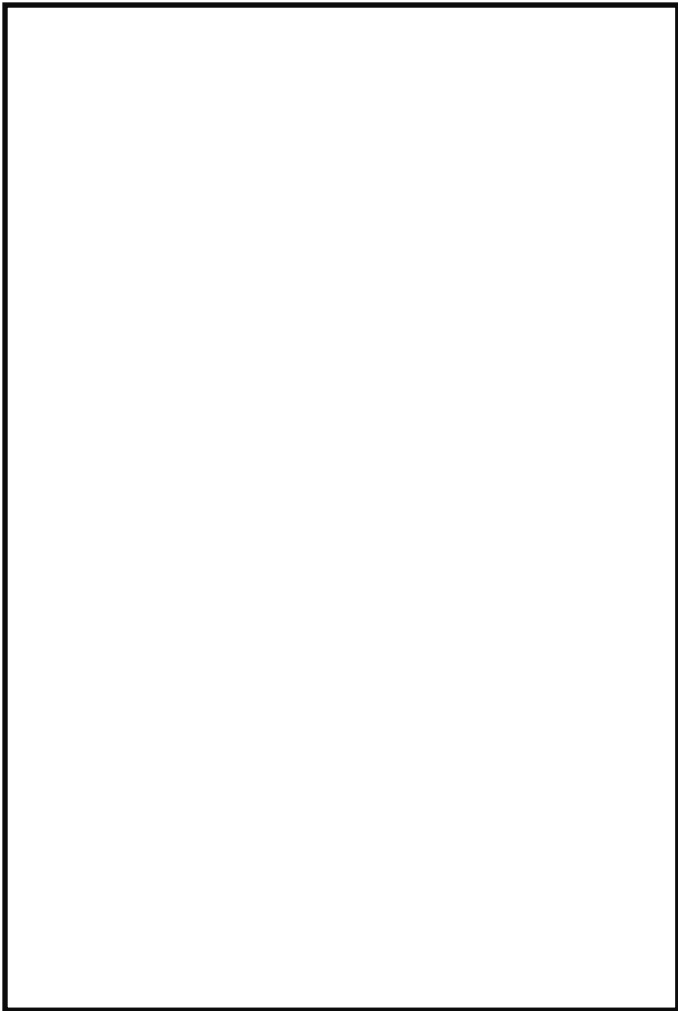
When large numbers of products are required, the best way to produce them is to set up a dedicated production line that does not need to change. This way their manufacture can be highly automated and use as little skilled labour as possible. Where manual workers are needed, the tasks tend to be simple and repetitive. Production lines need to have some highly skilled technicians to keep them running efficiently, as any downtime could be very costly.



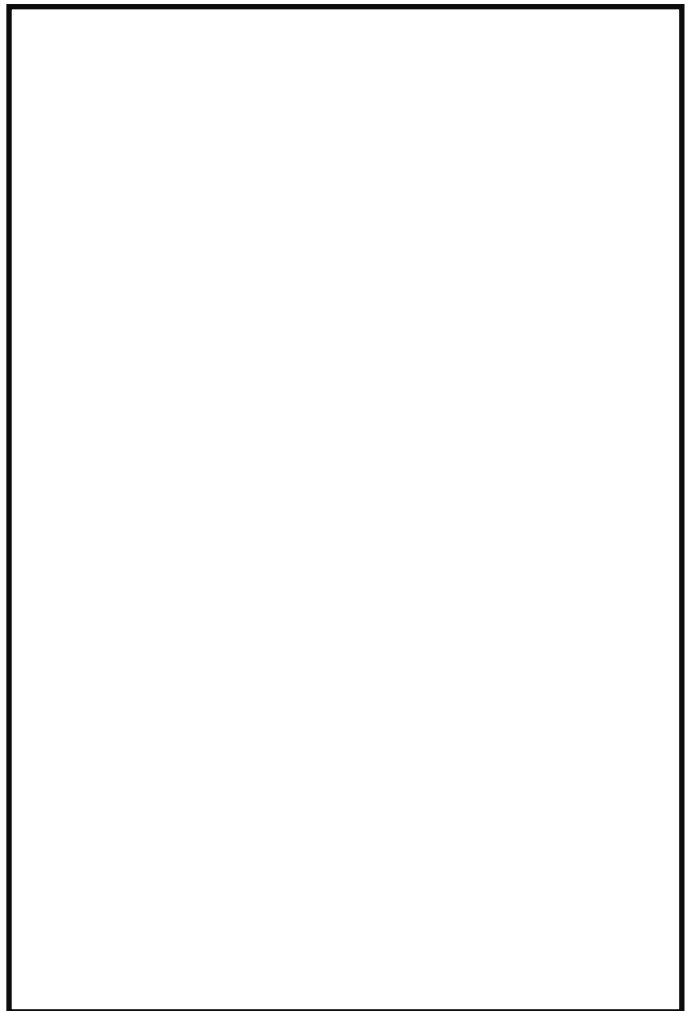
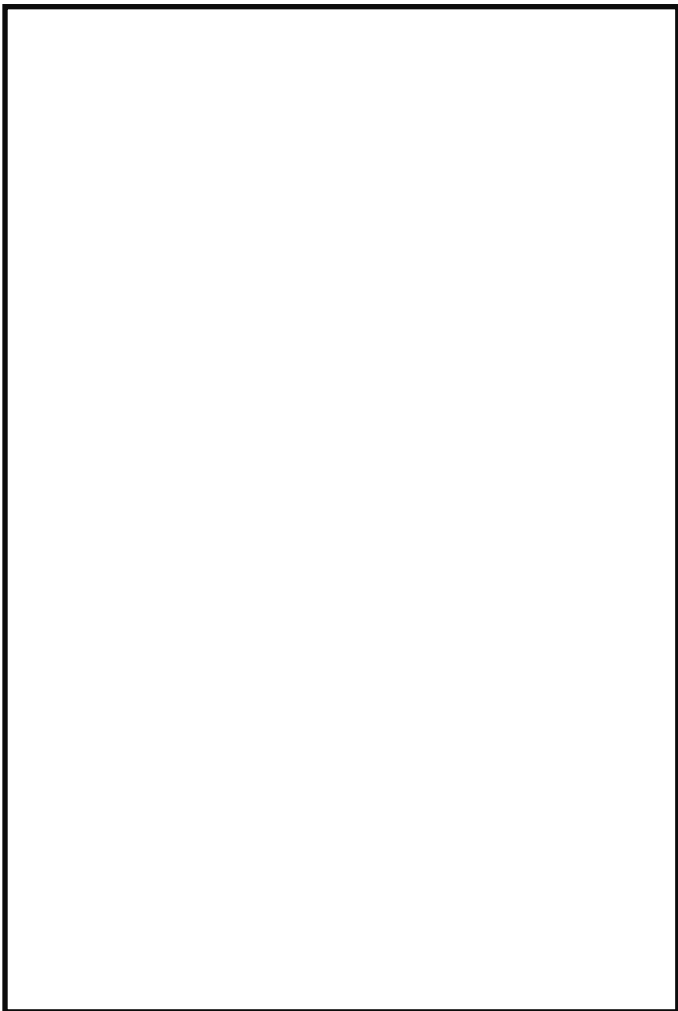
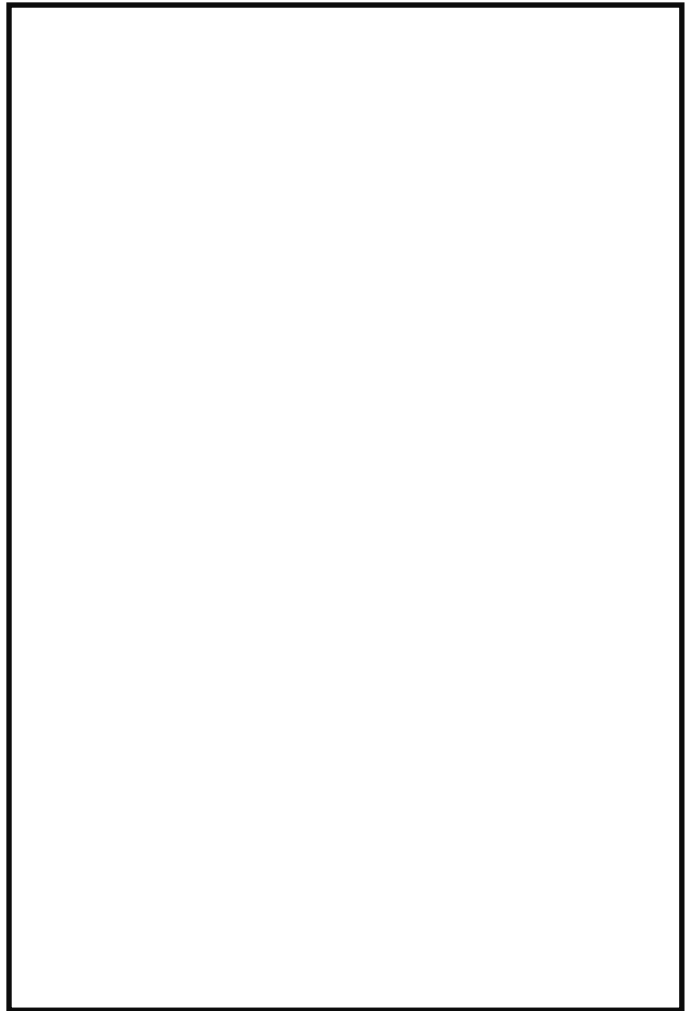
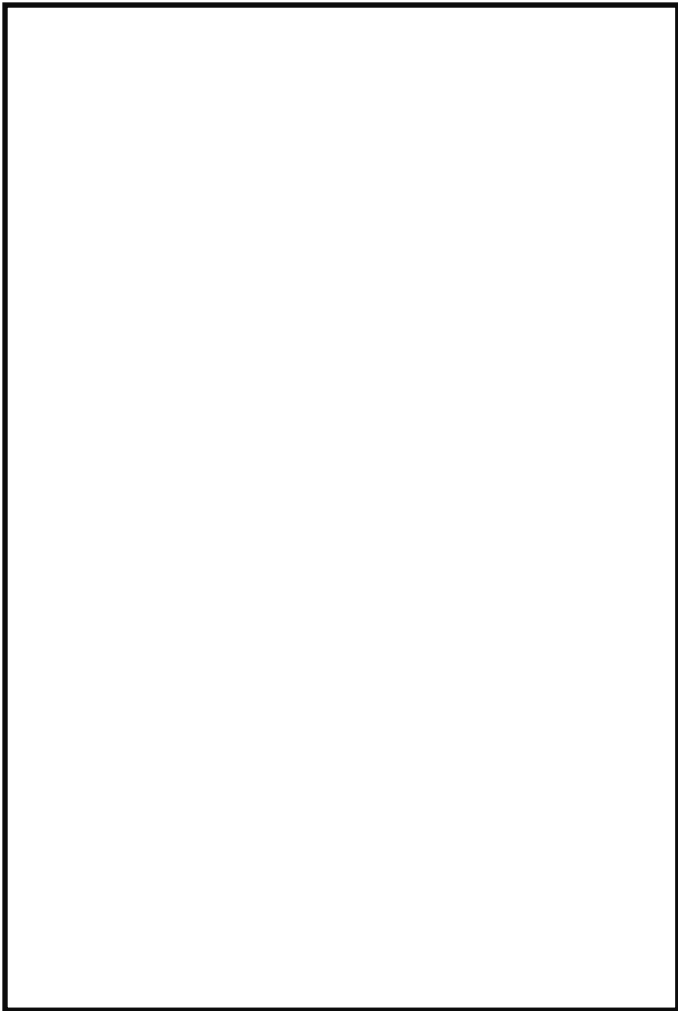
The high volume of goods being produced means that the very high set-up costs of specialised production line equipment and tooling can be quickly recovered, and the unit price can be kept low.

**Continuous production** is very similar to mass production although the products tend to be made to create stock or standard material forms (primary processing) before final processing or assembling elsewhere. The factory will operate up to 24 hours a day 7 days a week. Staff are mainly low-skilled and operate the factory in shifts. The products made rely on high levels of automation and this type of factory normally makes a very limited range of products. This saves any potential changes to the production line, avoiding any downtime.













