Name:

International
SCHOOL OF LONDON
Qatar

DP DESIGN TECHNOLOGY

TOPIC 4

RAW MATERIAL TO FINAL PRODUCT

NOTES & GUIDANCE BOOKLET

2021-2023

This booklet contains the Notes, and teaching support material for Topic 4

DP DESIGN WITH

MR MONEEB

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Teaching & Learning Presentations

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Topic 4.1: Materials and their properties

Essential Idea
Materials are selected for manufacturing based on their properties.

Nature of Design
The rapid pace of scientific discovery and new technologies has had a major impact on material science, giving designers many more materials from which to choose for their products. These new materials have given scope for “smart” new products or enhanced classic designs. Choosing the right material is a complex and difficult task with physical, aesthetic, mechanical and appropriate properties to consider. Environmental, moral and ethical issues surrounding choice of materials for use in any product, service or system also need to be considered .

Aim
Materials are often developed by materials engineers to have specific properties. The development of new materials allows designers to create new products, which solve old problems in new ways. For example, the explosion of plastic materials following the second world war enabled products to be made without using valuable metals.

Concepts and principles

- Physical properties: mass, weight, volume, density, electrical resistivity, thermal conductivity, thermal expansion and hardness
- Mechanical properties: tensile and compressive strength, stiffness, toughness, ductility, elasticity, plasticity, Young’s modulus, stress and strain
- Aesthetic characteristics: taste, smell, appearance and texture

Guidance
- Design contexts where physical properties, mechanical properties and/or aesthetic characteristics are important
- Using stress/strain graphs and material selection charts to identify appropriate materials

4.1 Properties of materials

All Resistant Materials have **Physical** and **Mechanical** properties that make them ideally suited for particular products.

- **Physical properties** are those that refer to the actual matter that forms the material

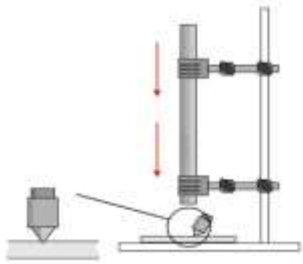
- **Mechanical properties** are those that determine how a material reacts to external forces

Hardness

Hardness is the ability of a material to withstand scratching, cutting and abrasion.

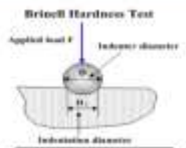
- What types of products might need to be hard?
- What materials are they made from?

Cutting tools such as drill bits usually made out of high speed steel because they are hard and much more resistant to heat
Ceramic floor tiles are extremely hard and resistant to scratching.



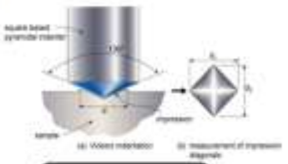
How to test hardness

A hardened steel ball is dropped into the material's surface. The indent is measured using a microscope and used to calculate the hardness number



Brinell

Uses a diamond pyramid to indent the materials. Measured using a microscope to give the hardness value.



Vickers

Used for finished products. Quick test with the hardness being shown on a screen https://www.youtube.com/watch?v=G2JGNIlvNC4

Rockwell

Thermal conductivity

Test – Fill two cups with boiling water and put a metal spoon in one and a wooden spoon in the other. Leave for one minute and feel the end of each spoon.

Thermal conductivity can be described as how easily heat energy can pass through a material.

Aluminium is an efficient conductor of heat, which makes it a popular choice when manufacturing pots and pans.

Thermal insulators are materials with low thermal conductivity, such as pan handles and loft insulation.

Conductors
Insulators

Electrical conductivity

Test – Simple electrical circuit – trialling a range of materials conductors/insulators

Electrical conductivity is how easily electrical energy can pass through a material.

Gold is an excellent conductor of electricity, and is used in high-end electrical components.

Conductors
Insulators

Thermal expansion

Is a measure of the degree of increase in dimensions when an object is heated.It is important when two dissimilar materials are joined. These may then experience large temperature changes while staying joined. Different material expand at different rates.

Why is thermal expansion so important in bridge building?

In large civil engineering projects such as bridges allowance has been made for movement caused by seasonal variations of temperature.

Mass

Is the amount of matter that a body contains.
Mass is different to weight and is measured in kg (this can be confusing).
Mass is a constant.
Weight varies depending on where it is measured due the graviton force that is exerted on it. Someone ways less on the Moon than they do on Earth

Aluminium mass - 2560 kg per m3
Stainless steel mass - 7480 kg per m3
Plywood mass - 600 kg per m3
Acrylic mass - 1180 kg per m3
Pine mass- 530 kg per m3
Polypropylene mass- 950 kg per m3
Copper mass - 8930 kg per m3

Weight

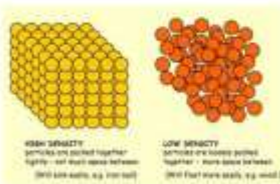
The gravitational force exerted on a body.
Mass (kg) and gravitational forces (m2) are used to calculate a measurable value, a force.
A mass of 1 Kg is equivalent to 9.8 Newton on (some parts of) earth.
Weight is measured (units are) in Newton (kg-m2)

Aluminium weight – 25088N
Stainless steel weight - 73304N
Plywood weight - 5880N
Acrylic weight - 11564N
Pine weight- 5194N
Polypropylene weight - 9310N
Copper weight - 87514N

Density

Density is a material's mass per unit volume.
It's importance is in portability in terms of a product's weight and size.

Can you think of examples of high density materials around you in the classroom?



Expanded polystyrene is used in packaging for protecting expensive or fragile products. It is chosen due to its low density.

Match activity

Match each material physical property with the correct definition and write the definition in your worksheet.

Add one example of a material or product that has that property.

Electrical conductivity

Thermal conductivity

Density

Weight

Mass

Thermal expansion

Hardness

Mechanical properties

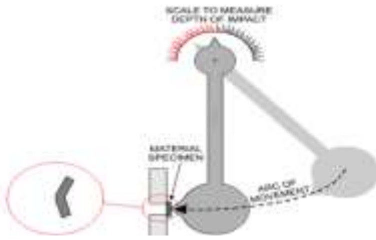
Mechanical properties are those that determine how a material reacts to external forces.

Toughness

Toughness can be described as a material's ability to withstand impact from a dynamic force.

Name examples of products that need to be tough?

Car bumpers are designed to resist impact. Children's toys are subjected to wear and tear, and need to be tough.



How to test toughness

Izod

Charpy

Houndsfield

https://www.youtube.com/watch?v=tpGhqQyftAo

How to test toughness

Test pieces have been standardised for each test. Explain why?

The more the sample piece absorbs the impact the tougher the materials

Elasticity

Elasticity is a measurement of a material's ability to stretch under force and return to its original shape without deformation when the force is removed.

Why do sportspeople wear fabrics that have elasticity?

Ductility

Ductility is a material's ability to be drawn or pulled in to a long length or wire without breaking.

Application of heat to a number of materials can alter their ductility.

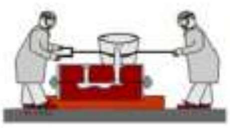
Think about electrical wires. As well as ductility, what other properties do they need?

Electrical conductivity and corrosion resistance.

Plasticity

Highly Plastic ⟷ Brittle

Materials which deform permanently when small forces are applied show plasticity. Metals and thermoplastics are generally more plastic when heated.



Blow moulding- requires plasticity to shape and form

Starck's Salif - cast juice

Plasticine and clay are examples of materials with good plasticity.

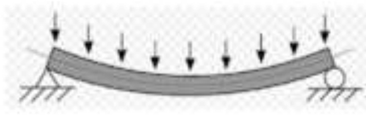
Soft metals like copper are highly 'plastic.' They are easy to hammer into a new shape or draw out into a wire. High-speed steel tools made for cutting have a very low plasticity. They are brittle.

Stiffness

The resistance of an elastic body to deflection by an applied force. It is important for maintaining shape is an important performance.

Examples are aircraft wing, diving boards or panels on cars, roof beams, bicycle frames

Stiffness and wing flex – Check out the blog

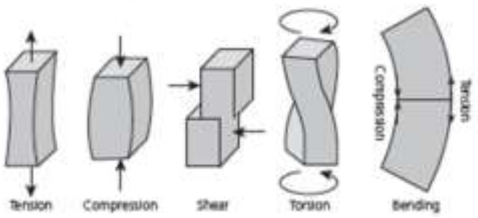


Stiffness- resistance to deflection

Strength

Strength is the ability of a material to withstand a constant force without breaking.

There are five forces that can act upon a material.



Tensile strength

The ability of a material to withstand pulling (apart) forces.It is important in selecting materials to resist stretching. Examples ropes (climbing or towing) and cables (in elevators and bridges).

Compressive strength

The ability of a material to withstand 'squashing' forces. Design Examples are ceramic floor tiles, concrete and bricks for buildings or anything that requires to bear weight.

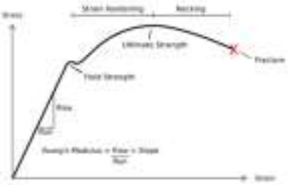
How to test tensile strength

A standard test piece is held between to machine vices. One vice is fixed while the other one moves vertically.

The test piece is then put under tension at a constant rate until it stretches or breaks. The distance being stretched is recorded and plotted against the load being applied – which is sensed by a load transducer fixed to the moving vice.

https://www.youtube.com/watch?v=aH9vcV7jzG0

Material	Yield strength (MPa)	Ultimate tens strength (MP
Acrylic, clear cast sheet (PMMA)	72	87
Aluminium alloy	414	483
Copper 99.9% Cu	69	220
High-density polyethylene (HDPE)	26–33	37
Polypropylene	12–43	19.7–80
Steel, stainless AISI 302 – cold-rolled	520	860
pine (parallel to grain)		40
Steel, high strength alloy	690	760
Carbon fiber (Toray T1100G ((the strongest man-made fibres)		7000 fibre alone



Stress and Strain

Stress is a measure of the force being applied per unit area of a material and is normally determined by applying a tensile force to a sample of material.

$$\sigma = \frac{F}{A}$$

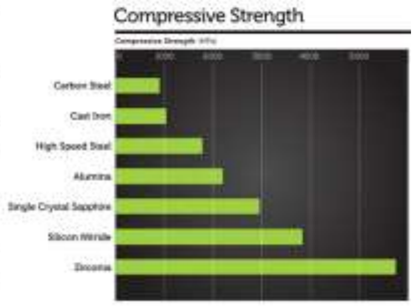
σ= stress
F= force
A= cross sectional area

$$\varepsilon = \frac{e}{lo}$$

E =strain
e = extension
lo = stretched length

Strain is the measure of the change in length occuring when under stress. After the tensile force is applied to a sample material. It is expected there will be some extension of the elongation in the sample.

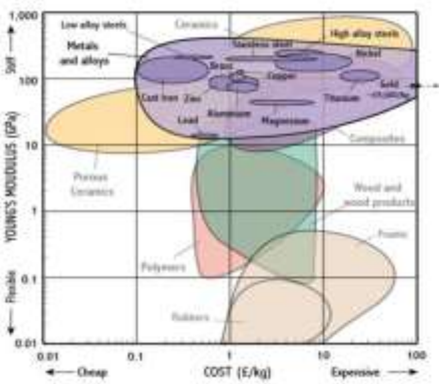
Material	Compression strength (MPa)
Porcelain	500
Bone	150
concrete	20-40
Styrofoam	~1
Bricks	80
Granite	130
Portland concrete	43
Glass	62

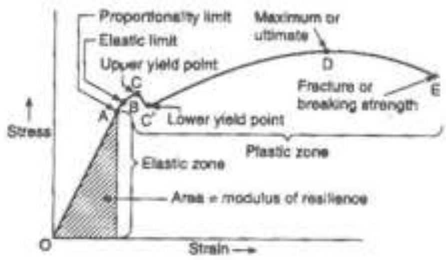


Young's modulus

Young's modulus is a measure of a material's elasticity. It is a intrinsic property of the material as it is closely related to the bonding force between the atoms.

The atoms of a material with high young's modulus are therefore more difficult to separate resulting in greater stiffness and higher melting point.



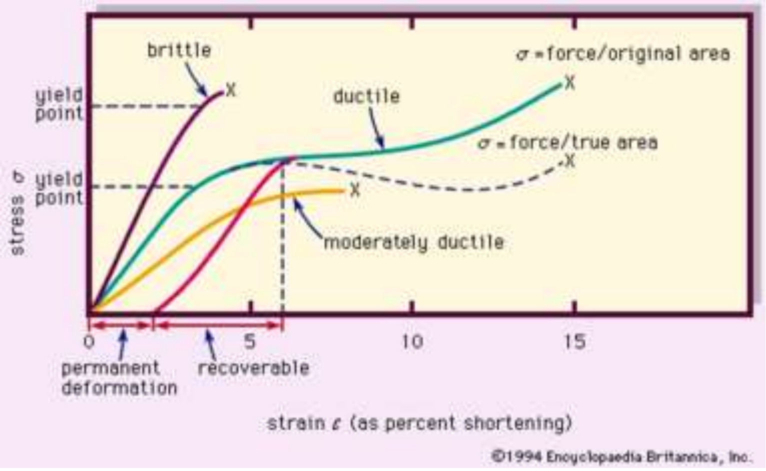


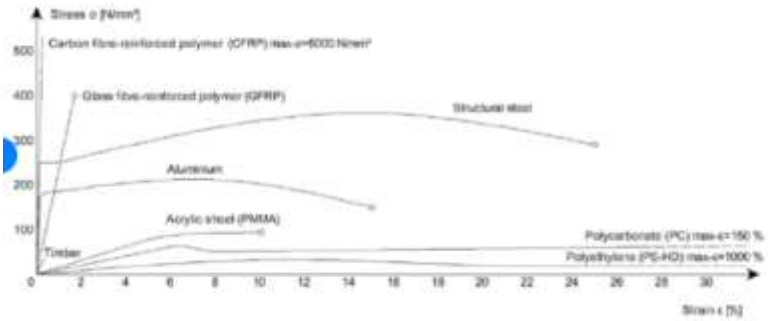
Every material will perform differently under the application of stress and strain and therefore each material's graph will be different.

How to read a Stress-Strain graph

The elastic region is generally a straight line until the yield point.

At the limit of proportionality it changes to a curved line which is plastic region until the fracture point.





Aesthetics characteristics

What determines aesthetic appeal is when a product is attractive to look at or pleasing to experience. It is ***through our senses.***

- **Smell**: the ability to perceive odours such as sweet, acrid or fragrant
- **Taste**: Sour, sweet, spicy.
- **Sound:** related to pitches but also the sound of a crisp bag - making a crinkling sound.
- **Texture**: it is how something feels or looks, it can be rough or smooth
- **Appearance**: must be aesthetically pleasing to attract a customer
- **Colour**: can be warm or cool, can have psychological affects (e.g. greens are calming)
- **Shape**: geometric or organic.

Although these properties activate people's senses, responses to them vary from one individual to another, and they are difficult to quantify scientifically, unlike the other properties.

2018 exam

14. The joints along railway tracks have noticeable gaps. This is not a design flaw as these gaps serve a purpose, see Figure 5.

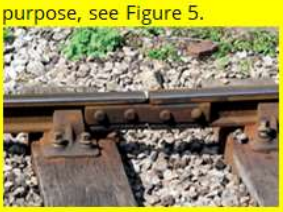


Figure 5: The gaps along railway tracks

What purpose do the gaps along railway tracks serve?

A. Easy access for maintenance
B. Allow for thermal expansion
C. Ease of transportation
D. To adjust the distance between the wooden sleepers

2017 exam

14. The glass face of a watch shown in Figure 6 needs to be hard-wearing and scratch resistant.

Figure 6: A watch with a glass face

What best describes a material with such properties?

A. Low stiffness
B. High hardness
C. Low tensile strength
D. High compressive strength

2016 exam

Figure 5 shows a comparative stress-strain diagram for four materials: A, B, C and D.

Which of the materials shown in Figure 5 is the most ductile?

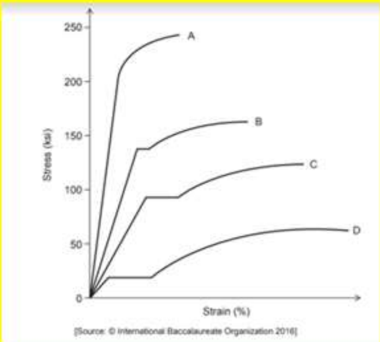


Figure 5: A comparative stress-strain diagram for four materials: A, B, C and D

2017 exam

7. Figure 11 shows a Butterfly Stool made of two identical pieces of plywood, joined in the centre with a single metal rod and connected under the seat by just two screws.

(b) Explain how the concept of stress is relevant to the design development of the metallic bar connecting the two pieces of plywood in Figure 11. [3]

Figure 11: Butterfly Stool

Stretch and Challenge Questions

Think on the properties you just tested and try to answer the questions below

The photographs show a toy for children aged 4 years and older.
Explain in detail why plastic is suitable for this toy.

The photograph below shows a sink. Explain in detail why stainless steel is suitable for the sink?

Use notes to critically evaluate the safety aspects of the kettle shown.

Topic 4.2: Metals and Metallic Alloys

Essential idea: Materials are classified into six basic groups based on their different properties.

Concepts and principles

- Extracting metal from ore - An overview of the metal extraction process is sufficient metal extraction
- Grain size - Basic principle
- Modifying physical properties by alloying,, work hardening and tempering
- Design criteria for superalloys - superalloy design criteria include creep and oxidation resistance
- Recovery and disposal of metals and metallic alloys

Guidance

- An overview of the metal extraction process is sufficient
- Super alloy design criteria include creep and oxidation resistance
- Contexts where different metals and metallic alloys are used

Aim:

Design for disassembly is an important aspect of sustainable design. Valuable metals such as gold and copper, are being recovered from millions of mobile phones that have gone out of use following the end of product life. Some laptops and mobile phones can be disassembled very quickly without tools to allow materials to be recovered easily.

Nature of design:

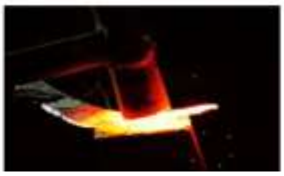
Typically hard and shiny with good electrical and thermal conductivity, metals are a very useful resource for the manufacturing industry. Most pure metals are either too soft, brittle or chemically reactive for practical use and so understanding how to manipulate these materials is vital to the success of any application.

Theory of knowledge:

How does classification and categorization help and hinder the pursuit of knowledge?

Metals

Typically hard and shiny with good electrical and thermal conductivity, metals are a very useful resource or the manufacturing industry. Most pure metals are either too soft, brittle or chemically reactive for practical use and so understanding how to manipulate these materials is vital to the success of any application. *IBO 2012*



Principles and concepts

Extracting metal from ore
Grain size
Modifying physical properties by alloying, work hardening and tempering
Design criteria for superalloys
Recovery and disposal of metals and metallic alloys

the smaller the grain size, the stronger the mate

Types of metal – more common metals shown below

Theory of Knowledge
How does classification and categorization help and hinder the pursuit of knowledge?

FERROUS ALLOYS - the group composed mainly of ferrite or iron with small additions of other substances (e.g. mild steel, cast iron, tool steel). Almost all are magnetic.

Mild Steel: Ferrous Metal. Iron 99.8% + Carbon 0.2%
- General engineering- structural steel girders
- Car body panels
- Nails, screws, nuts and bolts


Cast Iron: Ferrous Metal. Iron + 2.5 -4 % carbon
- Heavy crushing machinery
- Car brake drums or discs
- Vices or machine parts


Stainless Steel: Ferrous Metal Alloy 18% Chromium, 8% Nickel, 8% Magnesium
- Cutlery
- Kitchen Sinks
- Pots and Pans
- Surgical instruments



Tool Steel: Ferrous Metal. Iron +0.70-1.40% Carbon
- Chisels
- Handsaws
- Plane blades

High Speed Steel: Ferrous Metal Alloy. Medium Carbon steel +tungsten, chromium and vanadium
- Drills
- Lathe Cutting tools
- Milling Cutters

NON-FERROUS - the group of metals that contain no iron (e.g. copper, aluminium, lead).

Aluminium: Non – Ferrous, Pure Metal
- Window frames
- Soft drink cans
- Kitchen foil
- Engine components
- Castings

Copper: Non – Ferrous, Pure Metal
- Hot water cylinders
- Printed circuits

Tin: Non Ferrous Metal, Pure Metal
- Solder
- Tin Cans

Lead: Non Ferrous Metal, Pure Metal
-

Zinc Non – Ferrous, Pure Metal
- Galvanising – a protective covering for railings
- Negative battery terminal Batteries
- Die casting

Sources of metals

- Most metals are mined straight out of the ground in the form of ores. Ore is any part of the Earth's crust, often a mixture of rocks, loose soil and other earthly materials, from which a valuable material can be extracted. All metals with the exception of gold are found chemically combined with other elements in the form of oxides and sulphates.

Metal	Ore
Iron	Magnetite, haematite
Copper	Chalcopyrite
Aluminium	Bauxite
Lead	Galena
Tin	Cassiterite
Zinc	Zinc blende

Availability of metal ores

- 25 per cent of the Earth's crust is made up of metal ores.
- Aluminium is the most common ore, followed by **iron**.
- In general, the more rare the material, the more expensive it is. (However, some of the more common ores, e.g. aluminium, can be expensive to process.)

Extraction takes place locally with added value often occurring in another country. Australia has an abundance of Iron ore which is mined and then shipped to China and Japan where is it made into steel. Iron ore is 93 USD per tonne and Steel 649 per tonne in 2018.

Extracting pure metals out of ores

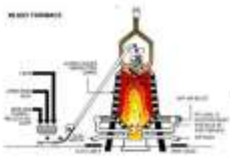
One common method of extraction is **smelting**, where refiners heat the ore to extremely high temperatures with the use of powerful furnaces. This makes it easier to get the pure metals out.

Extracting pure metals out of ores

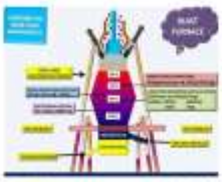
One common method of extraction is **smelting**, where refiners heat the ore to extremely high temperatures with the use of powerful furnaces. This makes it easier to get the pure metals out.

How steel is produced

pig iron

To make steel, the carbon content of the pig iron is reduced from over 3% to less than 1.5% and often below 0.25% for mild steel.
Other impurities are removed and small amounts of other elements are added.



http://www.youtube.com/watch?v=s0bLrWwuA

Short Video

http://www.youtube.com/watch?v=9l7IqonyoKA

Full video

Types of steel

Table 7 *Types of steel*

Base material	Additional element, carbon	Type of steel	Ductility	Hardness	Toughness
Iron	<0.3%	Low carbon steel (mild steel)			
	0.3–0.6%	Medium carbon steel			
	0.6–1.7%	High carbon steel			
	3.5%	Cast iron			Brittle

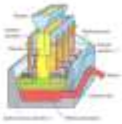
Table 8 *Typical uses for steels and cast irons*

Name	Common uses
Mild steel	Nuts, bolts, washers, car bodies, panels for cookers and other white goods
Medium carbon steel	Springs, general gardening tools
High carbon steel	Hand tools, scribers, dot punches, chisels, plane blades
Cast iron	Machine parts, brake discs, engines

How aluminium is produced

Aluminium ore, most commonly bauxite, is plentiful and occurs mainly in tropical and sub-tropical areas. Bauxite is refined into aluminium oxide trihydrate (alumina) and then electrolytically reduced into metallic aluminium.

To process aluminium, you spend 5 more times electrical energy than needed to produce steel.



Full video

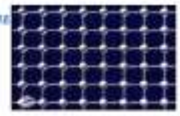
http://www.youtube.com/watch?v=1u8gooT-seg

Short video From 9-mins Graphic view of process

http://www.youtube.com/watch?v=iBai2Bou0G4

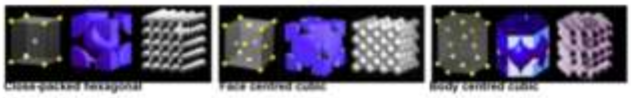
Grain size

http://www.youtube.com/watch?v=IIKbWK1aQhhg



In metal production, when metal solidifies, - the atoms rearrange into a regular pattern known as metallic structure. **They can have 3 forms:**

1. Close packed hexagonal - weak, poor strength to weight ratio - such as zinc and magnesium
2. Face centred cubic - very ductile and good electrical conductors - such as aluminium, silver, copper, gold and lead
3. Body centred cubic- hard and tough such as chromium and tungsten



Grain size

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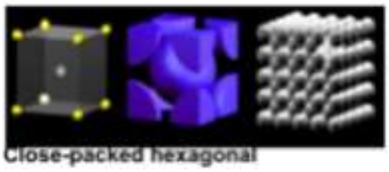
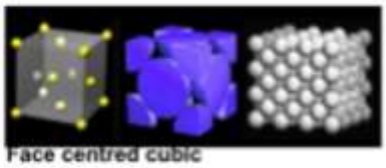


Grain size

Once a metal is produce when it solidifies - the atoms rearrange into a regular pattern known as metallic structure. **They can have 3 forms:**

2. Face centred cubic - very ductile and good electrical conductors -



Grain size

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3. Body centred cubic- hard and tough such as chromium and tungsten

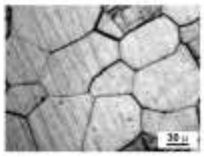
Grain size

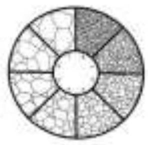
Metals are ***crystalline structures*** comprised of individual grains.
The grain size can vary and be determined by heat treatment, particularly how quickly a metal is cooled.
Quick cooling results in small grains, slow cooling results in large grains.

****Grain size in metals can affect the material properties such as****

the smaller the grain size, the stronger the material

- Density
- tensile strength
- Ductility
- Malleability
- Toughness





Modifying mechanical properties by alloying

Alloying is a mixture of two elements, of which one is at least a metal - e.g. Carbon and Iron = Steel. Copper and Zinc (two metals) = Brass

Adding in different (materials to) metals to ultimately create a harder and strong metal.

Alloys contain atoms of different sizes, which changes regular arrangements of atoms. This makes it more difficult for the layers to slide over each other- so alloys are harder than pure metals.

http://www.youtube.com/watch?v=9tH05B1n11k

Advantages of alloying

- Changes the melting point
- Changes the colour
- Increases strength, hardness and ductility
- Enhances resistance to corrosion and oxidation
- Changes electrical/thermal properties
- Improves flow properties, producing better castings

Table 11 The effects of alloying steels with other elements

Alloy steel	Alloyed with	Characteristics	Common uses
Stainless steel	Chromium, nickel, magnesium	Tough and wear-resistant; corrosion-resistant	Sinks, cutlery, sanitary-ware,
High speed steel (HSS)	Tungsten, chromium, vanadium	Very hard, will cut while at red heat	Cutting tools, such as drills
Tool and die-steels	Chromium, manganese	Very hard and tough, with excellent wear-resistance	Fine press tools, extruder dies, blanking punches and dies, some hand tools

Alloying steel

Stainless steel is produced by joining chromium, nickel and magnesium.

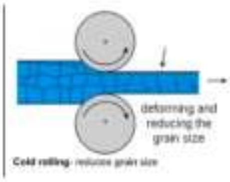
It has high oxidation-resistance to air at room temperature - normally achieved by the addition of chromium (a minimum of 13% up to 26% is used for harsh environments).

There are over 150 grades of stainless steel, of which fifteen are most commonly used. **Stainless steel is a hard and strong substance,** it is not a good conductor of heat and electricity, it is ductile, magnetic, retains its strength and cutting edge regardless of temperature.

http://www.youtube.com/watch?v=gLNtM8jcX

Modifying mechanical properties by work hardening

Work hardening or cold working, is the strengthening of a metal by plastic deformation. As the name suggests the metal becomes harder after the process. The metal is not heated at all. The process involves the metal passing through a set of rollers to reduce its thickness, it causes a permanent distortion of the crystal structure. It can be done with metals such as iron, copper and aluminium.



Cold rolling- reduces grain size

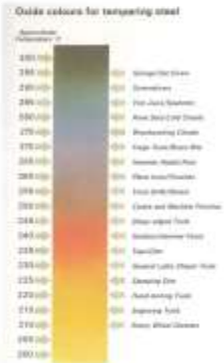
Cold rolling- adds hardness

Modifying mechanical properties by tempering

Tempering is the process of reducing brittleness after quenching

Tempering is a process of heat treating, which is used to increase the toughness of metals containing iron. Tempering is usually performed after hardening, to reduce some of the excess hardness, and is done by heating the metal for a certain period of time, then allowed to cool in still air.

technology student Link
http://www.technologystudent.com/equip1/heat1.htm

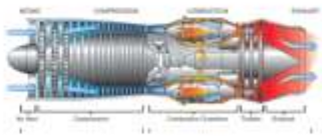


Design criteria for super alloys

Superalloy are metallic alloys which can be used at ***high temperatures***, close to the melting point. Creep and oxidation resistance are the prime design criteria. Superalloys can be based on **iron, cobalt or nickel** and are suitable for aeroengine applications.

Properties

- Excellent **mechanical strength** and creep resistance at high temperatures
- **Corrosion and oxidation resistant**



Superalloys - creep resistance

Creep is the gradual extension of a material under constant force.

Creep and its effect becomes more important at high temperatures.

Resistance to creep is vital when components are subjected to high temperatures for long periods of times - such as turbine blades.

http://www.youtube.com/watch?v=pbKFwAH-s9B

Superalloys - oxidation and corrosion resistance

Nearly all metals and alloys react with oxygen in the air to form oxides - that is to corrode.

Corrosion is a serious problem at high temperatures and in the presence of combustion products such as carbon dioxide and water vapor that exist in turbine engines.

Superalloys have **chromium** in their composition to ensure a tight oxide film is formed on the surface - this restricts access of oxygen to the metal surface so that the rate of oxidation is heavily reduced.

Recovery and disposal

Worldwide over 400 millions tonnes of metal is recycled every year. This is precious, as it protects the environment and saves energy. Using recycled metal means less use of natural resources (metal ores), savings in energy and reduced CO2 emissions.

