PROPERTIES

A property is a characteristic of a material.
A material will possess a range of different properties.
Designers use properties to help them select a material for a particular purpose.
The range of properties can be divided into mechanical, physical and aesthetic properties.
When selecting a material for a particular purpose it is necessary to consider properties for both service and manufacture.

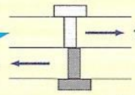
MECHANICAL PROPERTIES

Mechanical properties: these describe how a material will respond to different types of external forces.

Tensile strength – ability to withstand pulling (stretching) forces.

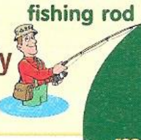
Compressive strength – ability to withstand pushing (squashing) forces.

Shear strength – ability to withstand forces which tend to cut the material in two.

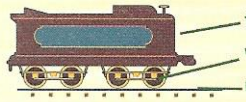


Torsional strength – ability to withstand twisting (rotary) forces.

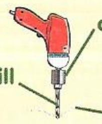
Bending strength – ability to resist bending forces.



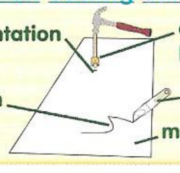
Toughness – is how well a material can withstand impact forces. The opposite of toughness is brittleness. A material is said to be brittle if it has low resistance to impact loads. Toughness is important for products such as hammers, machine parts, kitchen utensils, gardening tools and railway lines.



Machineabilty: this is how easily a material can be manufactured using machine tools.



Hardness – the ability of a material to withstand indentation or scratching. This is a requirement when a product or component needs to have good wear resistance. Examples include twist drills, chisels, roller bearings and kitchen cutting surfaces.



Elasticity – a measure of how flexible a material is. Elasticity is important in products such as vaulting poles and springs.

Ductility – the ability of a material to be permanently deformed by cold-working. This can be achieved by bending, twisting or pulling materials through a die. Materials for wires need to be ductile. Metals for car bodies need to be ductile so that they can be formed when pressed.

Malleability – the ability of a material to be hammered or forged into shape. The material may be shaped hot or cold.

AESTHETIC PROPERTIES

These relate to appearance:

- **colour**
- **surface texture**
- **surface decoration**
- **brightness**

Examiner's Top Tip
For revision look at a number of household, garden or toy products and identify their required properties.

MATERIALS AND COMPONENTS

PHYSICAL PROPERTIES

These describe how a material will respond to physical influences other than force.

Optical properties – how well light can pass through a material. A material can be transparent, translucent or opaque.

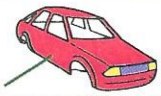
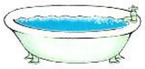
Resistance to corrosion – how well a material will resist corrosion. **Rusting** is the main form of corrosion in steels. Most steels have to be protected against rusting.

Thermal conductivity – how well a material will conduct heat. Soldering iron tips and saucepans need good thermal conductivity properties so that they can transfer heat quickly. Metals are good conductors of heat.

Electrical conductivity – how well a material conducts electricity. Electrical wires and terminals need to be good electrical conductors. Aluminium, copper and silver are examples of good conductors. **Insulators** are materials which do not conduct electricity.

PROPERTIES OF MATERIALS

SOME PROPERTIES OF COMMON MATERIALS

Mild steel	*good strength properties, tough, ductile, malleable, relatively hard, poor corrosion properties*	 car body – good hardness properties, tough and good tensile strength
Aluminium	*ductile, malleable, very good conductor of electricity and heat, good corrosion properties*	 ductile and malleable (so that they can be manufactured), good heat conduction, good corrosion properties, good aesthetic properties
Copper	*ductile, malleable, good conductor of heat and electricity, good corrosion properties, bright appearance*	 plug body is a good electrical insulator, tough, relatively good overall strength properties; pins are ductile (for extrusion during manufacture), good electrical conduction, tough, wear-resistant
Beech	*relatively hard, good surface appearance, tough and strong*	
Spruce	*relatively tough and strong, good appearance properties*	
Acrylic	*bright, brittle, good insulator of electricity, good optical properties, will scratch easily*	
Nylon	*tough, good insulator of electricity, good machineability, hard*	

QUICK TEST

1. What is meant by a property of a material?
2. List the three divisions of properties.
3. Define hardness.
4. Define toughness.
5. List three properties of aluminium.
6. List three properties of acrylic.
7. What are the property requirements for the body and the pins of an electrical plug?

1 A characteristic of the material.
2. Mechanical, physical and aesthetic.
3. Ability to withstand indentation or scratching.
4. Ability to withstand impact forces.
5. Good corrosion properties, malleable, ductile, good conductor of heat and electricity.
6. Brittle, will scratch easily, good insulator of electricity, good optical properties, bright.
7. Pins need to be ductile, good electrical conductors, tough, hard-wearing; plug body needs to be good electrical insulator, tough, good strength properties.

MATERIAL CHOICE IN DESIGN

MATERIAL SELECTION

Selecting the best material for a particular purpose is an important part of product design. Material choice depends upon its intended use and on how it will be manufactured. The environmental impact and the costs of using the material should also be considered.

PRODUCT USER NEEDS

These include the life service requirements of the product. For example, a bicycle frame needs to be rigid, strong enough to withstand the weight of the cyclist, be relatively lightweight and should not corrode during its useful life. From the needs analysis the service properties can be selected.

MANUFACTURING PROCESS

In addition to the service properties the manufacturing properties need to be considered. This is to ensure that the product can be made with the available equipment. For example, mild steel cannot be generally cast using the equipment in schools, workshops and thermosetting plastics cannot be injection-moulded. The manufacturing process must take into consideration available labour skills.

Selecting the best material depends upon the user needs of the product, the required properties and how it will be manufactured – the process.

SERVICE PROPERTIES

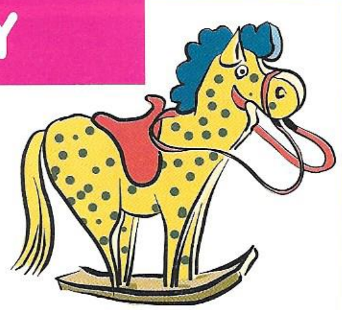
Needs of bicycle frame	Service properties
Rigid	good torsional (twisting) strength and high elastic modulus
Strong	good tensile strength
Lightweight	low mass and good strength-to-weight ratio
Must not corrode	good corrosion resistance properties

ECONOMIC FACTORS

Material costs are an important factor in materials selection. Where possible the lowest cost alternative is selected. Costs will include the cost of buying the material and the cost of manufacture and the cost of selling.