## Scales of Production: Questions

Q1. One-off productions are usually much more expensive than mass produced goods. Using a timber based example of a product, suggest reasons why a customer might ask a manufacturer to create a one off product for them. (4 marks)

Feedback:

Q2. Explain what is meant by the term lead time. (1 mark)

Feedback:

Q3. What scale of production would be suitable for a shoe manufacturer making a range of popular trainers?  
Give reasons for your answer. (2 marks)

Feedback:

Q4. Continuous production is normally used for simple products.

- a) Give 3 products that are made a continuous production line.
- b) What makes these products suitable for this type of manufacture?

(4 marks)

Feedback:

**Total marks : / 11**

**WWW?**

**EBI?**





**Timber based materials :  
sources, origins and properties**

## Timber conversion

After a tree is felled and cut into manageable lengths, it is then converted into planks at which point it is known as timber. Timber is supplied in two main types of finish: **rough sawn** or **planed all round (PAR)**. Rough sawn timber has not been planed and is rough to the touch. It is often used for exterior tasks or where the finish is not important. PAR has a much smoother finish as it has been mechanically planed down on all sides. It is used for furniture and internal features such as windows and doors. Finishes such as varnish or paint can be easily applied. Planed timber is less absorbent than rough sawn timber.



Timber is available in many different shapes and sizes, standardised to enable different varieties to be used together. This is covered in more detail in Chapter 28.

## Seasoning

Once timber is converted into a workable form, it is **seasoned** in order to reduce the moisture content. Typically, a newly felled tree will have a moisture content of over 50% and is known as green timber. The moisture content needs to be reduced below 20% for most exterior applications, below 15% for interior work and below 10% for interior areas that are constantly heated. Uneven evaporation of the water content can cause some common faults to occur such as twisting, cupping and bowing which can render the timber useless for many tasks. If the end grain dries too quickly it can cause the plank to split.

There are two methods of seasoning; air-drying or kiln-drying. Air dried timber is stacked so that air can circulate around the planks and evaporation can take place. It takes approximately one year per 25mm of plank thickness to season and in the UK the moisture content typically reduces to around 18%.

Kiln-dried timber can have a much lower moisture content and it is a much faster process, meaning the timber can be sold much sooner. It costs more than air drying, as heat and pressure is used, but no additional land is required to store the timber while seasoning takes place. Kiln dried timber is less prone to faults and the heat also kills off bacteria and insects that may attack the timber.

## Manufactured board

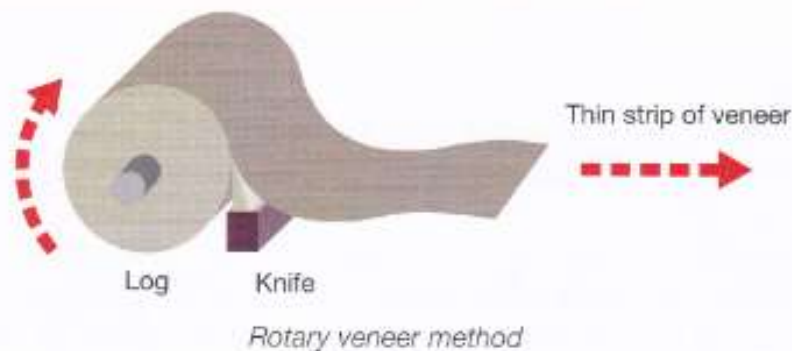
Natural timber is combined with adhesive to make manufactured boards. They can be made from waste, low-grade and recycled timber and are usually produced in a pale brown natural finish.

Each manufactured board is produced in a slightly different way; the two main processes used are **lamination** and **compression**. Plywood and blockboard use the lamination method where layers of wood are bonded together using an adhesive. Medium density fibreboard (MDF), chipboard, orientated strand board (OSB) and hardboard use the compression method where wood is shredded, chipped or pulped, then heated and compressed under high pressure, in most cases using adhesives to bond the particles together.

## Veneer

Some manufactured boards are covered in a thin slice of natural timber called a **veneer**. These natural wood slices are taken from the trunk of a tree and are bonded to the surface of cheaper sheet materials. Veneers are commonly seen on medium density fibreboard (MDF) and plywood.

There are two methods of veneer production; rotary and knife cut. Rotational veneer production produces the longest sheets and involves rotating a whole tree trunk on an industrial machine similar to a wood turning lathe. It is a bit like a huge pencil sharpener creating one long ribbon of veneer.






## Advantages and disadvantages of manufactured board



Advantages	Disadvantages
<ul style="list-style-type: none"><li>• Available in large sheets, very stable which saves time and energy joining narrow planks together</li><li>• No defects such as warping, twisting, cupping and splitting which occur in natural wood, meaning less waste</li><li>• They do not have knots or resin pockets which can be hard to work around, avoiding waste and protecting tools which can blunt easily</li><li>• Smooth finish which requires very little preparation</li><li>• Makes use of low grade, recycled and waste wood</li><li>• Available in many different finishes, veneers and laminates</li></ul>	<ul style="list-style-type: none"><li>• Adhesives used to bond the boards can contain hazardous particles or VOCs</li><li>• Machining and sanding some boards, especially MDF, causes very small particles of dust to be released, easily breathed in, even through a mask</li><li>• Tools can blunt easily owing to the adhesives in the boards</li><li>• Many traditional wood joints cannot be used effectively with manufactured boards</li><li>• Edges can be hard to finish</li><li>• Most boards are prone to absorb moisture if not treated</li></ul>

## Additional common manufactured boards

In addition to the list of natural timbers and manufactured boards in Chapter 15, it is worth knowing about the following:

Name	Appearance	Image	Characteristics	Uses
Blockboard	Attractive natural grain veneers glued to strips of wooden blocks usually 25mm wide		Stable, tough, relatively heavy, finishes well, indoor use owing to adhesives used	Furniture, doors, shelving, indoor construction
Hardboard	Mid to dark brown, smooth one side, rough texture on the reverse, no grain, painted finishes available		Flexible in large sheets, even strength, easily damaged by water unless treated, inexpensive	Furniture and picture frame backings, internal panelling
Oriented strand board / Sterling board (OSB)	Mid yellow to pale brown, textured natural wood shreds compressed and bonded		Rigid and even strength in all directions, good water resistance	Construction hoarding, interior and exterior house building

## Additional softwoods

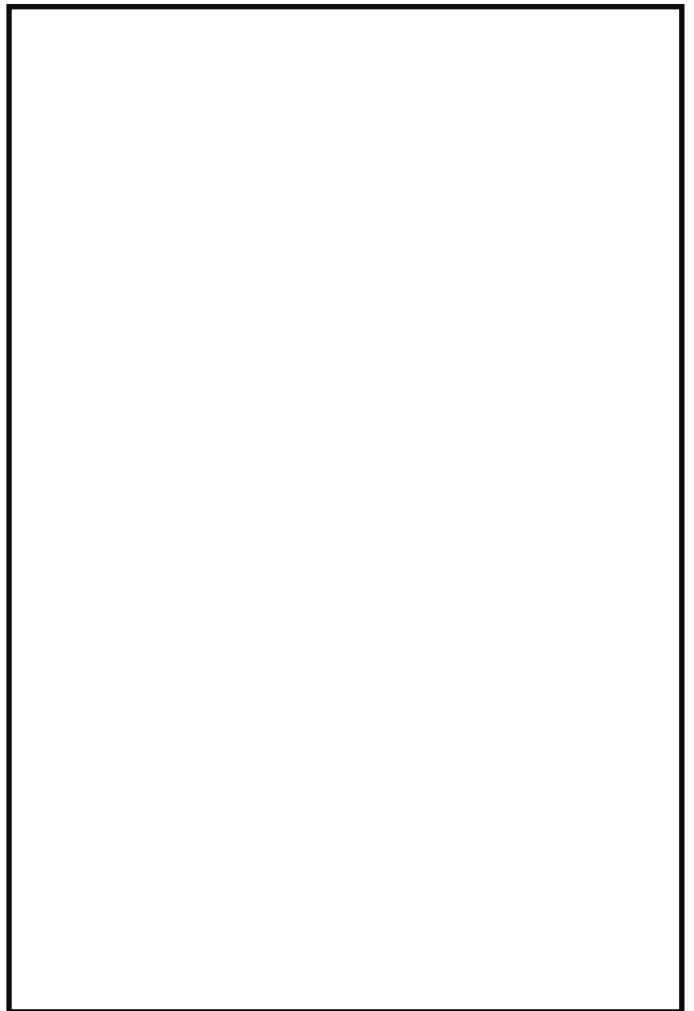
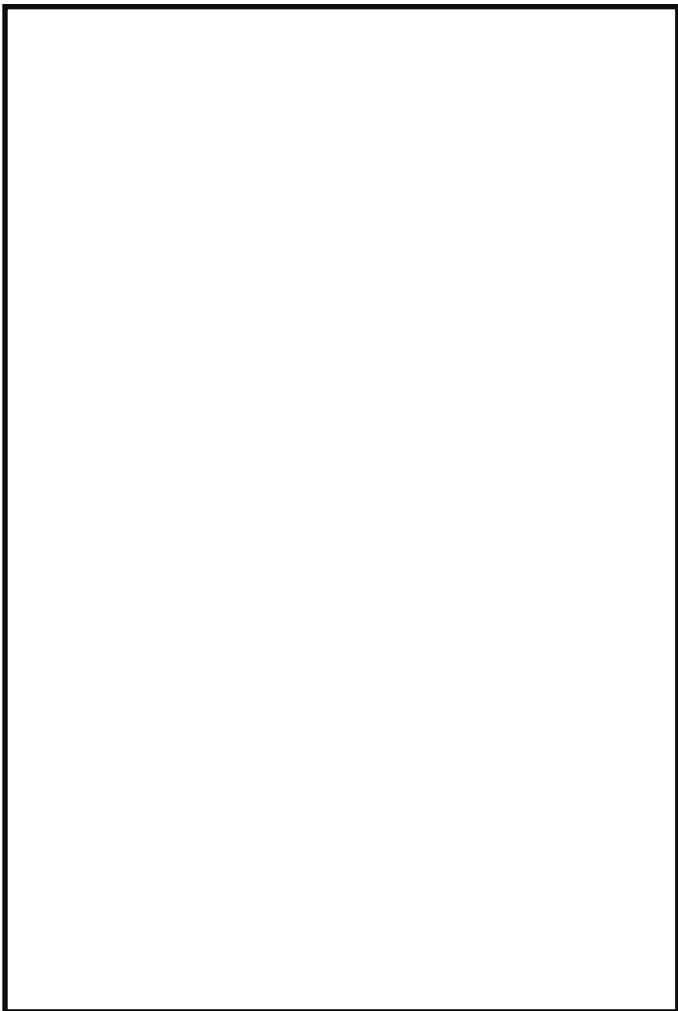
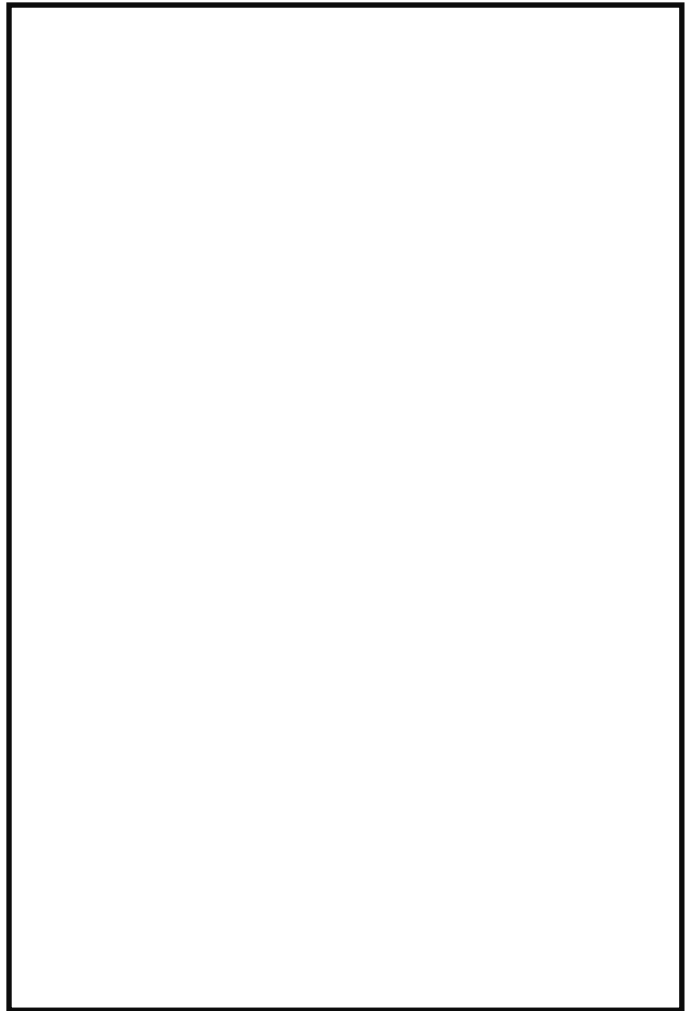
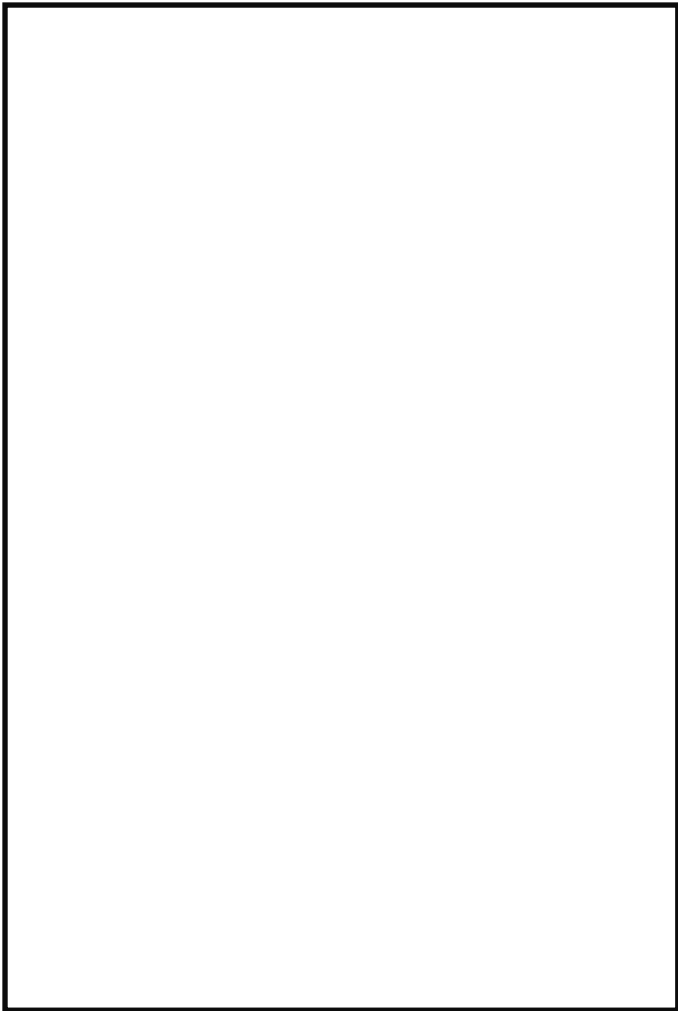
Name	Appearance	Image	Characteristics	Uses
Redwood	Pinkish brown to deep reddish brown, straight grain		Easy to work and machines well, some rot resistance	Outdoor furniture, beams, posts, decking, veneers
Cedar	Reddish brown, with straight, fine, even grain. Very aromatic		Easy to work, can blunt tools, finishes well, naturally resistant to rot	Outdoor furniture, fences, cladding for buildings, roof shingles