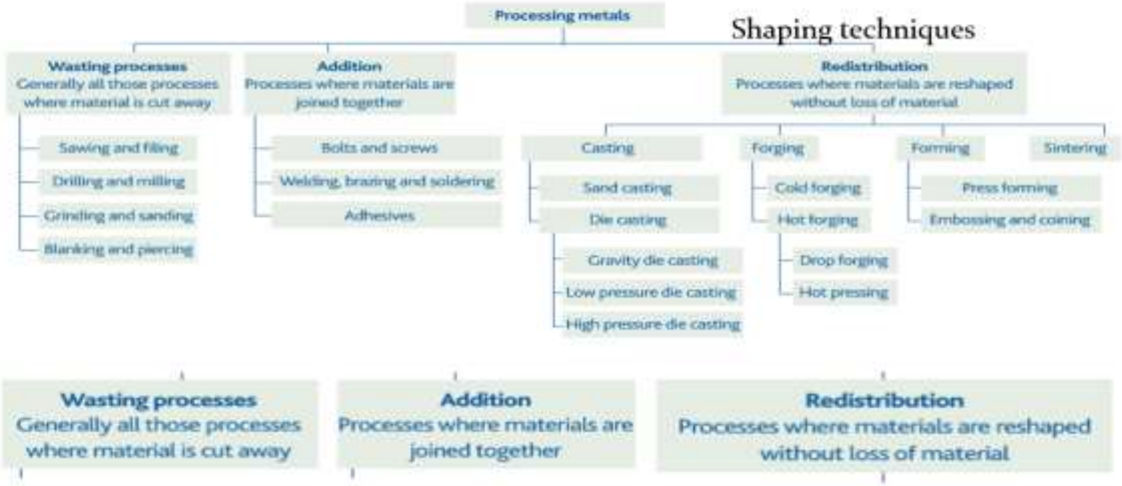
http://www.youtube.com/watch?v=WOmtFN1bf28

Energy saving in metal recycling

Recycling Scorecard	*New metals made using recycled metals*	*Energy saving*
Aluminium	39%	95%
Copper	32%	85%
Lead	74%	60%
Steel	42%	62-74%
Zinc	20%	60%

Processing metals

Shaping techniques



Revision questions

1. How is the structure of metals best described?
   - A. Fibres
   - B. Crystalline
   - C. Chains
   - D. An amorphous mass

   (Total 1 mark)

2. Which metal would be appropriate to use for a superalloy required to resist high temperatures?
   - A. Iron
   - B. Nickel
   - C. Cobalt
   - D. Silver

   (Total 1 mark)

4. What is **one** result of the plastic deformation of metal?
   - A. Increased grain size
   - B. The metal is work hardened
   - C. The metal becomes more malleable
   - D. The metal becomes an alloy

   (Total 1 mark)

5. What is an alloy composed of?
   - A. Only metals
   - B. At least one metal
   - C. Two or more substances
   - D. Only ceramics

   (Total 1 mark)

Describe how the rate of cooling of a metal controls grain size. *[2]*

3. Shopping trolleys, were originally designed in Oklahoma by store owner, Sylvan N Goldman. They were developed to encourage shoppers to purchase more in his store. The trolleys are effectively large stainless steel wire baskets mounted on a chassis. Shopping trolleys have now become a global product.

Figure 1: Shopping trolleys

(i) List **two** benefits of using stainless steel wire to make the baskets for the shopping trolleys. **(2)**

(ii) Outline **one** reason why ductility is an important property of the material for the manufacture of the basket for the shopping trolley. **(2)**

6. Describe how the tensile strength of a metal is increased by alloying. **(2)**

7. (a) Describe a superalloy. **(2)**

(b) Outline **one** reason why nickel-based superalloys are appropriate materials for application in aircraft engines. **(2)**

8. The figure below shows the Towelclip, a heated towel rail produced by the Eskimo Design company. The Towelclip is sold for approximately £350 ($700). It is manufactured from extruded polished tubular steel metal.

(i) Outline the importance of thermal conductivity to the function of the Towelclip. **(2)**

(ii) Outline **one** benefit of ductility to the production of the Towelclip. **(2)**

Figure 3 shows a safety pin made of steel wire. The safety pin was invented by Walter Hunt while wondering how to pay back a fifteen-dollar debt to a friend. In 1849, Hunt patented his invention and sold it to a manufacturing company for mass production. Steel wire is manufactured from pig iron in a number of steps of treatment in order to achieve the desired properties.

Safety pins may be made from steels with different percentages of carbon depending on the intended user. Hospitals would require safety pins with relatively high carbon content, whereas those purchased from stationery shops have a relatively low carbon content.

Figure 3: Safety pin

(e) (i) Outline how grain size of the steel material affects the properties of the safety pin. [2]

(ii) Explain the benefits of using hardening and tempering techniques in the manufacture of the safety pin. [3]

Topic 4.9a: Manufacturing processes for metals

4.4 Manufacturing Processes

Essential Idea: Different manufacturing processes have been developed to innovate existing products and create new products.

Concepts and Principles:

- Additive techniques: paper-based rapid prototyping, laminated object manufacture (LOM), stereolithography
- Wasting/subtractive techniques: cutting, machining, turning and abrading
- Shaping techniques: moulding, thermoforming, laminating, casting, knitting, weaving
- Joining techniques: permanent and temporary, fastening, adhering, fusing

Guidance:

- Selecting appropriate manufacturing techniques based on material characteristics (form, melting/softening point), cost, capability, scale of production, desired properties
- Advantages and disadvantages of different techniques
- Design contexts where different manufacturing processes are used

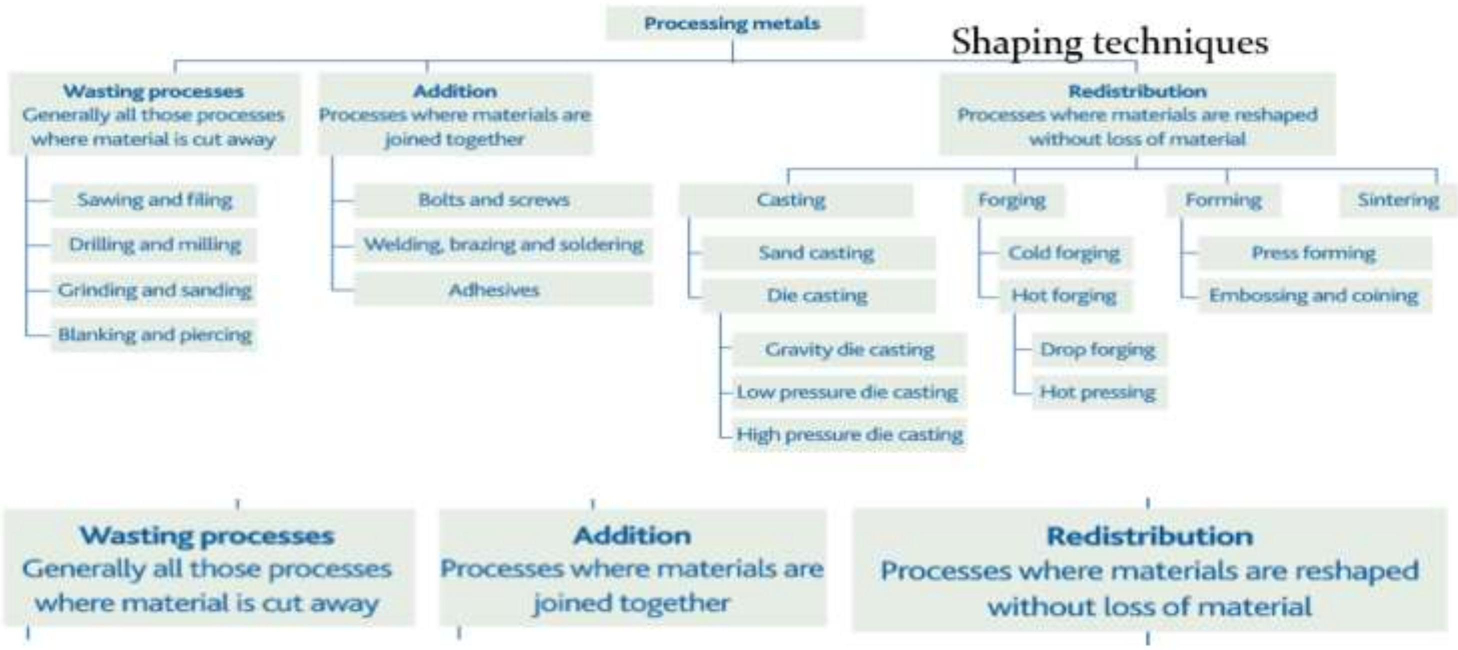
Aims:

Advancements in 3D printing have resulted in the ability to have a 3D printer at home. Consumers can download plans for products from the internet and print these products themselves.

Nature of Design:

Designers sometimes engineer products in such a way that they are easy to manufacture. Design for manufacture (DfM) exists in almost all engineering disciplines, but differs greatly depending on the manufacturing technologies used. This practice not only focuses on the design of a product's components, but also on quality control and assurance.

Processing metals



Shaping techniques - casting

Casting is the melting of a material into its liquid state and pouring it inside a mould until it sets. This is one of the oldest methods of manufacturing used. The type of casting used depends on

- the material used (you can cast metals, polymers, glass, ceramic and concrete)
- the desired shape
- the quality of the surface finish
- the quantity needed

Die Casting

Die casting is a versatile process for producing metal parts by forcing molten metal under high pressure, or under the action of gravity into reusable steel dies (moulds).

Aluminium, Zinc and Copper alloys are the materials predominantly used in die-casting. Their low melting temperature makes them particularly useful for large scale production.

Table 13 *Metals used in die casting*

Metal used	Melting temperature
Aluminium	660 °C
Magnesium	650 °C
Zinc	850 °C

Gravity die casting

Is a simple casting process which utilises reusable dies made of alloy steel under the force of gravity. The process is primarily used for simple shapes with some basic coring possible.

The two halves of the mould are sprayed with a coating and then put together using locating pins to align the two halves and clamped. The mould is heated using gas burners prior to pouring the molten metal.

Once poured the mould is allowed to cool before being opened to release the casting. **Further machining will be necessary** to remove any excess material and heat treatment may be required dependent on component use.

http://www.youtube.com/watch?v=i0lCvTJw4UQ

Gravity die casting

Applications – car wheels, components and engine parts

It is mostly suited to casting light alloys but can also be used for steel and cast irons.

Gravity die casting

Advantages	Disadvantages
-	-
-	-
-	-
-	-
-	

High pressure die casting

High-pressure die casting is a process in which molten metal is forced under pressure into a securely locked metal die cavity, where it is held by a powerful press until the metal solidifies.

After solidification of the metal, the die is unlocked, opened, and the casting ejected. After removal of the casting, the die is closed and locked again for the next cycle.

http://www.youtube.com/watch?v=i5yBsdJkQu8

High pressure die casting

Advantages	Disadvantages
-	-
-	-
-	-
-	-
	-

Applications----------------(uses)

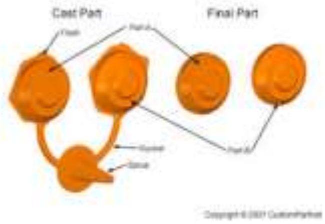
Applications

Are usually small detailed components used for automotive, aerospace and appliance manufacturing

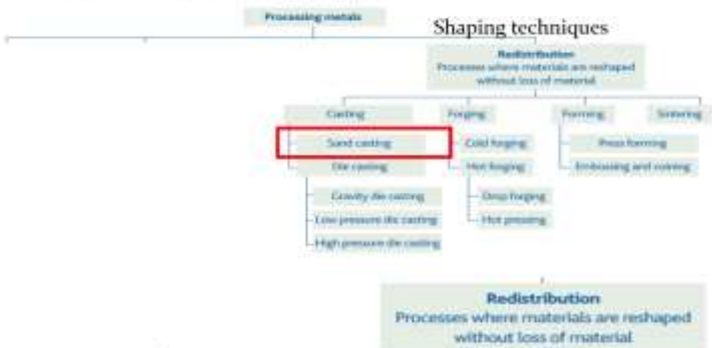
Parting line

The parting line is created where the two halves of the die meet. Gates, overflows, and vents will connect to the casting at the parting line.

Also, flash will form at the parting line when the pressure from the injected metal tries to force the die halves apart. During the trimming process the gates, overflows, vents, and flash will need to be removed by the trim die. A well designed parting line will ease the trimming process.



Processing metals



Sand casting

Sand is used to make the moulds.

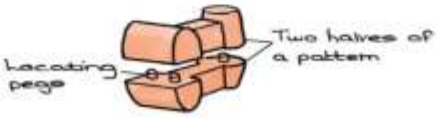
The sand is prepared with oils that act as binder that help the mould hold its shape while the poured metal is being cast into it.

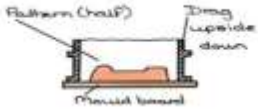
http://www.youtube.com/watch?v=KBSYhISGxN4

Sand casting – stages of the process

1. A pattern is made (can be made from a range of materials like woods – pine, metals- aluminium or polymers – polypropylene). Patterns can de made of more complex shapes.

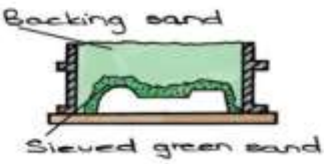
2. Each half of the pattern is placed on a baseboard. A mould box is placed over.





3. Sand is "tamped" around the pattern forcing it into contact with the pattern. This is followed by backing sand (usually recycled sand).

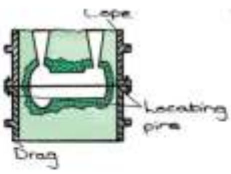
4. The pattern is removed. The runner and the riser gates are then cut in the top half of the sand mould.

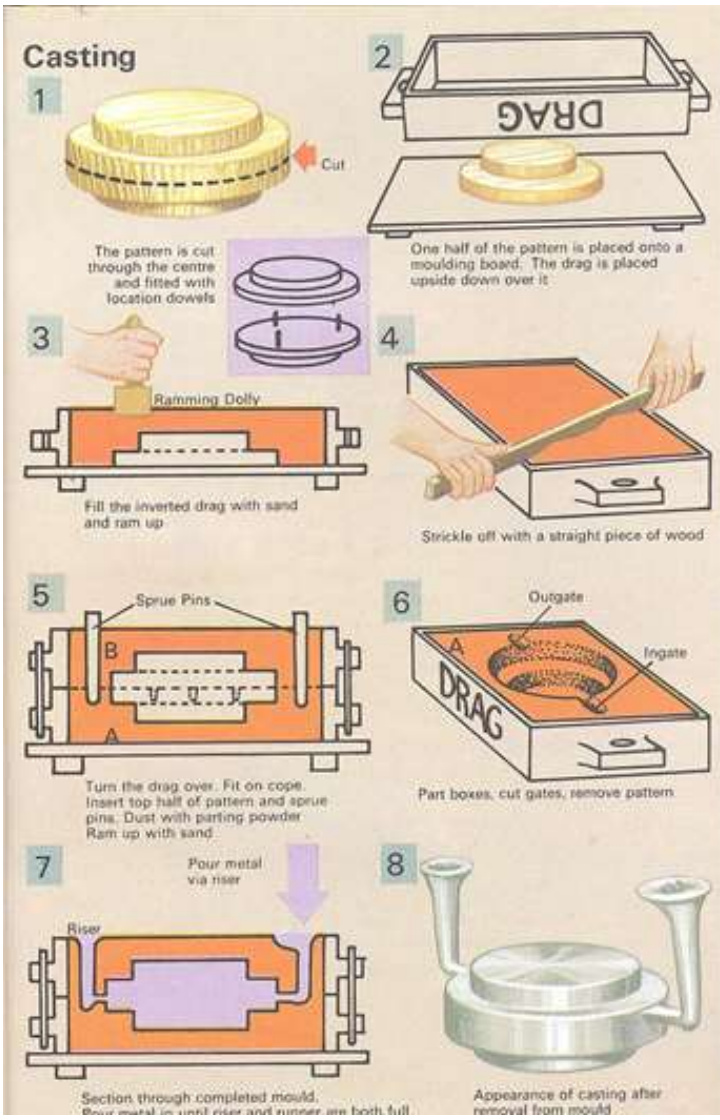


5. The mould halves are fitted together with locating pins to ensure correct alignment.

6. The molten metal is poured into the running gate. The riser is used to indicate when the mould is full.

7. Once the metal has solidified the sand mould is broken open, leaving the runner and riser gates attached.





Sand casting

Advantages

- Suitable for one-off or small production runs
- Complex 3D-Shapes can be produced
- Cores can be used to produce hollow sections
- Suitable for a variety of metals

Disadvantages

- Poor surface finish, some machining will be necessary
- Not accurate as die or investment casting
- Low rate of output therefore is suitable for small production runs
- Automated processes are needed for longer productions runs

Investment casting

This manufacturing technique is also known as the **lost wax process** or precision casting. Investment casting was developed over 5500 years ago and it's still used for materials with a high melting point. Parts manufactured in industry by this process include dental fixtures, gears, cams, ratchets, jewellery, turbine blades, machinery components and other parts of complex geometry.

Investment casting - process

1. A Wax pattern is produced to a high degree of accuracy.
2. This is then coated in a high temperature ceramic material.
3. Once dry it can be fired in a kiln. The wax pattern will melt leaving the cavity to be cast into.

Investment casting - process

4. When the ceramic mould cooled down the molten metal is poured in, usually using gravity to help fill the mould.
5. When the cast is cooled the ceramic mould is broken open.

Investment casting

Advantages	Disadvantages
-	-
-	-
-	-
-	
-	
-	

Revision questions

7. **Figure 12** shows the Tandem Sling Chair. It was originally designed by husband and wife design team Charles and Ray Eames for airports in Washington and Chicago. It is now widely used in airports and other public buildings around the world. The brief was to develop a multiple-seating system which facilitated security checks, looked good (aesthetics) and was easy to maintain (see **Figure 13**). The aluminium frame is produced by high-pressure die casting.

Figure 12: Tandem Sling Chair

www.hermanmiller.co.uk. Used with permission

Figure 13: The chair is widely used in airports and other public access areas

www.hermanmiller.co.uk. Used with permission

(a) (i) Describe the process of high-pressure die casting. *[2]*

. . . .

. . . .

. . . .

(ii) Outline **one** advantage of using high-pressure die casting to produce the metal frame. *[2]*

Figure 9 shows the Juicy Salif Citrus Squeezer designed by Philippe Starck and made from casting aluminum which is then polished.

(d) Explain three reasons why casting would be used to produce the Juicy Salif Citrus Squeezer in Figure 9. [**9 mark**]

Processing metals

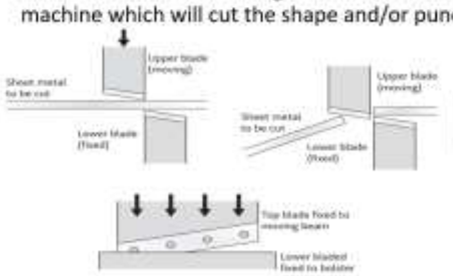
Wasting/subtractive techniques

Are manufacturing techniques that cut away material in order to create a product or component.

Usually done by cutting (abrasive water jet cutting, oxy-acetylene cutting, plasma cutting , machining (CNC router or milling), turning (metal lathe) or abrading (sanding, filling, grinding).

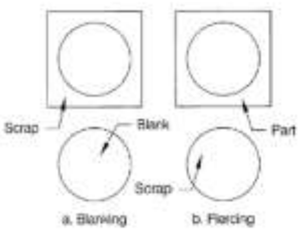
Mild steel – piercing and blanking (wasting processes)

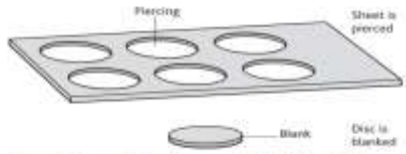
A guillotine is usually used to cut sheet metal off a roll into useable sheet sizes. The sheets will then go to a either manually operated or automatic machine which will cut the shape and/or punch a hole into it.



Mild steel – piercing and blanking (wasting processes)

A process whereby a particular shape is punched out of a sheet of metal, just like a cookie cutter and a sheet of dough. The difference is that with blanking the outside part is waste, whereas with piercing the inside part is waste.





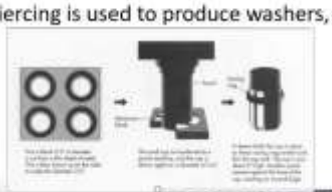
http://en.wikipedia.org/wiki/File:FPL-Technology_Multitool-Index.ogv

Mild steel – piercing and blanking (wasting processes)

Blanks are used to produce drink cans.

Piercing is used to make grids, vent holes for enclosures, etc.

Blanking and piercing is used to produce washers, gears, etc.



Mild steel – piercing and blanking (wasting processes)

Advantages

- Almost any sheet material can be punched or blanked in a large variety of thicknesses.
- Both processes could be use in the same part.

Disadvantages

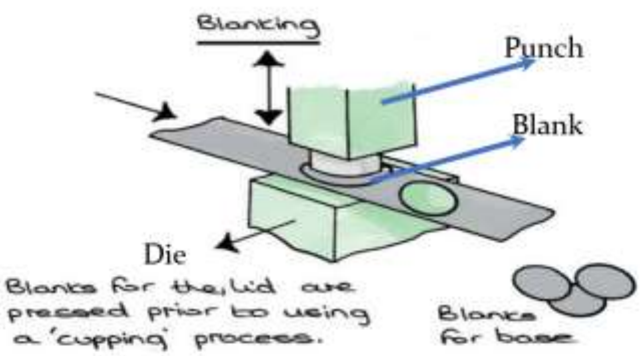
- Tight control of the clearance between punch and die is necessary and varies according to the material thickness - therefore, a die is usually tailor made for the specific material being punched.
- Waste is created needs to be collected and recycled.
- Burrs, slivers and splits are typical defects encountered in conventional trimming.

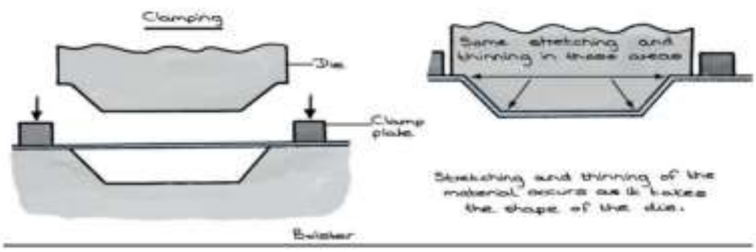
Press forming (redistribution process)

Press forming is a metal working process in which a flat blank, constrained between two surfaces is forced by a punch to take a required three-dimensional shape, eg. cups, gas cylinder domes.

The process is done at room temperature and relies heavily on the ductility of the material being pressed.

http://www.youtube.com/watch?v=ieRog07IHU





Press forming (redistribution process)

Advantages

- Increase stiffness – the material gains more stiffness and rigidity due to the shape formed
- The material is being stretched requires good ductility and by being pulled the material hardens – the material structural strength increases

Disadvantages

- Induced strain within the material during the processing
- Having to reprocess the unused metal during punching, perforating, etc
- Limited amount of detail and geometry available for punching

---

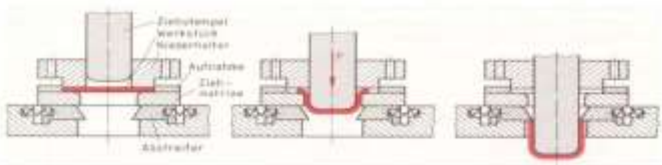
Press forming (redistribution process)

Main applications

Deep drawing

Deep drawing is a manufacturing process that is used extensively in the forming of sheet metal into cup or box like structures.

A basic deep drawing operation could be the forming of a flat sheet into a three dimensional cup, or a box. The shape of a deep drawn part is not limited to a circle or square, more complex contours are possible. However, as the complexity goes up, the manufacturing difficulties increase rapidly.



Deep drawing

Applications

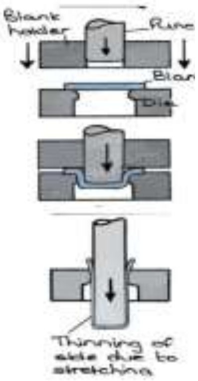
Pots and pans for cooking, cans, containers, sinks, automobile parts, such as panels and gas tanks, are among a few of the items manufactured by this process.

Advantages

– Very high production rates (e.g. cans)

Disadvantages

– Limited shapes
– Wall thickness is reduced due to the material being stretched
– Dies are expensive

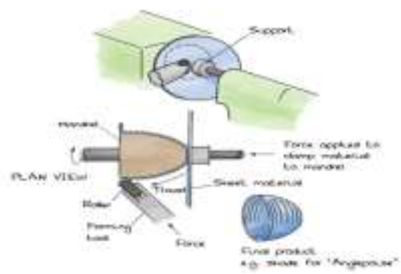


Spinning (redistribution – forming)

Metal Spinning is the process of forming three dimensional symmetrical parts from flat circles of metal.

Also known as spin forming or metal turning most commonly, is a metalworking process by which a disc or tube of metal is rotated at high speed and formed into an axially symmetric part. Spinning can be performed by hand or by a CNC lathe.

http://www.youtube.com/watch?v=[illegible]



Spinning (redistribution – forming)

Several materials are used in this process: Aluminium, Mild Steel, Stainless Steel, Brass, Copper.

advantages	disadvantages
More economic that press forming and casting	No repairs possible if cracks Only symmetrical products
No seam	

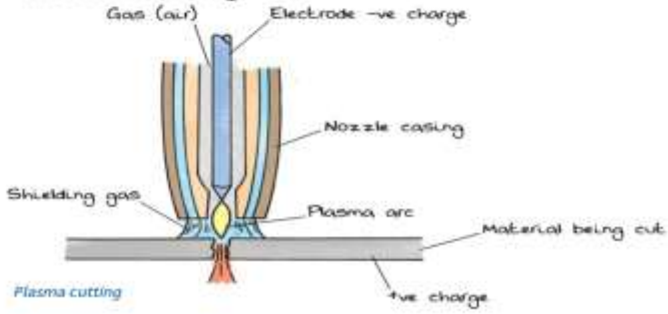
Plasma cutting

Plasma cutting is a process that is used to **cut** steel and other metals of different thicknesses using a plasma torch.

In this process, an inert gas (in some units, compressed air) is blown at high speed out of a nozzle; at the same time an electrical arc is formed through that gas from the nozzle to the surface being cut, turning some of that gas to plasma.

The plasma is sufficiently hot to melt the metal being cut and moves sufficiently fast to blow molten metal away from the cut.

http://www.youtube.com/watch?v=[illegible]



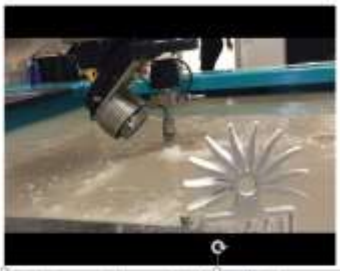
Plasma cutting

Plasma cutting

advantages	disadvantages

Water Jet cutting

A fine stream of water mixed with fine abrasive particles passes through a nozzle at ultra high pressure (from 280 to 690 MPa) and water speed of 400m/s and 600m/s are used to cut a wide variety of materials such as metals, leather, plastics, stone, paper and rubber.



http://www.youtube.com/watch?v=siEqXbXxpfg

Water jet cutting

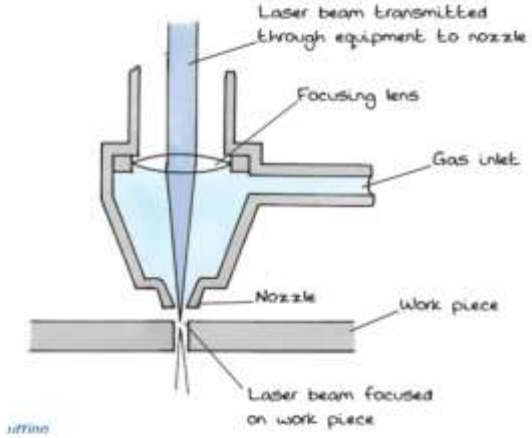
Advantages	Disadvantages

Laser cutting

Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications. Laser cutting works by directing the output of a high-power laser using a CNC machine, by computer.

The material then either melts, burns, vaporizes away, or is blown away by a jet of gas, leaving an edge with a high-quality surface finish. Industrial laser cutters are used to cut flat-sheet material as well as structural and piping materials.

Laser cutting



Laser cutting

advantages	disadvantages

Oxy-acetylene cutting

Is a process in which acetylene and oxygen supplied from separate pressurised containers are supplied via rubber hoses to a cutting torch - were the gases are mixed to produce a flame that burns at around 3500C.

The flame is used to preheat the workpiece - it is heated to a cherry red colour - in this condition the steel surface is oxidised allowing it to be cut.

It has an extensive use in cutting steel due to its portability.

http://www.youtube.com/watch?v=Dub_GI8zwk

Oxy-acetylene cutting

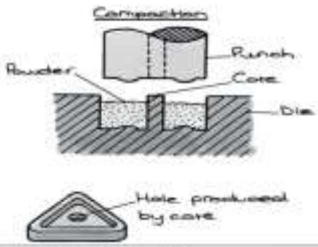
advantages	disadvantages

Sintering

Sintering is a method for creating objects from **powders**, including metal and ceramic powders.

It is based on atomic diffusion. In most sintering processes, the powdered material is held in a mould and then heated to a temperature below the melting point.

The atoms in the powder particles diffuse across the boundaries of the particles, fusing the particles together and creating one solid piece. Often used for shaping materials with extremely high melting points such as tungsten carbide.



Activity task

Activity

Create a series of sketches showing how a stainless steel kitchen sink may be produced. Use the stages shown above as a guide.

Activity

Identify three products where manufacturing has involved sintering. Explain why sintering is appropriate in each case.

Activity

Give at least three examples of sand cast products.

State the material used to manufacture each of the products. Identify further manufacturing processes that the products have undergone.

http://www.youtube.com/watch?v=[illegible]

Activity

Give at least three examples of sand cast products.

State the material used to manufacture each of the products. Identify further manufacturing processes that the products have undergone.

Cast Marine Anchor
Carbon steel

Sand cast aluminium railway door

Vane wheel - Bronze

Valve - Bronze

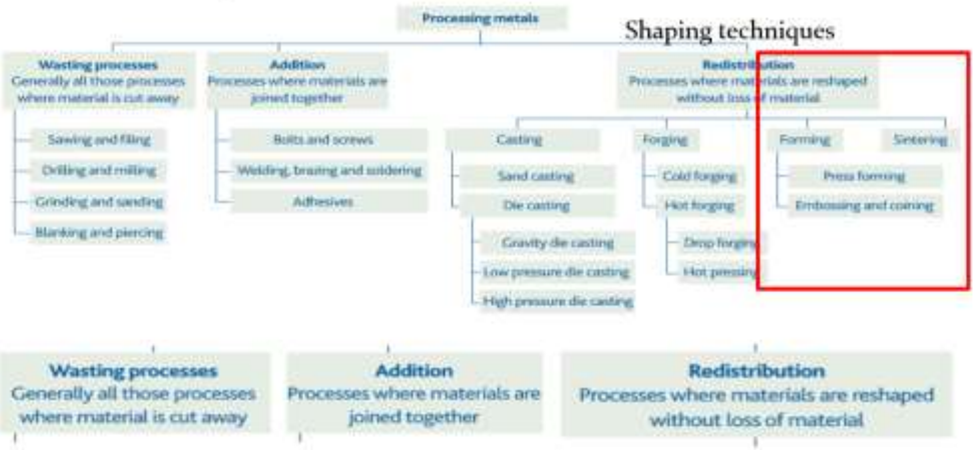
Activity

Identify three products where manufacturing has involved sintering. Explain why sintering is appropriate in each case.