Some manufacturing processes such as the extrusion or pressing of metals use more energy to produce the product than many plastic processing methods. This will tend to make the metal option more expensive. The manufacturing costs will depend upon the costs of preparation and finishing, the chemicals and services consumed and the size of the production area.

MATERIAL COSTS FOR A WOODEN TOY



Cost of buying the wooden parts (purchase prices)

Cost of cutting out shapes (labour and tools)

Cost of marking out and machining (labour and tools)

Cost of finishing before paint spraying (labour and chemicals)

Cost of spraying (labour and paints)

Cost of quality checks (labour and wastage or reworking)

Cost of packaging (labour and materials)

Examiner's Top Tip
Remember to consider both service and manufacturing properties when selecting materials for a product.

MATERIAL AVAILABILITY

Materials are generally available as standard sections and parts. Metals come in: plates, strips, bars, tubes, angle irons and channels. Woods come in: dowels, sheets, planks and squares. Plastics can come in a range of forms from films and rolls to sheets and granules. Designs are often influenced by what sectional shapes are available from suppliers.

ENVIRONMENTAL CONSIDERATIONS

The following factors should influence selection:

Whether the material is a scarce resource and its use will deplete them further (e.g. using some hardwoods).

Whether the material will be harmful to the persons using it (e.g. lead-based paints).

Whether the material is disposable after use (e.g. using biodegradable materials are more environmentally friendly than non-biodegradable materials).

Whether the material can be easily recycled (e.g. steel scrap can be recycled easily).

QUICK TEST

1. State two material selection factors.
2. Why are manufacturing requirements important?
3. What factors can make up material costs?
4. State two environmental considerations when designing

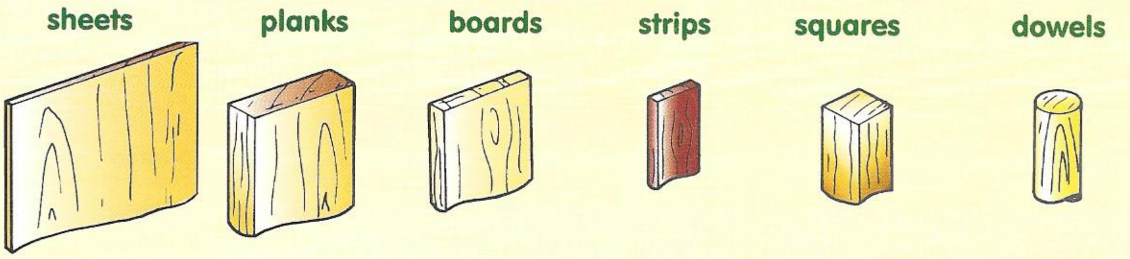
1. Needs of the product, manufacturing properties and service properties.
2. So that the material chosen can be processed easily and cheaply.
3. Cost of buying parts, cost of cutting, cost of marking out and machining, cost of finishing, etc.
4. Are the materials used a scarce resource? Can the material be harmful? Can the product be recycled? Is the product biodegradable?

MATERIAL FORMS

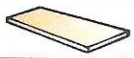
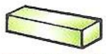
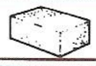
SHAPES AND SIZES

Materials are available in a number of standard stock sizes. Manufacturers' catalogues give the ranges available. Softwood timbers are sold in a range of machined sizes. Hardwoods tend to be sold by volume. Plastics are available in a range of forms including sheets, foams and extrusions. Metals are available in a range of different cross-sections.

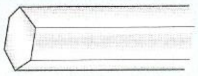
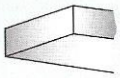
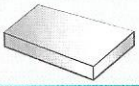
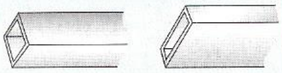
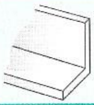
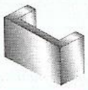
TIMBER



PLASTICS

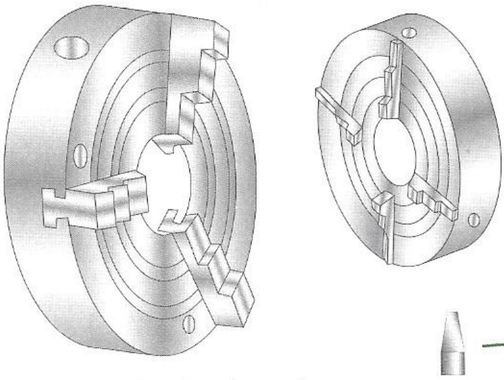
Material form		Examples of where used
films		labels, stickers and wrappers
sheet		vacuum forming or line bending
hexagonal bar		general work
square bar		general work
rods		general work
tube		general work
resins		reinforced plastics hand lay-ups
powders		injection moulding
granules		injection moulding
foams		for packaging and insulation

METALS

hexagonal bar		*flat bar*	
sheet		*square and rectangular tube*	
angle sections		*round tube*	
round bar		*channel*	
square bar		*I-sections*	

Steel sections come in either black mild steel or bright drawn mild steel (BDMS). Black mild steel has a black appearance and its dimensions are not too accurate. It tends to be used for forge work. Bright drawn mild steel has been drawn through dies to give an accurate finish.
It can be used directly in machine vices and lathe chucks and provides a good datum surface for marking out.

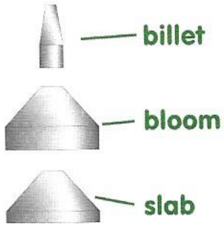
Hexagonal bars and round bars can be placed directly in three jaw chucks on centre lathes.



Square bars and rectangular bars require four jaw chucks.

Examiner's Top Tip
Look in suppliers' catalogues to identify common forms and sizes of stock materials.

During the steel-making process semi-finished products include billets, blooms and slabs.
These go on to produce some of the standard stock sections by rolling or tube manufacture.