## Sustainable timber production

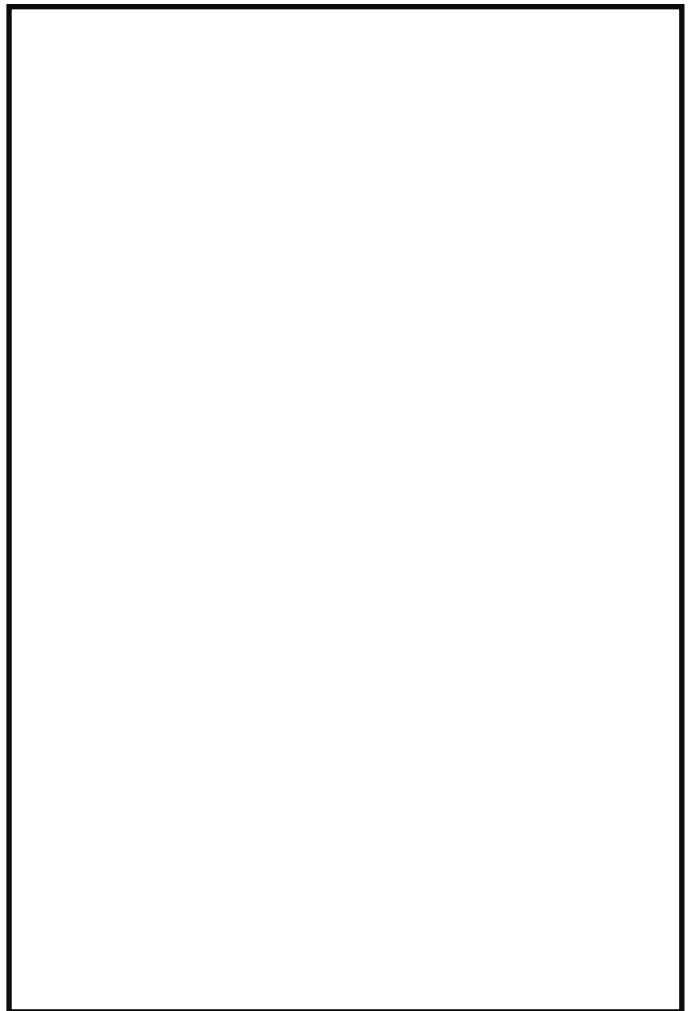
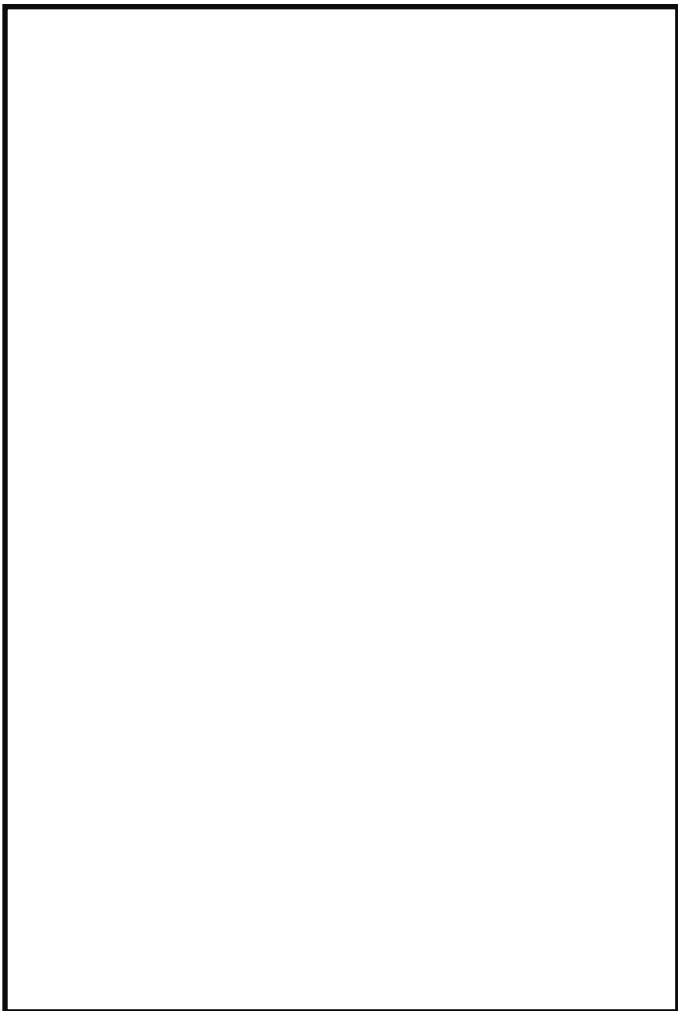
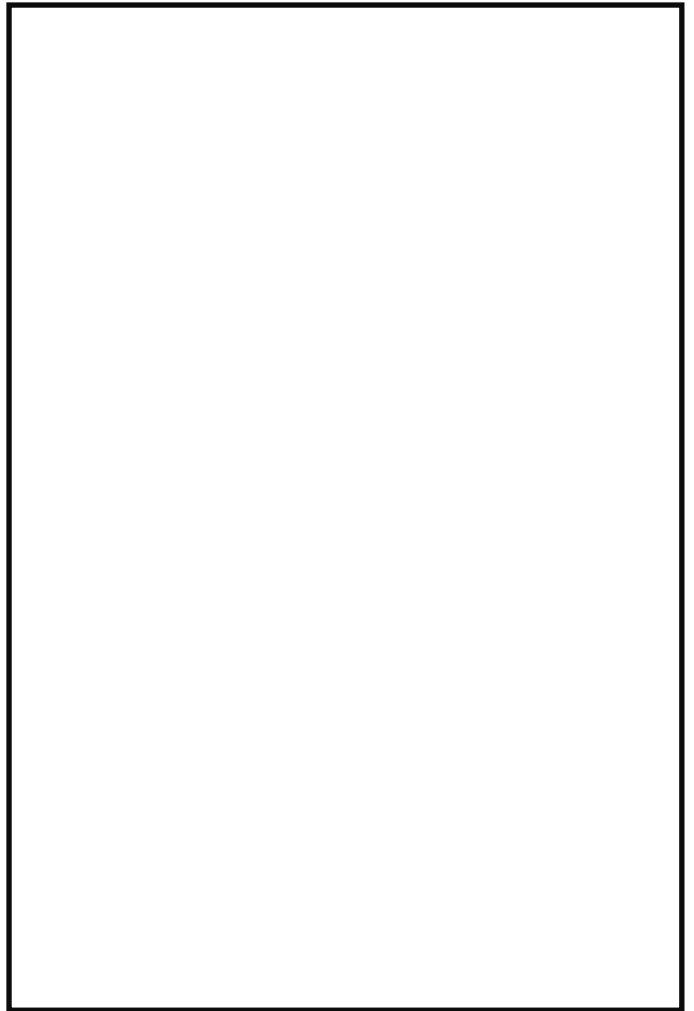
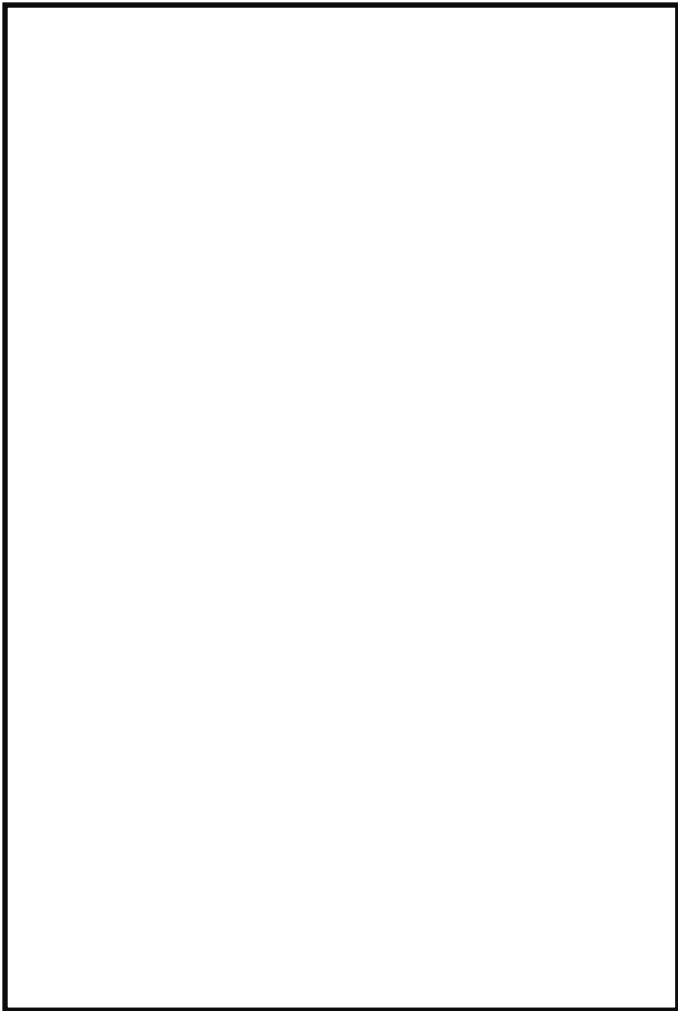
Wood is considered to be a sustainable product, as new trees can be grown to replace those used for timber and fuel. The main issue facing timber production is that in many parts of the world, it is being used at a far greater rate than it is being replanted. The result is an unsustainable supply of timber, which is frequently illegally obtained. This is causing many problems to the land in the countries where it is happening. Some countries are suffering from **desertification** due to **deforestation**. This activity is also thought to be a contributing factor in **global warming**.