Aluminium heat sink
This technology has range of benefits over traditional die-cast and extruded materials has it can handle big temperature variations.

Gears for automotive industry
Material: steel
Sintering technology is an ideal choice for these components as it produces more compact and more robust products.

Processing metals



Machining - subtraction process

Machining is a subtraction process in which a cutting tool moves across a work piece to remove material from the surface.

Metal turning

Is a machine operation performed on a lathe, the material is clamped securely between a head stock and a tail stock and rotated at high speed . A cutting tool is attached to a movable tool post and moved along the surface of the material - removing the material needed. Used for symmetrical shapes.

http://www.youtube.com/watch?v=[illegible]

Machining - subtraction process

Milling

Is a machining operation using a rotating cutter head, around which a number of cutting inserts are fixed, that remove material from a workpiece secure to a bed or vice.

Machining - subtraction process

Abrading

Involves the physical wearing away of surfaces by the means of rubbing, friction or erosion.

Abrasives may be

- Rigid tools such as files and abrasive wheels
- Suspended in a liquid eg water jet cutting
- Carried by a jet of compressed air as in sand, steel shot or iron grit blasting

Forging

When metals are hot they are much easier to bend, twist and stretch. Working hot metals is called forging – the craft of the blacksmith.

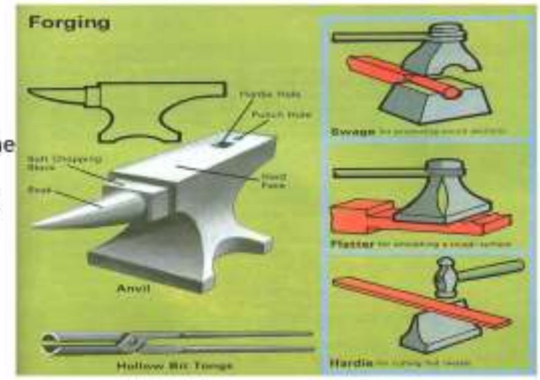
Forging methods can be done either by hand or machine.

Large forces can be achieved by the use of mechanical hammers.

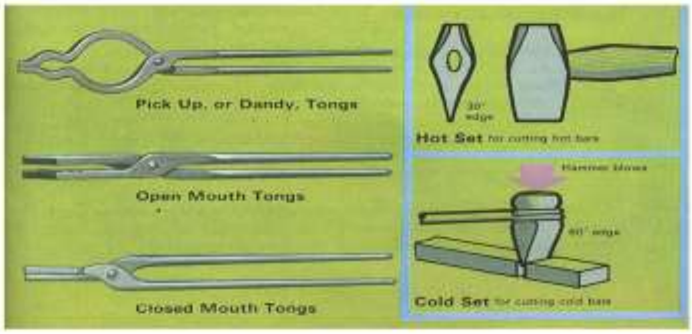
Processes include; bending, drawing down, punching and drifting, twisting and scrolling, and drop forging.

Forging

Basic hand processes are carried out with the use of hammers, swages and anvils.



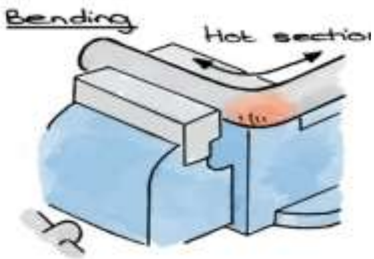
Forging



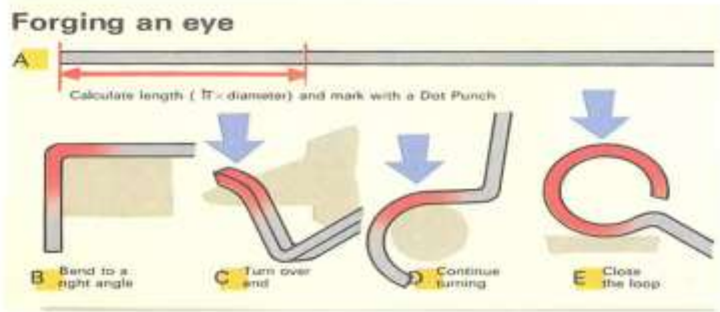
Bending

A bend is produced in the piece being bend. Bending can be either sharp or gradual. A more gradual bend could be achieve with the material cold while a sharp bend will require the metal to be heated.

Bends can be made using the beak of the anvil but they can also be made by using a former of a suitable diameter held in the vice.



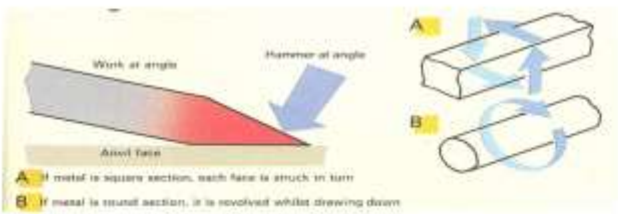
Forging an eye



Drawing down

Most common of all hand-forging processes, consist in reducing the thickness of the material by hammering.

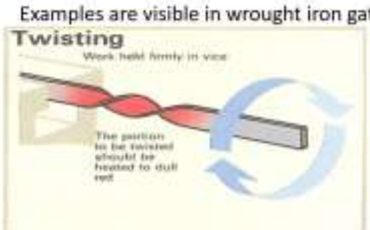
The most common example is making a point at the end of a bar. This point can be square tapered or round tapered.



Twisting

Is used as a decorative feature on much iron work. The metal is evenly heated until it is red and then is twisted.

Examples are visible in wrought iron gates, door handles.

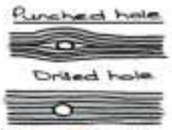


Scrolling

Scrolls are also decorative features used in gates, fences and screens. They can be formed over the beak of the anvil or more, usually on a scrolling tool held in a vice.

Punching

Punching is done by hammering a spiked tool into the metal being worked. Holes can be produced in any shape, it depends on the shape of the punches. Punching is done using a punch and a repousse hammer.



Marking-out tools

Accurate marking-out and measuring are vital to good metalwork. Metal can be worked to very fine limits; one thousandth of an inch (·025mm) is commonplace. Many jobs consist of a number of components and without accurate marking-out at an early stage the parts would not fit.

The *scriber* is the metalworker's pencil. It has a hard, sharp point which scratches a fine, bright line onto the metal.

The *rule* is made of steel in varying lengths. It has a zero end and is calibrated with imperial or metric measurements, or both.

The *try square* is accurately set to 90° and is used for marking-out and testing right angles.

Spring dividers act like a compass and are used for drawing circles, dividing lengths and transferring measurements from rule to work.

Odd leg calipers, sometimes called jenny calipers, are used for marking lines parallel to edges. *Inside and outside calipers* are used for gauging the diameter of circular parts. The tips of the legs are adjusted to touch the work gently and are then checked against the rule.

The *centre punch* is used mainly for marking the positions of drilled holes. Its mark prevents the tip of the drill from wandering.

For increased accuracy in marking-out, a *surface plate, scribing block* and *vee blocks* are used. The plate is a perfectly flat surface and measurements above it are set up on the scribing block using its fine adjustment mechanism. Precise vee blocks ensure that the work is set up at right angles to the plate. The vee-shaped grooves are to support rods for marking-out.

Metals are often painted with a quick-drying marking fluid, which is usually blue in colour, so that scratched lines stand out clearly.

The *micrometer* is a high precision tool for measuring. Each turn or part turn of its fine thread can be checked exactly against a scale engraved on it.

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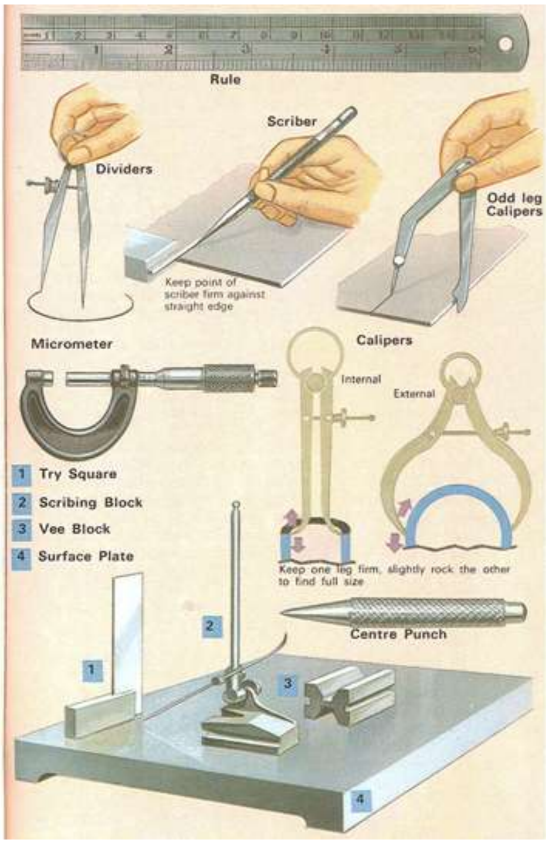

Files and filing

The file is an essential tool used on almost every job. Files are made of cast steel, hardened and tempered on the blade but with the tang left soft. The tang fits into the wooden handle. Files are classified according to their size, cut and shape.

The *size* is the measurement of the blade only and can range from 3 to 20 inches (76mm – 508mm).

The *cut* is the number and size of the teeth, i.e. the coarseness. There are five main cuts: rough, bastard, second-cut, smooth and dead smooth.

The *shape* is the cross-section. The hand file has one edge without teeth; this is called the safe edge and it is especially useful for filing internal right-angled corners.

For very fine work *needle* or *Swiss* files are available in a large range of shapes.

File handles are usually of ash or beech. *It is highly dangerous to use a file without a handle.*

Accurate filing demands considerable skill. The work should always be held firmly in the vice, as low as possible and horizontal. A comfortable stance, with feet apart slightly to the left of the vice, is best. For cross-filing a long edge, the file is placed on the work at an angle and the stroke is made forwards and sideways simultaneously. The file must be kept horizontal throughout the stroke and downward pressure applied on the forward movement to make a cut. The return stroke is relaxed. Common errors are filing 'uphill' or 'downhill', or with a rocking motion which produces a rounded edge.

Drawfiling is a technique used to produce a fine filed surface. For this the file is gripped around the blade with both hands and balanced across the work. Drawing the file back and forth produces fine scratches all in one direction. For a highly polished surface emery cloth can be wrapped tightly round the blade and the drawfiling action continued.

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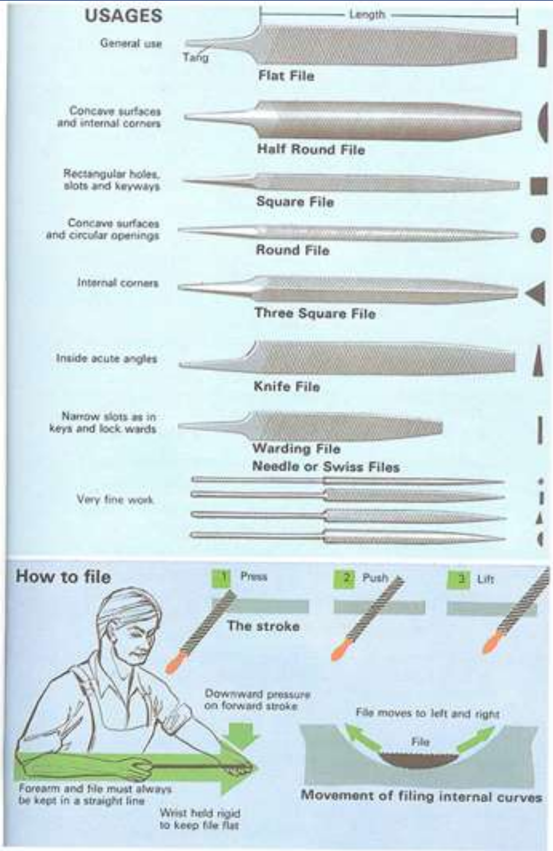

Saws and sawing

Accurate sawing is an important metalwork skill. A feature of all metalwork saws is the renewable blade; even with careful use they eventually wear out.

The *hacksaw* is the general purpose metalwork saw. The frame is adjustable to take blades of from 8 to 12 inches (203mm to 305mm). The number of teeth on the blades varies from 14 to 32 per inch (25mm) so that the most suitable blade can be selected for each job. Generally, thin and hard metals require a fine blade; for thick and soft metals a coarse blade is best. Blades are sold in two kinds: *flexible*, a mainly soft blade with hardened and tempered teeth, and *high speed steel*, which are hardened and tempered throughout. The latter are usually painted bright blue.

Hacksawing is done with a slow, steady stroke with pressure applied on the forward cutting movement. Care must be taken not to twist the blade in the cut. The frame of the hacksaw normally restricts the depth of the cut, but by revolving the adjusting pins the blade can be set at right angles to the frame, allowing deep cuts to be made.

A *junior hacksaw* is small and inexpensive. It is very useful for cutting thin metals and light sections.

A *padsaw* is a simple handle which utilises pieces of broken hacksaw blades for working in places inaccessible to the framed saw.

For fine sawing on jewellery and for silversmithing, a *piercing saw* is used. The blade is little more than $\frac{1}{16}$ inch wide (1·6mm), a simple wing-nut clamp holds it in the springy frame which supplies the necessary tension.

For cutting curves the *tension file* blade is used in an ordinary hacksaw frame with special adapting clips. The blade is like a fine round file and can be manoeuvred very easily.

All blades are fitted so that the teeth point away from the handle in the direction of the cut.

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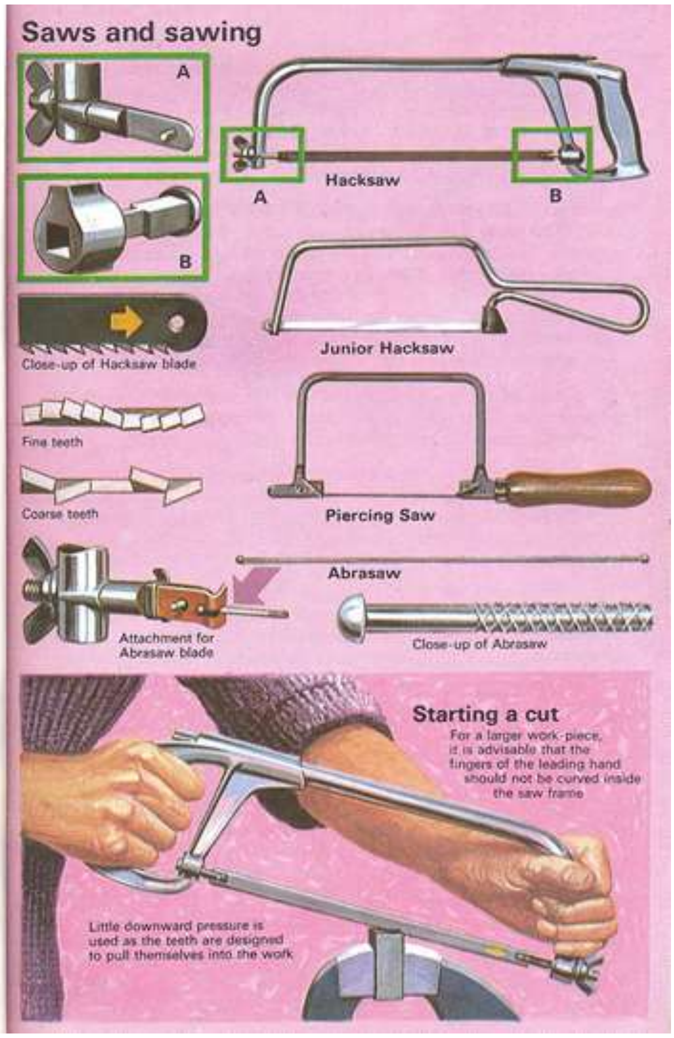

Drills and drilling

Most metalwork drilling is done with Morse twist drills which are available in many sizes. They are made of carbon steel (bright, shiny and fairly cheap) or high speed steel (black in colour and expensive). For power tools the latter drills are almost essential.

Twist drills have two cutting edges and the waste metal is lifted from the bottom of the drilling by the twin helical *flutes*. So that the body of the drill does not rub on the 'wall' of the hole, only a narrow strip called the *land* is the full nominal size. The *shank* of the drill is the part that fits into the drill chuck. On the larger sizes the shank is sometimes tapered so that it will lock into a tapered hole in the spindle of the drilling machine.

Drills become blunt after continual use and have to be reground. This operation takes skill but becomes easy with practice; beginners should seek expert help.

A sharp drill gives a clean cut and usually shavings are produced. A blunt drill will rub, squeak, become overheated with friction, eventually burn and be ruined. A sharp drill cuts well under gentle pressure (*the feed*) and should not be forced.

The speed of drills is important. Most large drilling machines have variable speeds which are changed by moving a belt on a series of pulleys. Charts show correct speeds, but a rule easy to remember is: *The bigger the drill the slower the speed.* Low speeds are also best on hard metals.

To reduce friction and overheating, cutting fluids are used, such as soluble oil on steels, and paraffin on aluminium.

There are several special drills, such as the countersink drill which opens out holes to take screw or rivet heads. Tank cutters and ring saws make large diameter holes in sheet metal.

Drilling on power machines can be dangerous. Concentration and obedience to safety rules is vital.

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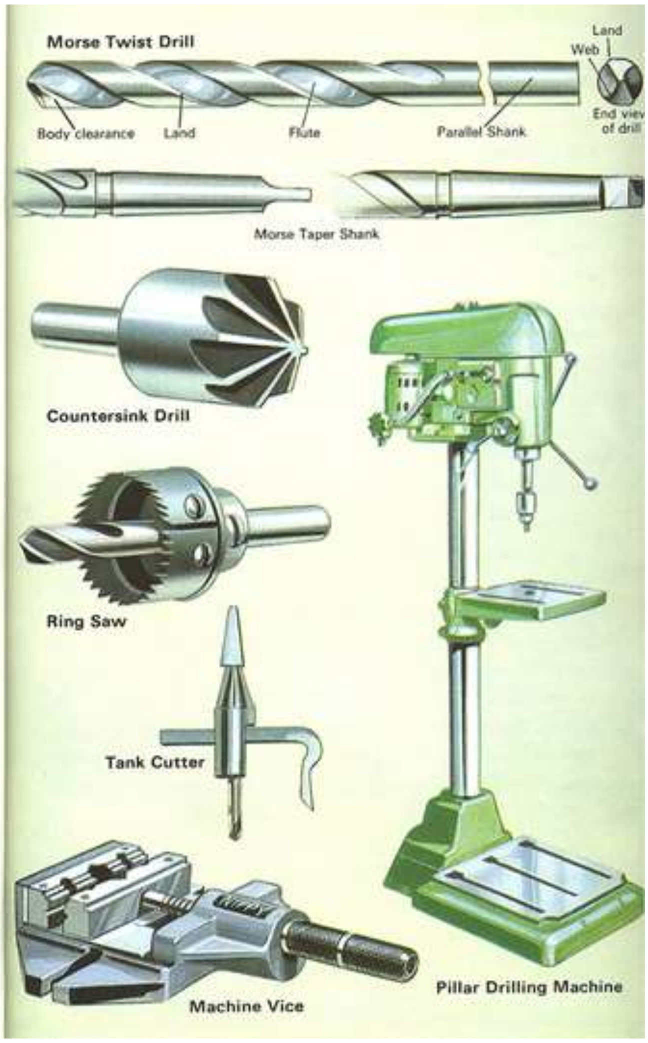


Drop forging

Drop forging is a forging process where a hammer is raised and then "dropped" onto the work piece to deform it according to the shape of the die.

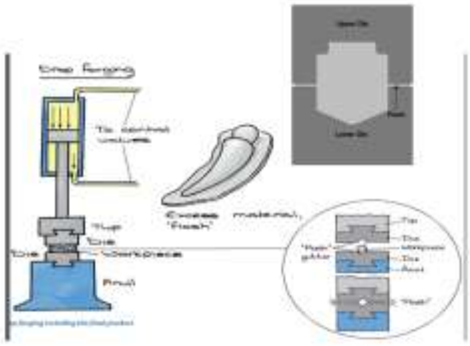
During *hot forging* the metals are heated to above their recrystallization temperature. The main benefit of this is that work hardening is prevented due to the recrystallization of the metal as it begins to cool.

Products manufactured using this process are cam shafts, stub axles, gears, tools, and so on.

http://www.youtube.com/watch?v=Wf4NDkl2w6E

Drop forging

One half (the upper half) is attached to a vertical sliding hammer. A large force is inserted onto the metal blank between the die halves, forcing it into the shape of the dies. Its usual that the component being produced will pass through a number of dies before the final shape is achieved.



Drop forging

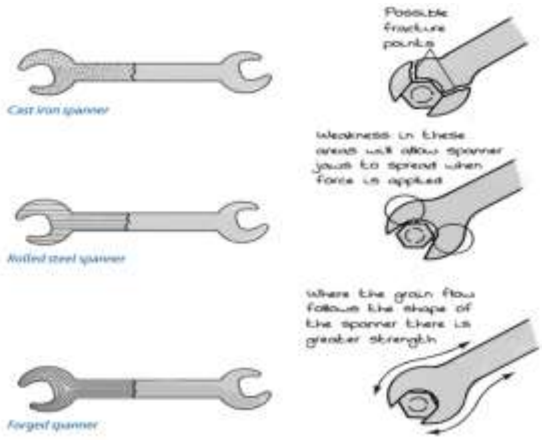
Advantages	Disadvantages

Why do tools have "Drop Forged" stamped on them?

The reason why manufacturers want you to know that a tool is drop forged is because this tells you something about the strength and durability of the tool. The other two ways to make a tool would be casting it from molten metal or machining it (cutting material away) from a larger block of metal. The advantage of forging is that it improves the strength of the metal by aligning and stretching the grain structure. A forged part will normally be stronger than a casting or a machined piece.

Spanner

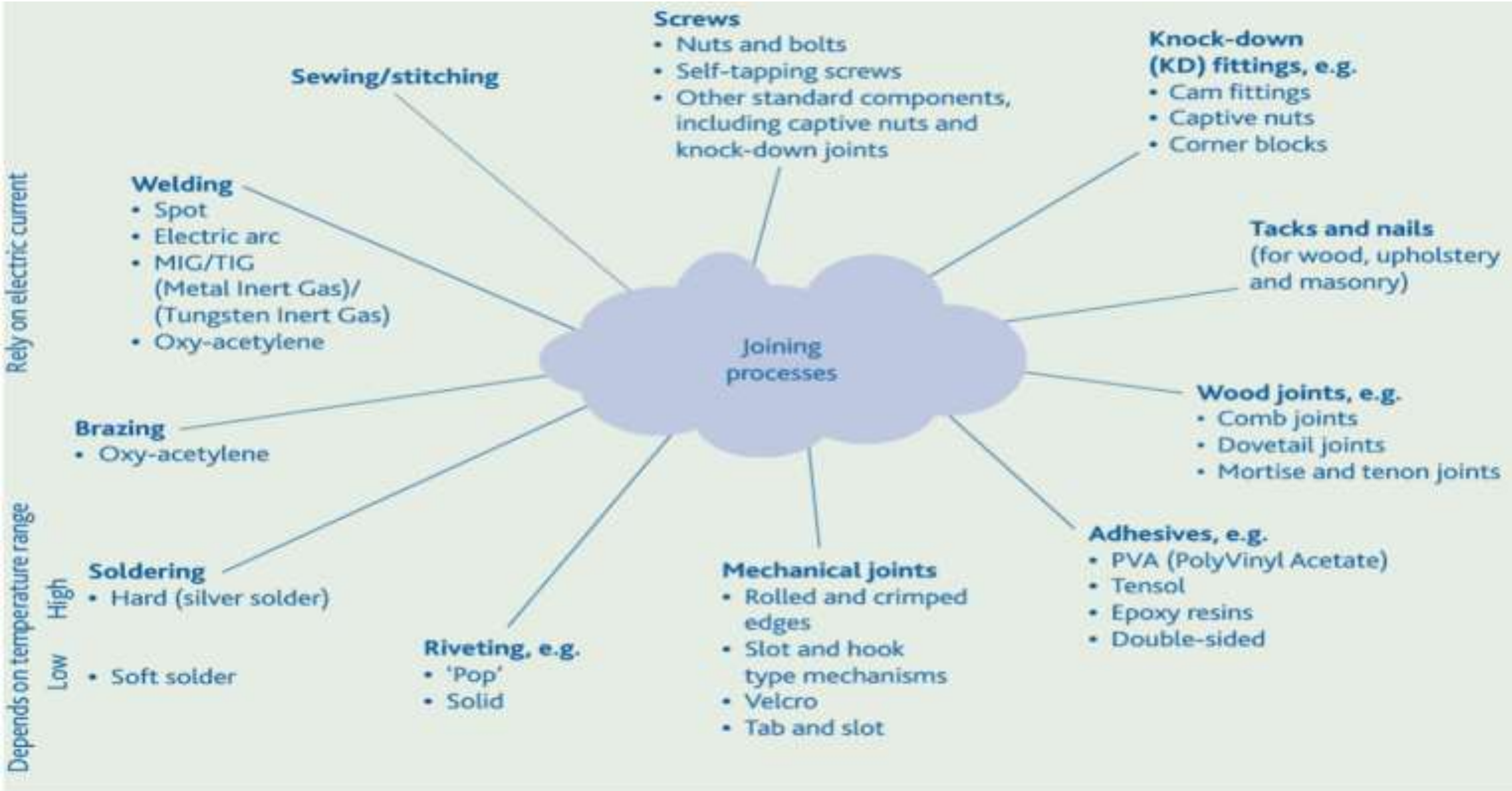
A spanner that has been drop forged will be better than casting or a machined piece. Because forging improves the strength of the metal by aligning and stretching the grain structure, making it a durable, strong and tough product.



Joining metals

Metals can be joined using different joining methods. Joints could be either permanent or temporary. We have already seen possible mechanical fasteners that can be used for metal such as nuts and bolts, machine screws and screws. I

We will study other metal joining methods such as seam joints, riveting, soldering, brazing and welding.



External screw threads

Nuts, bolts and screws are made in a wide range of shapes, sizes and materials. (See front end-paper.) These fixings provide a means of joining materials together so that they can be taken apart later; parts of bicycles and motorcycles are good examples. Screw threads can also be cut on component parts to provide fixings.

External threads are cut on to metal rods using a *die* which is made of hardened and tempered cast steel. The die is held in a diestock by means of screws that can be adjusted to increase or decrease the cut of the die. The size stamped on the face of the die must equal the rod diameter, measured with calipers. Hitherto dies in Britain have been mainly in fractional imperial sizes, i.e. $\frac{3}{16}$", $\frac{1}{4}$", $\frac{3}{8}$", $\frac{1}{2}$", etc. Slowly changes are being made towards metric sizes, i.e. 6mm, 8mm, 10mm, etc. Both systems are likely to be used for the time being.

Screw threads are classified according to their profile, or shape; the many types include B.S.W. (British Standard Whitworth), B.S.F. (Fine) and B.A. (British Association). Gradually they are being replaced with a more uniform ISO metric system.

The clearance holes and the thread of the die are ground so that the die cuts best when the size and type markings are facing *downwards* onto the metal. Great care must be taken to start the thread true; the metal must be vertical in the vice and the die at right angles to its axis. Suitable lubricants help the cutting. The forwards and backwards action, shown in the illustration, allows the waste metal to break away and fall from the clearance holes. If the waste is allowed to clog the die it breaks off the crest of the thread and an inferior job results.

If the cut thread does not fit an internal thread, adjustments can be made with the grub screws and the thread re-cut.

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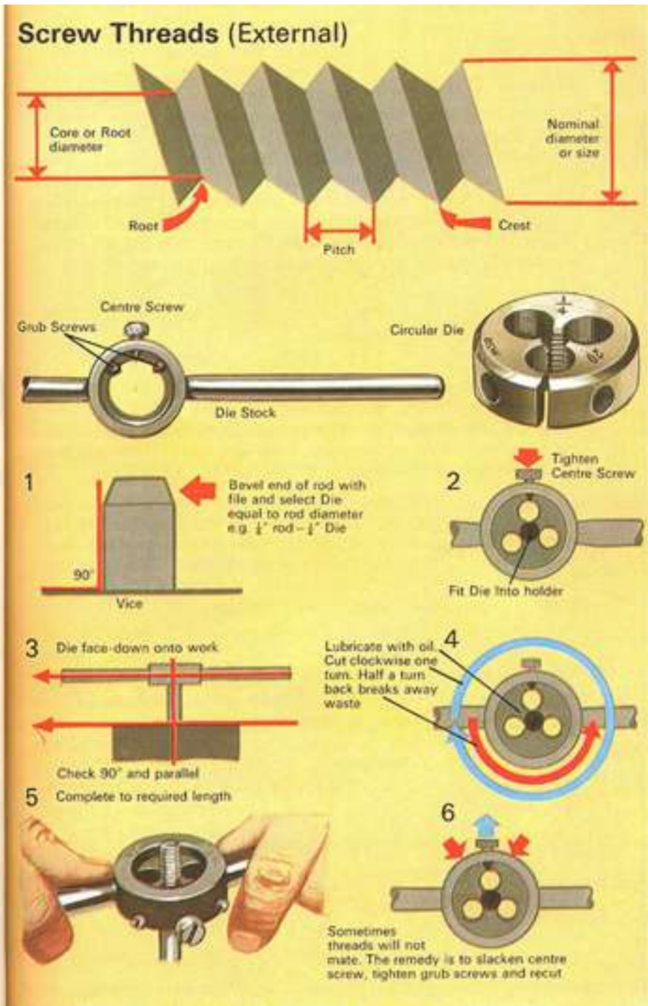

Internal screw threads

Threads are cut into the 'wall' of a hole with a tap. The process is called *tapping*. Taps are made of hardened and tempered cast steel and high speed steel. The *taper* tap is tapered for almost half its length; this enables it to get started and begin to cut. The *second cut* has a smaller taper. The final cut is made with a *plug* tap; this has hardly any taper and is especially useful for finishing threads to the bottom of 'blind' holes (i.e. holes that do not go right through the metal). It is sometimes called a *bottoming* tap for this reason.

The size and type of tap is selected to match exactly that of the die or bolt to be used.

A suitable hole must first be drilled. This stage often confuses beginners. The *tapping size* hole must be *smaller* than the size marked on the tap to allow the thread to be cut into the 'wall' of the hole (see diagram). The tapping size hole for each size of tap can be found in tables.