QUICK TEST

1. Name three forms of timber.
2. What is meant by the term BDMS?
3. How might black mild steel be used in the school workshop?
4. Name three types of semi-finished steel-making products.
5. State one use each for plastic sheet, films and granules.

1. From sheets, planks, boards, strips, squares or dowels.
2. Bright drawn mild steel.
3. For forge work.
4. Billets, blooms and slabs.
5. Vacuum forming, labels or stickers, injection moulding.

METALS

TYPES OF METALS

Metals are classed as either ferrous or non-ferrous.
Ferrous metals contain iron.
Non-ferrous metals do not contain iron.
In general ferrous metals tend to corrode and therefore need some form of protection against corrosion.
Non-ferrous metals do not tend to corrode in the same way.

PURE METALS

Pure Metals

- Aluminium, non-ferrous
- Copper, non-ferrous
- Tin, non-ferrous
- Lead, non-ferrous
- Zinc, non-ferrous
- Pure iron, ferrous

METALS AND ALLOYS

Metals are available in pure or alloy form.

Pure metals, such as pure aluminium or pure copper, contain only one type of metal. They are not mixed with any other metal.

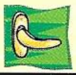
Alloys are mixtures of two or more pure metals.

Alloys tend to have better strength properties than pure metals.

Alloys and pure metals often have special physical properties. For example, pure copper is used where electrical conductivity is required; tin and copper alloy is used for making bronze objects.

NON-FERROUS ALLOYS

Some common non-ferrous alloys:

Material	Composition
brass	copper and zinc 
bronze	copper and tin  
duralumin	aluminium and copper 
solder	tin and lead

FERROUS METALS

The range of ferrous metals includes plain carbon steels, tool steels, stainless steels and cast irons.

***Plain carbon steels* are mixtures (alloys) of *iron* and *carbon*. The *carbon content* varies from about 0.01% up to about 1.5%.**

***Tool steels* are special steels, which are alloys of iron and carbon but with other additions such as *tungsten*. This helps to increase their *wear resistance*.**

***Cast irons* are alloys of iron and contain around *3.5–4.5% carbon*. They are generally used in *sand-cast products*.**

Stainless steels do not corrode. They are used for applications such as sinks and kitchen utensils. Stainless steels are alloys of iron and carbon but also contain chromium or nickel. These additions give it its anti-corrosive properties.

PLAIN CARBON STEELS

Plain carbon steels are alloys of iron and carbon. They can be divided up into three main groups: mild steel, medium carbon steel and high carbon steel.

Mild steels have 0.15–0.35% carbon
Medium carbon steels have 0.35–0.7% carbon
High carbon steels have 0.8–1.5% carbon

Increasing the carbon content in the steel increases its hardness increases its toughness but reduces its ability to be cold-worked.

Examiner's Top Tip
Gain an understanding of how ferrous metals can be protected against corrosion using different methods for different applications.

USES OF FERROUS METALS

Material	Uses	Notes
Cast iron	Vices, lathe beds, kitchen pots	Hard skin. Strong under compression. Cannot be bent or forged.
Mild steel	Nuts and bolts, screws, car bodies	Tough, ductile and malleable. Easily joined but with poor resistance to corrosion. Cannot be hardened or tempered.
High carbon steel	Tools	Very hard, but less ductile, tough and malleable. Difficult to cut. Can be hardened and tempered.
Stainless steel (alloy)	Kettles, sink surrounds, cutlery	Hard and tough. Resists wear and corrosion. Quite difficult to cut or file.
High-speed steel (alloy)	Drill bits	Very hard. Can be used as a cutting tool even when red-hot. Can only be shaped by grinding.

USES OF NON-FERROUS METALS

Material	Uses	Notes
Aluminium	*Saucepans, window frames*	*High strength/weight ratio. Difficult to join. Good conductor of heat and electricity. Corrosion-resistant. Polishes well.*
Copper	*Wire, piping, circuit board*	*Malleable and ductile. Good conductor of heat and electricity. Easily joined. Polishes well. Expensive.*
Lead	*Car batteries*	*Very heavy, soft, malleable and ductile. Corrosion-resistant. Low melting point. Difficult to work and expensive.*
Tin (tin plate)	*Food cans, biscuit tins*	*Soft and weak. Ductile and malleable. High corrosion resistance. Low melting point. Used to coat steel to produce 'tin plate'.*

QUICK TEST

1. Name two types of pure metals.
2. What two metals make up brass?
3. What two metals make up solder?
4. Name three ferrous metals.
5. What are stainless steels used for?
6. Name the three categories of plain carbon steels.
7. Give some uses for cast iron.
8. What effects does increasing the carbon content have on the properties of plain carbon steels?

1. Aluminium, tin, copper, lead, pure iron, zinc (any two)
2. Copper and zinc
3. Tin and lead
4. Stainless steel, cast iron, mild steel, tool steel, medium carbon steel, high carbon steel (any three)
5. Sinks, baths, kitchen utensils and other applications where corrosion resistance is important.
6. Mild/low carbon steel, medium carbon steel and high carbon steel.
7. Vices, lathe beds, some kitchen pots, car cylinder blocks.
8. It increases hardness, increases toughness and decreases the ability to be cold-worked.

HEAT TREATMENT PROCESSES

CHANGING THE PROPERTIES OF METALS

The properties of some metals can be altered by heat treatments.
Heat treatment processes may be used to improve the properties of the metal.
They are also used to help soften the metal for use in processes such as cold rolling, cold extrusion and wire drawing of metals.
During heat treatment the metal is heated and cooled in a controlled way to give the required properties.

HEAT TREATMENT

The main heat treatment processes are:
The annealing of non-ferrous and ferrous metals to make them less brittle.
The normalising of medium carbon steels to make them more stable.
The hardening and tempering of steels above 0.4% carbon content to improve toughness on impact.
The case-hardening of mild steels to improve strength.

HARDENING AND TEMPERING

HARDENING AND TEMPERING

Hardening and tempering of steels can only be used for steels that have a carbon content greater that about 0.4%. Steels that have less than this amount can however be case-hardened.
Hardening and tempering is used to increase the hardness of products such as chisels, hammers, scribers, centre punches and hacksaw blades. The process is also used to give springs their 'springiness'. Components are first hardened and then tempered. Tempering reduces the brittleness that results from the hardening process. Products are therefore more reliable in service.