To ensure that timber comes from a reputable source, it is vital to know the **provenance** of the wood. This means that the supplier or retailer should be able to prove that it has been sustainably harvested. This can be very difficult to do, so there are organisations that make the process much easier. The Forest Stewardship Council® (FSC®) and the Programme for the Endorsement of Forest Certification (PEFC™) are both dedicated to ensuring that timber supply is regulated. If a product is labelled as approved, the company selling it will need to have proved that the timber came from a properly managed forest. FSC and PEFC timber is readily available in the UK, Europe and a growing number of countries worldwide.













## Timber based materials, sources, origins and properties:

### Questions

Q1. Which type of timber surface do you think is the most expensive to produce, PAR or rough sawn? Justify your answer. (2 marks)

Feedback:

Q2. Why does timber for interior use need a lower moisture content? (2 marks)

Feedback:

Q3. How long would it take a 100mm thick piece of timber to air dry? (1 marks)

Feedback:

Q4. The end grain of timber planks is often covered with sealant. Why do you think this is done? (1 marks)

Feedback:

Q5. Veneered manufactured board is often used as a replacement for solid wood planks in the manufacturing of furniture.

- a) Why is it cheaper to use veneered boards rather than solid planks? (2 marks)
- b) Which parts of a tree (that will not be made into natural planks) could be used in the production of non-veneered, man made boards such as chip-board and MDF? (1 mark)
- c) Why could the use of manufactured board be considered to be more sustainable than solid timber? (2 marks)

Feedback:

Q6. Why is hardboard commonly used for the backs of wardrobes and drawer bottoms? (3 marks)

Feedback:

Q7. If you had the choice of 2 identical tables made from mahogany, one sustainably sourced which costs £200 and one from an unmanaged supply costing £100, which would you choose and why?

**Total marks : / 14**

**WWW?**

**EBI?**



**Working with timber**

## Selecting suitable natural and manufactured timber

Which type of timber-based material to use for a product depends on a number of factors, including:

- Aesthetics
- Size of product
- Where it will be used
- Stability
- Cost
- Size of material available
- Required finish
- Availability of stock
- Weight
- Desired properties
- Workability
- How long it is to last

## Standard material stock forms, types and sizes

Most wood-based material comes in a range of standard shapes and sizes. This enables materials to be more interchangeable, and the manufacturers of tools to be aware of the material they will need to cope with. When ordering material, you should ensure you have the correct measurements to hand. Standard practice is to use *length x width x thickness* for planks and boards, and *length x diameter* for rods and dowels.

### Board and plank sizes

- Manufactured boards come in a series of standard sizes. Thicknesses tend to start at 3mm and 4mm. From 6mm thicknesses rise in 3mm steps to 9mm, 12mm and so on.
- Single veneer thicknesses vary from 0.4mm to 4.5mm but are commonly 1.5mm thick.
- A full size sheet of manufactured board is 2440mm long by 1220mm wide (based on the old imperial size of 8 feet by 4 feet). Boards are commonly available in half and quarter sheets and frequently smaller. Many DIY stores and timber suppliers offer a cutting service and will prepare the exact size needed.
- Plank widths are of standard sizes and generally increase in 25mm stages (again based on the imperial for 1 inch). A common size is 50mm x 25mm, used for frame and carcass construction. 50mm x 25mm would be the size of the rough sawn version; however, if you were to ask for it planed all round (PAR), it would measure approximately 45mm x 20mm as this would account for the material removed by the planing process. The PAR sizes will always be 2-3mm less per side in width and thickness than rough sawn, meaning around 5mm less width and 5mm less thickness will be available. This reduction needs to be considered when designing, as it could lead to inaccurate construction sizes.
- Plank lengths vary and can often be bought by the metre. Common lengths are 1.2m, 1.5m, 1.8m, 2.4m, 3m and 3.6m, normally increasing to a maximum of 4.8m.

### Dowels and mouldings

Many specially shaped sections of wood are available and these are known as **mouldings**. The most common variety can be seen around door frames and is called **architrave**; you may also have noticed ornate **skirting boards** in older style houses which is another form of moulding. Some modern mouldings are made from manufactured board such as MDF and can come pre-painted – however, the majority are made from different types of timber.



**Dowel rods** are circular sections of timber that come in many different diameters. Some dowel is pre-cut and ridged for use in a dowelled wood joint. Dowels and mouldings are machined using industrial milling machines and routers.

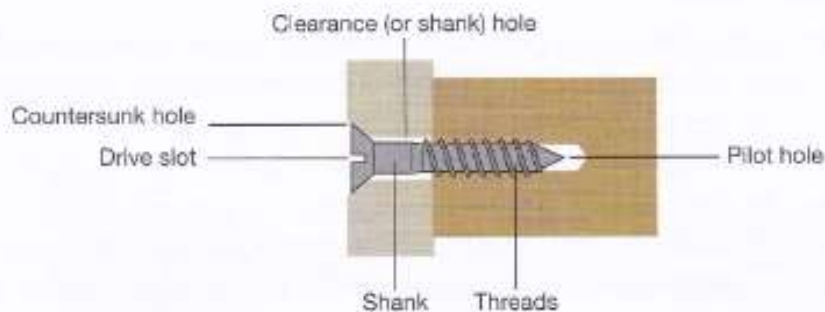


## Woodscrews

To fix two pieces of wood together, woodscrews are used. They are available in many different lengths and diameters. Screws come with different driving methods, the most common being slotted, Phillips and Pozidriv®. Allen key and Torx® drive are becoming more widely available and offer a more reliable connection when using powered screwdrivers, as they are less prone to slipping and result in fewer stripped heads.



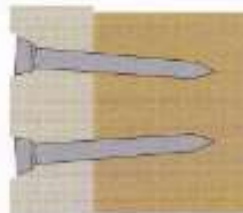
When connecting two pieces of timber together it is best to select a screw that has a shank so that it does not grip the first piece of timber and create a gap between the two separate pieces. First, a pilot hole of about the core diameter of the screw is drilled through both pieces of wood. Then the clearance hole is drilled through the top piece only, to at least the diameter of the shank.



Finally, if using a countersunk screw, a countersunk hole should be drilled to the depth of the head of the screw, so the screw lies flush with the surface of the material. A countersink bit is used for this purpose.







## Nails and pins

Nails and pins are threadless versions of screws and are either hammered into position or a powered nail gun can be used along with special cartridges of nails. They are generally used for permanently fixing wood together. Pins tend to be thinner than nails, have less of a pronounced head and are used to attach materials that have finer detail as the head is easily hidden below the surface.



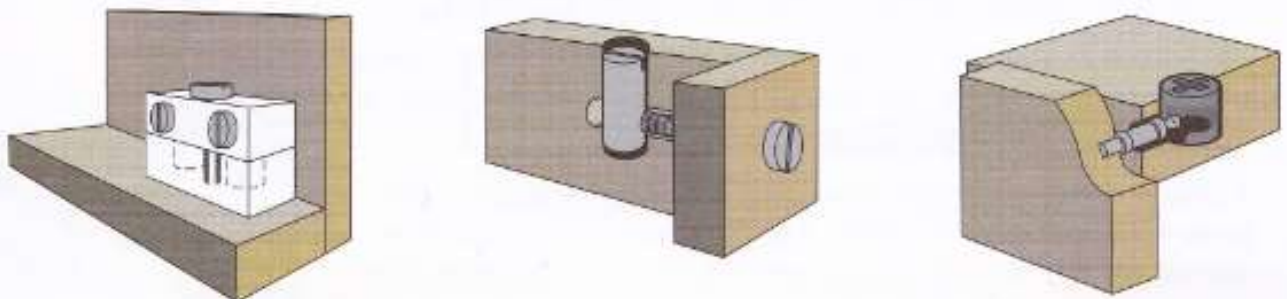
To attach two pieces of wood together, a method of skewing the nails or pins at an angle (known as 'dovetail' nailing) is ideally used, as it gains some mechanical advantage and reduces the chance of the joint working itself loose through vibration and pressure.

## Common types of nails and pins

Name	Characteristics	Image	Name	Characteristics	Image
Round wire nail	All-purpose nail with a wide flat head, can be galvanised for exterior use		Oval wire nail	Shaped nail with small head, prevents wood splitting, best for interior use	
Panel pin	Thin diameter with a discrete small head, pin punch used to set below surface		Tack	Sharp, short, wide head, used to attach material such as upholstery or carpets to wood	
Clout nail	Very wide head, often galvanised, used to attach roofing felt and plaster board		Lost head nail	A thicker version of a panel pin, used where the head should not be visible. A pin punch is used to set down	

## Knock-down fittings

Flat-packed furniture relies almost entirely on different types of **knock-down fittings (KDF)**. These are a form of temporary fixing that joins two or occasionally three pieces of material together, normally via a screwing method. They provide a secure and tight joint (although not as rigid as a permanent joint), and they are easily dismantled for transportation or storage. You may have used these before or have identified them on furniture you have seen.









## Hinges

Hinges are used to attach doors, windows and other openings to frames and carcasses. They can be made from many different materials but most commonly are metal. Most varieties are made from polished brass or steel and are often sold in pairs.

Hinges need to be carefully aligned to ensure accurate operation. The process of **rebating** or recessing the hinge is used to ensure a flush fit between the frame and the door or window.

## Common types of hinge

Name	Characteristics	Image	Name	Characteristics	Image
Butt hinge	Standard hinge for doors and windows, needs rebating to fit flush		Piano hinge	Long butt style hinge, cut to required length, fine and close join possible	
Flush hinge	Not as robust as a butt hinge, does not require rebating		Concealed hinge	Used in flat-packed furniture and kitchens, specialist jig needed to fit	
Butterfly hinge	Decorative version of the butt hinge, used in cabinet making		Tee hinge	Often galvanised, painted or black japanned for outside use on sheds and gates	

## Shaping, processing and machining wood

A vast array of tools is available in workshops in order to help make the products we require. Tools enable us to mark out materials, cut to them size, waste them (remove material), shape them and apply a finish.







### Drilling

Drilling a hole into a piece of wood seems a simple task but there are a number of factors to consider. Selecting the correct type of drill bit is important so that the right amount of material is removed. Additionally, the correct speed is needed; large drill bits require a slower speed than smaller diameter bits to avoid overheating and potential scorching of the wood. The depth of cut needs to be considered as you may not want to drill all the way through a piece of material, as does the feed rate which can put excessive strain on the drill and the drill bit if it is too fast.

A pillar drill is good for accuracy and it is powerful enough to drill larger holes in thicker materials. A cordless drill is very adaptable and usually has variable speeds and a clutch which can help avoid overtightening of fixtures and fittings.



## Common drill bits used with wood-based materials

Name	Characteristics	Image	Name	Characteristics	Image
Wood drill bit	Designed to drill holes in wood, flutes carry waste wood away		Hole saw	Used to cut large holes, they can easily overheat due to high peripheral speed	
Twist drill bit	General purpose bit, also used on plastic and metal		Flat bit	Efficient way to make larger holes, removes waste efficiently, long shank for greater depth	
Countersink bit	Used to allow countersunk screw head to be flush with the surface		Forstner bit	Accurate hole cutting bit, good for flat-bottomed partial-thickness holes	

## Cutting and sawing

Saws are used to cut materials and joints to size. The tenon saw, rip saw and cross-cut saw are common hand saws that are used for cutting straight lines in wood. The tenon saw is used for cutting wood joints and for small section material. Rip and cross-cuts saws are used for cutting large panels. The coping saw enables curved lines to be followed. The band saw is powered and can be used for straight cuts and gentle curves through thick and thin material.