The square shank at the end of the tap fits into the *tap wrench*. The cutting action is the same forward and backward movement used with a die. The forward movement cuts the thread; the backward movement breaks away the waste metal which falls down the *flutes* along the length of the tap.

Tapping 'blind' holes calls for great care; the waste metal collects at the bottom of the hole and can cause the tap to jam tight. Because cast steel is very brittle, taps can easily snap off inside the work: this causes, at best, a delay and, at worst, a ruined job. For this reason the waste should be knocked out of the hole periodically. Lubrication also helps.

Very great care must be taken to start the tap vertically to the axis of the hole by using an engineer's square; otherwise a distorted thread will result.

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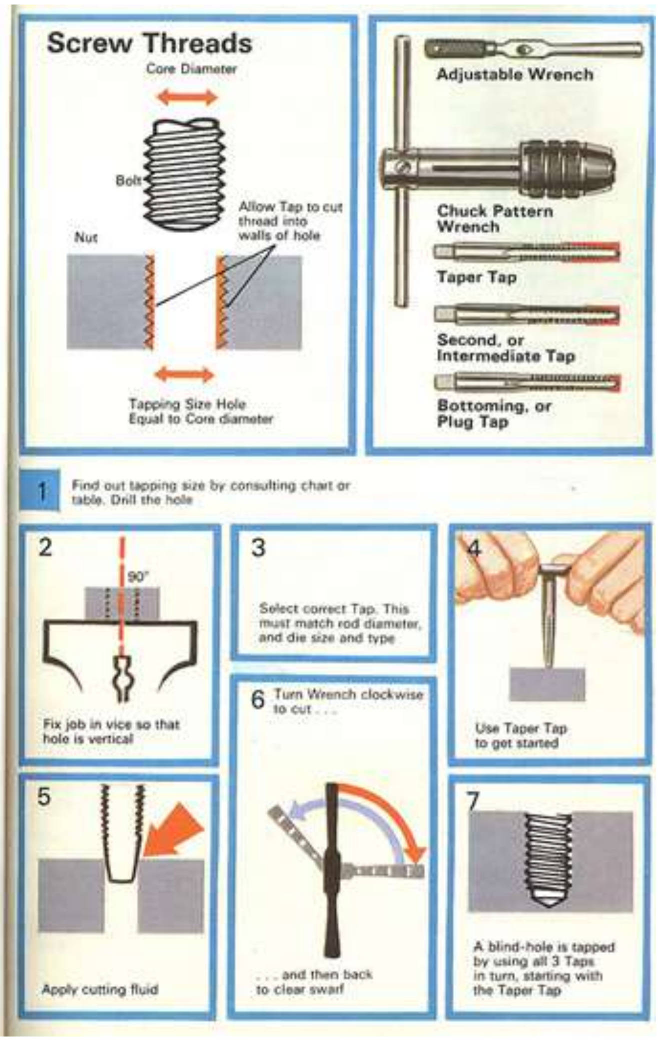
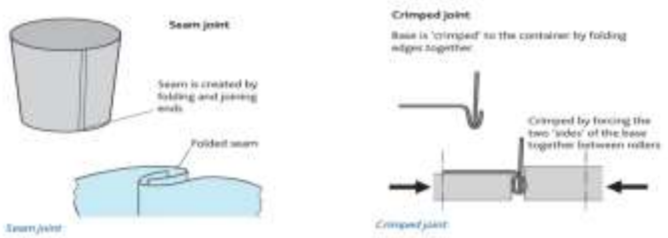
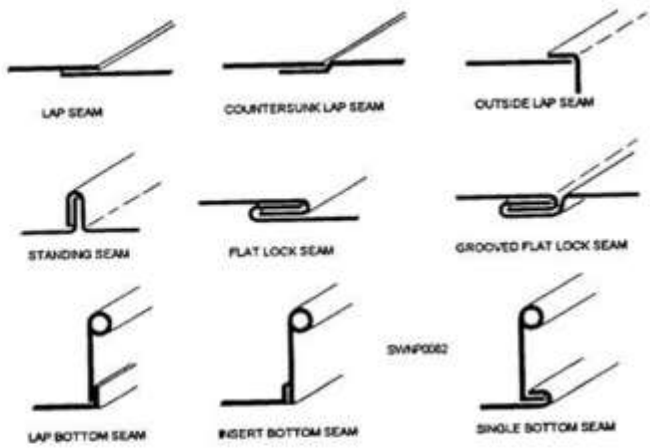


Seam joint

Simple joints can be made out of metal sheets were both pieces are folded over and interlocked as shown in the diagram below and finally locked into the sealed Grooved Seam using a grooving tool.



Seam joints



http://www.tpub.com/steelworker2/22.htm

Riveting

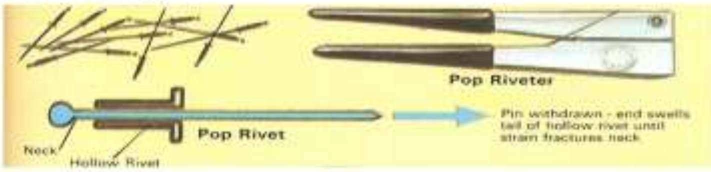
Is a simple and effective way of joining metals. It is used extensively in ship building, aircraft constructions and civil engineering.

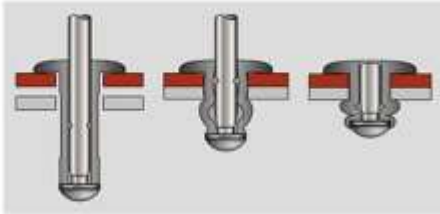
Rivets are available in several metals – copper, brass, aluminium and soft iron being the most common. Usually the material of the rivet should match the materials being joined.

The shape of the rivet head is an important feature and must be selected to suit the job.

Riveting

Riveting





Processes involving heat

All the processes name below use heat to joined materials together usually using a fillet material that is fuse to the materials being joined.

1. Soldering
2. Brazing
3. Welding

Soldering

Soldering requires lower temperature when comparing with brazing and welding.

There are a range of solders available from soft to hard.

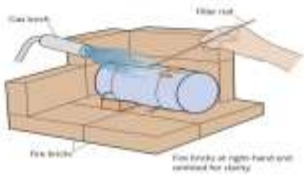
In soft soldering the heat comes from the soldering iron. Soft solders are used to joined electronic components to a circuit board, or to solder small copper or brass components. Soft solder melts around 200 degrees.

Hard soldering are used for products that require additional strength. There are two types of hard soldering – Brazing and silver soldering.

Hard (silver) solders melt between temperatures of 600 to 800 degrees.

Making a soldered joint

1. Materials to be joined are cleaned to remove grease and dust. Flux must be used to kept the joining area clean.
2. The mating surfaces must be fitting together and held securely.
3. A blowtorch is used to heat the material around the joint. The solder filler rod is rested on the joint, the heat melts the solder.
4. When the joint completely filled it should be allowed to cold down.

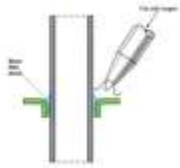


Brazing

Brazing takes place at a higher temperature than soldering, the filler rod (made out of brass alloy) melts around 800 degrees.

Materials that can be joined include copper and steel (generally mild steel).

You use the same process as soldering – just instead of using flux to clean the areas to be joined you use borax. Parts are held securely when being heated.



Welding

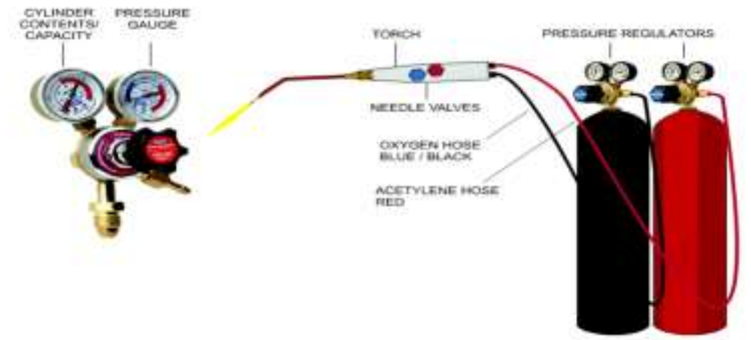
The difference between welding and brazing or soldering is when welding the materials being joined must be all the same, as well as th filler rod.

Oxy-acetylene welding

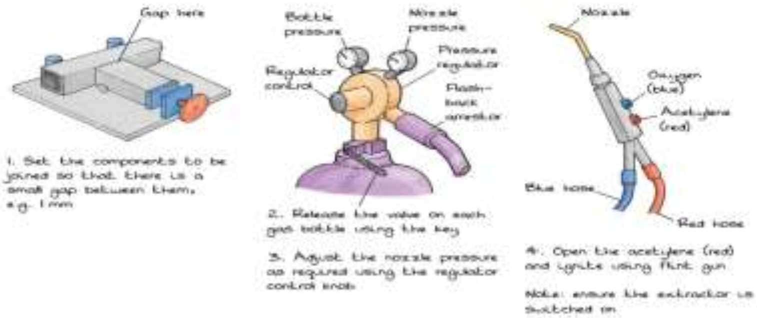
Oxyacetylene gas welding is commonly used to permanently join mild steel. A mixture of oxygen and acetylene, burns as an intense / focussed flame, at approximately 2,500 degrees centigrade. When the flame comes in contact with steel, it melts the surface forming a molten pool, allowing welding to take place, by melting the filler rod and fusing the edges together. Oxyacetylene can also be used for brazing, bronze welding, forging / shaping metal.

This type of welding is suitable for the prefabrication of steel sheet, tubes and plates.

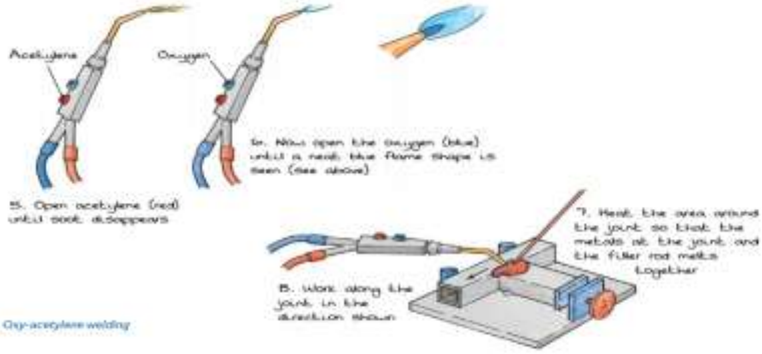
Oxy-acetylene welding



Oxy-acetylene welding



Oxy-acetylene welding



Oxy-acetylene welding

Welding and safety

Welding inevitably means exposure to extremely high temperatures. For this reason, a leather apron and leather gloves are essential.

Special welding goggles protect the eyes from the potential 'splatter' of molten metal during the welding process. They also protect the welders eyes from the dangerous ultraviolet and infrared light waves, produced by light emitted by the intense flame of the torch. The goggles usually have 'flip up' lenses. These allow the welder to look through normal lenses when arranging the metals to be welded and the 'flip down' tinted lenses when welding.

All welding must be carried out in a well ventilated area, as breathing the fumes that are generated during welding, can be dangerous.
The welding area should be clear of any potential fire and trip hazards.

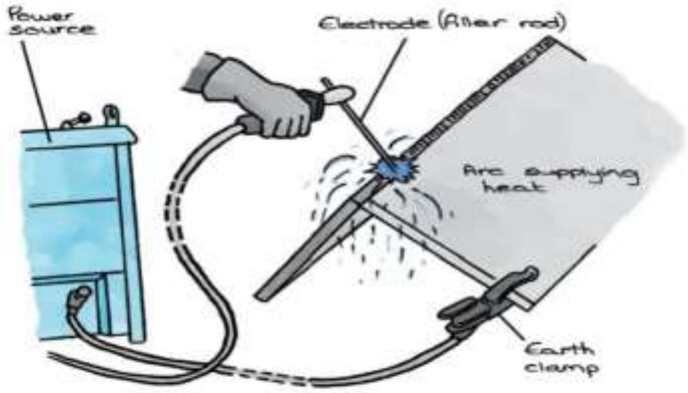
Electric arc welding

Is a type of welding that uses a welding power supply to create an electric arc between an electrode and the base material to melt the metals at the welding point.

The electrode is coated in a flux which when melted prevents the joint are from becoming oxidised.

Arc welding processes may be manual, semi-automatic, or fully automated.

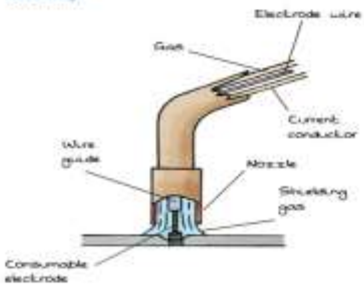
Electric arc welding



MIG welding

MIG welding, or Metal Inert Gas welding, combines two pieces of metal together with a consumable wire connected to an electrode current. A wire passes through the welding gun at the same time as the inert gas. The inert gas protects the electrode from contaminants.

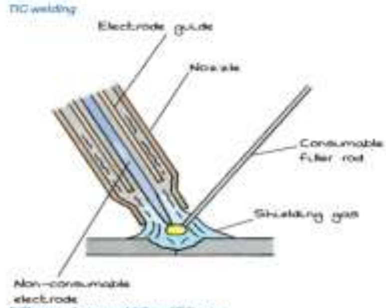
MIG welding



TIG welding

TIG welding, also known as Tungsten Inert Gas welding, uses non consumable tungsten, along with an inert gas, to weld two work pieces together. The tungsten electrode provides the electricity, but not the filler, for the welding process. While it can use filler, it sometimes creates a weld where one part melts into another.

TIG welding

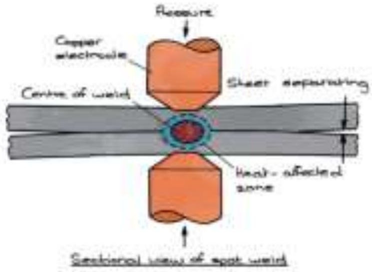


Difference between MIG and TIG setup

Comparing Arc, MIG and TIG: http://www.youtube.com/watch?v=ACwTmW3Uyh4&safe=active

Spot welding

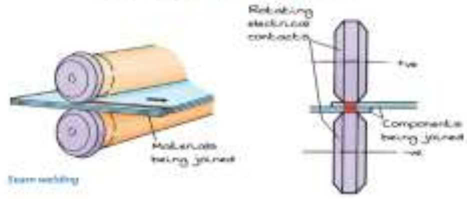
Spot welding is a technique generally used to bond metals shaped into sheets no thicker than 3 millimetres. Unlike other welding techniques, spot welding can create precise bonds without generating excessive heating that can affect the properties of the rest of the sheet. This is achieved by delivering a large amount of energy in a short time in order to create controlled and reliable welds.



Seam welding

Seam welding is a continuous process using electrode wheels on generally overlapping work pieces.

Used to close tin coated mild steel cans for food and drink.



Adhesives suitable for metal

Topic 4.3: Timber

Essential ideas: Materials are classified into six basic groups based on their different properties.

Concepts and principles:
- Characteristics of natural timber: hardwood and softwood
- Characteristics of man-made timbers
- Treating and finishing timbers
- Recovery and disposal of timbers

Guidance:
- Characteristics include tensile strength, resistance to damp environments, longevity, aesthetic properties
- Design contexts in which different timbers would be used

Aim:

Designers have great influence over the materials that they specify for products. The move towards using timber from sustainably managed forestry gives consumers confidence that rare species found in rainforests have an opportunity to recover.

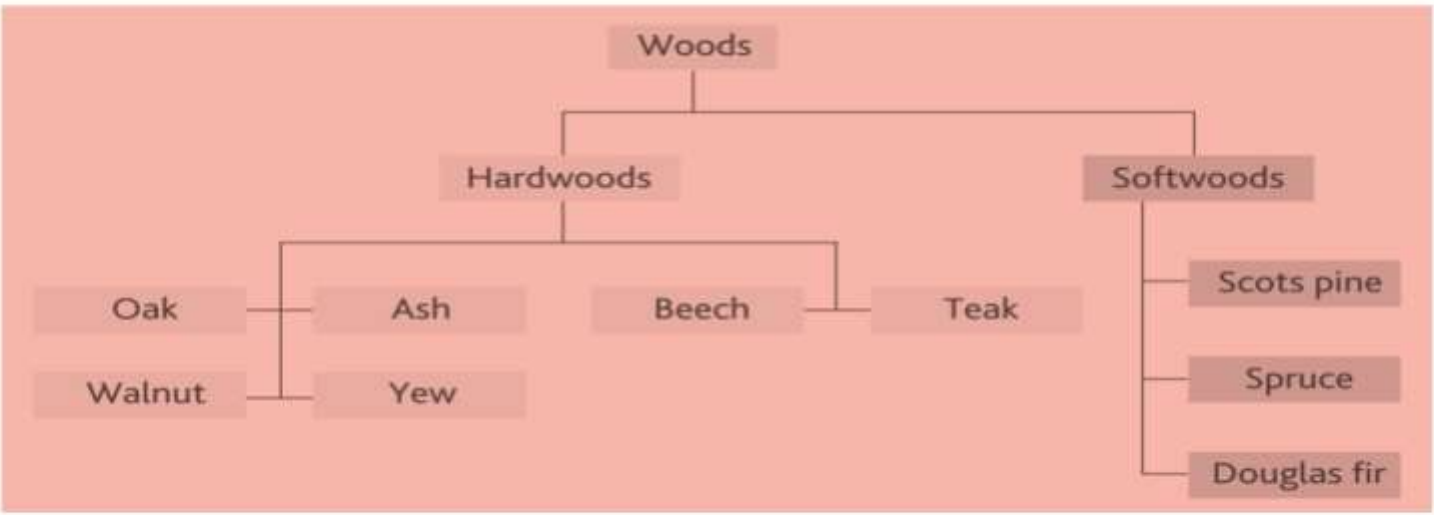
Nature of design:

Timber is a major building material that is renewable and uses the Sun's energy to renew itself in a continuous cycle. While timber manufacture uses less energy and results in less air and water pollution than steel or concrete, consideration needs to be given to deforestation and the potential negative environmental impact the use of timber can have on communities and wildlife.

Theory of knowledge:

Designers are moving from exploitation of resources towards conservation and sustainability. Is the environment at the service of man?

TYPES OF WOODS



Sources of Wood

- Wood has been used as a structural and decorative material for thousands of years and it still is. Paper making is one of its mains applications.
- Wood is a natural material and can be found all over the world in different species.
- 31% of the earth land surface is forests

Softwoods

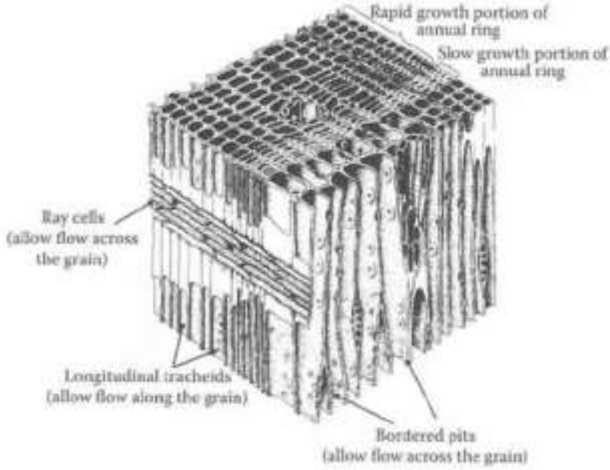
- Softwoods belong to the group of trees know as conifers and have needle shaped leaves with the seeds contained in cones. Conifers are usually evergreen. Classified as Gymnosperms and they grow in cooler climates.

- Softwoods can often be harder than hardwoods. Douglas Fir has a higher tensile and compressive strength than many hardwoods.
- Balsa wood, although technically a hardwood, is mechanically weak, has low tensile strength, low hardness and toughness.

Softwoods

Softwood	Colour/Texture	Uses
Scots pine - A straight-grained softwood but knotty. Light in colour. Fairly strong but easy to work with.		
Spruce - Creamy-white softwood with small hard knots. Not very durable.		
European redwood - Quite strong. Lots of knots, durable when preserved.		
Parana pine - Hard and straight-grained. Almost knot free. Fairly strong and durable. Expensive. Pale yellow in colour with red/brown streaks.		
Yellow cedar - A pale yellow-coloured softwood with a fine even texture. Light in weight but stiff and stable.		

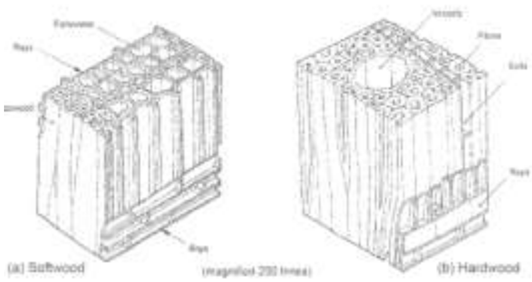
Typical structure of softwood species



Softwoods definition =

Hardwoods

- Hardwoods belong to the group of trees know as deciduous broad-leaved tree or angiosperm trees, and have broad leaves with the seeds contained in a see case - for example acorns.. Deciduous trees usually lose their leaves in autum They can take 100 years to mature. They grow in temperate, subtropical and tropical areas regions of the world.



Hardwoods definition=

Hardwoods

Hardwood	Colour/texture	Uses
Beech - A straight-grained hardwood with a fine texture. Light in colour. Very hard so is ideal to be used where it is being bashed around and used often. Beech is also very easy to work with.		
Teak - A very durable oily wood which is golden brown in colour. Highly resistant to moisture as it contains natural oils.		
Oak - A very strong wood which is light in colour. Open grain. Hard to work with. When treated it looks very classy and elegant.		
Mahogany - An easy to work wood which is reddish brown in colour. This wood is very expensive. A hardwood.		

Conversion - Green timber

- Once the tree is felled is cut into logs, which are usually slice along the length of the tree. At this stage the wood is called TIMBER. It is usually not used as it is still **green** and contains a lot of sap. Usually has 85% of moisture on its cells.
- The timber needs to be dry out until its water content is 10 to 20%. This is done by **seasoning** in a way its not affected by splitting or warping.
- If the moisture is not reduced to a level below 20% the timber will be subject to decay and attack by fungus - often referred as dry rot. The drying is not done to remove all moisture but achieve a equilibrium moisture content (EMC).

Softwoods versus hardwoods

http://www.youtube.com/watch?v=BZpNtwET28s

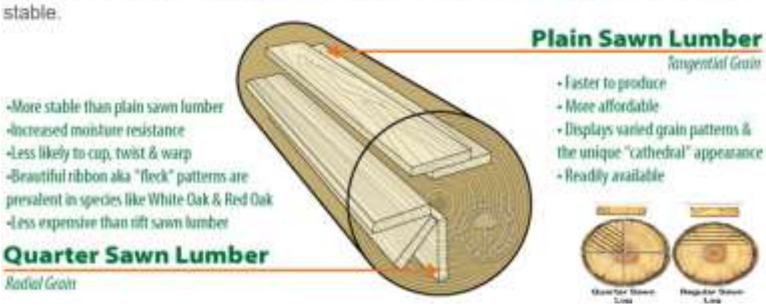
Factors affecting the strength of timber

- Moisture content
- Duration of loading
- Defects - such as knots, splits, shakes, etc
- Chemical treatment - some treatments have an adverse effect on mechanical properties

Many of these factors are related to the growth rate of the wood rather than classification as hardwoods or softwood.

Conversion

There are two basic forms of conversion – the **slab sawn** and the **quarter sawn**. The choice of conversion method can use the grain better to help make the material more stable.



Air seasoning

- Air seasoning is a natural way to let timber dry out. The timber is stack in layers, separated by sticks and left in a open side shed with a sloping roof.
- Air circulates in between the layers reducing the water content by 20%. This process takes 1 to 2 years depending on the thickness of the timber.
- The stacking of the timber is important, as badly stacked timber may split or twist as it dries.

Kiln seasoning

- Kiln seasoning is a quicker process. The timber is stacked and stored in a sealed kiln, where the temperature and humidity are controlled. This process also reduces the water content by 10 to 20% and it takes about 10 weeks.
- Temperature within the kiln are typically controlled between 70 and 100C.

ADVANTAGES OF SEASONING

- It increases the strength and stability of the timber
- By reducing the moisture content you reduce the risk of the timber causing corrosion when in contact with metal
- **The wood is less prone to rot and decay**
- **Easy to paint, glue, nail, screw and machine**

Constraints

- During the initial drying of the wood only free moisture is removed and no structural changes occur. Once the free moisture has been removed the loss of absorbed moisture begins - at this stage the moisture is below 30% and structural changes will happen such as shrinkage.
- If the seasoning process in not controlled - stresses could develop within the timber surface and centre that can lead to warping and splitting.

Man-made boards

Manufactured boards are timber sheets which are produced by gluing wood layers or wood fibres together. Manufactured boards often are made using waste of wood materials. They have been developed manyly for industrial production - as they can be made in very large sheets of consistent quality. Boards are available in many thicknesses but commonly 3,6,9,12,15,18,20 &25mm.

Table 15 *Wood products*

Man-made board	Made up of:
Plywood	Layers of veneers and resins; always an odd number of veneers
Block board	Strips of wood bonded together with a veneered surface
Chipboard	Fine chips of woods mixed with resins
MDF	Very fine wood fibres mixed with resins
Hardboard	As MDF – can be impregnated with oil
Sterling board	Shavings of wood compressed into resins

Characteristics of man made timber

- **Tensile strength:** depends on the man-made timber
  - Plywood – high tensile strength in all directions
  - Particle board and MDF – very low
- **Resistance to damp environments**: depends on the man-made timber.
  - Exterior plywood – excellent.
  - Interior plywoods very low
  - Particle board and MDF – very low
- **Durability:**
  - Plywood is high
  - Particle board and MDF is low to medium
- **Aesthetic properties:**
  - Plywood if the top layer is of a nice timber like Beech will be good
  - Particle board and MDF requires finishing or a sheet of lamination (see previous section)

Timber

Hardwoods

These come from ________ or _______-leafed trees. They are generally ____ growing (typically 60-100 years) which tends to make them ________, ________ and generally more _______. However not all hardwoods are hard, Balsa for example is very light and soft. Other examples are ___________, Beech, Ash, _____ and Teak.

Mahogany	broad	expensive	slow
tougher	deciduous	harder	Oak

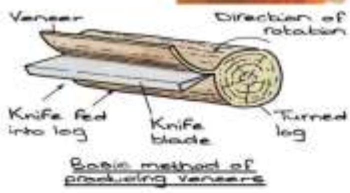
Softwoods

These come from ________ trees which have ________ rather than leaves. Softwoods generally grow _____ (typically 20-30 years) than hardwoods and are usually _______ to work with, can ______ easily and are much ______ than most hardwoods. Some common softwoods are ___________, Parana Pine, _______ and Spruce (whitewood).

Cedar	coniferous	split	faster
cheaper	needles	Scots Pine	softer

VENEERS

- **Veneer refers to thin slices of wood that have been shaved off the trunk of a tree. Hardwoods are normally used to make veneers due to being more durable than softwoods and because the wood tends to be more decorative.**
- Usually thinner than 3 mm, they are typically glued onto core panels to provide a more decorative surface to inferior quality man made boards (typically particle board or MDF). They are used for products such as doors, tops and panels for cabinets, parquet floors and parts of furniture.



Basic method of producing veneers

Table 14 Veneers and base materials

Suitable veneers	Suitable base materials
Beech	Medium Density Fibre board (MDF) Chipboard Block board Plywood
Oak	
Ash	
Walnut (including burr walnut)	
Yew	

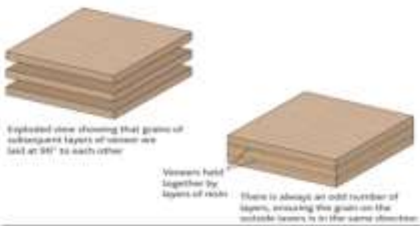
Medium Density Fibreboard

MDF is an engineered wood product made by breaking down hardwood or softwood residuals into wood fibres, combining it with wax and a resin binder, and forming panels by applying high temperature and pressure.

MDF - Smooth, even surface. Easily machined and painted or stained. Also available in water and fire resistant forms.
Used mainly for furniture and interior panelling due to its easy machining qualities. Often veneered or painted.

PLYWOOD

- Plywood consists of at least three layers or veneers of wood which have been plied together with the grain running crosswise(90 degrees) to add strength and resilience. The sheet material is very stable against warping.



Main Uses	Advantages
•	•

Medium Density Fibreboard

MDF is an engineered wood product made by breaking down hardwood or softwood residuals into wood fibres, combining it with wax and a resin binder, and forming panels by applying high temperature and pressure.

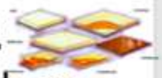
MDF - Smooth, even surface. Easily machined and painted or stained. Also available in water and fire resistant forms.
Used mainly for furniture and interior panelling due to its easy machining qualities. Often veneered or painted.

Chipboard

Also known as **particleboard**, low-density fibreboard (LDF) and chipboard – is an engineered wood product **manufactured from wood chips,** sawmill shavings, or even sawdust, and a **synthetic resin** or other suitable binder, which is pressed and extruded.

Main Uses	Advantages
	•

Manufactured Boards



These are timber _______ which are made either by _______ wood _______ or wood _______ together. Manufactured boards have been developed mainly for __________ production techniques as they can be made in very _____ sheets of consistent _____.

layers large sheets gluing
industrial quality fibres

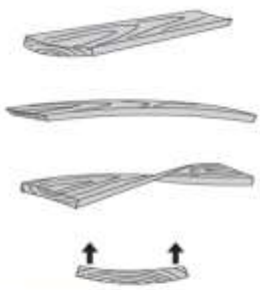
Properties of timber

Match the properties with the definitions

toughness	the ability of a piece of timber to withstand bending forces
stability	how well timber can withstand a sudden impact without breaking
durability	how well timber can withstand wear and tear
bending	the ability to resist changes in shape and size over time

Defects in wood - Shrinkage

- **Shrinkage** happens as the material dries out from a green timber to an oven dry state.
- **Moisture** is very important depending in the wood application. If I used a wood for an outside space that has a 5% moisture content it will easily absorb the moisture in the air and be prone to rotting. If I use a wood a higher than 5% moisture content indoors the wood quickly will dry out and show evidence of shrinkage.



Defects due to drying

Defects in wood - Knots

- Knots are common types of natural defects. As the tree grows branches will begin to grow out of the trunk. Knots can weaken the structure of the material, will produce irregular grain and makes the wood more difficult to work.

DRY AND WET ROT

- **These are the 2 most common forms of fungal decay in wood.**
- **Dry rot** is a wood destroying-fungus which **feeds on moisture in timbers.** Reduces the wood to a dry, powdery consistency resulting in little strength. Dry rot can cause widespread structural damage to other materials as well.