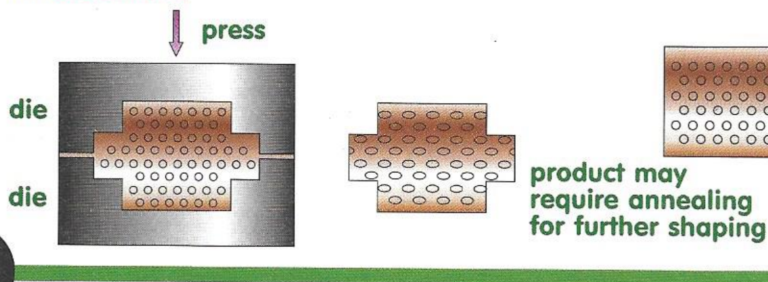
WORK HARDENING

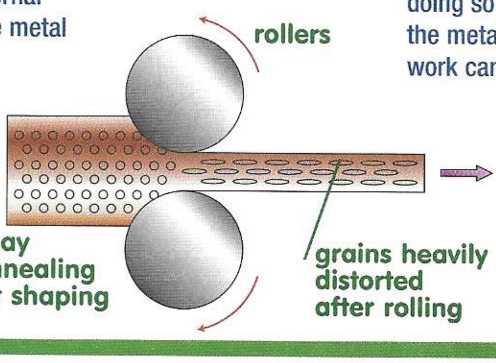
When a metal is hammered, rolled, squeezed or pulled through a die it will tend to become harder. As the metal hardens it becomes more difficult to work with. It will eventually become so hard that no more work can be carried out without it cracking or breaking. Annealing softens the metal so that further cold work can be carried out. Annealing can be carried out in the school workshop using a brazing torch. In industry it tends to be carried out using furnaces at the required annealing temperature.

FORGING AND ROLLING

When a cold metal is squeezed during forging or rolling its internal grain structure distorts. The greater the distortion the more the metal will work-harden.

Annealing will change the distorted grains back to their original shape. In doing so it will re-soften the metal and further cold work can be carried out.





ANNEALING

***Annealing** is a heat treatment process which is used to **soften a metal** once it has become **work-hardened**. Annealing can also be used to reduce **internal stresses** which occur during **cold work**.*

ANNEALING TEMPERATURES

Annealing temperatures for some common metals are given in the table.
The temperatures show furnace settings for the correct treatment. The colours give an approximate indication of the temperatures reached when using a brazing torch in the school workshop.

TYPE OF METAL	ANNEALING FURNACE SETTINGS (°C)	COLOURS FOR USE WITH BRAZING TORCH	HOW COOLED
Non-ferrous metals			
Copper	500	Heat to a dull red	In air
Brass	560	Heat to a dull red	In air
Aluminium	370–410	Cover the metal with soap. When the soap turns black the correct annealing temperature has been reached	Leave to cool slowly
Ferrous metals			
Steel	730	Heat to a cherry red	Cool slowly in a furnace

NORMALISING

Normalising is an industrial process used to improve the **strength** and **toughness** of products when they have been **forged** or **rolled**. Normalising improves the internal structure of the metal and reduces the **internal stresses** that have been produced by **hot working**. The temperature at which the steel is heated depends upon the **carbon content** of the steel. After heating the steel is cooled in air.

QUICK TEST

1. What is meant by the term 'heat treatment'?
2. Name four heat treatment processes
3. What is meant by 'annealing'?
4. What materials are normalised?
5. How can household soap be used to indicate the correct annealing temperature of aluminium?
6. What do the colours indicate when tempering with a brazing torch?
7. Which metal is usually hardened by case hardening?

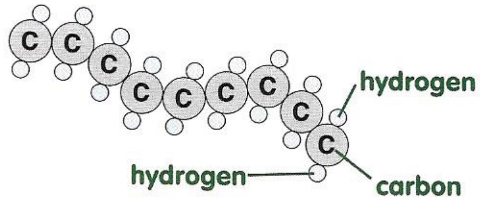
1. Heating and cooling a metal in a controlled way to alter its properties.
2. Annealing, normalising, hardening and tempering and case-hardening.
3. To soften a metal after it has work hardened.
4. Steels.
5. When it turns a black.
6. The temperature the metal is at.
7. Mild steel.

PLASTICS

Plastic materials can be classed as either thermoplastics or thermosetting plastics. Thermoplastics have the ability to return to their original shape when reheated. This is termed plastic memory. Thermosets cannot be reformed when reheated. Thermoplastics can be recycled in manufacturing processes such as injection moulding. Thermosetting plastics cannot be recycled in this way. Thermosetting plastics can generally withstand higher operating temperatures than thermoplastics.

THE STRUCTURE OF PLASTICS

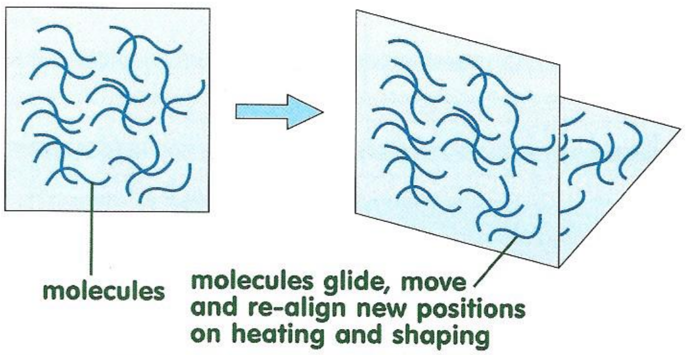
Plastic materials are made up of many long chain molecules called polymers. These consist of a 'backbone' of carbon atoms with other types of atoms attached to it. These may be hydrogen, oxygen, chlorine or nitrogen atoms. Different types of plastics have different arrangements of atoms attached to the main backbone. A plastics material will have many thousands of individual polymer chains which are held together by the atomic forces between the chains.



atomic structure of polythene

THERMOPLASTICS

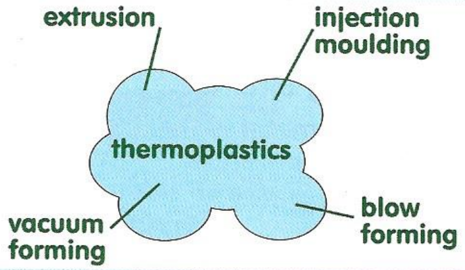
When a thermoplastic is heated and reshaped the atomic bonds between the molecules are weakened. The molecules can then slide, move and re-align themselves into new positions. If the plastic is re-heated the bonds can be weakened again. This will allow further re-shaping or a return to its original shape.