The scroll saw is also a powered tool and is used to cut curved lines through thin material.



*Tenon saw*



*Coping saw*



*Rip saw / Cross-cut saw*

## Wasting by hand and abrading

Using hand tools to accurately shape wood is a skill that is learned over many years. Accuracy is vital and mistakes are easy to make which can be costly. Practice is needed in order to achieve the quality that you need at GCSE level, therefore it is recommended that you use some scrap wood to become acquainted with the following tools first; especially chisels. Planes can take some delicate setting up before they work correctly but it is worth taking time to ensure an even cut is made.

### Wasting tools

### Abrading tools

Name	Characteristics	Image	Name	Characteristics	Image
Smoothing plane	Smoothing plane removes very thin layers of wood, smooths and flattens along the grain.		Rasp	Like a file with very rough teeth for fast removal of material, different profiles available	
Chisel	Different versions used with a mallet to remove wood to form rebates and recesses		Surform	For fast removal of material, cheese grater-like blade is sharp but brittle, different profiles available	

## Sanding

Sanding wood to give it a smooth finish can be performed with machines or by hand. A disc or belt sander is best used for easy-to-reach sections that can be held safely. There are also cylindrical sanding machines called bobbin sanders which are useful for internal curves.



*Bobbin sander*

Hand sanding using **glasspaper** is best for hard-to-reach areas and it also allows you to apply the force where it is needed most, perhaps to remove scratches or a glue stain. Glasspaper comes in different grades; the grit density (measured in grit per square inch) determines how rough or smooth it is. 40 to 60 grit is very coarse and will scratch most materials, 600 grit is very smooth and has almost a polishing effect. Electric hand sanders are useful and some come with accessories for working on hard-to-reach areas.

## Wood Turning

Wood lathes are used to turn bowls and spindles. The size of the material being turned is important; the speed needs to be reduced as the diameter of the object being turned gets larger.

A special set of chisels is used to shape the wood when turning. The most commonly used tools are the scraper, the gouge and the parting tool.



## Laminating

Laminating involves bonding strips of material together in layers. It can be done with thick materials in order to create very strong structures which can be used as roofing beams and bridge supports.

If thinner materials are used for laminating, the curves made can be quite complex and have reasonably tight radii. The process involves layering the material with adhesive and holding it in the chosen position using a **former** or **jig** and pressure through clamps or by using a vacuum. See Chapter 20. Flexi-ply is often used for lamination as it is very workable and can make a robust product with a high quality finish.

## Bending

Bending natural wood into ornate shapes and curves can be achieved by soaking it in water until it softens. A thin branch on a young tree will bend without snapping. This is because of the high moisture content in green wood. Soaking the wood is a way of increasing the moisture content temporarily while it is bent and shaped.

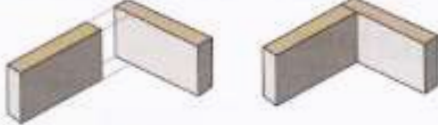
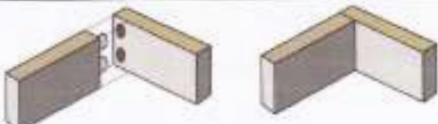
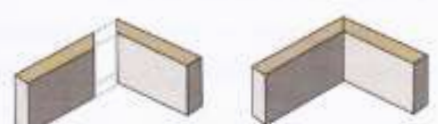
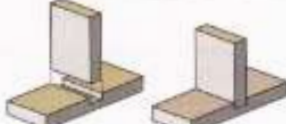

The most effective way to soften wood is by steaming it for around one hour per 25mm of thickness. A **steamer box** can be used to speed up the process. The thinner the wood being bent, the tighter the radius that can be achieved. The wet or steamed wood needs to be bent around a former, then clamped into position (the same as the laminating process) and left to set or cool for up to an hour. It will then take a few days to dry out, depending on the thickness of the material used. The best results are obtained by using oak, hickory, elm, walnut and ash. Generally softwoods and tropical hardwoods do not bend as well.



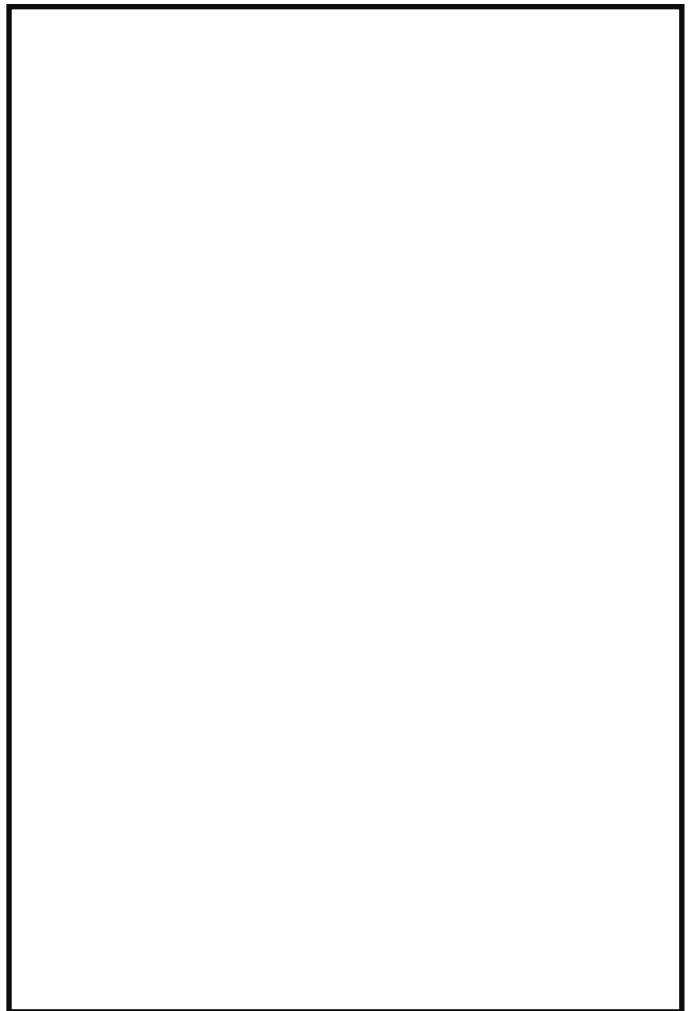
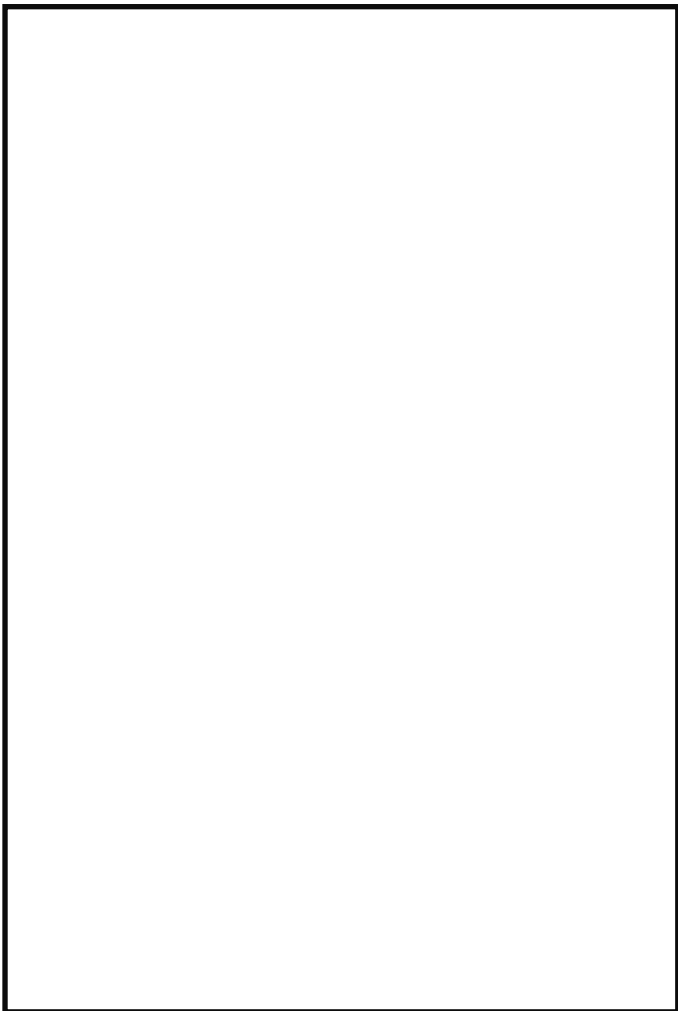
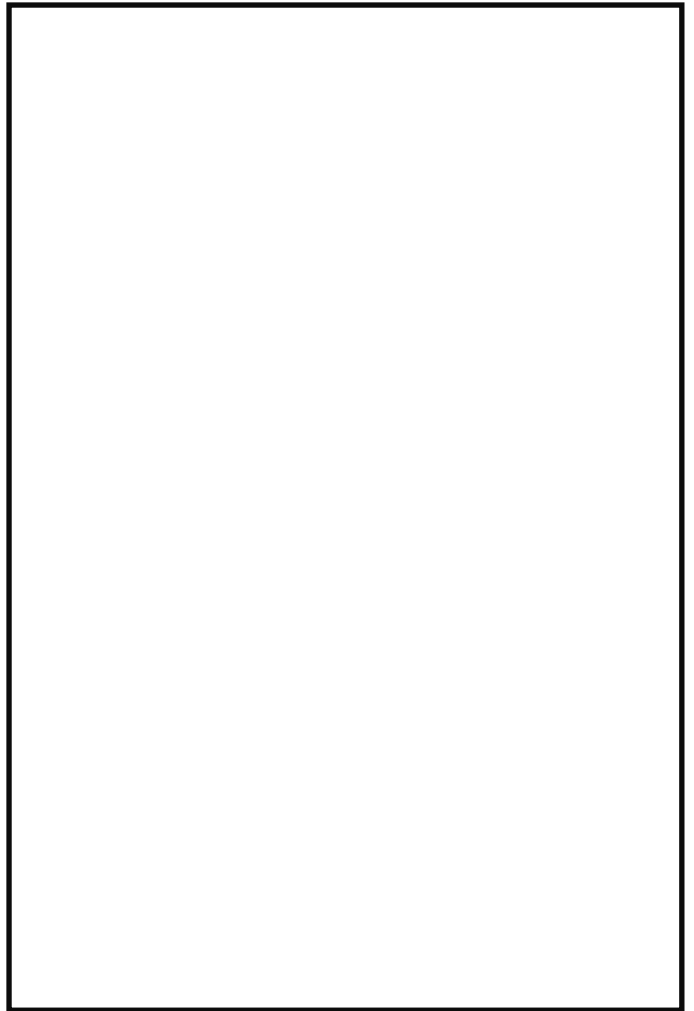
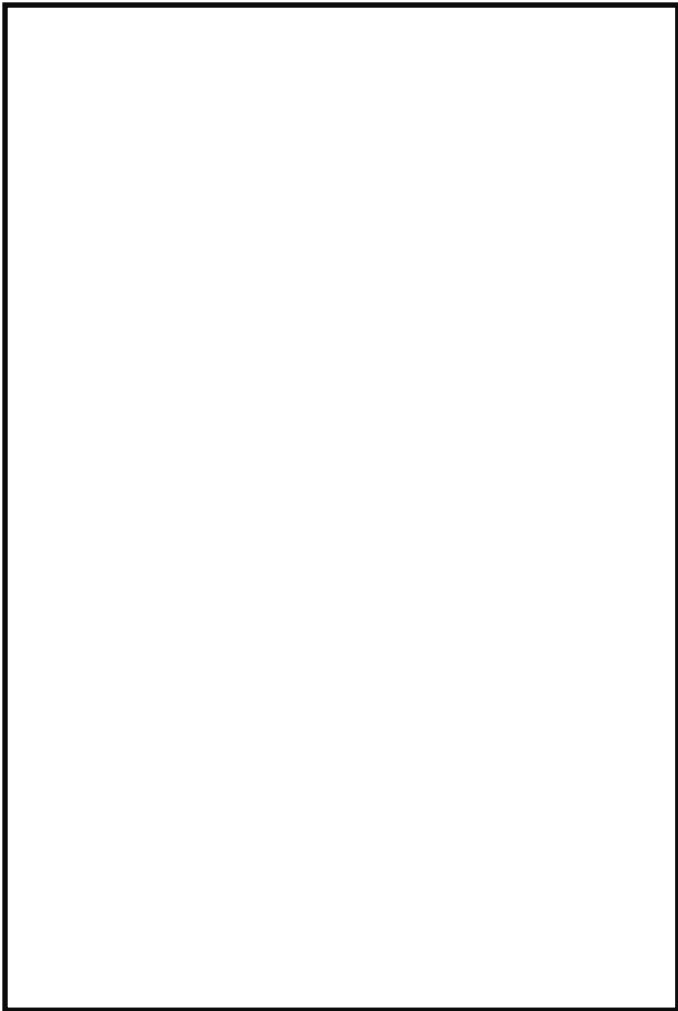
*'New Sling' - Steam bent seat by David Trubridge*