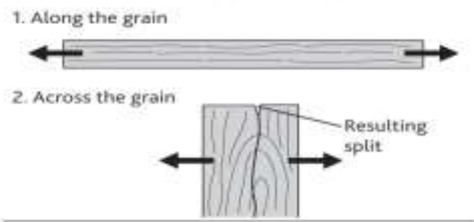
Wet rot occurs more frequently, but is less serious; decay is typically confined to the area where **timber has become and remains wet.** So the material will start to decompose.

INSECT ATTACK

- Examples of insects are the wood worm (seen in softwoods) and the death watch beetle (seen in hardwoods). Both attack the material by laying their eggs in the cracks.
- The eggs hatch over a period into larvae, which then burrow into the timber, feeding on the cellulose content and subsequently weakening the timber.
- At the end of the pupal stage the adult emerges from the timber through flight holes, ready to commence the life cycle again.
- This ongoing cycle will lead to the progressive breakdown of the timber structure infested, ultimately resulting in complete collapse.

Defects in wood - Splits

- **Splits are breaks** at the end of a board that run along the grain. They are usually restricted to the end of a board.
- **Usually caused by rapid drying.**
- **Can effect the strength and appearance**



FINISHING PROCESSES FOR WOOD

- **Unprotected wood absorbs water and expands.** This causes the resins that joined the cells together to break down and loses its strength starting to decay. Also bacteria and fungus are more likely to attack the wood.
- **Hardwoods have a greater resistance to the environment than softwoods**, due to its grain structure being more dense and therefore it will last longer. Teak for example contains oils that help repel rainwater and protect the material – therefore is an ideal wood to use in outdoor furniture and decking's.

Teak log

FINISHING PROCESSES FOR WOOD

- When applying a surface finish to wood it's important to remember the wood must be
1. Keep clean – surfaces should be smooth as possible(sanded), free from marks, scratches, glue, resin from any knot, etc
2. Keep out moisture to preserve the wood – the surface of the wood can be sealed with a primer paint, that helps the next layer of varnish or paint not being absorbed by the wood.
3. Add to its appearance – a stain could be used to add colour, however this is not a final finish and needs some other sealing and protective coating. Several coats of stain would darken the colour.

Timber treatments- are an additive preservative to improve the timber's resistance to attack and improve its durability is enhanced to a level which is suitable for the intended use.

1 Wood destroying fungi - resulted from moisture
2 Wood destroying insects - borers, white ants

Wood preservers- soak into the fibres, protect against insects & fungi.

Wood preserver: soaks or penetrate into the fibres of the timber, rather than sit on the surface. It provides protection from excess moisture which would cause the timber to split and rot.

Creosote: penetrates the timber fibres protecting the integrity of the wood from attack from borer, wood lice and fungal attack. This is used in outside conditions or for posts below the soil.

Stain preservers: soaks deep into the fibres of the timber and provides a tone or colour to the timber. protects against fungus, moisture and insect infestation

Timber finishes- are applied to the surface of the timber and is usually carried out to achieve one or both of the the following reasons:

1 Aesthetics- to improve the materials natural beauty
2 Function- to protect it from environmental impact, heat, moisture

Finishes - protects the timber against moisture & temperature differences

Varnish/Estapol- provide a hard and very tough surface which are suitable for covering timber floor board. It increase the surface hardness and by sealing the timber protects the wood fibres from moisture and insect attack.

Finishing Oils- often made from linseed or mineral oils, this liquid protects from moisture and provides low sheen finish.

Wood wax- wax provides a dull gloss shine, often made from beeswax dissolved in a solvent, it is applied to timber using a cloth. It is often used on good quality furniture and has the ability to lift the colours of the grain for a highly aesthetic and pleasing finish.

FINISHING PROCESSES FOR WOOD

- When applying a surface finish to wood it's important to remember the wood must be

1. **Keep clean** –

2. **Keep out moisture to preserve the wood** –

3. **Add to its appearance** –

NATURAL BARRIERS – OILS AND WAXES

- When a natural appearance is required, one method is to apply an oil to the wood surface. This highlights the wood's own colour, grain, making it water resistant with a non-shine finish – ideal for any kitchen top or cutting board.
- Most oils are applied with a cloth across the grain. Ideal more than one coat and left to dry 24 to 48 hours in between coats.
- Different oils can be used such as

  - a) olive oil – used when wood is in contact with food
  - b) linseed oil - can be used in most woods (makes light woods such as beech, ash and pines become dirty and discoloured very quickly)
  - c) Teak oil – Very good protection.
- Beeswax is another natural looking finish. But before the wax is applied it needs to be sealed with a cellulose sealer, so the finish will last. More than one layer could be applied and polished at the end.

OIL BASED PAINT

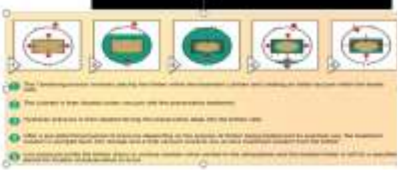
- Generally used for woods. This wood is also sealed with an undercoat before the final coat is applied. This can take a form of high-gloss, semi-gloss and matt finish. These paints are suitable for indoors and outdoor use as they are waterproof and durable. Usually used for windows and door frames.

POLYURETHANE PAINT

- This paint is very tough and scratch resistant and can stand quite high temperatures without being damaged. It is ideal to paint things such as toys, furniture, tables, doors, etc.
- It follows the same principle – it needs a undercoat.
- If the natural grain of the wood is required, then sealing could be used by applying a layer of transparent polyurethane varnish. A stain or paint could be applied before to achieve the right colour tone of wood.

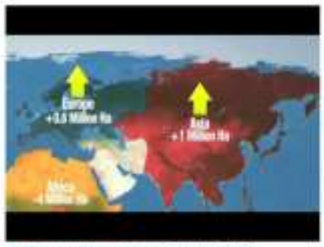
WOOD PRESERVATIVES - TANALISING

- Timbers can be obtained tanalised. This is a process where timbers, usually softwoods, are treated by the preservative prior to the making of a product.
- The process involves the **impregnation** of the timber with a solution of copper sulphate and other salts in large pressure vessels.
- Timber products treated this way could last up to 50 years



Recovery and disposal of timbers

- **Wood recycling** is the process of turning waste timber into usable products.
- **Recycling timber** is a practice that was popularized in the early 1990s as issues such as deforestation and climate change prompted both timber suppliers and consumers to turn to a more sustainable timber source.
- **Recycling timber** is very common in countries such as Uk, Australia and New Zealand. Old timber is chipped down to wood chips and used to make man made boards, animals bedding or being as biomass to power homes.



REVISION QUESTIONS

1. Explain the difference between softwoods and hardwoods.
2. Name three hardwoods and three softwoods and its main properties.
3. Name a reason why greenwood is undesirable as a commercial timber?
4. Name two methods of log conversion.
5. What is the advantage of quarter sawing a log?
6. What is the main cause of splits in timber?

Table 2.1 Composition of recycled municipal waste in the Netherlands 2001-2010 in 1000 tonnes

Recycling of MSW	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Paper and cardboard	1 013	1 006	992	1 027	1 045	1 081	1 106	1 124	1 077	1 063
Glass	335	342	341	342	338	341	344	349	345	351
Cartons for beverages	1	1	2	2	3	2	3	2	3	3
Metal packaging	2	2	3	3	2	2	2	2	2	2
Plastic packaging	2	3	4	5	5	6	6	8	26	62
Other plastics	-	-	-	-	-	-	4	5	6	7
WEEE	53	57	61	67	71	70	74	81	82	84
Metals from household waste	75	76	77	77	77	81	83	82	83	73
Furniture	14	24	28	28	35	40	39	38	39	38
Bulky garden waste	353	356	377	397	406	407	452	426	444	452
Wood	246	273	283	310	316	341	349	342	326	323
Organic, kitchen and garden waste	1 404	1 408	1 340	1 407	1 302	1 298	1 315	1 299	1 302	1 298

Source: Statistics Netherlands, 2012

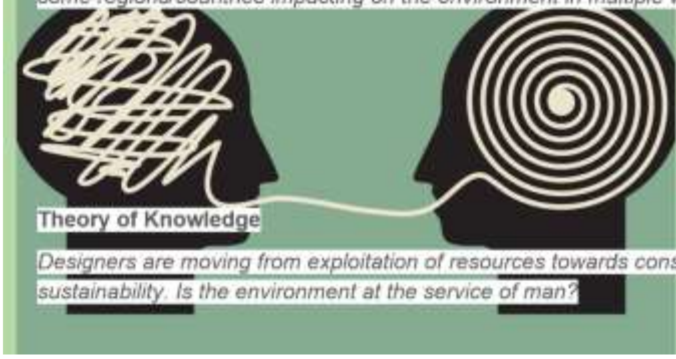
Reforestation

- Reforestation is the process of restoring tree cover to areas where woodlands or forest once existed. If this area never returns to its original state of vegetative cover the destructive process is called deforestation.
- Reforestation may take a variety of forms. In many zones in the US it occurs naturally as the native hardwood forests are so resilient that can re-establish themselves. However, urban sprawl and agriculture requires more land which leads to deforestation. Artificial reforestation is required where nutrient deficient soils generate erosion-prone environments.

Sustainable forest

International Mindedness

The demand for high-quality hardwoods results in the depletion of ancient forests in some regions/countries impacting on the environment in multiple ways.



Read pages 112 and 113 under these headings in your theory book

Theory of Knowledge

Designers are moving from exploitation of resources towards conservation and sustainability. Is the environment at the service of man?

Product analysis exercise

Look at the products below and analyse them in terms of being design to be environmentally friendly throughout its life cycle.

Carlton room divider, designed in 1981 by Ettore Sottsass, in wood and plastic laminate.
Unlimited edition with a numbered metal label.
SIZE L 190 P. 40 H. 196 cm Price 13.800 euros

Paper softwall
design by Stephanie Forsythe + Todd MacAllen
Made from layers of paper structured with flexible honeycomb geometry
SIZE 1830x235mm Price 1100 euros

EXAM STYLE QUESTIONS

5. When can timber be defined as renewable?

A. When a new tree is planted to replace used timber
B. When it is re-engineered
C. When it is sourced from a rainforest
D. When it has been recycled

15. Man-made timbers can be convenient for industrial use.
Which of the following man-made timbers is created from thin layers glued together?

A. Chipboard
B. MDF
C. Particle board
D. Plywood

16. What is an advantage of man-made timber over natural timber?

A. High tensile strength with resistance to damp environments
B. A renewable source of material
C. The creation of large sheets of consistent quality
D. Can be recycled more easily

18. What is generally true of hardwoods compared to softwoods?

	Density	Resistance to damp environments
A.	Low	Low
B.	Low	High
C.	High	Low
D.	High	High

7. Figure 11 shows a Butterfly Stool made of two identical pieces of plywood, joined in the centre with a single metal rod and connected under the seat by just two screws.

Figure 11: Butterfly Stool

(d) Explain three characteristics of plywood that are important in the design of the Butterfly Stool. [9]

8. Figure 8 shows the PlayShapes product by Miller Goodman. PlayShapes is a set of 74 modular hardwood shapes which are finished with paint or varnish. They can be used by young children of various ages to create hundreds of three-dimensional designs.

(a) (i) State one advantage of using paint to finish the parts of the PlayShapes product. [1]
(ii) State one disadvantage of using paint to finish the parts of the PlayShapes product. [1]
(b) Explain one characteristic of hardwood timber which is important for the nature of the PlayShapes design. [3]

(b) Compare the use of pine wood with mahogany as materials for flooring in relation to safety for users. [3]

Topic 4.9B: Manufacturing Processes (Timber)

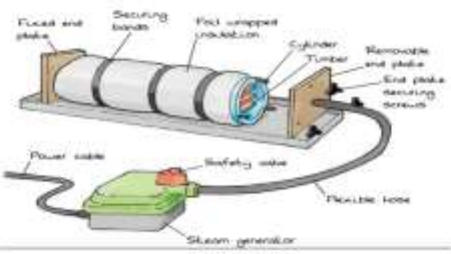
LAMINATION

- Is the technique of manufacturing a material in **multiple layers**, so that the composite material achieves improved strength, stability, sound insulation, appearance or other properties from the use of differing materials. A laminate is usually permanently assembled by heat, pressure, welding, or adhesives. Examples of laminates include surface for kitchen worktops, laminate flooring products, parts of chairs or furniture.

LAMINATION

STEAM BENDING

- This method has been used in the manufacturing of a diverse range of products, some examples being wooden boat building where it is used in the shaping of hull's ribs and lap boards, the production of traditional wooden musical instruments such as violins and in the manufacture of wooden furniture.



When working with plywood care should be taken, as prolonged immersion in the steam chest will delaminate the material.

STEAM BENDING

- Is a woodworking technique where strips of wood are steam heated using a steam box. The applied heat and moisture makes the wood pliable enough to easily bend around a mould to create a specific shape.
- The moulding process is usually done by clamping the strips of wood to a positive form, with the strips of wood often reinforced on the outside with a metal band to prevent blowout.

http://www.youtube.com/watch?v=[illegible]

Milling (subtractive process)

- Milling is the process of cutting and drilling material (like wood or metal). A milling machine, regardless of whether it's operated manually or through CNC, uses a rotating cylindrical tool called a milling cutter. It is held in a spindle and can vary in form and size.
- The main difference between a milling machine and any other drilling machine is the ability to cut in different angles and move along different axes. For this reason, there are several kinds of milling machines, which are designated by number of movement axes from (2 to 5) but are operated through a computer. No manual operation required.

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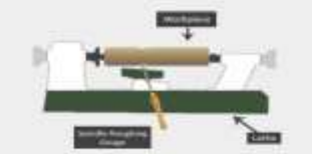
Wood turning (subtractive process)

Spindle Turning	Faceplate Turning
	
• Grain of wood runs parallel to the bed of the lathe. • Workpiece is shaped from the side while it rotates on its center axis.	• Grain of wood is perpendicular to the bed of the lathe. • Tools like bowl gouges are used to shape and hollow the rotating workpiece.

Laser cutting (as seen in metals unit)

- Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications. Laser cutting works by directing the output of a high-power laser using a CNC machine, by computer.
- The material then either melts, burns, vaporizes away, or is blown away by a jet of gas, leaving an edge with a high-quality surface finish. Industrial laser cutters are used to cut flat-sheet material as well as structural and piping materials.

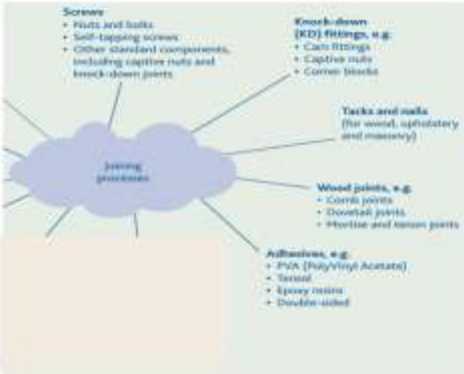
Living hinge

A living hinge is a thin flexible hinge (flexure bearing) made from the same material as the two rigid pieces it connects. It is typically thinned or cut to allow the rigid pieces to bend along the line of the hinge. The minimal friction and very little wear in such a hinge makes it useful in the design of microelectromechanical systems, and the low cost and ease of manufacturing makes them quite common in disposable packaging.

On wood, a variant on the kerf bend can be used to create living hinges in laser cut wood. The technique is popular for making light-duty hinges with large radius. It is also possible to create a living wood joint by hand, but the result is less accurate.

JOINING WOOD

As with other materials, wood can be joined temporarily or permanently using different joining methods.

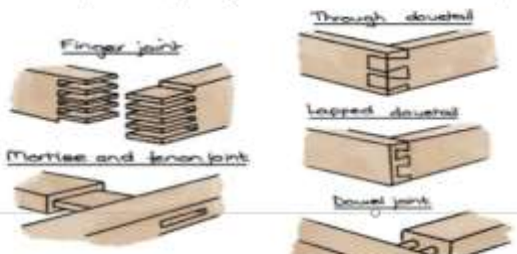


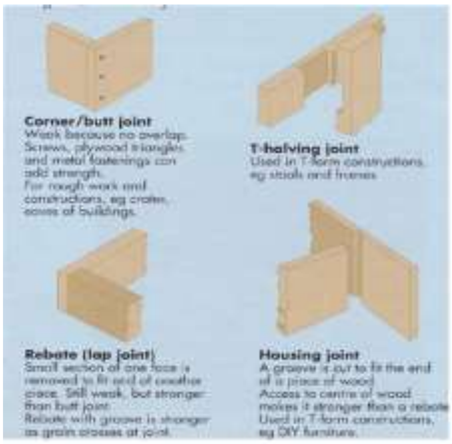
JOINING WOOD

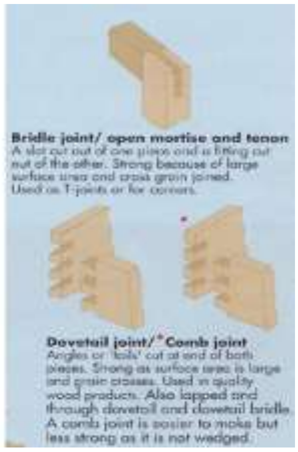
- In the case shown below a barn wall is being supported by a framework that is bolted together.
- In a modern roof truss is produced in a different way without the traditional wood joints. Each of the timbers is cut to size and shape and once set up in a jig, plates with nails are used in both sides of the joints.

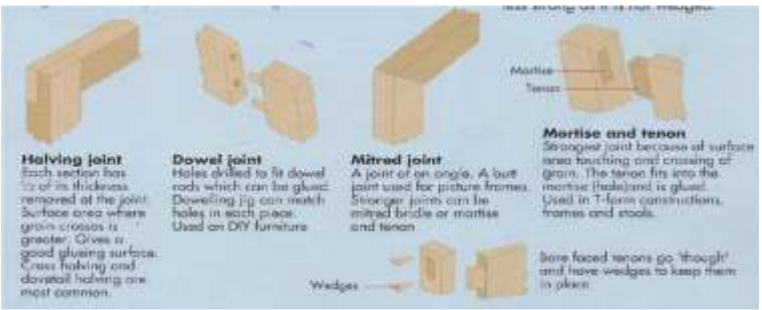
TRADITIONAL WOOD JOINTS

- All wood joints will be secured with an adhesive such as PVA making them permanent. The adhesive would be spread on the two halves of the joint, the whole joint clamped together until the adhesive is dry.



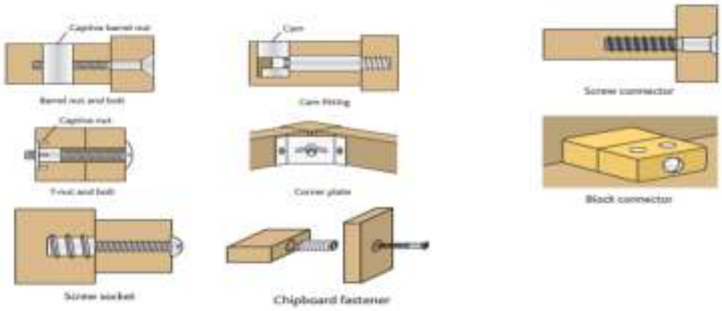






SELF ASSEMBLY FURNITURE

- Flat pack furniture is put together using self-assembly parts with a range of fixings – usually knock down (KD) fittings.



- Along with these **KD fittings** other fixings could be used as hinges (fit into pre-drilled holes) or a range of screws.

Product analysis exercise 5: Wood and manufactured boards

Laminated dining chair

1 Study the photo of the dining chair.

a The chair is made from laminated beech veneers. Explain why beech is suitable, making reference to the following requirements:
- aesthetic
- functional
- manufacturing.

b Use notes and diagrams to sketch how the veneers are laminated into the shape of the seat.

c Sketch how the seat could be joined to the legs.

d The seat is finished with a polyurethane varnish. Explain why this is suitable and how it would be applied.

2 The table top pictured is made from MDF. Explain why this material is often used in such furniture.

3 The table top is finished with a melamine formaldehyde laminate. Explain why this is used.

CASCAMITE

- Usually comes in powder to be mixed with water.
- It gives a strong joint which is heat and waterproof resistant.
- The main disadvantage is that it can stain the wood.
- Setting time is 4 to 6 hours.

1. Pour water and powdered cascamite into a glass container.
2. Stir thoroughly until a smooth creamy paste is produced.
3. Apply to both surfaces using a spreader.
4. Use G Clamps to lock the two pieces together until the adhesive sets.

WOOD ADHESIVES

- One of the simplest ways of joining wood. Spread an adhesive over the clean joining surfaces and clamp them together until the adhesive dries. The strength on the joint will depend on the type of adhesive and if the two surfaces are a close fit.
- You should also consider where and how the product will be used. For example if the product is to be used outdoors, then the adhesive must be waterproof.

POLYVINYL ACETATE (PVA)

- This is a resin glue which is ready mixed for instant use.
- It provides a quick setting, it doesn't stain the wood as it dries clear, however its not waterproof.
- The glue sets in one hour but its full strength is achieved after 24 hours.
- The work needs to be clamped together.

CONTACT ADHESIVE

- It's not a glue to join two pieces of wood together but rather an adhesive for fixing other materials to wood (e.g. plastic laminates, tiles).
- It's a synthetic rubber glue and has to be spread on both surfaces being joined. It is left until is touch dry.
- Parts can then be joined but they must be match together in the right position.

EPOXY RESIN

- This type of adhesive will bond almost any material together.
- Its an expensive adhesive so its usually used for small joining parts.
- It comes in 2 parts the resin and the hardener. They have to be mixed in equal amounts.
- The mixture should be spread over both surfaces and left to set for 24 hours.

WOOD ADHESIVES – COSHH IMPLICATIONS

- http://www.hse.gov.uk/woodworking/hazard.htm
- The Control of Substances Hazardous to Health Regulations (COSHH) requires employers to ensure that the exposure of employees to substances that are hazardous to health is either prevented or, where this is not reasonably practicable, adequately controlled.
- http://www.hse.gov.uk/coshh/industry/woodworking.htm

Substance	Health risk	Controls to consider
Wood dust		
Hardwood, softwood and wood composites - chipboard, medium density fibreboard (MDF) etc.		Substitute high risk woods that may cause asthma. These include some hardwoods and softwoods such as Western Red Cedar. Use dust extraction. Use vacuum equipment that meets at least the dust class M (medium hazard) classification for cleaning. Use respiratory protective equipment (RPE) with an assigned protection factor (APF) of 10 for low dust levels of low risk woods. Use RPE with an APF of 20 for high dust exposures or when working with more toxic woods.
Solvents		
Varnish Paint Thinners Adhesive Paint stripper Stain Wood preservative		Select safer material like waterborne products. Use extraction ventilation. You may also need RPE. Use air fed RPE (breathing apparatus) in restricted spaces. Use a high efficiency spray gun. Provide protective clothing including protective gloves. Provide good general ventilation. Provide good washing facilities and skin creams.
Reactive systems		
Isocyanate based products, eg 2pack (2K) paints, varnishes and adhesives Epoxy systems		Spray in an enclosed spray booth or room with extraction. Use air fed RPE, protective clothing and gloves for spraying. Use protective gloves and clothing for brush and roller application. Provide good washing facilities and skin creams.
Wood preservatives		
Solvent or water borne products		Cut out and replace diseased timbers. Kill disease by drying out. Use breathing apparatus in confined spaces. Provide good washing facilities

HAZARD SYMBOLS

Hazard symbols are recognizable symbols designed to warn about hazardous materials, chemical, poisons, and other things. The use of hazard symbols is often regulated by law and directed by standards organizations.

Health Hazard
Not corrosive but will make the skin red or blister.

Corrosive
Attacks and destroys living tissues, such as skin and eyes.

Toxic
Can cause death, eg if swallowed, breathed in or absorbed by skin

Highly flammable
Catches fire easily.

Environment al hazard
Chemicals toxic to aquatic wildlife.

EXAM STYLE QUESTIONS

6. Figures 6 and 7 show the Teanest compact table and chairs set by designer Jody Leach.

The two chairs tuck neatly under the table (Figure 7). The furniture is manufactured from composite timber (plywood) and is designed to be self-assembled (flat-pack). It is available in white, black or red with a protective finish (varnish).

Figure 6: Teanest table and chairs

Figure 7: Teanest table and chairs (compact)

(a) (i) State the manufacturing technique used to join together the components of the table and chair set. [1]

(ii) Discuss three considerations for the design of the table and chairs in relation to cost-effective manufacturing. [9]

Topic 4.4 - Glass

Concepts and principles:

- Characteristics of glass
- Applications of glass
- Recovery and disposal of glass

Guidance:

- Characteristics include transparency, colour and strength
- Design contexts in which different types of glass are used

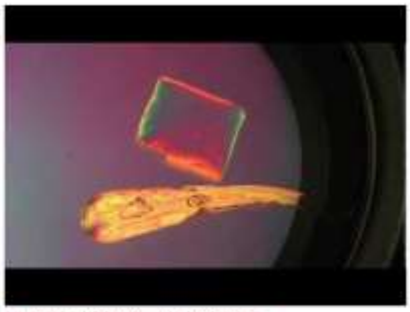
Aims:

The earliest found examples of glass objects come from the third millennium BCE, and up until the 1850s glass was considered a luxury item. Since then, glass has permeated and revolutionized many aspects of human life and culture in diverse fields such as the arts, architecture, electronics and communication technologies.

Nature of design

The rapid pace of technological discoveries is very evident in the manufacture and use of glass in electronic devices. Different properties have been presented in glass for aesthetic or safety considerations for many years but the future of glass seems to be interactivity alongside electronic systems.The structure of glass is not well understood, but as more is learned, its use is becoming increasingly prominent in building materials and structural applications.

What is glass?



http://www.youtube.com/watch?v=[illegible]

The main component for glass is **silica sand** (silicon dioxide) however it takes temperatures of 1700 celsius to fuse it . In order to reduce energy requirements soda ash (sodium carbonate) is added reducing the fusing temperatures to 800 to 1000 celsius. However like this glass if soft and water soluble - to give glass stability and hardness other materials like limestone and dolomite are added. Also scrap glass is added to make the process more economical.

Types of glass

There are many types of glass with different chemical compositions and therefore with different physical properties. The main types are:

- **Glass fibre**
- **Lead glass**
- **Commercial glass** also known as soda-lime glass
- **Borosilicate glass** (low coefficient of thermal expansion - example: pyrex)

Glass can be create to meet almost any requirement. For many specialised applications in chemistry, pharmacy, the electrical and electronics industry, optics, the construction and lighting industry. Also as modern materials such as glass ceramics composites.

Characteristics of glass

Transparency, allows light to pass through thus allowing you to see the contents of a jar or through a window. Leads to a variety of uses both functional and aesthetic.

Aesthetic appeal - glass is extremely **plastic**, allowing it to be formed, drawn, blown and joined into any imaginable shape. Is a found material for artistic expression on addition to its functional use. **Colour** can be designed in my adding metallic oxides.

Brittleness, it has a low impact strength and thus will shatter easily (low toughness).

Characteristics of glass

Hardness, high hardness and wont scratch readily.

Chemically inert -so leaching of acid based contents is not a problem.

Non-Toxic due to its un-reactivity therefore suitable for food storage.

Non-porous, thus will hold liquids or stop moisture seeping from outside.

Electrical Insulator because of this has extensive use on high voltage overhead electrical lines.

Biocompatibility -= the compatibility of the material to its environment

Commercial glass

Most manufactured glass is soda-lime composition used to **make bottles, tableware, lamp bulbs**, **windows** and **plate glass**. This is a cheaper glass.

Poor thermal shock resistance, which means it can crack and shatter due to rapid temperature change, as different parts of the glass expand at different rates.





Borosilicate glass (Pyrex)

shock resistance properties

therefore expands and contracts less than soda glass.

Pyrex glass is used for the design of **measuring jugs**, **thermometers**, **lab equipment such as test tubes**, **microwave doors**, **oven doors**, **mirrors of large telescopes etc.**

Willow glass

Willow Glass is a flexible borosilicate glass used as a substrate in LED displays. It's ultra-thin, lightweight & conformable. Is a perfect hermetic barrier that protects sensitive materials from moisture, oxygen, and staining.



http://www.youtube.com/watch?v=QvZrVLPXam0

Gorilla glass

Gorilla Glass is a brand of chemically strengthened glass developed and manufactured by Corning, now in its sixth generation.

It's designed to be thin, light and damage-resistant. The alkali-aluminosilicate sheet glass is used primarily as cover glass for portable electronic devices, including mobile phones, portable media players, portable computer displays, and television screens.

The glass gains its surface strength, ability to contain flaws, and crack-resistance by being immersed in a proprietary hot, potassium-salt, ion-exchange bath.

Find out more

https://electronics.howstuffworks.com/everyday-tech/gorilla-glass.htm

Applications of Glass - Laminated glass

Laminated glass consists of 2 thin sheets of glass that have a sheet of plastic glued between them.

When glass is put under pressure and the glass fractures - the plastic bonded sheet retains the fragments. The plastic layer stops the propagation crack. Bullet proof glass is possible - the bullet does not pass through the glass since the plastic laminate absorbs the energy of the moving bullet.

Laminated glass is used in construction structures such as stairs, in automobile windshields, in exterior storefronts, curtain walls and windows.


Applications of Glass - Toughened glass

- Toughened or tempered glass has been heat treated - with the outside of the glass being held in compression while the inside is in tension. This is achieved by heating the glass to almost melting point then chilling the outside of the glass with air jets while the centre remains hot and plastic.
- The outside of the glass therefore cools and hardens before the inside. On cooling, glass will contract but due to the different rates of cooling, the degree of contraction will be different between inner and outer parts of the glass. This leaves the outside in compression and the protected inside in tension.
- Toughened glass shatters into small granular pieces not sharp shards when broken.
- Used for balcony doors, athletic facilities, swimming pools, facades, shower doors and bathroom areas, exhibition areas and displays, etc.

http://www.youtube.com/watch?v=GCxQVVfpkk

Recovery and disposal of glass

- Glass can be recycled endless as has been for many years. In the EU 71% of glass bottles and jars are recycled greatly reducing the need for virgin materials.
- Adding crushed glass (called cullet) to the melt promotes the melting of sand lowers the furnace temperatures reducing the amount of raw materials and energy required. Using 25% cullet will reduce energy by 5% and therefore reducing emissions.
- Green glass is now commonly made from batches containing 95% cullet.

http://www.youtube.com/watch?v=6RBYGbGbf08

Recovery and disposal of glass

- It is estimated that it takes 1 million years for glass to degrade, however it does not contaminate soil in the same way as other materials due to its chemical resistance.
- Off-cuts and faulty glass products are broken up (cullet) and reused by missing them with virgin materials to form the batch. There is no degradation of glass quality in this process so it can be repeated indefinitely. As a result there is usually very little waste during manufacture.