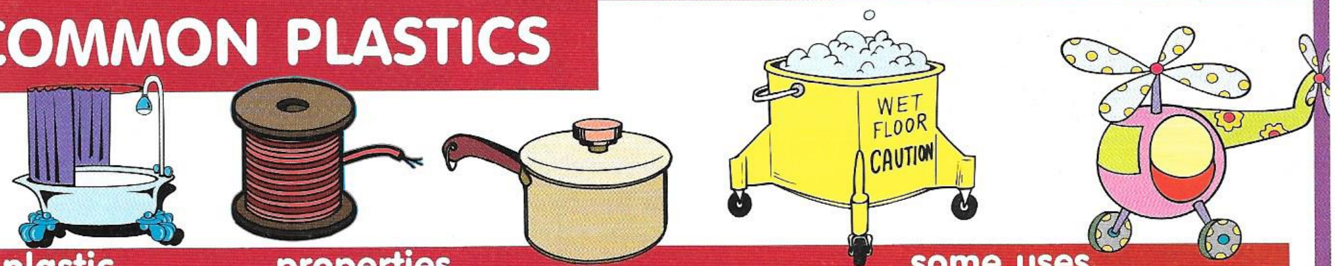
THERMOSETTING PLASTICS

In order for thermosetting plastics to be formed they need to go through a curing stage. During curing molecular links are formed between the original long chain molecules. This is termed cross-linking. Cross-linking is irreversible and so thermosetting plastics cannot be re-formed once curing has taken place. Because of cross-linking thermosetting plastics tend to be more rigid than thermoplastics. They can also withstand higher operating temperatures.
Because thermosets need to have a curing stage during moulding they are manufactured by compression moulding or transfer moulding.

PRODUCTION PROCESSES FOR THERMOPLASTICS



COMMON PLASTICS



plastic	properties	some uses
Thermoplastics		
Acrylic	Hard and stiff. Can be clear (Perspex™). Scratches easily. Good electrical insulator. Can be coloured.	windows, lighting units, baths.
Polystyrene	Good resistance to moisture. Can be used with foodstuffs. Light and stiff. Can be used in expanded form for packaging.	packaging, disposable plates and cups, picnic boxes, model toys
Nylon	Hard and tough. Good machining qualities, low frictional properties. Good chemical resistance.	knock-down fittings, bearings, gears and ropes
Polythene	Good chemical resistance and tough. Good strength properties. Good electrical insulator.	detergent bottles, carrier bags, outside cover of cables, food packaging
Polypropylene	Good chemical resistance. Tough with good strength properties. Can have a wide range of colours. Can have either a high or low density.	string, rope, milk crates, kitchenware, chairs, buckets, baths,water pipes
PVC (polyvinyl chloride)	Stiff, hard and tough. Good resistance to chemical attack. Good electrical insulating properties. Wide colour range available.	pipes and gutters, window frames.
ABS	High impact strength. Tough. Withstands scratching. Resistant to chemicals.	safety helmets, casing for household goods, car parts
PTFE	Low frictional properties. Tough. Good chemical resistance Used for bearing surfaces	surface for non-stick pans, plumbers' tape,
Thermosetting plastics		
Polyester resin	Hard, strong and brittle. Good electrical and heat insulating properties.	used with reinforced plastics for boat hulls and chemical vessels
Urea-formaldehyde	Hard, stiff and brittle. Good electrical and heat-resistant properties.	electrical fittings, electrical switches
Melamine formaldehyde	Hard, stiff. Resists scratching. Good heat-resistant properties. Stain-resistant. Good range of colours available	work surfaces, kitchenware.

QUICK TEST

1. What is meant by thermoplastic material?
2. Name two types of thermosetting plastics materials.
3. Name two types of thermoplastics materials.
4. What happens to a thermosetting plastic when it is cured?
5. State two production processes used to form thermoplastics.
6. Name a production process used to form a thermosetting plastics.
7. Give a use for polystyrene.
8. Give a use for PVC.
9. State two advantages of using plastics.

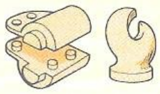
1. A plastic that can return to its original shape when re-heated.
2. From polyester resin, urea-formaldehyde or melamine formaldehyde.
3. Nylon, acrylic, polystyrene, polythene, polypropylene, PVC, ABS or PTFE.
4. Molecular cross-links are formed.
5. Injection moulding, blow moulding, vacuum forming or extrusion.
6. Compression moulding or transfer moulding.
7. Packaging, disposable plates and cups, picnic boxes and model toys.
8. Pipes and gutters and window frames.
9. Can be coloured, does not corrode, resistant to chemical attack, good electrical insulator, can be formed at low operating temperatures.

WOODS

Wood can be divided into natural and man-made timbers. Natural timbers are further sub-divided into hardwoods and softwoods. Man-made timbers include plywood, MDF and blockboards. Hardwoods come from broad leaf trees, many of which shed their leaves in autumn. Softwoods come from coniferous trees. All timbers require protection against rotting and fungal disease.

HARDWOODS AND THEIR USES

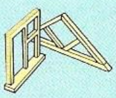
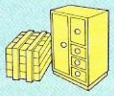
The terms 'hardwood' and 'softwood' are not physical classifications which refer to hardness of the wood. They are biological classifications. Hardwoods come from trees which carry their seeds in the form of fruit. Softwoods come from cone-bearing trees. Some hardwoods are soft to work. Common examples are willow and balsa wood. Hardwoods are slow-growing, taking many decades to reach maturity. They are more expensive than softwoods and take longer to re-grow.