## Wood joints

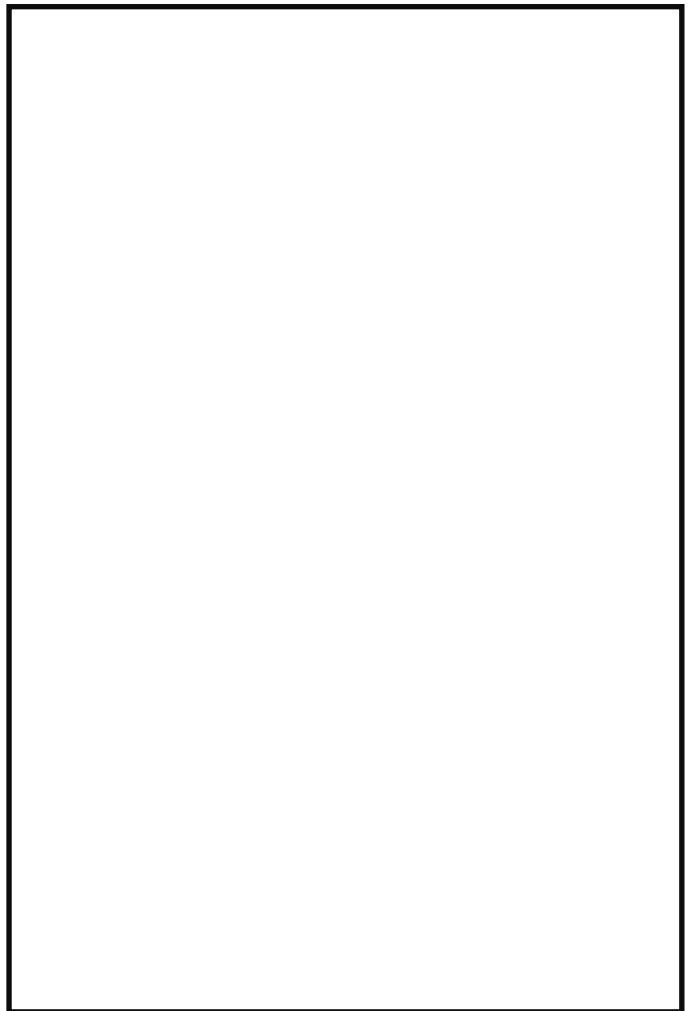
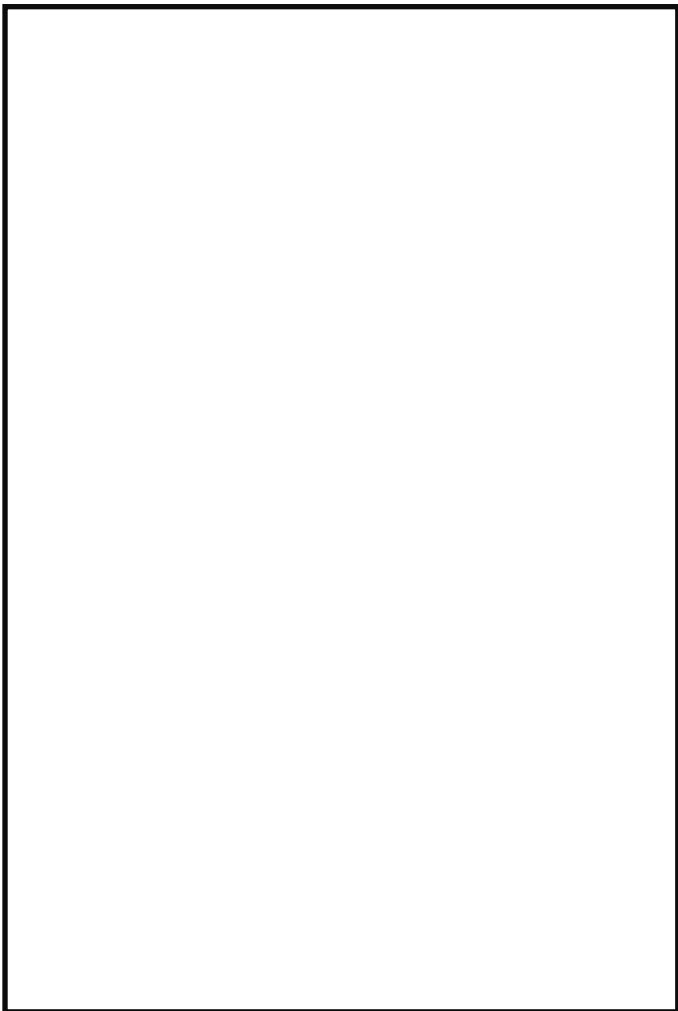
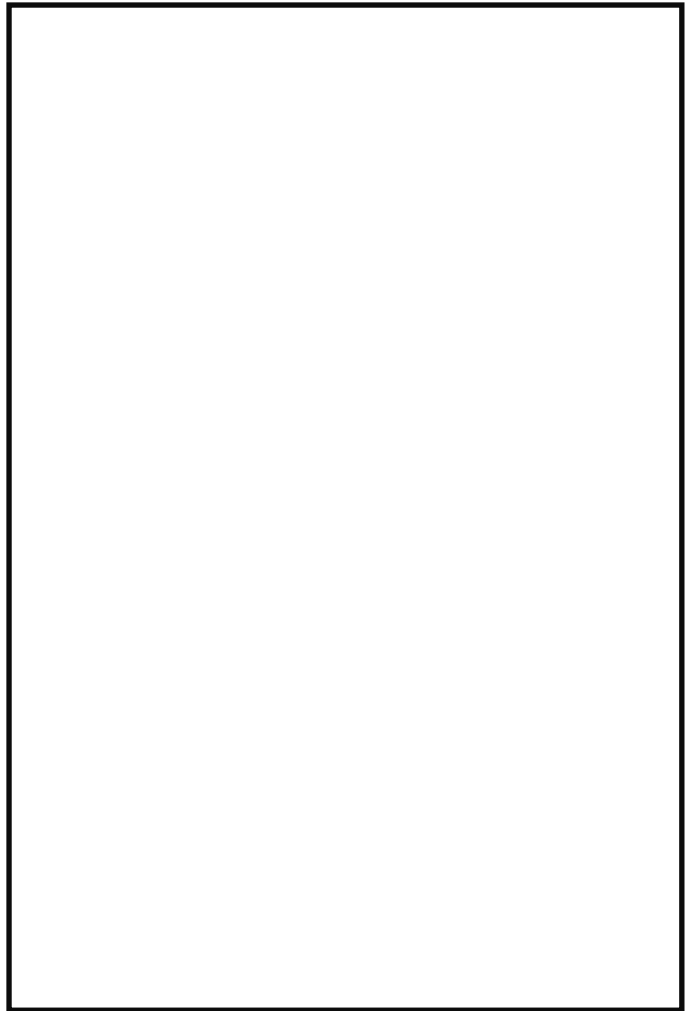
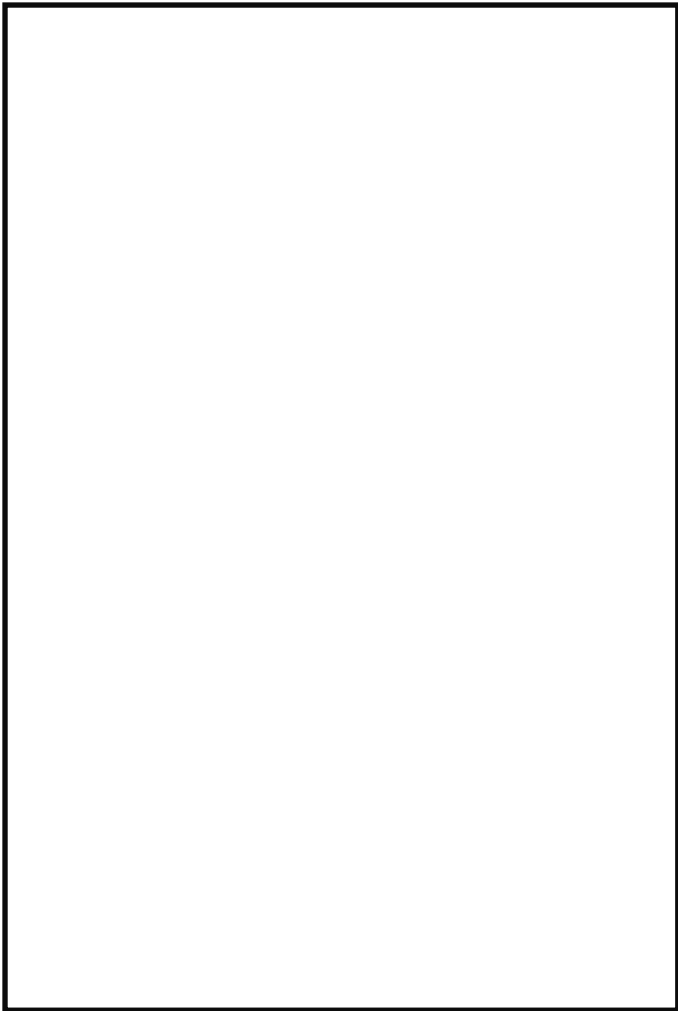
One of the most effective ways to join two or more pieces of wood is with a wood joint. Wood joints can be used to fabricate carcass constructions e.g. a drawer or bookshelf, and frame constructions e.g. tables, chairs and picture frames. Joints need to be made precisely and time should be taken to mark out accurately and ensure that any cuts are made on the waste side of the marked out lines. Joints are best pared down with a chisel if they do not fit first time. It is preferable to have wood joints that are a tight fit rather than ones which are too loose and require filling, as this can weaken them.

Name	Characteristics	Image
Butt joint	The most basic joint, not very strong due to little surface area for the adhesive and no mechanical advantage. Pins or nails often used	
Dowelled joint	Similar to the butt joint but with wooden dowels that add strength and assist rigidity. Dowels are glued in for extra strength	
Mitre joint	More attractive than the butt joint and used for picture frames and surrounds. Weak due to lack of surface area, metal splines can be used to help strengthen them	
Housing joint	A stronger joint that has larger surface area for glueing and the physical advantage of the wood being supported by three sides	
Mortise and tenon joint	A strong joint used in table and chair construction. Very large surface area for glue and good physical advantage created by the tenon	













## Working with timber based materials:

### Questions

Q1. How many square metres of material are there in a standard full size board of 2400mm x 1220mm?  
(1 mark)

Feedback:

Q2. What would be the finished PAR width and thickness of a piece of timber that was machined from a sawn plank starting out at 150mm x 50mm? (1 mark)

Feedback:

Q3. Why is it good practise to drill a pilot hole before adding a screw? (1 mark)

Feedback:

Q4. Why are Allen key and Torx screws less prone to slipping when being driven in? (2 mark)

Feedback:

Q5. How can steel hinges be modified to protect them from rust? (2 mark)

Feedback:

Q6. What is the most essential item of PPE to be worn when using a drill? (1 mark)

Feedback:

Q7. Do some research on saw blades and explain the terms:

- Tooth pitch
- Kerf

(2 marks)

Feedback:

Q8. What 3 pieces of PPE would be most appropriate to use when mechanically sanding? (3 marks)

Feedback:

Q9. When sanding a rough piece of timber to a finish, would you start with a high number grit and work lower or a low number and work higher? (1 mark)

Feedback:

Q10. What must you check for before releasing the shaped laminate from the former? (1 mark)

Feedback:

Q11. Which joint from a butt joint, dowel joint, mitre joint, housing joint, mortise and tenon joint do you think would best suit the following tasks?