Container	Energy (MJ)
Aluminum can used once	7.4
Glass bottle used once	3.9
Recycled aluminum can	2.7
Recycled glass bottle	2.7
Refillable glass bottle used 10 times	0.6

Glass recycling: energy use chart

Exam style questions

1. What is not a characteristic of glass?
A. It is a hard, solid material.
B. It has a crystalline structure.
C. It is inert and biologically inactive.
D. It is 100% recyclable.

2 Which is the principal component of glass
A. Silicon dioxide
B. Lead oxide
C. Sodium oxide
D. Calcium oxide

3. Glass can be processed in many ways to achieve different properties. Which of the following processes describe tempering?
A. Heat treating
B. Laminating
C. Moulding
D. Etching

Exam style questions

2. Figure 4 shows a glass pool table. The playing area is made of a toughened glass.
However, pool cannot be played on a glass surface as there is not enough friction to make the game realistic.
To make the surface more realistic the toughened glass is covered by a thin transparent surface, known as Vitrik, which replicates the cloth of a traditional pool table (Figure 5).

Figure 4: Glass pool table

Figure 5: A traditional pool table

(a) (i) Outline why the glass pool table is made from toughened glass. [2]
(ii) Outline why the pool table may be made from glass rather than the traditional materials of slate covered by a green material shown in Figure 5. [2]

Exam style questions

3. The Volkswagen (VW) Beetle is considered a design classic. In the 1999 car of the century competition it came fourth (after the Ford Model T, Mini and Citroen DS).
Since the production of the first car in 1941 the car has changed very little in appearance, see Figure 10. Initially the bodywork was made of steel, but more recently this has changed to a range of materials such as alloys, composites and plastics.
Other materials that make up the VW Beetle have also changed. For example, the windscreen (windshield) is made of laminated glass whereas it was originally made of toughened glass.

Figure 10: The VW Beetle 1941–2015

(a) Explain why the Volkswagen (VW) Beetle uses laminated glass for its windscreen. [3]

Topic 4.5: Plastics

Essential Idea

Materials are classified into 6 basic groups based on their different properties.

Essential understanding

Most plastics are produced from petrochemicals. Motivated by the finiteness of oil reserves and threat of global warming, bio-plastics are being developed. These plastics degrade upon exposure to sunlight, water or dampness, bacteria, enzymes, wind erosion and in some cases pest or insect attack, but in most cases this does not lead to full breakdown of the plastic. When selecting materials, designers must consider the moral, ethical and environmental implications of their decisions.

Aim

Early plastics used from 1600 BCE through to 1900 CE were rubber based. Prompted by the need for new materials following the first world war, the invention of Bakelite and polyethylene in the first half of the 20th century sparked a massive growth of plastic materials and as we identify the need for new materials with particular properties, the development of new plastics continues.

Concepts and principles

- Raw materials for plastics
- Structure of thermoplastics
- Structure of thermosetting plastics
- Temperature and recycling thermoplastics
- Recovery and disposal of plastics

Guidance

- Properties of PP, PE, HIPS, ABS, PET and PVC
- Properties of polyurethane, urea-formaldehyde, melamine resin and epoxy resin
- Design contexts in which different types of plastics are used

History of plastics

- *Plastic* is a word that originally meant "pliable and easily shaped." It only recently became a name for a category of materials called polymers. The word *polymer* means "of many parts," and polymers are made of long chains of molecules.
- Polymers abound in nature. Cellulose, the material that makes up the cell walls of plants, is a very common natural polymer.
- The first synthetic polymer was invented in 1869 by John Wesley Hyatt, as a substitute for ivory. By treating cellulose with camphor, Hyatt discovered a plastic that could be crafted into a variety of shapes and made to imitate natural substances like tortoiseshell, horn, linen, and ivory.

http://www.youtube.com/watch?v=[illegible]

Bakelite

In 1907 Leo Baekeland invented Bakelite, the first fully synthetic plastic, meaning it contained no molecules found in nature.

Baekeland had been searching for a synthetic substitute for shellac, a natural electrical insulator, to meet the needs of the rapidly electrifying United States.

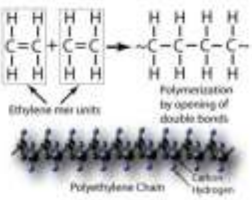
Bakelite was not only a good insulator; it was also durable, heat resistant, and, unlike celluloid, ideally suited for mechanical mass production. Marketed as "the material of a thousand uses," Bakelite could be shaped or molded into almost anything, providing endless possibilities.

Nowadays

Over the last century and a half we have learned how to make synthetic polymers, sometimes using natural substances like cellulose, but more often using the plentiful carbon atoms provided by petroleum and other fossil fuels.

Synthetic polymers are made up of long chains of atoms, arranged in repeating units. It is the length of these chains, and the patterns in which they are arrayed, that make polymers strong, lightweight, and flexible. In other words, it's what makes them so *plastic*.

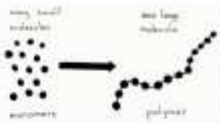
Usually manufacture of hydrocarbons of ethylene and propylene obtained from crude oil or natural gas.



Processing plastic

Polymers are mainly processed from oil but sometimes they can be made from gas.

1. Oil is extracted from underground drilling



3. From passing nathpha through a steam cracking process ethylene is made - which then can be produced into propylene - the linking of molecules is called polymerisation.

2. Its heated in a refinery which separated it into different chemicals. This is called fractional distillation. One of this fractions is naphtha.

4. Different chemicals can be added to the polymer to change its properties

5. Plastics are available in a range of shapes and sizes (called stock forms - see slide 9)

6. Plastics don't need any surface finish

Stock forms

Plastics can present themselves in many of shapes and sizes

Films and **rolls** are good for vacuum forming and for packaging with windows

Foam is used for protective packaging, making models and insulation

Sheets, rods and **tubes** can be cute to size and bend/shaped

Granules are used to be melted down and used in injection moulding and extrusion

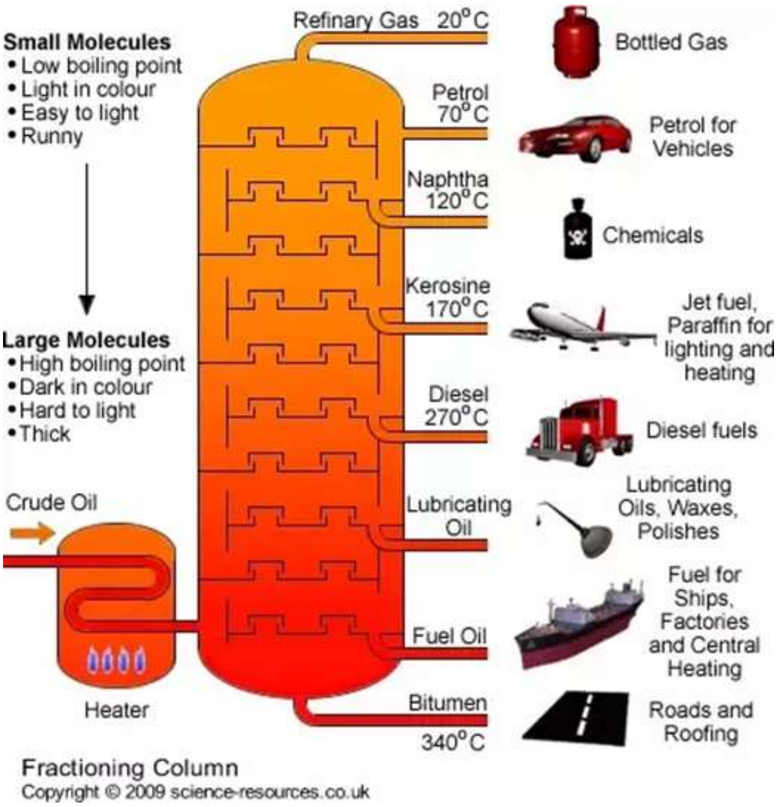
Fibres used to make a wide range of clothing

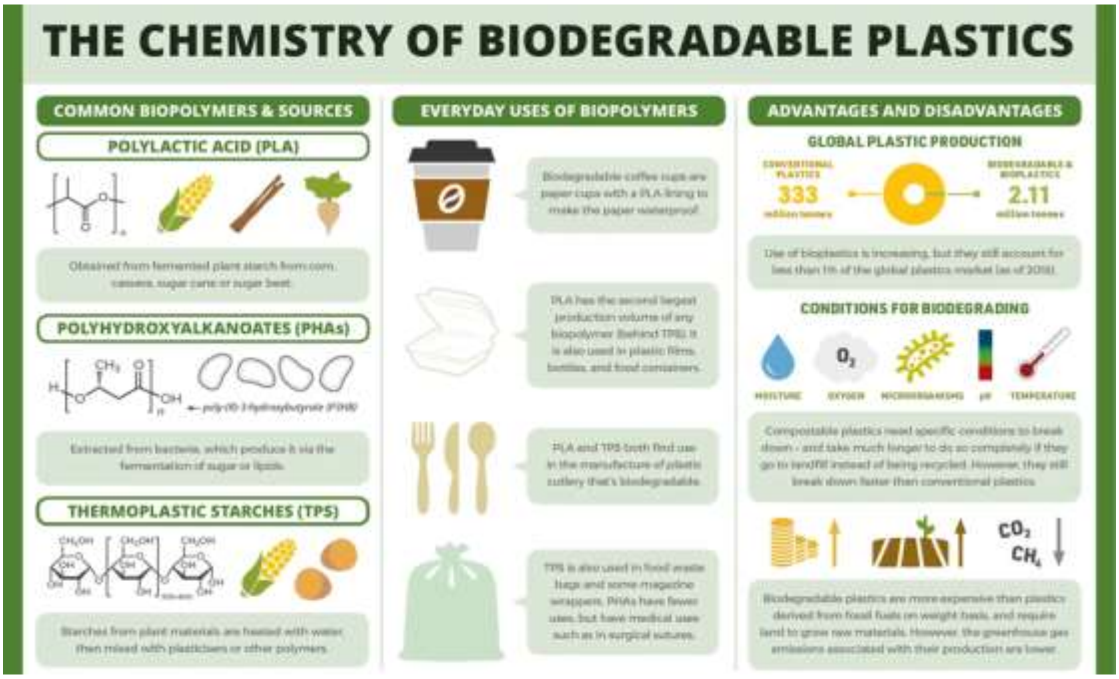
Liquid used for seals, covers and moulded flexible parts such as baking trays.

Biodegradable plastics

As a response to the fact crude oil is a non renewable source, the industry has look at vegetable products as an alternative. Biodegradable plastics derived from plant sources such as hemp oil, soy bean oil, corn starch, cellulose and sugar.

This plastics are truly biodegradable and will degrade and became compost when exposed to ultraviolet light, water or bacterial action.





Biodegradable polymers

Polylactides (PLA) is derived from fermented plant starch. Is transparent and has similar properties to PET and PP, so it can be made using the same methods for thermoplastic. Used for packaging (bottles, films), gardening products, disposable nappies. Certain types of PLA have been used in medical implants and in sutures - because of their ability to dissolve over time.

PHA also known as **Biopol** is produced naturally by using bacteria to aid in fermenting plant sugar. PHA are used in medicine as dispersible fixative such as films, screws and bone plates.
The most popular of this type is **PHB** and its is used in packaging since it has similar properties to PP.

Oxo-degradable polymers have additives that promote short degradation times - eg less than 5 years. The polymer will break into a fine powder, from the effects of heat, oxygen, moisture and even mechanical stress.

Biodegradable polymers

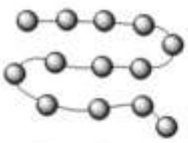
Water soluble plastics degrade in contact with warm water. They are used for laundry bags for example in hospitals. We are used to see them used to contain the right amount of detergent for the dishwasher to the washing machine in tablets.

The cost of producing biodegradable plastics remains more expensive than conventional plastics. However with increasing interest in these materials, scales of production are likely to increase - so bringing the costs down.

13

Structure of thermoplastics

Thermoplastics can be considered as a tangle of long-chain molecules. These molecules are held together by strong electrostatic forces, called **van der Waals bonds**. These bonds can be released with the application of heat, making it possible for the material to be reshaped.



Thermoplastic

Thermoplastics

Characteristics of thermoplastics

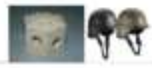
Thermoplastic molecules can be easily stretched by uncoiling the strands. The long chain molecules give plastics their ductility and toughness.

Reheating a thermoplastic will cause forces between the molecules to become weaker which allows them to slip over one another and the component can be reshaped. On cooling the weak bond between chains are re-established and the material acquires a new form.
The shaping of thermoplastics is reversible.

Due to their linear structure, thermoplastics can be drawn into fibres.

General characteristics

- Ductile
- Easily fabricated
- Easily drawn into fibres
- Can be injected into a mould
- Can be remelted and remoulded
- Easily to be recyclable

Material	Properties	Applications
PP (Polypropylene)	• Polymer resin • Extremely versatile • Lowest density of all thermoplastics • Stiff • Chemical resistance • One of the most cheap thermoplastic materials	
PE (Polyethylene)	• Most common plastic • There are different density levels of PE such as Low density, High density, Medium density and Linear-Low density • Different properties depending on density • **LDPE**- Semi-rigid, translucent, very tough, weatherproof, low cost • **HDPE**- Flexible, translucent/waxy, waterproof, good low temp toughness (to -60 degrees)	 LDPE  HDPE
High Impact PS (Polystyrene)	• Versatile material • Easy to machine (manipulate, shape) and construct • Low cost • Impact resistant • Good aesthetics • Good dimensional stability	
ABS	• Low cost engineering plastic • Good resistance to impact • Able to maintain stable, original dimensions (dimensional stability) • Easy to paint and glue • Good machinability, easier to shape • Good aesthetics • Strong and stiff • Heat resistant	• Product prototyping - It's stability and ease of manipulation make it ideal for testing product design • Covers • Products that are required to be impact resistant e.g. - covers, helmets 
PET (Polyethylene Terephthalate) 	• Most common type of thermoplastic polymer resin of the polyester family • Cheap to produce • Strong and impact-resistant • Rigid, or semi-rigid, can hold liquid, gases, and alcohol. Thermal-resilient	• Used for plastic bottles, food containers, and packaging • easily recyclable, however since it retains food residue after being used as a food container, PET is usually recycled into cheap products.
PVC (Poly-vinyl chloride) 	• 3rd most widely used Synthetic Plastic Polymer • Can be rigid or flexible, when exposed to a plasticizer called Phthalates • High hardness, flexible when soft, good insulator, but bad thermal resilience, raw PVC starts melting at 160°C	• Pipes and fittings • Cables and flooring • Medical devices (Medical packaging) • Electronic equipment (Circuit Boards) • Credit cards/ membership cards • Piping and plumbing, sometimes used as replacement for rubber

Structure of thermosetting plastics

Thermosetting plastics also consist of long-chain molecules but differ in that these molecules are held together by **rigid cross-links**, which in turn prevent them from being reheated and reshaped.

This rigid 3 dimensional structure leads to these materials exhibiting high strength but low ductility.
On further heating the bonds are broken and the material decomposes.

General characteristics

- Rigid
- Cannot be remelted or remoulded
- Higher strength than thermoplastics

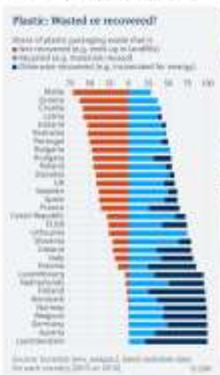
thermosetting polymer

Material	Properties	Applications
Polyurethane 	- strong electrical insulator (resistance) - good tensile and compressive strength - good thermal resistance - can be fairly hard and tough - can be easily bonded - can be flexible and elastic	- wheels - foam - varnish - paint - glue 
Urea-formaldehyde 	- high tensile (tension) strength - high heat distortion temperatures - low water absorption - high surface hardness - weight/volume resistance	- decorative laminates - textiles - paper - sand molds - wrinkle resistant fabrics - cotton blends - insulation
Melamine resin 	- high electrical resistivity - very low thermal conductivity/ high heat resistance - hard/ solid - scratch resistant - stain resistant - available in a range of thicknesses and sizes - http://www.makeitfrom.com/material-properties/Melamine-Formaldehyde-MF/	- kitchen utensils - plates, bowls (not microwave safe) - camping and nursery market - textiles: improve wrinkle resistance, reduce shrinkage, improve the stiffness/ resiliency - used to treat banknotes - decorative and protective laminate - wood adhesive
Epoxy resin 	- Tough - Chemical resistance (also water) - Fatigue and mechanical strength (Tensile strength and compressive strength) - Electrical insulation - Temperature resistant (maintains form and strength) (Though some are vulnerable to light) - Expansion of glue minimal - Can be used on metal (The adhesive)	-Adhesives -Rigid foam -Fiber reinforced fiber -Cement and Mortars -Pipes -Aeroplane parts -Coating for protection 

Recovery and disposal of plastics

Plastics are widely used in our life nowadays for things such as pipings, wire insulation, structural panels and all the consumers products such as containers for detergents, food, etc.

Domestic waste material is collected for recycling. One of problems is the variety of plastics in use. The most common plastics have been labelled from 1 to 6 - see next slide and number 7 category exists for all other types. All of these are thermoplastics due to their structure they can all be recycled.



Recycling symbols

Table 3 International symbols for polymers

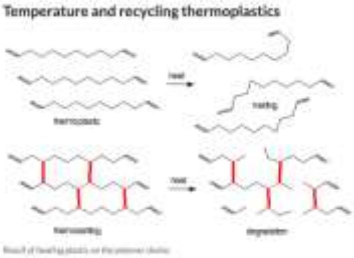
SPI code	Type of polymer	Common uses
1	PETE (or PET), polyethylene terephthalate	Soft drinks and water bottles; deli and baking trays; oven-safe film and food trays, carpets and fibre filling
2	HDPE, high density polyethylene	Milk, juice, shampoo, butter and yoghurt containers; grocery, rubbish and retail bags; cereal box liners; heavy-duty pipe; bottles for laundry products, oil and car washing fluid
3	V (or PVC), polyvinyl chloride	Pipes, film, clear packaging and carpet backing; containers for non-food items
4	LDPE, low density polyethylene	Bread, frozen food and dry cleaning bags; carrier bags; squeezable bottles
5	PP, polypropylene	Yoghurt and margarine containers; medicine bottles; car parts, carpets, industrial fibres
6	PS, polystyrene	Meat trays, cups, plates, cutlery and compact disc sleeves; video- and audio-cassette cases
7	Other (any polymer or combination of polymers not covered by categories 1-6). Includes ABS, acrylonitrile butadiene styrene	Reusable water bottles, trays for the microwave, mobile telephone outer cases, computer parts, monitors, keyboard parts

Recycling plastics

Thermosets are not so easy to recycle and they are very expensive to do so. They need to be ground into a powder which adds time and costs. Unfortunately they are often sent to landfill.

Some plastics are not accepted at the recycling plant due to its chemical compound and the facilities capabilities. One examples is PVC.

Incineration is also a concern due to the potential for the release of toxic by products such as dioxins.



Advantages and disadvantages of waste incineration

Disposal of plastics

Unfortunately not everyone recycles and plastic end ups in the landfill site or is litter by people into the environment.

Plastic doesn't biodegrade so it takes many years to break down (its predicted around 100 years). This plastic finds its ways into waterways, posing a danger to wildlife.

Topic 4.9c: Manufacturing Process for Plastics

4.4 MANUFACTURING PROCESSES

Essential Idea
Different manufacturing processes have been developed to innovate existing and create new products

Essential understanding
Designers sometimes engineer products in such a way that they are easy to manufacture. Design for manufacture (DfM) exists in almost all engineering disciplines, but differs greatly depending on the manufacturing technologies used. This practice not only focuses on the design of a product's components, but also on quality control and assurance.

Aim
Advancements in 3D printing have resulted in the ability to have a 3D printer at home. Consumers can download plans for products from the internet and print these products themselves.

Principles and concepts
- Wasting/subtractive techniques: cutting, machining, turning and abrading
- Shaping techniques: moulding, thermoforming
- Joining techniques: permanent and temporary, fastening, adhering, fusing

Guidance
- Selecting appropriate manufacturing techniques based on material characteristics (form, melting/ softening point), cost, capability, scale of production, desired properties
- Advantages and disadvantages of different techniques
- Design contexts where different manufacturing processes are used

Manufacturing processes for plastic

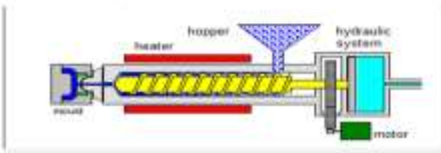
WASTING – Processes where the material is cut away
- Sawing, filing, drilling
- Water jet cutting
- laser cutting
- Machining (turning, milling and abrading)

ADDITION – Processes where materials are joined together
- Bolts and screws
- Adhesives
- Ultrasonic welding
- Integral snap fittings

SHAPING TECHNIQUES – Processes where the material is reshaped without the loss of material
- Injection moulding
- Extrusion
- Blow moulding
  - Injection blow moulding
  - Extrusion blow moulding
  - Stretch blow moulding
- Rotational moulding
- Thermoforming
- Calendering
- Compression moulding

Injection moulding

It involves the injection under pressure of molten thermoplastic into a close die mould consisting of at least 2 metal parts. The dies are typically made of hardened steel to provide wear resistant surfaces.
Parts can be small to moderate - up to 16kg and its used to produce complex 3D shapes.
Products are created one after the other in an automated cycle. Watch the video below.



The piston moves forward forcing molten plastic into the mould

Injection moulding

Products have a complex 3-D shape and can only be produced by a moulding technique.

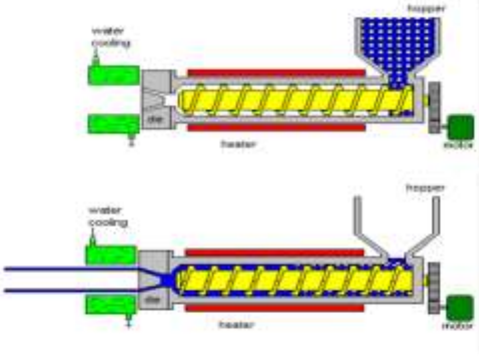
There are some **ejector pin** marks.

Advantages
- highly accurate
- fast production
- Large material choice

Disadvantages
- Requires expensive equipment
- restrictions on part dimensions and forms

Plastics usually used for injection moulding
ABS polyethylene polycarbonate polyamide (nylon) High impact polystyrene polypropylene

Extrusion



This process can be compared to squeezing toothpaste from a tube. It is a continuous process used to produce both solid and hollow products that have a constant cross-section. E.g. window frames, hose pipe, curtain track, garden trellis

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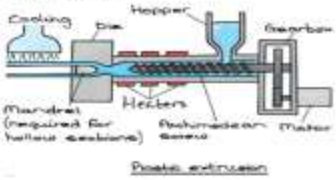
Extrusion



In extrusion, the process forces molten plastic through a die that has the required cross-sectional shape.

Stages of the process

Step 1 Thermoplastic powder is placed in the hopper, this powder then falls onto the rotating Archimedean screw, which in turn pushes the material towards a heated section of the extruder.

Step 2 The heaters soften the plastic, which is then forced through the die by the rotating screw.

Step 3 On exiting the die, the plastic product is then cooled using a water jet.

Step 4 Further along the transfer table, the product is cut to the required length.

Wires can be insulated with the aid of a special mandrel arrangement that allows the wire to pass through.

Advantages and disadvantages of extrusion

- Extrusion has the advantage of generally being a low-cost process that requires only simple dies.
- Its main disadvantage is that it can only produce continuous cross-sectional shapes.

Plastics widely used for extrusion

Thermoplastics such as PVC (polyvinylchloride), LDPE (low-density polyethylene, or polythene), HDPE (high density polyethylene) and PP (polypropylene) can all be extruded. Thermoplastics are pliable when they are heated but form a rigid shape once cooled.

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Blow moulding

http://www.youtube.com/watch?v=NE4ctgeePbI

Is used to make large hollow objects such as a bottle. The process involves a parison (semi-molten plastic tube) within a mould. The parison is a softening temperature so when compressed air is blown into the open the tube expands until it conforms with o the shape of the mould.

There are 3 variants

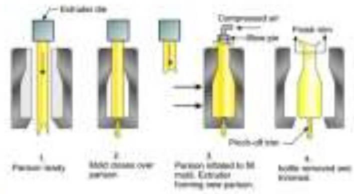
- Extrusion blow moulding
- Injection blow moulding
- Stretch blow moulding

Products have hollow shapes with one end sealed only while the other remains open. Includes a sprue, usually at the bottom of the product. Seam lines are visible on the outside of the product showing where the mould halves have been joined.

Extrusion blow moulding

The extruded tube passes between the 2 halves of the mould open.

The mould is closed and compressed air pressed through the bottle top expanding the plastic against the mould wall. The the plastic is cooled the mould is opened and the bottle removed.



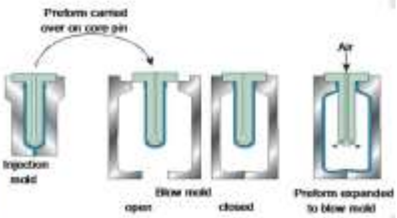
Advantages
- Low capital and tool costs
- High production rate
- Viable for small production runs

Disadvantages
- Poor surface finish
- Limited wall thickness control
- Scrap needs to be trimmed from the bottle

Widely used for Polyethylene (PE), low density polyethylene (LDPE) and high density HDPE) and Polyvinyl chloride (PVC).

Injection blow moulding

The first part of the process involves an initial injection of molten plastic into a mould containing the parison core. The parison is then transferred to the blow mould while still hot and compressed air is blown in forcing the parison against the mould wall. When it's cooled the product is ejected.



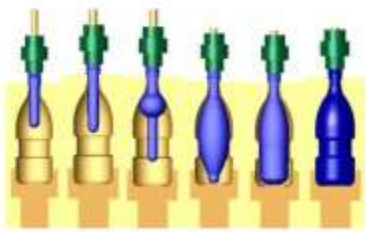
Advantages
- High production rate
- Little or no scrap to be trimmed
- Superior transparency
- More control of the shape and size

Disadvantages
- 2 moulds are needed
- High initial capital costs

Widely used for Polyethylene (low density LDPE and high density HDPE), polypropylene (PP), Polyethylene-Terephthalate (PET) and Polyvinyl chloride (PVC).

Stretch blow moulding

Involves positioning the parison body into a mould where the parison body is heated to softening temperature. When the temperature is reached, a blowing rod blows compressed air longitudinally while air is also ejected from the surface of the blowing tube pushing the parison against the watercooled mould walls. The stretching operation aligns the molecular chains increasing the strength of the walls and improves solvent resistance and transparency.



Advantages
- Low scrap and labour costs
- Good surface finish and high production rates

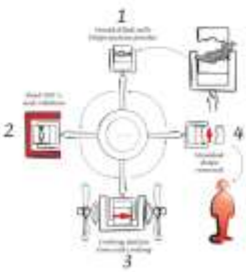
Disadvantages
- Process needs to be controlled better

Widely used for PET, PE and PVC bottles. The high wall strength produced allows to contain pressures associated with carbonated drinks.

Rotational moulding

Also known as rotomoulding is used to produce hollow plastic products and involves the rotation or spinning of the mould in 2 axes to allow centrifugal forces to press the molten plastic against the inner surface of the mould.

http://www.youtube.com/watch?v=q2xE-VfAmE



1. Fill the mould chamber with the thermoplastic powder
2. Heat mould chamber until the plastic is molten
3. Spin the mould chamber to evenly distribute the molten plastic within the mould
4. Cool the chamber to solidify the plastic
5. The mould is then stopped and the product removed.

Rotational moulding

Products are hollow.

There are no sprues but you can see seam lines where the mould halves have been together.

Widely used for PE (LDPE, HDPE), PP, Polyamide (PA), polycarbonate (PC) and thermoplastic elastomer (TPE).

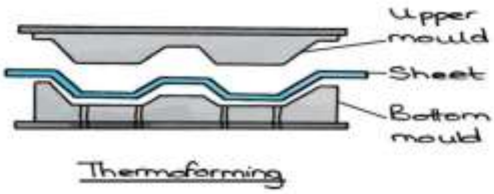
Advantages
- molds are lower cost to produce
- ideal for large forms, compared to other processes.
- ideal for rigid and flexible shapes
- low waste

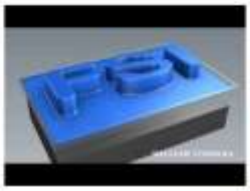
Disadvantages
- material costs can be higher compared to other processes

Thermoforming / Vacuum Forming

It involver heating of a thermoplastic sheet or film until it has softened sufficiently that it can be made to conform to a shape under vacuum, pressure or direct mechanical force.

What is the difference between vacuum forming and thermoforming.





Thermoforming

Products are made from sheet materials.

Stretching occurs making the sides of the product thinner than the base.

There are no sprue marks. There will be marks showing where the product has been cut.

Product contain detail e.g lettering.

Advantages
- Short lead times
- Low costing tools and forming pressures
- Very good quality
- Cheap available patterns/moulds
- High production rates

Disadvantages
- Inability to form holes or threads

Widely used for packaging and most common plastics used ABS, HIPS, HDPE, PVC and PET.

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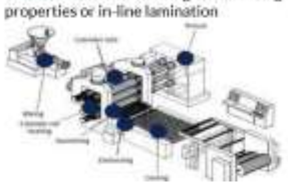
Calendering

- Calendering is a method of producing plastic film and sheet by squeezing the plastic through the gap between several counter-rotating cylinders.
- The melted polymer is subject to heat and pressure in an extruder and formed into sheet or film by calendering rolls. The temperature and speed of the rolls influences the properties of the film.
- Calendering allows speciality surface treatments of the film or sheet such as embossing or enhancing the physical properties or in-line lamination



http://www.youtube.com/watch?v=0ESL_SaPxDE

Plastics used in this process are vinyl, ABS and to a lesser extent HDPE, polypropylene and polystyrene. It can be also used for paper and textiles materials.

Calendering

Advantages

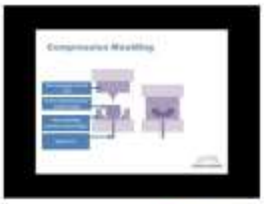
- Best quality plastic sheets
- Adapted for heat-sensitive polymers
- Good opportunity to mix with solid additives
- Cost Saving Opportunities for raw materials

Disadvantages

- Holes or voids may occur for workpieces thinner than 0.15mm
- Risk of air pockets

Compression moulding

- Is a method of moulding in which the moulding material, generally preheated, is first placed in an open, heated mould cavity.
- The mould is closed with a top force or plug member, pressure is applied to force the material into contact with all mould areas, while heat and pressure are maintained until the moulding material has cured.
- The process employs thermosetting resins in a partially cured stage, either in the form of granules, putty-like masses, or preforms



Widely used for thermosetting materials.