Wood	Typical uses	Wood	Typical uses
Mahogany 	indoor furniture, shop fittings, veneers	Teak 	quality furniture, veneers, boat building
Beech 	chairs, workbenches, tools	Jelutong 	patterns for moulds, product models
Ash 	tool handles, hockey sticks, ladders	Balsa 	modelling
Oak 	garden furniture, high-quality indoor furniture, boat hulls	Willow 	sports equipment, outdoor wicker work

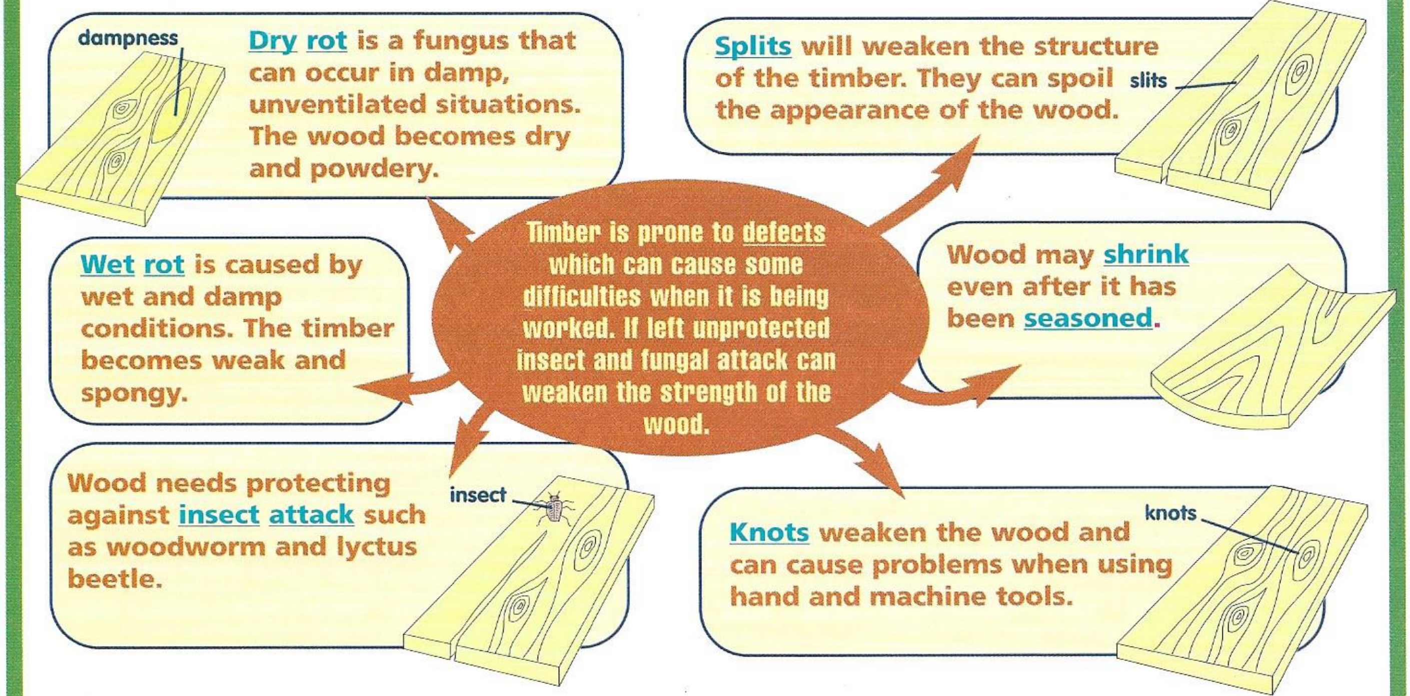
Examiner's Top Tip
Learn some uses for common hardwoods and softwoods.

SOFTWOODS AND THEIR USES

Softwoods come from coniferous trees, which reach maturity in around 30 years. This allows them to be replaced at a far faster rate than hardwoods. This is better for the environment and also reduces the cost. Softwoods tend to be used much more than hardwoods.

Wood	Typical uses	Wood	Typical uses
Scots pine 	constructional work and joinery	Western red cedar 	wall panels, out door furniture, sheds and fences
Spruce 	general indoor work, furniture	Parana pine 	good quality joinery, staircases and built-in furniture

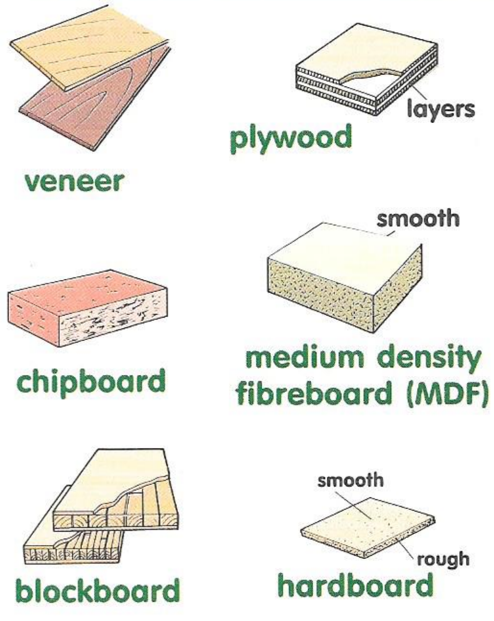
TIMBER



MANUFACTURED BOARDS

Advantages of using man-made boards

- Available in large sheets of uniform thickness.
- Not affected by humidity.
- Can be used with veneers.
- Do not have a grain structure.
- More easily worked than natural timbers.
- Can be easily joined with knock-down fittings.



QUICK TEST

1. What are the two main divisions of timber products?
2. Name two types of hardwoods.
3. Name two types of softwoods.
4. What classification is balsa wood?
5. State a use for ash.
6. State a use for Scots pine.
7. Name two defects that may be found in timbers.
8. State two advantages of using man-made boards.