Feedback:

- A shelf
- Architrave around a door frame
- A raised vegetable bed made from railway sleeper

(3 marks)

**Total marks : / 18**

**WWW?**

**EBI?**



**Commercial manufacturing,  
surface treatments and finishes**

## Timber and manufactured board for commercial products

Commercial products are nearly always aimed at a certain price point and this often determines the quality of the chosen construction material.

Traditional wooden toys aimed at children are frequently made from beech as it has a fine dense grain which gives it resistance to splintering and chipping when dropped or thrown. It is also non-toxic and finishes well. It can be sanded to a very fine and smooth finish and is equally appealing either in its unfinished pinkish grain or painted.

If the manufacturer wanted to save production costs, they could decide to use a softwood such as pine or spruce. The result would have slightly different aesthetics, being yellower with a more pronounced grain. The blocks would be prone to denting and splitting over time due to a more open grain structure which makes the wood softer and less durable than beech.



*Toy building blocks in beech and in pine*

## Flat pack furniture

Manufactured boards are most often seen commercially in flat-pack products.

<b>Advantages of flat-pack furniture</b>	<b>Disadvantages of flat-pack furniture</b>
<ul style="list-style-type: none"><li>• Compact for ease of transportation</li><li>• Low cost compared to traditional furniture</li><li>• A large choice of styles and finishes</li><li>• Easy to assemble with limited tools and experience</li><li>• Can be disassembled for storage/moving</li></ul>	<ul style="list-style-type: none"><li>• Needs to be constructed yourself or by someone else at additional cost</li><li>• Not as robust as traditional furniture</li><li>• Can be complex to construct for some</li><li>• Prone to damage by moisture</li><li>• Can chip and break more easily</li></ul>

As manufactured board is so dimensionally stable it can be processed, transported, stored and assembled without the risk of developing the faults of natural timbers, although it can be prone to absorbing moisture in damp and humid conditions.



### Commercial routing and turning

In industry, most machining and shaping of furniture, artefacts and components is now done using CNC (Computer Numerical Control) routers for flat materials and CNC lathes for cylindrical objects. Great repetitive accuracy, and a level of detail that would be very difficult to manage by hand, can be achieved. Routers are available in very large formats that are capable of producing flat-packed furniture but they can also create detailed ornate profiles if required.



*Industrial carpenter routing the detail into a wooden door*

## Quality control

When products are made, checking that they are being produced correctly is an essential stage. This is known as **quality control** (QC) and ensures dimensional accuracy is consistent or that the product is safe to use.



To save checking every vital measurement on every product with an accurate measuring device, special tools known as **go/no go** gauges are used. These tools are set to the specific minimum or maximum **tolerances** allowed for that particular component. It is then a simple task of placing the fixture onto the part of the workpiece being measured. The gauge will indicate whether the part is 'go' or 'no go' (too big or too small) and can be easily rejected if it is the incorrect size.

## Surface treatments and finishes

Most woods, whether natural or manufactured, perform better if they have a finish applied to them. The reasons for applying a finish fall into two main areas: aesthetics and protection.

**Aesthetics** can mean colouring or staining to:

- match or contrast with existing materials
- enhance the natural grain of the timber
- give it a sheen or shine or even a matt surface finish

**Protection** can mean making it:

- waterproof
- less prone to fungal or insect attack
- tougher so it resists knocks and bumps
- easy to wipe clean and disinfect

When purchasing rough-sawn timber, particularly for outside use, there is the option of having it pressure-treated or **tanalised**. This is a process of forcing wood preservative into the cell structure of the timber under pressure in a vacuum. The wood preservative does not go right through the timber but the process is more effective than painting it on the surface alone. Tanalising protects timber from fungal and insect attack and will delay the onset of rot but it does not make the wood waterproof.



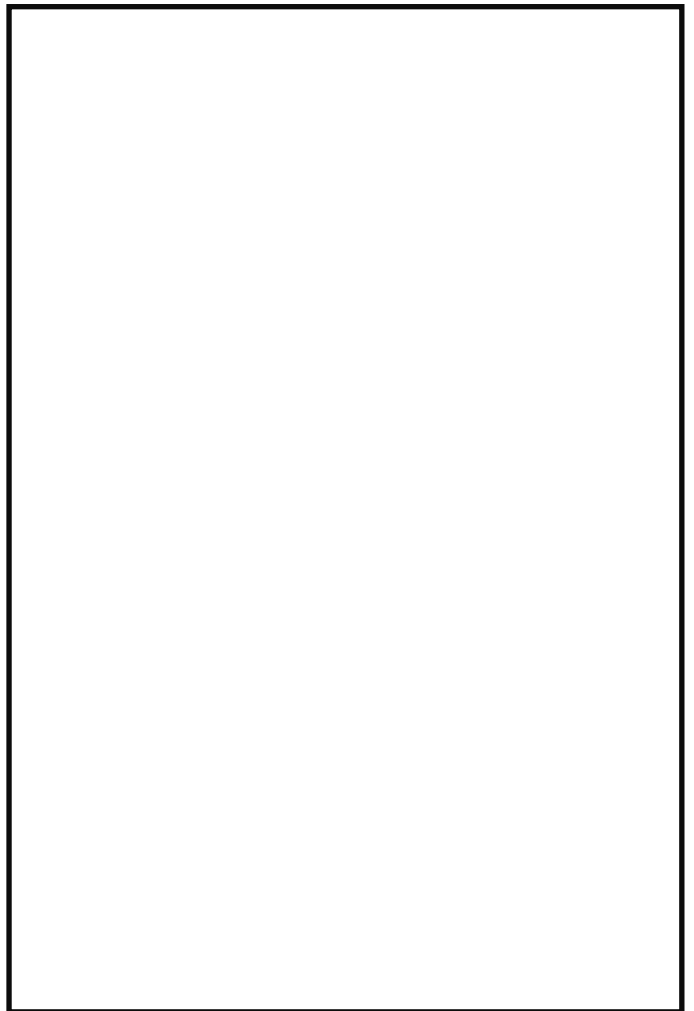
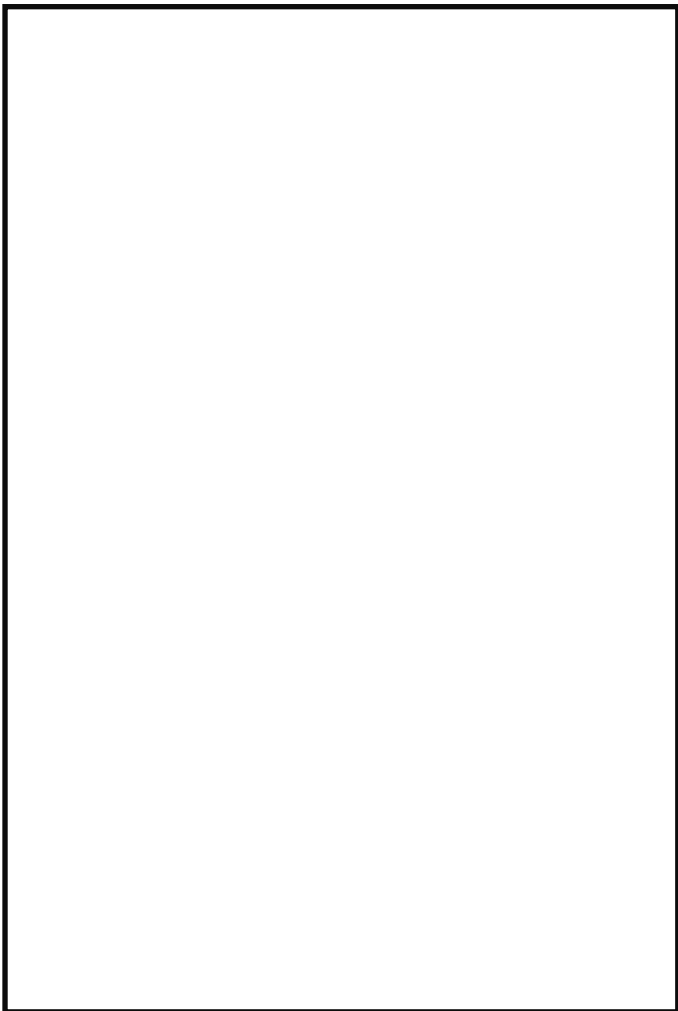
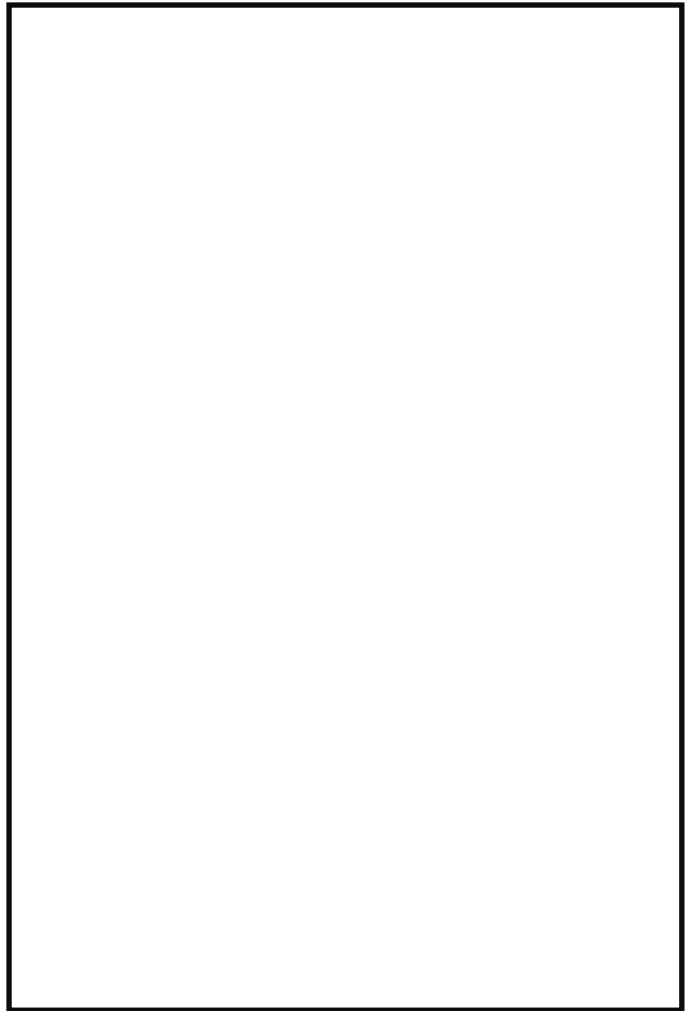
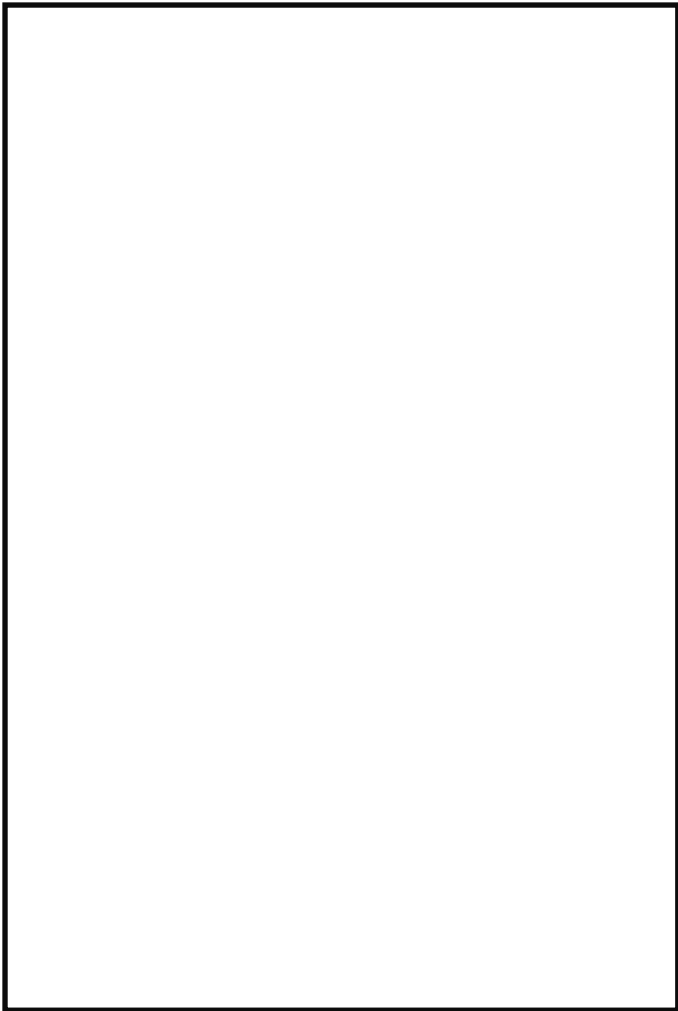
*What treatments might you want to apply to a spruce garden fence?*