Advantages
- Lower cost tooling
- Good for small production runs
- No gates, sprues or runners
- Good large parts

Disadvantages
- Waste created
- High labour costs and slow process of production

Modern additive manufacturing

Also now as rapid prototyping - consists of a range of processed used to produce solid components through the deposition and fusing of consecutive layers of material.
1st the CAD model is converted to a STL (Stereo Lithography) file. The process converts surfaces into polygons with their geometries saved as mathematical coordinates.
Thermoplastics are amongst the cheapest materials being used:

- Acrylonitile butadiene styrene (ABS)
- Polylactic acid (PLA)
- Polyvinyl alcohol (PVA)
- Polycarbonate

This topic will be seem more in depth in topic 3.5 rapid prototyping

CASE STUDY - plastics used in detergent packaging

With the invention of liquid washing detergents, plastic bottles are used to replace the old washing powder cardboard box.
The image on the side shows an example seen in any retail area.

1. Name a suitable plastic for this detergent bottle.
2. Explain why the material is suitable.
3. The top bottle is made using blow moulding. Use notes and diagrams to explain the process.
4. Name a suitable material for the bottle top.
5. Explain why is this materials suitable.
6. The refill packaging is made out of low density polyethylene film. Name a suitable manufacturing method to produce this sachet.
7. Explain how the designer has considered the environment in the development of this sachet.
8. Sometimes consumers end up using too much washing detergent for the ½ load or 1 load of laundry they do. Suggest one improvement that helps prevent this problem.

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IDENTIFYING PLASTICS' PROCESSES

?

In pairs, try to match the right manufacturing process with the right characteristics and with the right examples

INJECTION MOULDING
BLOW MOULDING
ROTATIONAL MOULDING
THERMOFORMING
EXTRUSION
CALENDERING
COMPRESSION MOULDING

Products have a complex 3-D shape and can only be produced by a moulding technique.

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JOINING POLYMERS

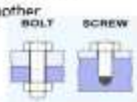
ADDITION
Processes where materials are joined together

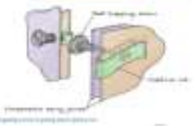
- Bolts and screws
- Adhesives
- Ultrasonic welding
- Integral snap fittings

A large number of mechanical fasteners can be used for joining plastic parts together and to another material.

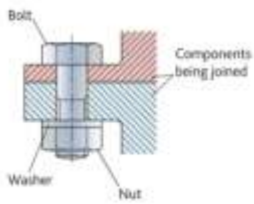
This means using for example

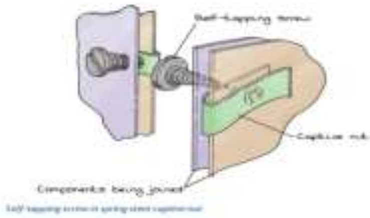
- Nuts and bolts
- Machine screws
- Self-threading screws
- Rivets
- Spring fasteners and clips





Nut and bolt assembly | Captive nut





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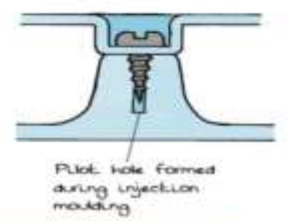
Integral snap fixing



Self-tapping screw and screw post

Click fixings

Plastics can be used to manufacture complex 3D-Shapes, and one big advantage is designing fixings for screws for example within the plastic product. Even securing clip can be all made integral to the component being joined.

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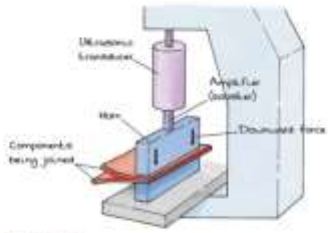
Ultrasonic welding

This process forms permanent joints using ultrasonic waves in the form of high-energy vibration.

It is the least expensive plastic welding process therefore is widely used to join plastic materials together as well as metals or plastic and metal.



Ultrasonic welding

Is generally used for consumer products (mobile phones, hairdryers, shavers, printer cartridges), children's toys and automotive products. The packaging industry uses ultrasonic welding for joining and sealing cartons of juice and milk, ice cream tubes, toothpaste tubes, blister packs and so on. Applications in the textiles industry include nappies, seat belts, filters and curtains.

Advantages
- Very quick method and safe

Disadvantage
- Very high financial investment

CASE STUDY – DYSON DC24 VACUUM CLEANER

The DC24 Dyson Ball vacuum cleaner is a good example of a product that shows a range of temporary joints used throughout the casing and the functional parts of the cleaner.

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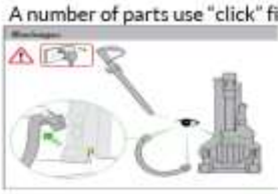
CASE STUDY – DYSON DC24 VACUUM CLEANER

The cover that fits over the brush is joined using self-tapping screws ⟶ screws enable cover to be removed so blockages can be cleared and in the event the drive belt breaks it can be replaced easily

A number of parts use "click" fittings such as the handle and the dust canister.



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The motor housing and other parts that contain electrical parts the manufacturer has used temporary fastenings such as machine screws with torx heads ——→ to prevent unqualified consumers tampering with parts that could lead to electrical shock. However temporary fixings are used to allow maintenance of such parts.

- The casing of the vacuum cleaner is made from recyclable plastics. Dyson has a facility that enables owners to return their cleaner at the end of its life, so plastic parts can be recycled.
- The use of temporary fastenings allows disassembly to be made easily.
- The casing is made using injection moulding ➡ fewer joints are necessary.

dyson recycle

Have a quick read

http://www.dyson.co.uk/support/weee.asp

http://www.recycle-more.co.uk/banklocator/banklocator.aspx

FINISHING PROCESSES - PLASTIC

FINISHING PROCESSES - PLASTIC

Plastics are known as **self finishing** materials.
This means the material has an acceptable finish after processing. Generally plastics don't need any further processing to produce the required finish, they can be given a very-high quality finish by being produced in **moulds** that have a **good high-quality** finish ensuring that trimming of plash or excess material is kept to a minimum.

For example, injection moulded products are formed in a mould which is either textured or highly polished - this finish is imparted to each product produced by the mould.

FINISHING PROCESSES - PLASTIC

Plastic can be **self-coloured** by including pigments with the powder or granules in the hopper of the moulding machine, a product can be produced with the desired colour.
Textures can be applied to the surface of the mould. This is directly transferred to the plastic product due to the pressures inside the mould.

2018 Exam style questions

1. Which of the following is an advantage of thermoset plastics?
A. Retain their strength and shape when heated
B. Returns to original form on heating
C. Re-mouldable when heated
D. Increases hardness when heated

2 (a) List two properties of ABS that make it suitable for use in the Wakati power unit. [2]

(c) Explain how injection moulding minimizes costs and waste during production of the Wakati power unit in Figure 9. [6]

5. Which physical property of a thermoplastic favours the use of thermoplastic rather than glass in the production of Coca-Cola® bottles?
A. Density
B. Melting point
C. Thermal expansion
D. Hardness

6. Which combination of moulding techniques would be used in each phase of producing Coca-Cola® PET bottles?

	Phase 1	Phase 2
A.	Blow moulding	Blow moulding
B.	Injection moulding	Blow moulding
C.	Blow moulding	Injection moulding
D.	Injection moulding	Injection moulding

7. What is a major advantage of using PlantbottleTM packaging for Coca-Cola® bottles?
A. Reduction in the volume of PET being sent to landfill
B. Reduction in the use of virgin petroleum-based resources
C. Increased recyclability of PlantbottleTM PET plastic
D. Increased use of non-renewable resources

8. Which plastic material would be most suitable for making foam cushions?
A. Polypropylene
B. Polyethelene
C. Polyurethane
D. Polyvinyl chloride

9. What explains the effect of creep in a plastic material under a heavy load?
A. Molecular chains remain static
B. A 3D molecular structure is formed
C. Secondary bonds weaken
D. Primary bonds weaken

Specimen paper

Lego® is an extremely popular children's construction toy and a design classic based on interlocking bricks (Figure 8). Lego pieces are made of acrylonitrile butadiene styrene (ABS) and produced by injection moulding to precise sizes. Lego offers a wide range of products based on themes, for example, space, robots and pirates (Figure 9). New Lego products take around twelve months to develop in three stages: first, identifying market trends through designers going to toyshops and interviewing children; second, designing and developing the new product using 3D modelling software to generate CAD drawings from initial design sketches and third, prototyping using stereolithography. Prototypes are evaluated by the design team and in focus groups with parents and children. Designs are modified in line with the feedback obtained.

Figure 8: Lego® bricks

Figure 9: Lego® set based on a pirates theme

10. Which combination of toughness and plastic type characterizes the ABS plastic used for the manufacture of Lego bricks?

	Toughness	Plastic type
A.	Low	Thermoplastic
B.	Low	Thermoset
C.	High	Thermoplastic
D.	High	Thermoset

11. Which advantage of injection moulding contributes to the precision manufacturing of Lego bricks?
A. High production rates
B. Close tolerances on small intricate parts
C. Very little post-production work is required
D. Waste material can be recycled

12. Discuss why the use of thermoplastic renders a product green but not sustainable. [3]

Figure 8: Flexible smart phone screen

13. The screen, shown in Figure 8, is a flexible screen developed for smart phones. This flexibility is achieved by replacing the layers of glass in conventional screens with a new plastic material. The screen has been developed so electronic products that use it can bend without breaking.
(a) Outline one advantage of electronic products that use this flexible screen other than flexibility. [2]
(b) Explain one advantage of flexible screens for outdoor advertising. [3]

Topic 4.6 - Textiles

Essential idea: Materials are classified into six basic groups based on their different properties.

Concepts and principles:

- Raw materials for textiles
- Properties of natural fibres
- Properties of synthetic fibres
- Conversion of fibres to yarns
- Conversion of yarns into fabrics: weaving, knitting, lacemaking, and felting
- Recovery and disposal of textiles

Guidance

- Properties of wool, cotton and silk
- Properties of nylon, polyester and Lycra ®
- Consider absorbency, strength, elasticity and the effect of temperature
- Design contexts in which different types of textiles are used

Aim:

There are many ethical considerations attached to the production of natural fibres. The strongest natural silk known to man is harvested from silk spiders and notoriously difficult to obtain, and labour intensive. In an effort to produce higher yields, scientists have altered the genome of goats so that they produce the same silk proteins in their milk.

Nature of design:

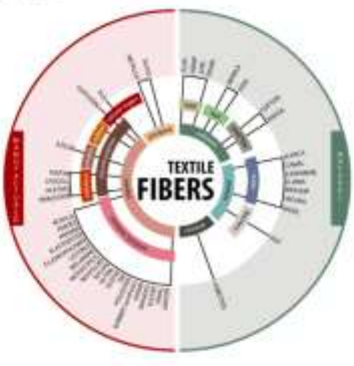
The continuing evolution of the textiles industry provides a wide spread of applications from high- performance technical textiles to the more traditional clothing market. More recent developments in this industry require designers to combine traditional textile science and new technologies leading to exciting applications in smart textiles, sportswear, aerospace and other potential areas.

Theory of Knowledge:

Designers use natural and man-made products. Do some areas of knowledge see an intrinsic difference between these?

Raw materials for textiles

Textiles are manufactured from ***fibres***, the origin of which can be subdivided into 2 basic groups - **natural (organic)** or **synthetic (man made)** sources. Fibre is an elongated hair like strand or continuous filament. The length exceeds 200 times the diameter. Fibres can be twisted using the spinning process and converted into yarn or fibres can be used in their raw form and manufactured to create felt.



	Description	Properties	Application uses
Natural Fibres 			
Synthetic Fibres 			

Natural fibres

Materials produced by plants or animals that can be spun into a thread, rope or filament.
Common examples include: wool, linen, cotton and silk. Wood, linen and cotton are short fibres, called staple fibres. Silk is a long continuous filament fibre can be up to one kilometre in length.

Silk, the ancient material of the future - Fiorenzo Omenetto

Properties of natural fibres

- Absorbency – is very high in natural fibres which usually allows the removal of perspiration from the skin - this property lead to engineers creating breathable fabrics.
- Easy to dye
- flammable
- Poor resilience as it has low elasticity
- Can be attacked by mildew (fungus)
- Dimensionally stable
- Good absorbency (fibres are hydrophilic)

Synthetic fibers

Fibres originated from an industrial chemical process in which a polymer is forced through a small orifice know as a spinneret. The fibres are produced in continuous long lengths and are generally more smoother than natural fibres.
Their properties depends of the composition of chemical and their molecular structure.

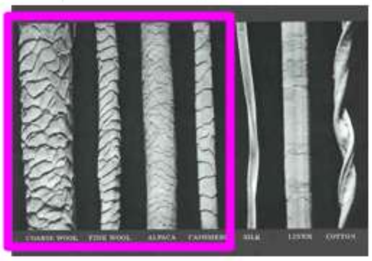
Properties of synthetic fibres

- Absorbency – Difficult to dye
- Good resilience
- resist mildew (fungus)
- Thermoplasticity
- Dimensionally unstable
- Low absorbency

Properties of natural fibres - wool

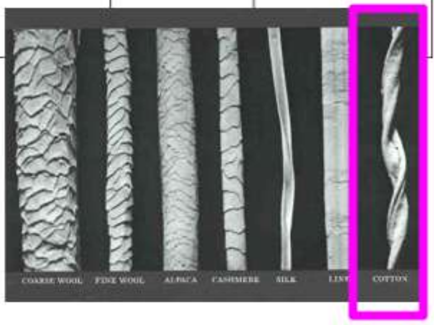
Natural Fibre	Characteristics	Absorbency Moisture Regain	Strength/Tenacity/ Tensile strength	Elasticity	Effect of Temperature
Wool  	Used for jumpers, suits and blankets and has the following qualities: -warm to wear -absorbent, dries slowly -breathable, repels rain -soft or coarse handle -can shrink, should be -dry cleaned -good drape & not durable -increases drop out	Absorbs up to 30% of its weight yet does not feel perceptively damp to the touch (hydroscopic moisture). Moisture regain 11-18%	Lowest dry strength Considerably weaker when wet (78-90%) (Dry breaking strength 1.23, 1.59 grams/denier)	Quite elastic. Can be stretched significantly when dry and wet. 65-99%	Chars without melting. Burns and smolders.

- Wool is an animal fibre - typically obtained from sheep, although some comes from alpaca, cashmere and angora goats. Fibres consist of overlapping scales of keratin that grow from follicles in the skin of the animal. **Scaly surface** of the fibre can feel scratchy when worn next to the skin. Fine wool, alpaca and cashmere are more valued for clothes.
- Fibres can vary from 25 to 200mm long. Wool exhibits the **lower tensile strength** and **stiffness** of all the natural fibres but absorbs dyes readily, is **flame resistant**, provides **good insulation** against heat and cold.



Properties of natural fibres - cotton

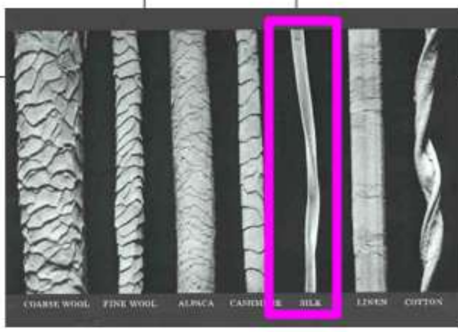
Natural Fibre	Characteristics	Absorbency Moisture Regain	Strength/Tenacity/ Tensile strength	Elasticity	Effect of Temperature
Cotton  	Used for making jeans, T-shirts and towels and has the following qualities: -cool to wear -very absorbent, dries slowly -soft handle -good drape -durable -creases easily -can be washed and ironed	Attracts water molecules. Hydrophilic - ability to hold up to 25 times its own weight in water. Moisture regain 7-8.5%	Medium dry strength Stronger when wet (110%) (Dry breaking strength 2.1-4.2 grams/denier)	The twisted nature of the fibre makes it more elastic in character. 45-75%	Low ignition temperature (around 250C) Burns intensely and rapidly Chars without melting. Burns and smolders.



Cotton is a vegetable fibre from the cotton plant. The cross-section of the cotton fibre is tubular, laid down in helical layers. One of the most widely used textile - 2nd place after polyester. Fibres are short from 12 to 60mm. Lustre is poor (lustre refers to the sheen or gloss a fibre possesses) but fabric drape is good (drape is how the fabric folds or pleats). Stronger wet than dry.

Properties of natural fibres - Silk

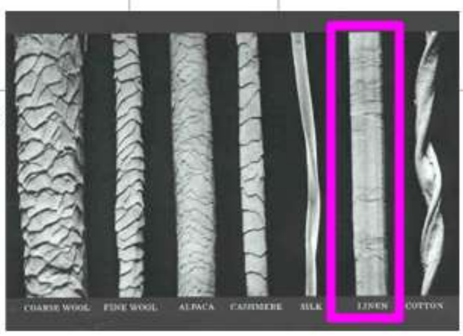
Natural Fibre	Characteristics	Absorbency Moisture Regain	Strength/Tenacity/ Tensile strength	Elasticity	Effect of Temperature
Silk  	Used for evening wear and ties and has the following qualities: -warm to wear -absorbent -soft handle -good lustre and drape -durable -creases drop out -dry clean	Absorbs considerable moisture without becoming perceptively damp. Moisture regain 12%	Strongest natural fibre when dry Weaker when wet (80-85%) (Dry breaking strength 4.3-5.2 grams/denier)	Silk can be stretched up to 10-25%	More heat resistant than other fibres and is difficult to burn. Chars without melting. Burns and smolders.



- Silk is a natural protein fibre composed of fibroin produced from the cocoon of the silk worm and is classified as an animal fibre.
- In order to obtain eggs to continue production, the cocoons are steamed, killing the worm. Following, the cocoons are then placed in bowls of hot water to soften and loosen the thread. Then the fibre is drawn together to form a yarn.
- The fibres have a triangular cross section with rounded edges and a smooth appearance. The prism like structure contributes to the lustrous shimmer for which the fabric is known. Fine and flexible fibre.
- Silk resists wrinkling, has excellent drape and resists mildew. One problem it creates static charge when wear.

Properties of natural fibres - Linen

Natural Fibre	Characteristics	Absorbency Moisture Regain	Strength/Tenacity/ Tensile strength	Elasticity	Effect of Temperature
	Use in bed sheets, curtains, table cloths and handkerchiefs. When used for apparel are blend with other fibres such as polyester and cotton. - Comfortable to wear - Good strength - Well absorbent of dyes and prints - No static problems - In hot weather lowers body temperature up to 4%	Standard moisture regain is 10 to 12%	It's a strong fibre. It has tenacity of 5.5 to 6.5dm/den.	Linen fiber has not enough elastic recovery properties like cotton.	Linen has an excellent resistance to degradation by heat. It protects from sunlight.

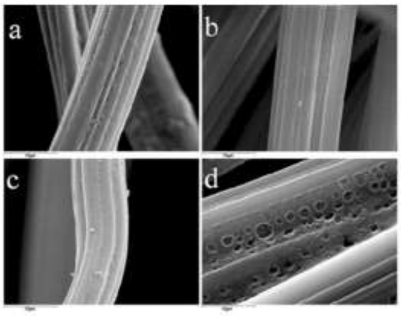


- Linen originates from the flax plant. Fibres are cylindrical in shape with distinctive nodes occuring at regular intervals along the length - similar in appearance to bamboo. Fibres can vary from 300 to 500mm in length.
- Fibres are strong, lustrous and exhibit good absorbency. Linen is one of the stiffest natural fibres therefore it has poor drape.
- It also has low resilience, so it can break is exposed to repeated bending.

Properties of natural fibres - Viscose rayon

Natural Fibre	Characteristics	Absorbency Moisture Regain	Strength/Tenacity/ Tensile strength	Elasticity	Effect of Temperature
 	Use in apparel when blended with other fibres. Use in home furnishings as bedsheets, curtains and tablecloths. - Silk alike aesthetics and good feel - Highly absorbent - Easy to dye - Drapes well - It is biodegradable	It absorbs more moisture than cotton. 13% at 21C.	Less when wet than dry. It is 1.5-2.4 gdp (grams per dernier) in the dry state and 0.7 -1.2 gpd in the wet state	Less than 2-3%	At 150C or more it loses it's strength and begins to decompose at 175-205C

- Viscose rayon is a man-made fibre manufactured from a natural source called cellulose. It's a regenerated cellulose product with properties similar to cotton. Manufactured from wood pulp or bamboo, that is dissolve in caustic soda to form a soda cellulose called Xanthate - this is then mechanically processed and dried. The fibres exhibit a circular serrated or corrugated appearance.
- Fibres have excellent strength and high lustre. Rayon can be produced in a range of strength and elasticity levels from low to high, however it is weakened when wet and has low dimensional stability.

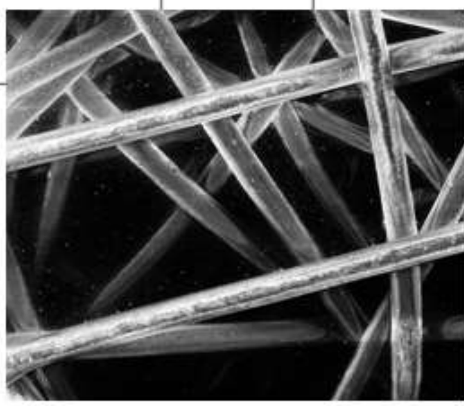


Synthetic fibers

Fibres originated from an industrial chemical process in which a polymer is forced through a small orifice know as a spinneret. The fibres are produced in continuous long lengths and are generally more smoother than natural fibres.
Their properties depends of the composition of chemical and their molecular structure.

Properties of synthetic fibres - Nylon

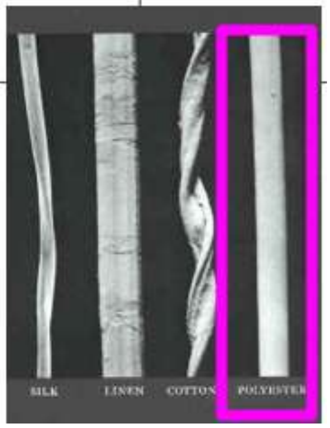
Synthetic Fibre	Characteristics	Absorbency/ Moisture Regain	Strength/Tensile strength/Tenacity	Elasticity	Effect of Temperature
Nylon  	Used for active sportswear, fleece jackets, socks and seat belts and has the following qualities: -warm to wear -absorbent, dries slowly -breathable, repels rain -soft or coarse handle -can shrink, should be dry cleaned -good drape & durable -increases drop out	Non-absorbent (hydrophobic) Moisture regain low 4.5%	High tensile strength Abrasion resistant (Dry breaking strength 4.5 -5.5 grams/denier)	High resistance to stretching (Wet or dry)	Ignites easily (250-350C) Melts readily Ironed safely up to 356F



- Nylon is a polyamide. The fibres are smooth and translucent with a uniform circular shape. They exhibit a high natural lustre which can be controlled when processing. Strength and elasticity are high. Drapes properties can vary depending on the fibre diameter. The low absorbency of nylon leads to it feeling clammy in humid weather and it can melt easily when exposed to heat - so ironing needs to be a lower temperatures. It will not support combustion but the melted fabric will cling to the body causing severe burns.
- Can be blended with other fibres to improve strength and stability of the fabric.

Properties of synthetic fibres - Polyester

Synthetic Fibre	Characteristics	Absorbency/ Moisture Regain	Strength/Tensile strength/Tenacity	Elasticity	Effect of Temperature
Polyester  	Used for raincoats, fleece jackets, children's nightwear, medical textiles and working clothes and has the following qualities: -low warmth -non-absorbent, dries quickly -soft handle -good drape & very durable -crease resistant -easy care -can be recycled	Resists water absorption Does not absorb moisture or oil Moisture regain very low 0.5%	High tensile strength (Dry breaking strength 4.4 -5.0 grams/denier)	High resistance to stretching (Wet or dry)	Ironed safely up to 356F



Polyester is known as PET (polyethylene terephthalate), Dacron and Mylar. It started being produced in 1947 and is the most widely fibre in the world. Polyester fibres are smooth and translucent with an uniform circular shape. Lustre can be bright or dull. Fibres have high dimensional stability, good to excellent strength, elasticity is greater than cotton or rayon, however the drape is poor and it burns slowly.

Properties of synthetic fibres - Lycra

Synthetic Fibre	Characteristics	Absorbency/ Moisture Regain	Strength/Tensile strength/Tenacity	Elasticity	Effect of Temperature
Lycra  	Used for active sportswear, fleece jackets, socks and seat belts and has the following qualities: -warm to wear -breathable, repels rain -soft or coarse handle -can shrink, should be dry cleaned -good drape & durable -increases drop out	Wicks away moisture Moisture regain low 0.8-1.2%	Durable and abrasion resistant (Dry breaking strength 0.6-1.25 grams/denier)	Elastomer properties, with the ability to stretch up to 600% and spring back to its original length	Burns and melts when ironed at 356F

- Lycra is a man-made elastic fibre invented and produced by DuPont® which is also known as estomer or spandex. It's remarkable properties of stretch and recovery enhance all fabrics and garments in which it is used, adding easy comfort and freedom of movement and improving fit and shape retention. Swimwear and lingerie owe their figure-flattering fit to lycra.
- Lycra belongs to the generic elastane classification of man-made fibres (known as spandex in the US and Canada) and is described in technical terms as a segmented polyurethane it is composed of "soft", or flexible, segments bonded together with "hard", or rigid, segments. This gives the fibre it's built-in, lasting elasticity. Lycra can be stretched four to seven times its initial length, yet springs back to it's original length once tension is released. While it appears to be a single continuous thread, it is in reality a bundle of tiny filaments.

Blending

Blending has the name says it involves twisting together a mixture of natural and synthetic fibres to form a yarn. The benefits of blending include:

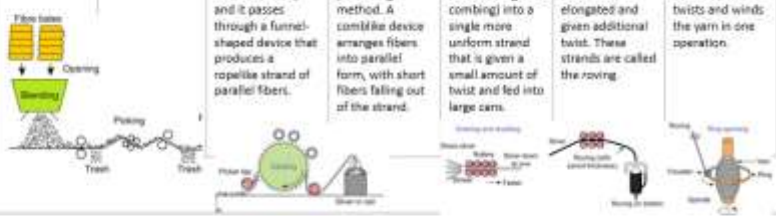
- Reduced costs
- Improved processing
- Adding bulk and warmth
- Resistance to wrinkle
- Multi-colour fabrics
- Improved physical properties
- Improved dimensional stability

Examples of typical blended textiles

- wool/polyester - men's suits
- cotton/nylon/elastane - socks
- Nylon/Polyester - women's jackets
- Cotton/lycra - stretch jeans
- polyester/cotton - crease resistant shirts

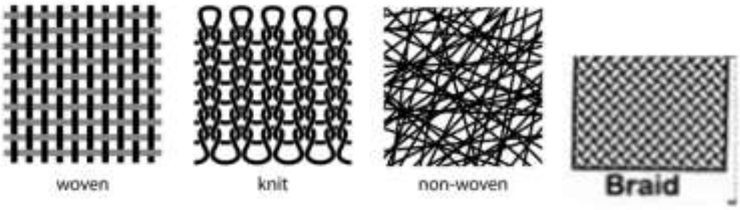
Conversion of fibres to yarn

	1st stage Preparing the fibers	2nd stage Carding	3rd stage Combing	4th stage Drawing out	5th stage Twisting	6th Stage spinning
Natural Fibres	Cleaning the fibres	The carding machine separates the fibers and pull them into somewhat parallel form. A thin web of fiber is formed, and it passes through a funnel-shaped device that produces a ropelike strand of parallel fibers.	When a smoother, finer yarn is required, fibers are subjected to a further paralleling method. A comblike device arranges fibers into parallel form, with short fibers falling out of the strand.	A series of rollers rotating at different rates of speed elongate the sliver (fibre mass created after carding and combing) into a single more uniform strand that is given a small amount of twist and fed into large cans.	The sliver is fed through a machine called the roving frame, where the strands of fiber are further elongated and given additional twist. These strands are called the roving.	The spindle turns the bobbin at a constant speed. This turning of the bobbin and the movement of the traveler twists and winds the yarn in one operation.
Synthetic Fibres	Separating the fibres					



Conversion of yarn into fabrics

A fabric is made of interlacing of yarn by weaving, knitting or braiding to produce a continuous sheet.



Weaving

Weaving is done by a loom. Every woven piece of cloth is made up of 2 distinct systems of threads - known as the warp and filling (weft), which are interlaced in each other to form a fabric.

http://www.youtube.com/watch?v=YYWlevX7Kw0

Weaving

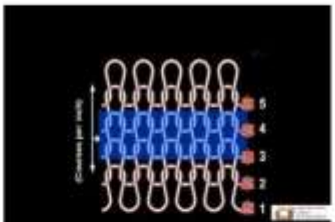
Nowadays weaving is a fully automated for mass production. The interlacing of the warp and weft can be accomplished in a number of ways - see illustration below.

Knitting

- Is the process of forming fabrics by looping a single thread, either by hand or by means of a machine. Knitting is carried on without making knots but rather through the formation of interlocking loops.
- Therefore the destruction of one loop threatens the destruction of the whole web.
- Two distinct variations of knitting occur: warp and weft knitting. Warp knitting is always done by machine and involves a series of zig-zag stitches in parallel columns along the length of the fabric as seen on the images aside.

Knitting

- Werf knitting may be done by hand or machine and uses one continuous yarn - as seen in the images.
- Fabric produced by knitting as great elasticity as a result of its interlocking loop construction.



http://www.youtube.com/watch?v=U1bk4Z0Qxc

Felting

- Felting is the process of entangling fibres with each others (no yarns are created with this process).
- Felt is produced as fibers and/or fur are pressed together using heat, moisture, and pressure. Felt is generally composed of wool that is mixed with a synthetic in order to create sturdy, resilient felt for craft or industrial use. However, some felt is made wholly from synthetic fibers.
- Felt may vary in width, length, color, or thickness depending on its intended application.

http://www.youtube.com/watch?v=khQ-ZsDfsVg

Lace-making

- Lace making is an openwork, stitched fabric, patterned with holes. Originally made from linen, silk, silver or gold thread, lacework is now most common made from cotton.
- Can be made by hand with a needle or with a machine and is created by looping, plaiting one thread with another, independent of any backing material. Machinery may be used to make it.
- Synthetic threads are often used for machine manufactured lace and it can produce intrinsic pattern sheer laces.