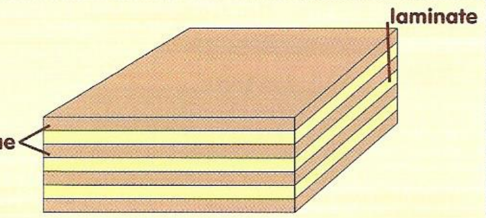
1. Natural and man-made.
2. Mahogany, beech, ash, oak, teak, jelutong or willow.
3. Scots pine, spruce, western red cedar or Parana pine.
4. Hardwood.
5. Tool handles, hockey sticks or ladders.
6. Constructional work and joinery.
7. Shrinkage, knots, splits, dry rot, wet rot or insect attack.
8. Available in large sheets, can be veneered, do not have a grain structure, easily joined, not affected by humidity.

COMPOSITE MATERIALS AND SMART MATERIALS

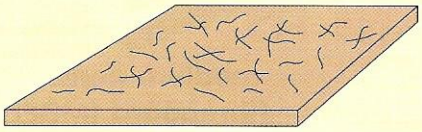
MODERN REPLACEMENT MATERIALS

Composites are now being widely used as replacements for metals and plastics.
Two of the main types are fibre-reinforced composites and sandwich beam constructions.
Fibre-based composites consist of strong fibres such as glass, carbon or kevlar embedded in a metal or plastics matrix.
Sandwich beam constructions consist of a lightweight core material sandwiched between thin-skin materials.
Smart materials are materials whose properties can change due to changes in pressure, force or temperature.

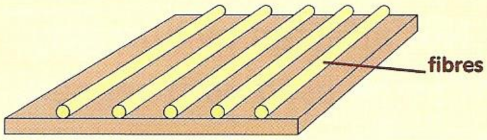
FIBRE-BASED COMPOSITES



Fibre-based composites are made up of layers of fibre embedded in a matrix material. Each layer is called a lamina (plural laminae) and a number of layers make up a laminate. Common fibres are glass fibres (fibre glass), carbon fibres and kevlar. They all have good tensile properties and their use in the composite improves the stiffness and strength of the material.
The matrix material can be either a thermoplastic or thermosetting plastic or a metal such as aluminium or titanium.

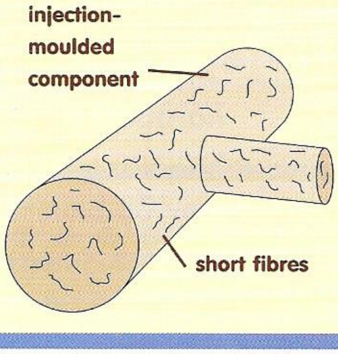


chopped strand mat
Short fibres arranged in a non-uniform way.
The chopped fibres are sprayed onto a thin sheet of matrix material to produce the laminae.

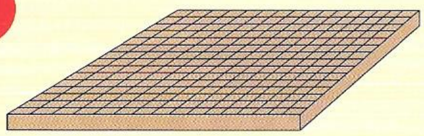


uniaxial fibres
These stretch along the axis of the material.

types of reinforcement

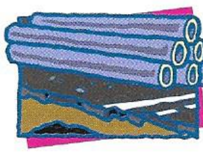


short random fibres



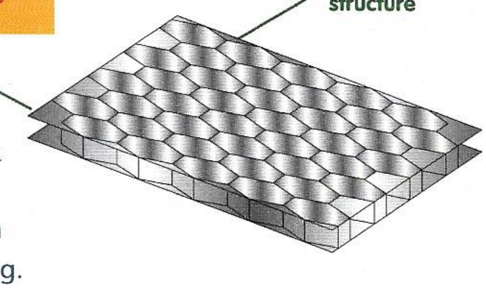
woven mats

USES OF FIBRE-BASED COMPOSITES

Sports equipment
Chemical vessels and pipework
Transport applications
Boat hulls
Bullet-proof vests
Crash helmets
Aircraft parts

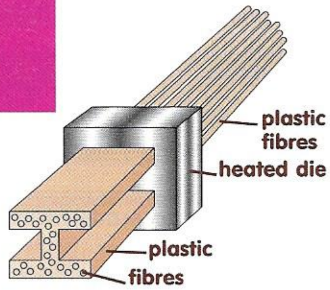

SANDWICH CONSTRUCTIONS



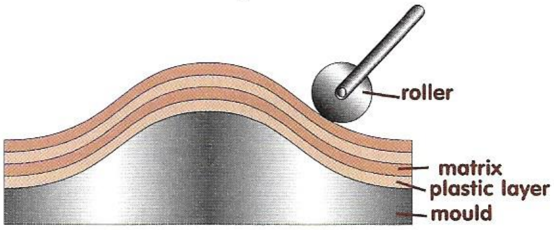
Sandwich constructions are used in many transport applications. A common type is a lightweight core material such as paper or aluminium honeycomb sandwiched between two tough outer skins. The skins are bonded to the core material by a strong adhesive. This construction is used in many aircraft structures and in house doors. These structures are lightweight as well as being strong.

SOME METHODS OF FIBRE COMPOSITE MANUFACTURE

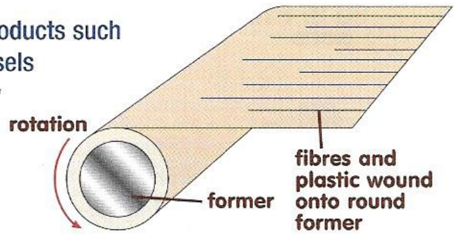
Pultrusion where constant cross sections of fibre and matrix can be pulled through dies.



Hand lay-up where alternative composite layers are moulded onto a former. This method can be used in school workshops.

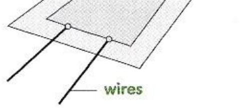


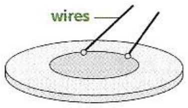
Filament winding where products such as pipes and chemical vessels are produced automatically on a filament-winding machine.



SMART MATERIALS

Smart materials have properties which can alter in response to an input.
They are mainly used for sensors.
The main types are piezoelectric sensors and shape memory alloys.
Piezoelectric sensors produce an output voltage when squeezed. Typical uses are burglar alarm pressure sensors.
Shape memory alloys are able to change their shape in response to changes in temperature. One application is in glasshouse window openers. Here the material responds to changes in temperature and is as part of the ventilation mechanism.





examples of piezo actuators

QUICK TEST

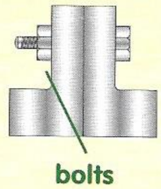
1. Name two types of composite materials.
2. Name two types of smart materials.
3. Give two uses of fibre-based composites.
4. Give a use for smart materials.
5. State two methods of manufacturing composites.
6. Give two advantages of using composite materials.