## Common protections and finishes for timber-based products

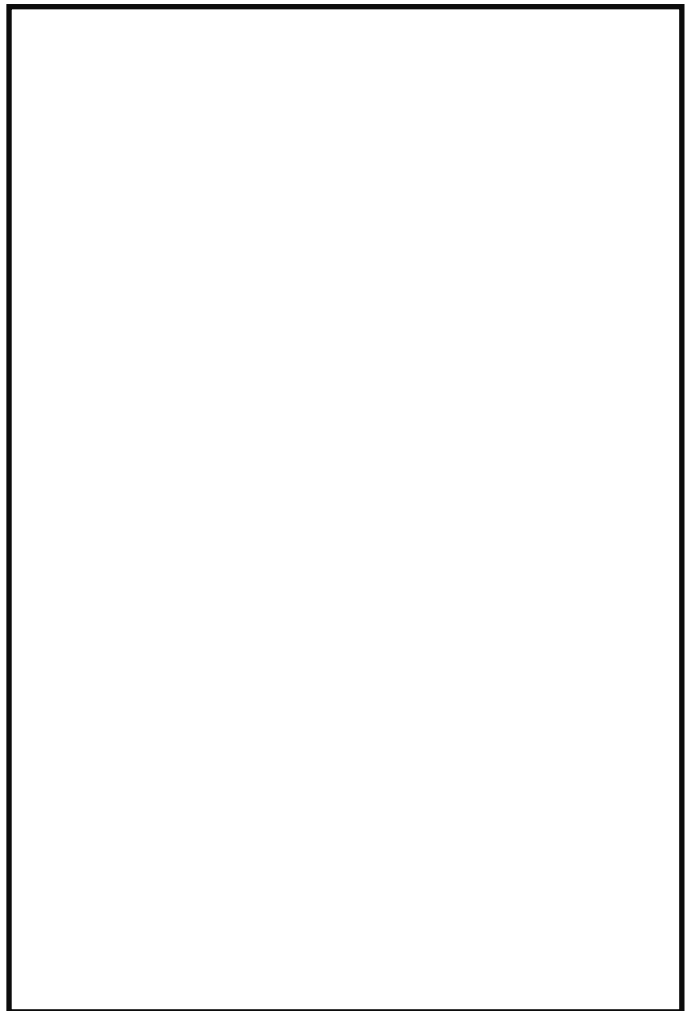
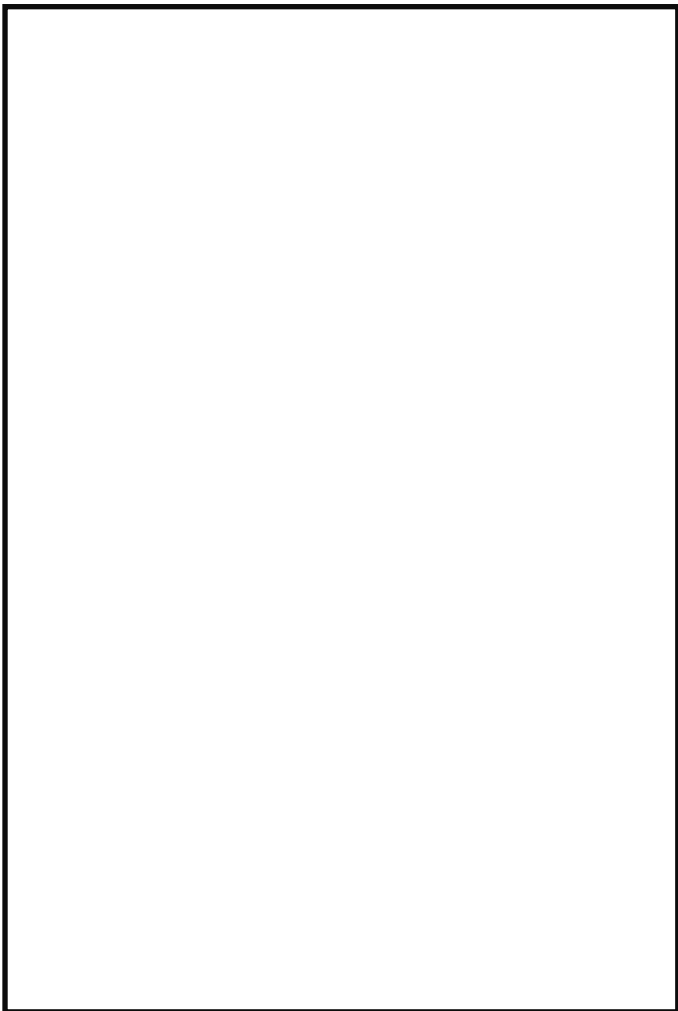
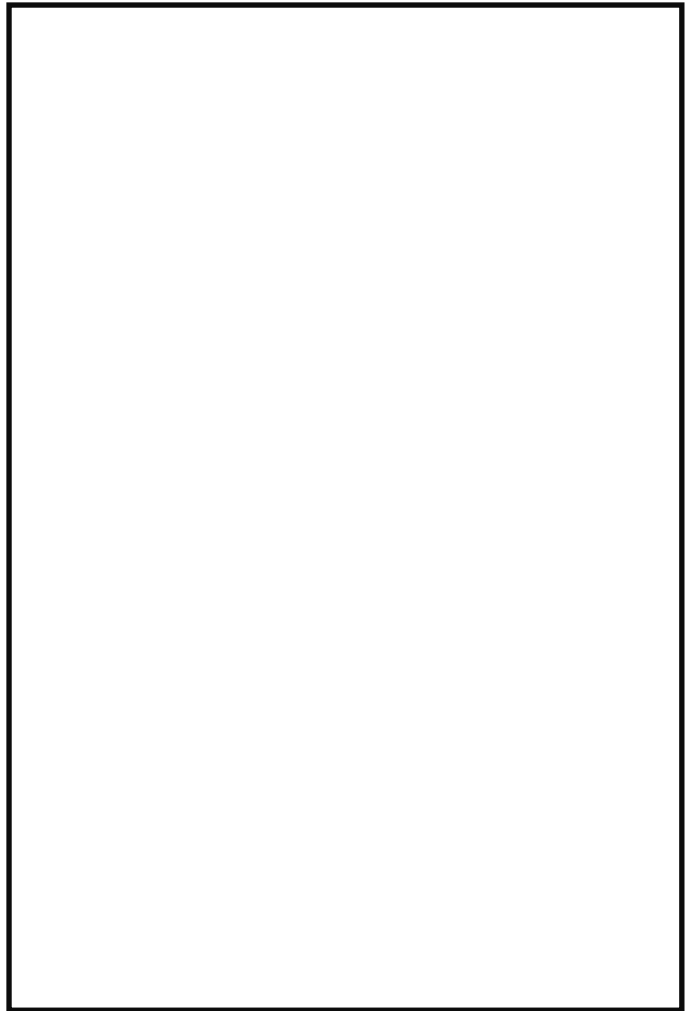
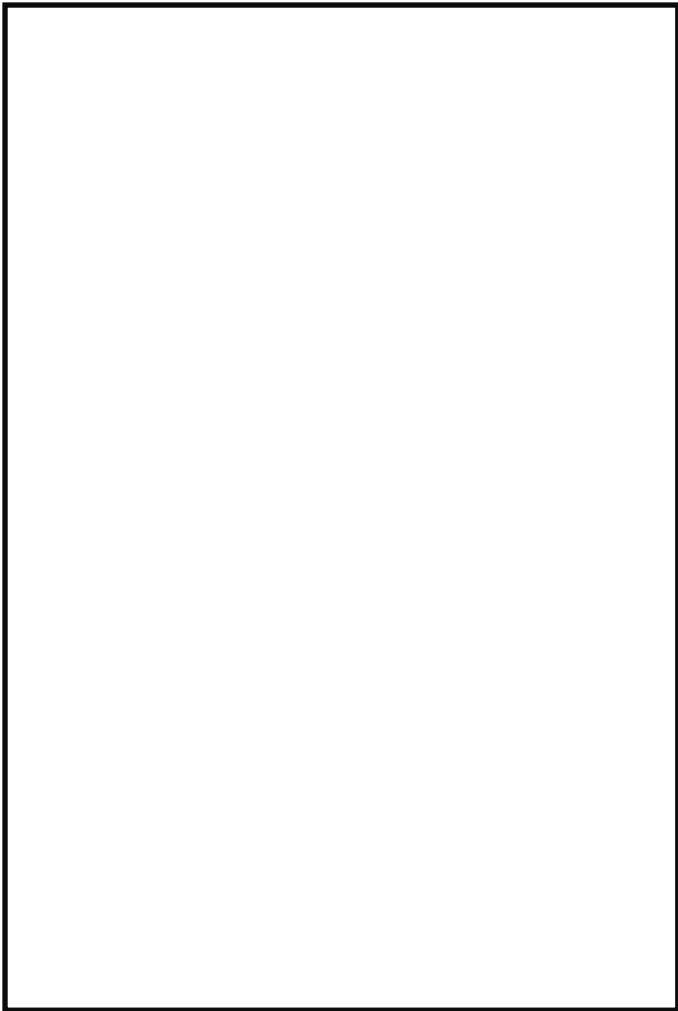
Most finishes for woods are available with a range of different base liquids. The three categories are oil-based, solvent-based and water-based. Traditionally oil and solvent-based products were used, and these are still considered the longest lasting. However, they are not very environmentally friendly as they usually contain high **volatile organic compounds** (VOCs). This means that they give off fumes that are considered hazardous to health and should be used according to the manufacturer's instructions, normally wearing a mask in a well ventilated area. Water-based products are becoming much more popular and are kinder to the environment. These should be used where possible around children and animals, as they are non-toxic.

Name	Characteristics	Image	Name	Characteristics	Image
Wood preservative	Painted on to protect wood from fungal or insect attack and prevent rot and decay, needs reapplication to maintain the levels of protection		Paint	Painted with brush or roller, usually needs primer and undercoat on bare wood, wide range of colours available	
Varnish	Protects from moisture, can be coloured with stain, enhances grain, gloss, satin or matt finish, yellows with age		Stain	Permanently colours wood, does not protect it, results vary depending on base wood and colour	
Oil	Similar effect to varnish but soaks into the timber rather than sitting on the surface, needs reapplying frequently		Wax	Rubbed into the wood with cloth or wire wool, enhances natural grain, needs regular reapplication	













## Commercial manufacturing, surface treatments and finishes:

### Questions

Q1. Give 3 possible advantages to manufacturers of producing a range of flat pack furniture? (3 mark)

Feedback:

Q2. Why is flat pack furniture more prone to moisture damage than traditional furniture? (1 mark)

Feedback:

Q3. What factors make flat pack furniture cheaper than traditional pre assembled furniture? (3 mark)

Feedback:

Q4. Name 2 benefits of using go/no go fixtures in production? (2 marks)

Feedback:

Q5. Why should you reapply treatments and finishes in accordance with the manufacturer's instructions, or when signs of wear appear? (2 mark)

Feedback:

**Total marks : / 11**

**WWW?**

**EBI?**