1. Fibre composite and sandwich beam.
2. Piezoelectric and shape-memory alloys.
3. Sports equipment, pipework, transport applications, boat hulls, bullet-proof vests, crash helmets or aircraft parts.
4. Burglar alarm sensors and parts of greenhouse window openers.
5. Hand lay-up, pultrusion and filament winding.
6. Light weight, good strength-to-weight ratio, good corrosion resistance, easily manufactured.

COMPONENTS AND ADHESIVES

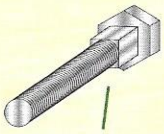
Standard components such as **nuts**, **bolts**, **set screws** and **washers** are used in the assembly of products and systems. They also include **gears**, **pulleys** and **bearings**. **Standard components** are usually **bought in** from suppliers. Buying in standard components tends to be a **cheaper option** than manufacturing them individually. Most standard components are classified as **temporary fixings**. These can be **taken apart** if required. **Adhesives** form **permanent joints**. Adhesives can be used to **bond metals**, **plastics** or **wood materials**.

TEMPORARY FIXINGS



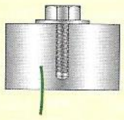
bolts

Bolts tend to made from mild steel. High tensile steels are used for higher strength applications. The thread of a bolt does not go all the way to its head.



coach bolt

Coach bolts are used for attaching metal parts to wood. They have a domed head with a square underneath. The square embeds in the wood and acts as a locking device.

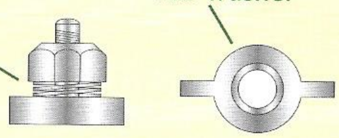


set screws

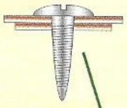
Set screws have threads that go the whole way along its length. They tend to be used where an accurate assembly of parts is required.

spring washer

tab washer



Washers protect the surfaces from damage when nuts are tightened up. Spring washers and tab washers may be used to make the nuts more secure.

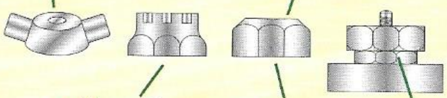


self-tapping screw

Self-tapping screws are made from hardened steel. They cut their own thread when they are screwed in to pre-drilled metal. They are generally used for joining together sheet metal parts.

wing nut

fibre insert



castle nut

locknut

locknut

There are many types of nuts which can be used with set screws and bolts.
Castle nuts are used with a split pin to lock it place. Locknuts have nylon inserts to prevent them from working loose due to vibrations. Thin lock nuts can be used with a standard nut to prevent it from working loose.

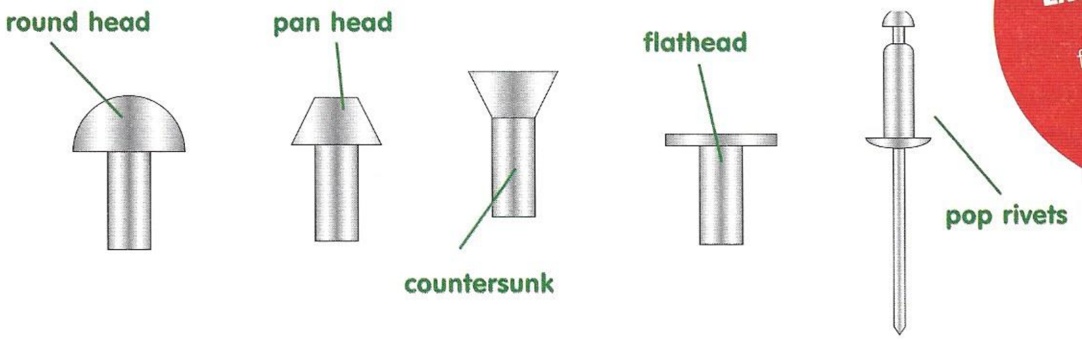
TAPPING DRILL SIZES

When internal threads are produced using taps the holes are drilled using an appropriate tapping drill size. Clearance holes are used to ensure that the bolts and set screws fit through holes without interference.

thread size (mm)	tapping drill size (mm)	thread size (mm)	tapping drill size (mm)
3	2.5	10	8.5
4	3.3	12	10.2
5	4.2	14	12.0
6	5.0	16	14.0
8	6.8		

PERMANENT FIXINGS

Examiner's Top Tip
Be able to sketch fastening devices in some detail.



Rivets are one type of standard component which gives a permanent fixing. They can be used to join metals or plastics together. Standard rivets can have a round head, flat head, pan head or be countersunk. Pop rivets are used to join sheet materials together.

ADHESIVES

Adhesives can either be natural or synthetic. Synthetic types tend to be toxic and have to be handled with care. Contact adhesives are used for large surface areas.

Adhesive	Use
Polyvinyl acetate (PVA)	White wood glue. Easy to use. Not waterproof.
Synthetic resin (Cascamite)	Used to glue wood. Stronger than PVA. Supplied as powder and mixed with water. Good waterproof properties.
Epoxy resin (Araldite)	Can be used on metals, wood and plastics. It is a two-part glue which needs to be mixed together.
Acrylic cement (Tensol)	Used to bond together certain plastics.

Good adhesive joints depend upon:
- Ensuring that the gluing surfaces are clean and free from dirt and moisture.
- Using the correct adhesive for the job.
- Using clamps to apply pressure to the joints.
- Cleaning the excess adhesive from the joints prior to setting.

QUICK TEST

1. Name three types of standard components.
2. Name the type of bolt used for attaching metal parts to wood.
3. Name two types of nuts.
4. What are spring washers used for?
5. Name two types of rivet head.
6. What is Tensol cement used for?

1. Nuts, bolts, set screws, washers, self-tapping screws, bearings and gears.
2. Coach bolt.
3. Wing nut, locknut or castle nut.
4. To stop nut and bolt working loose if vibrated.
5. Round head, flat head, pan head or countersunk.
6. Bonding certain plastics.