Needle lace, showing button hole stitch

Bobbin lace made on a pillow with bobbins and pins

Recovery and disposal of textiles

- Wastage from textiles can be divided into pre and post-consumer.
- Pre-consumer waste is generated by products of production processes suitable to use in soft furnishing, automotive, construction and paper industries.
- Post-consumer waste refers to clothing of household textiles reused or recycled instead of being disposed.
- Recycling involves the reprocessing of used clothing, fibrous materials, fabric scraps and waste from the manufacturing processes.

http://www.youtube.com/watch?v=[illegible]

http://www.youtube.com/watch?v=[illegible]

Recycling

- Natural fibres such as wool, cotton, silk and linen as well as the most common synthetic fibres such as polyester, polyamides and acrylics can all be recycled.
- Once collected, cleaned and sorted, recyclable textiles may be processed some to be re-spinned into yarn, others to be used in their fibrous state as insulation, padding or raw material for felting.
- Cotton may be used to make high-quality paper.
- Buttons, zips and other hardware may be recovered for reuse.

Advantages of recycling fabrics

- Reducing use of virgin materials
- Reducing landfill space and costs
- Generated less air and water pollution
- Keeping materials out of the waste stream
- Using less energy in production

International mindedness

The economics and politics of the production and sale of clothing by multinationals can be a major ethical issue for consumers and the workforce.

- Multinationals have establishing their own manufacturing plants in developing nations. Garment assembly mostly involves lower levels of technology and can be labour intensive. This generates local employment but this workforce (usually women and children) work long hours, in poor conditions and for a very poor wage. However the financial benefits tend to be with the manufacturers selling their products in global markets.

http://www.youtube.com/watch?v=[illegible]

THE IMPACT OF TEXTILES AND THE CLOTHING INDUSTRY ON THE ENVIRONMENT

- **According to the Ellen Macarthur Foundation**

- textile production produces 1.2 billion tonnes of greenhouse gas every year. The United Nations estimates that 10 percent of total global emissions come from the fashion industry.
- Dyes used to produce toxic chemicals pollute waterways.
- Gathering the materials for wood-based fabrics like rayon, modal and viscose contributes to deforestation.
- Popular polyester fabrics washed in domestic washing machines shed plastic microfibers make their way to into drinking water and aquatic food chains (including in fish and shellfish eaten by humans).
- Cotton, another eminently popular material, is a pesticide and water-intensive crop; according to the World Resources Institute, the amount of water required to make one cotton t-shirt is the same as one person drinks in two-and-a-half years.

2018 Exam style questions

1. Modern sportswear often advertises its technical capabilities, such as wicking properties, see Figure 6.

What material is best suited for this application?
A. Silk
B. Cotton
C. Polyester
D. Wool

2016 Exam style questions

21. Which combination of absorbency and elasticity characterizes cotton fibres?

	Absorbency	Elasticity
A.	Low	Low
B.	Low	High
C.	High	Low
D.	High	High

5. Figure 5 shows the Woven Easy chair by Alexander Mueller. The chair has a hardwood frame (ash) which is stained to darken the wood. The seat and back of the chair are made from a single waxed cord. Cord is a textile material made from fibres.

(a) Outline one reason why the textile cord is treated with wax. [2]

(b) Explain why it is necessary for the textile fibres to be formed into a yarn to create the cord for the Woven Easy chair. [3]

(c) Discuss the design of the Woven Easy chair in relation to the balance between form and function. [6]

(d) The manufacturers of the Woven Easy chair are considering an incremental change to the design that uses multiple cords instead of a single cord for the seat and the back of the chair.

Explain the implications of making this change with respect to production costs, ease of maintenance and durability. [9]

Topic 4.7 - Composites

Essential idea: Materials are classified into six basic groups based on their different properties.

Concepts and Principles:
- Form: fibres/sheet/particles and matrix
- Process: weaving, moulding, pultrusion and lamination
- Composition and structure of composites: concrete, engineered wood, plywood, particleboard, fibreglass,
- Kevlar®, carbon reinforced plastic, laminated veneer lumber (LVL)

Guidance:
- Fibres/sheets/particles: textiles, glass, plastics and carbon
- Matrix: thermoplastics, thermosetting plastics, ceramics, metals
- Advantages and disadvantages of composite materials
- Design contexts in which different types of composite materials are used

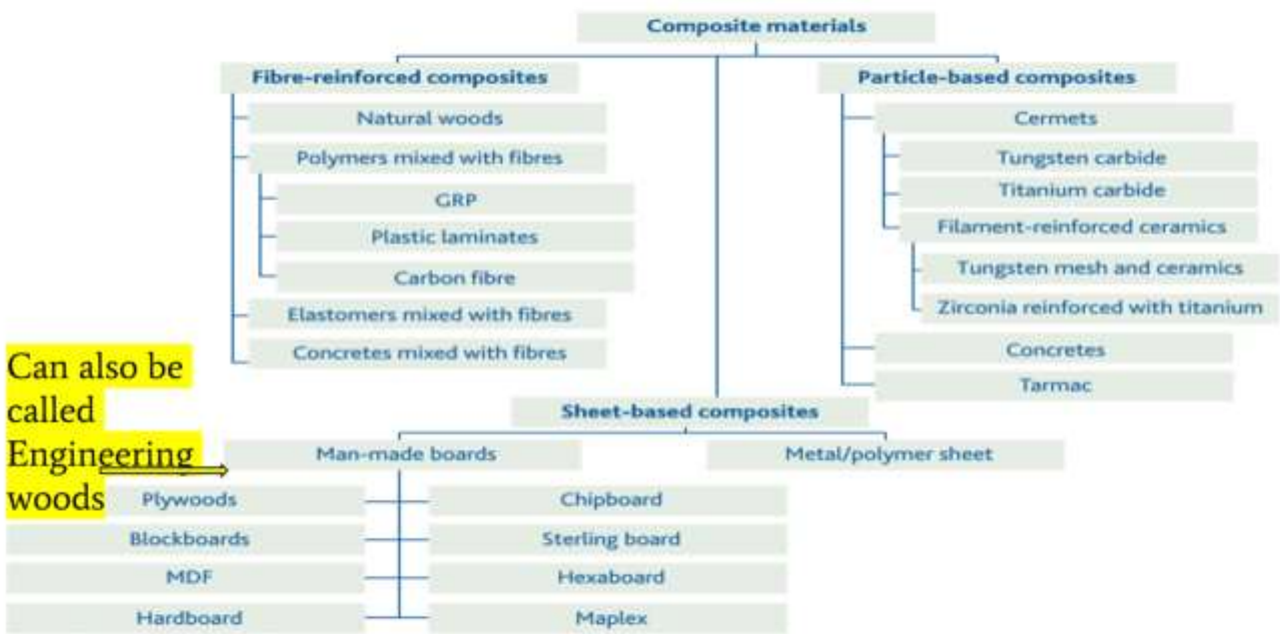
Aim:

As designers develop new products, they should always be aware of the materials available. In an effort to increase productivity and lose weight, carbon fibre parts are often glued together. The use of an epoxy adhesive rather than traditional fastening methods allows manufacturers to create complex shapes quickly and easily. These materials and methods are being transferred to consumer products.

Nature of design:

Composites are an important material in an intensely competitive global market. New materials and technologies are being produced frequently for the design and rapid manufacture of high-quality composite products. Composites are replacing more traditional materials as they can be created with properties specifically designed for the intended application. Carbon fibre has played an important part in weight reduction for vehicles and aircraft.

Types of composite material



Types of composite materials

What are Composites?

http://www.youtube.com/watch?v=t2hH2B-EI1I

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. This type of material takes advantage of the different strengths and abilities of its different elements

Why we use composites?

- The biggest advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application - the improvement can be mechanical, physical, chemical or electrical properties.
- Composites also provide design flexibility because many of them can be moulded into complex shapes. The downside is often the cost. Although the resulting product is more efficient, the raw materials are often expensive.

Advantages	Disadvantages
• high strength-to-weight ratio • high tensile strength • weave of the cloth can be chosen to maximise strength and stiffness of final component • can be woven in different patterns to create aesthetically pleasing surface patterns	• very expensive • requires specialist manufacturing facilities • weak when compressed, squashed, or subject to a high shock or impact • small air bubbles or imperfections of the matrix will cause weak spots and reduce the overall strength

Types of composite material

- **Fibre-reinforced** are the most important composites since they are commonly used in product manufacture. Used in many applications, like in aircraft parts. We will look in detail at GRP, carbon fibre and kevlar.
- **Particle based composites** are the cheapest and most widely used. They fall in two categories depending on the size of the particles.

- **Sheet/Laminar based composites** are those sheet bonded together to form a new material. Advantages of using man made boards are they increase stability against warping, they have equal strength in all directions – unlike natural timbers. We will look in detail at plywood, particleboard and laminated veneer lumber (LVL)

SHEET/LAMINAR based composites

You have studied man-made boards, such as plywood - this is the most common recognised laminar material. **Plywood** is characterised for high-strength, resistant to cracking, breaking, shrinkage, twisting and warping. However many other materials are produced through lamination.

You have also studied **laminated glass** - which is another good example of a sheet based composite. 2 layers of glass pressed together with a interlayer of polyvinyl butyral (PVB) joined under heat and pressure. When broken the PVB holds the pieces of glass together.

Types of composite material

Advantages	Disadvantages

• Fibre-reinforced	
• Particle	
• Sheet/Laminar	

PLYWOOD (topic 4.2b)

Plywood consists of at least three layers or veneers of wood which have been plied together with the grain running crosswise(90 degrees) to add strength and resilience. The sheet material is very stable against warping.

Main Uses	Advantages
• Floors, walls and roofs in home constructions • Wind bracing panels • Vehicle internal body work • Packages and boxes • Fencing • Scaffolding materials • Furniture • Musical instruments	• It has very good strength and durability compared to MDF - high tensile strength in all directions • Plywood usually made out of different wood species. • It is less susceptible to water damage than MDF. • It can be easily polished or painted. • It can provide smooth surface for laminate or veneer to stick on. • It can hold screws well. • It can be cut in any shapes. • It is resistive to shrinking, warping, twisting and cracking. • It is available in large size compared to solid wood a • It is economical as compared to solid wood.

Glued Laminated Timber (Glulam)

The term glulam is an abbreviated term that stands for glue-laminated timber. A glulam is made with multiple layers of solid wood lumber bonded together with high-strength adhesive to form a single structural unit.

Glulam has greater strength and stiffness than compared natural wood. When comparing Kg by Kg is stronger than steel - this means glulam beams can span long distances with minimal need for intermediate supports. Its is a eco friendly materials as it uses low levels of formaldehyde and from certified sustainable forestry.

Particle board

Particle board – also known as particleboard, low-density fibreboard (LDF) and chipboard – is an engineered wood product manufactured from wood chips, sawmill shavings, or even sawdust, and a synthetic resin or other suitable binder, which is pressed and extruded.

Main Uses	Advantages

Laminated Veneer Lumber (LVL)

Is a structural laminated composed of a number of layers of timber veneers (usually 3.2mm thick) glued together. LVL is similar in appearance to plywood, although in plywood the veneers switch direction while stacking and in LVL the veneers all stack in the same direction.

LVL is stronger than natural wood. The product is normal a beam or a billet form. It's advantages are

- Can be curved into shapes or arches
- Can be produced in almost any length

Parallel Strand Lumber (PSL)

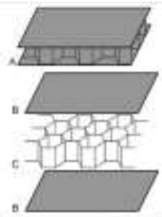
Is a form of engineered wood made from parallel wood strands bonded together with adhesive. It is used for beams, headers, columns, and posts, among others uses.

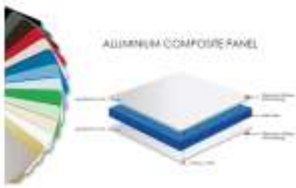
This results in a much denser and stronger material. Because knots and other imperfections are randomly dispersed throughout the product (and filled up and fortified with glue). PSL has much higher usable values for bending, tension parallel to grain, and compression parallel to grain.

Parallam is the brand name for the product invented

SHEET/LAMINAR based composites

Laminar composites may be also be refer as sandwich materials. The sandwich structure consists of layers of thin uni or bidirectional fibres or metal sheet (B) held apart by a light core (C) (foam or honeycomb style structure).





Aluminium foam core composite used in building cladding

Carbon/silicon carbide (C/SiC) fabric used to reinforce ceramic matrix composite face sheets - creates a sandwich structure capable of withstanding high-heat-flux environments - ideal for aerospace vehicles

Made of carbon fiber and different core materials like nomex, PVC, etc - it has high fatigue resistance, anti chemical corrosion ability, etc...

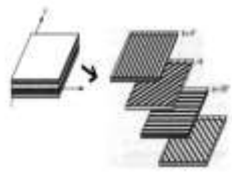
SHEET/LAMINAR based composites

Plain bearing, used in crankshafts are also an example of laminar composites - several layers of different materials laminated. PTFE bearings are made with a steel or bronze backing as standard. A sintered bronze layer is applied to the backing. This layer is provided with a PTFE-based self-lubricating lead-free sliding surface. The bronze intermediate layer ensures efficient heat dissipation and makes for a strong joint between the backing and the sliding surface. The steel backing has a layer of tin to prevent corrosion.

Is a sailcloth a laminar composite?

Yes a sail cloth is a laminar composite.

This example is laminate made with ZigZag yarn technology making the sail made of radial panels that matches the modern rigging of dinghy or yacht. The result is lightweight, extremely durable and fast sail.



Case Carburising and nitriding (case hardening)

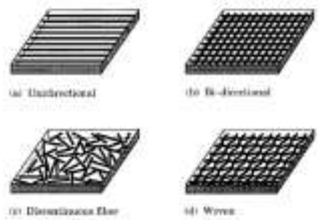
Carburizing and nitriding generally refer to surface chemical heat treatment of steel.

Carburizing must be made of low carbon steel or low carbon alloy steel. It can be divided into solid, liquid and gas carburizing. The heat treatment after carburizing the carburized workpiece should actually be considered as a composite material with a wide difference between the surface and the center content. Carburizing can only change the carbon content on the surface of the workpiece, and the final strengthening of the surface and the core must be achieved by proper heat treatment. The workpiece after carburizing needs quenching and low temperature tempering. The purpose of quenching is to form high carbon martensite or high carbon martensite and fine carbide structure on the surface. Low temperature tempering temperature is 150–200C.

FIBRE-REINFORCED composites

Are composed of fibres embedded in a matrix. The matrix material - in powder or in liquid form - is combined with reinforcing fibres in a mould and the combination subjected to heat and pressure until fusion occurs. Different materials can serve as a matrix including ceramics, metals and plastics but it's the bond obtained between the fibre and the matrix that provided the strength of the composite.

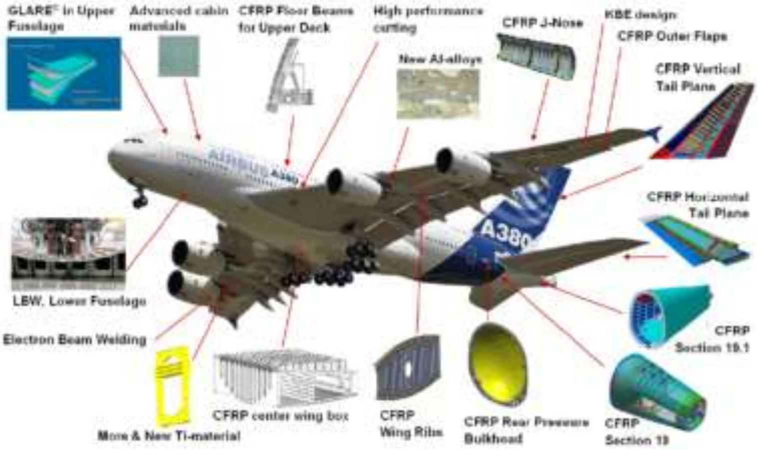
Fibres are excellent in tension however they need to be structure to support compressive forces. See examples on the side of possible fibre arrangements.



FIBRE-REINFORCED composites

Since the early 80's the aerospace industry has used extensively fibre reinforced polymer composite parts in aircraft construction.

Composites are used in aircraft construction due to improved
- Strength
- Stiffness
- Fatigue resistant
- Corrosion resistant
- Weight benefits



FIBRE-REINFORCED composites

Sports equipment have also make great use of fibre reinforced plastics to increase strength and stiffness while reducing weight.

FIBRE-REINFORCED composites

Concrete composites - such as Fibre reinforced concrete (FRC) - incorporate fibres randomly throughout the concrete to increase its structural integrity. The fibre used can vary from steel to glass, depending on the properties desired.

Fibre-reinforced composite - GRP

The first modern composite material was GRP - Glass Reinforced Plastic. It is still widely used today for boat hulls, sports equipment, building panels and many car bodies.
The matrix is a thermoplastic or thermosetting plastic(resin) and the reinforcement is fibreglass - typically E-glass that has been made into fine threads and often woven into a sort of cloth - using pultrusion process.

A mould is necessary for GRP and it can be made out of a range of materials like woods, metals and polymers.

Carbon fibre reinforced plastic (CFRP)

Carbon fibre is a super strong material that's also extremely lightweight. Engineers and designers love it because it's five times as strong as steel, two times as stiff, yet weighs about two-thirds less. Its is replacing glass fibers where the additional cost can be justified.

Carbon fibre is basically very thin strands of carbon -- even thinner than human hair. The strands can be twisted together, like yarn. The yarns can be woven together, like cloth. Although strong in tension carbon fibres are very weak in shear and can be cut easily. Once embedded in a plastic matrix the CFRP is strong in all directions.

Fibre-reinforced composite - GRP

On its own, the glass is very strong but brittle and it will break if bent sharply. The resin holds the glass fibres together and also protects them from damage by sharing out the forces acting on them.

Properties of E-Glass
- highly electrically resistive glass made with alumina-calcium borosilicates.
- known as a general-purpose fiber for its strength when woven - as individual fibres are stiff and strong in tension

Glass Reinforced Plastic

Health and Safety Issues for GRP

- Fibreglass handling presents problems such as irritations of the eyes, skin, or respiratory tract.
- The mechanical action of the fibres scraping against skin may cause a condition known as dermatitis.
- To protect yourself, wear long sleeve shirts and pants to keep the fibres off your skin, and wear clean clothes every day. Gloves and eye protection may also help. Use soap and warm water to remove any fibres that you do get on your skin.
- Dust is produced when mat or cloth is rolled out, where chopper guns are used, and in finishing operations where flashing is removed or sanding occurs. So always wear a dust mask in these areas to help avoid inhaling glass fibres.

SIMPL Safety in Manufacturing Plastics & Composites

Carbon fibre reinforced plastic (CFRP)

Advantages vs Disadvantages

- These materials are lighter and stronger than fibreglass but more expensive to produce.
- Having more products using carbon fibre would save a lot of oil, but it will generate a lot of waste. Carbon fibre can't be melted down, and it's not easy to recycle. When it is recycled, the recycled carbon fibre isn't as strong as it was before recycling.

Applications

They are used in aircraft structures and expensive sports equipment such as formula one racing cars, tennis rackets, etc.

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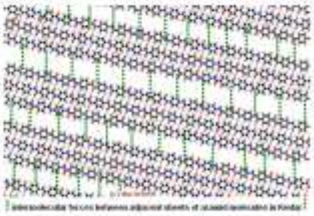
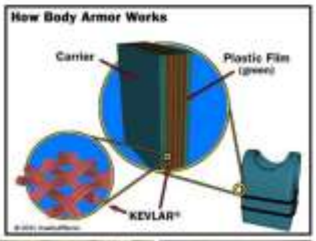
FIBRE-REINFORCED composites - Kevlar

- Kevlar is another special composite that has good protective properties due to the materials used and the way it has been processed.
- Kevlar is a polymer containing aromatic and amide molecules.
- When Kevlar is spun into fibres, the amide groups are able to form hydrogen bonds between the polymer chains, which act like glue holding the separate polymer chains together.
- The polymers have a crystalline arrangement, with the polymer chains oriented parallel to the fibre's axis.



Fibre-reinforced composites - Kevlar

- Kevlar is able to stop a bullet due to its molecular structure.
- It is a light, polyarylamide plastic fabric, which has a high tensile strength. this means it takes a huge amount of energy to make its fibres stretch even a little.
- Each Kevlar molecule looks like a long twisting coil. During polymerisation these coils of molecules become tangled, causing it to be hard to stretch.
- Inside a bulletproof vest are many strips and layers of Kevlar. When a bullet hits the vest, it tries to force it through the layers, but to do this it must push the fibres apart.
- The fibres are woven and resist this very effectively. The movement is translated into a stretching force on the fibres. Some will break, but most will absorb the energy of the bullet by stretching a small amount.



Kevlar - Applications

- Body protection such as bullet proof vests
- Sports equipment such as skis, helmets and racquets
- Sails for windsurfing
- Run-flat tyres
- Gloves to use in glass and sheet-metal industries

Kevlar – Advantages

- High strength to weight ratio
- low electrical conductivity
- High chemical resistance
- High toughness
- High-cut resistance
- Flame-resistant and self-extinguishing

Disadvantages

- Absorb moisture
- Reacts well under a tensile force (stretching force) but badly under a compressive force
- Reacts badly to UV light (sunlight)
- Suffers some corrosion if exposed to chlorine

PARTICLE BASED Composite

Typically consists of a soft matrix in which hard particles are embedded. These particles might be symmetrical or asymmetrical.

General properties of particle-based composites are

- High strength in compression and less in tension
- Good stability
- Uniform structure ensuring consistent strength, stiffness due to its isotropic properties.
- Free form surface defects

PARTICLE BASED Composite - Concrete

Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together .

The properties of the concrete are determined by the ratio of the constituent parts.

Cement or binder

Aggregate or filler

Concrete – Advantages and disadvantages

Advantages and disadvantages of concrete

Advantages

- It can be moulded into complex shapes.
- It has properties similar to stone.
- Components are more readily extracted than stone.
- It can be cast in situ (on site), whereas stone has to be quarried and cut to shape.
- It is good in compression.

Disadvantages

- It is poor in tension, making it necessary to reinforce the concrete when spanning large distances.

PARTICLE BASED Composite - Cermets

A mixture of both metal and ceramic particles. A common example is **tungsten carbide** – a combination of ceramic tungsten carbide and metal cobalt. This material is use in industrial machinery, cutting tools, abrasives, other tools and instruments, and jewellery.

Tungsten carbide is

- two times stiffer than steel
- much denser than steel or titanium
- comparable with sapphire/ruby in hardness
- resist high temperatures
- tough and shock resistant

Disadvantage

Because cermets resist very well high temperatures they can only be processed using Sintering.

Topic 4.9d - Manufacturing processes for Composites

Weaving

Textiles along with glass and carbon fibres are commonly used to create woven preforms that are later bonded with resin.

By using weaving, large quantities of flexible manting can be produced that can be cut to size and positioned to follow the contours of a mould in order to create complicated shapes.

See more on topic 4.2e textiles

http://www.youtube.com/watch?v=...

Laying up

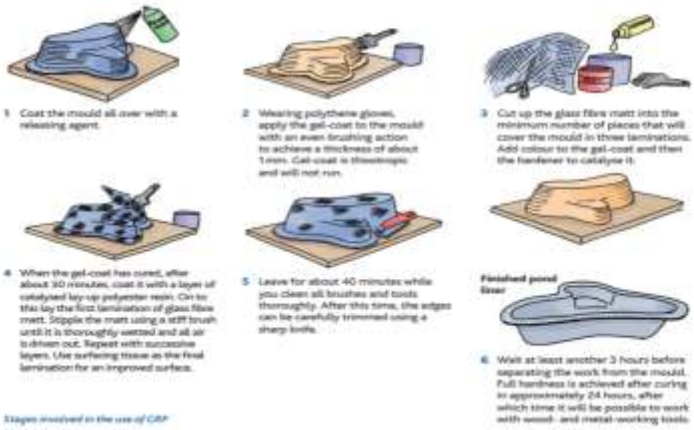
Involves the creation of composite textiles encased in a resin - typically polyester. This process can be done manually or semi-automated as spray lay-up.

For hand lay up - see the next slide diagram as well as the 1st video.

For spray up process see the 2nd video. The textile fibres are cut and mixed with the resin before being sprayed together into the mould by a semi-automated spray system.

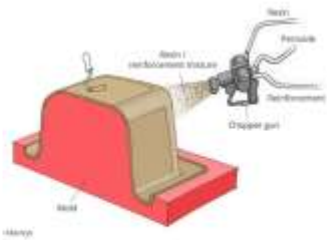
http://www.youtube.com/watch?v=TkD8n4XwdWA

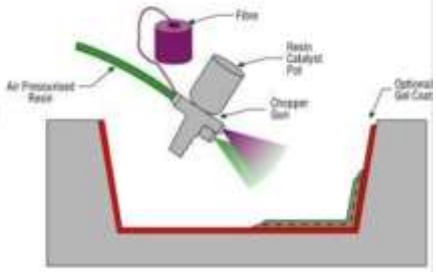
Laying up



Stages involved in the use of GRP

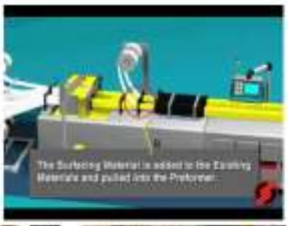
Spray up





Pultrusion

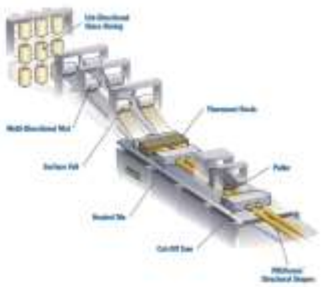
Pultrusion is similar to extrusion with the exception that material formed is pulled through the shape of the die rather than being pushed. The name is contraction of pull and extrusion. Mats of glass or carbon fibre stored in reels are pulled through a thermosetting resin impregnation bath and then guided through heated dies to cure the resin. The cured composite exits the die in a continuous length and is then cut to size.

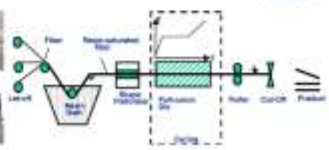


Pultrusion

This process produces continuous lengths of cross sections with high stiffness and flexural strength used in the production of supports for optical fibre.

Flexural strength is highest stress experienced within the material at its moment of yield.





LAMINATION

Is the technique of manufacturing a material in **multiple layers**, so that the composite material achieves improved strength, stability, sound insulation, appearance or other properties from the use of differing materials. A laminate is usually permanently assembled by heat, pressure, welding, or adhesives. Examples of laminates include surface for kitchen worktops, laminate flooring products, parts of chairs or furniture.

Also seen in topic 4.2b Timber

Activity

Product analysis exercise 2

Glass-reinforced plastics

1. Glass-reinforced plastic is often used in products such as boats, sports equipment, water tanks and car body panels. Explain why GRP is suitable for such products.
2. Use notes and diagrams to explain how such products are manufactured using GRP.
3. An alternative to GRP might be carbon-fibre reinforced plastic. Explain the advantages of using this.
4. Materials such as FRP and GRP are known as composites. Define the term 'composite'.
5. Describe the health and safety precautions you would take when using composites such as FRP and GRP.

A yacht made from composite materials

Practical activity

1. In pairs or small groups take a camera on a trip around your school or college. Photograph a range of (up to 10) different products that are made from composite materials. (These can be individual products or parts of the fixtures and fittings.)

Create a collage of these in a short PowerPoint presentation. Add notes to:

a. identify a product and its function
b. name the composite material and state its component parts
c. state what non-composite materials the current material is replacing.

Case study – carbon fibres in bicycles

One of the most famous applications of carbon fibre reinforced plastic is the development and manufacture of the Lotus Bicycle, designed by Mike Burrows and ridden by Chris Boardman in the 1992 Barcelona Olympics.

Currently the British Olympic track bike team is developing a new bike using laminar carbon fibre with 3D printed titanium joints.

Watch the video and take notes how the team of designers and engineers are developing this new bike for the upcoming Olympics.

2017 Exam style question

1. Which of the following processes can be applied to a composite material?

I. Pultrusion
II. Moulding
III. Weaving
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

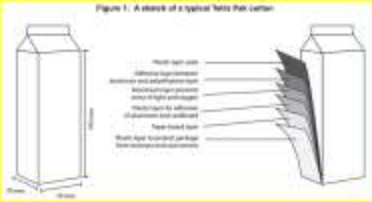
2016 exam style question

2. Figure 1 shows a sketch of a typical Tetra Pak carton. Tetra Pak cartons were developed in Sweden in 1951 to replace the glass containers commonly used at the time.

(b) (i) Outline one advantage of the multiple layer construction of the Tetra Pak carton. [2]

C (ii) Explain one advantage of the Tetra Pak cartons compared to the glass containers that they replaced. [3]

Figure 1. A sketch of a typical Tetra Pak carton



3. What is defined as: "a mixture of two or more substances with one acting as the matrix or glue"?
A. Compound
B. Molecule
C. Alloy
D. Composite

4 (a) State why timber is a natural composite material. [1]

4 (b) Explain why composite materials are usually difficult to recycle. [3]

5. The 2016 BMW 7 series may be considered a breakthrough in the use of carbon-fibre reinforced plastic in a mainstream car, see Figure 7.
What advantage is BMW seeking in using this composite material?

A. Flexibility
B. Increased rigidity
C. Light and strong
D. Lower costs

6a) Describe how the structure of LVL timber makes it suitable choice of material for roof beams spanning a roof 25m long. (2)

6b) Describe why LVL beams often made of resemble beams made from solid natural timber (2)

(a) State **one** function of the glue in a composite matrix. *[1]*

....

....

(b) Explain why the technique of weaving is appropriate to manufacture composite materials. *[3]*

Topic 4.8 - Scales of Production

Essential Idea and Understanding

The scale of production depends on the number of products required.

Decisions on scale of production are influenced by the volume or quantities required, types of materials used to make the products and the type of product being manufactured. There are also considerations of staffing, resources and finance.

Concepts and principles

- One-off, batch production and continuous flow
- Mass customization

1. One-off Production

One-off production is where you make a single product. This is often made to an individual design for one customer, such as 'custom-made' furniture.

One-off products are often made by hand by skilled craftsmen.

One-off products are normally expensive, because of the amount of time taken to make them.

2. Batch Production

Batch production makes small quantities, from a few to a few thousand, depending on the type of product.

Each batch of products will have the same design. However, different batches might be customised in some way. For example, the same design might be made in a different colour or size.

Batch production normally uses machine tools, and costs less to make products than with one-off manufacture, because you don't have to spend as much time setting up machines to make each product.

3. Mass Production (High Volume Production)

Mass production makes large quantities of the same product. Most things that you use every day are mass produced, including cars, mobile phones and chocolate bars.

Mass production is usually carried out on an assembly line. This is a collection of machines, often robots, that are just used to make that product. Each machine will just do one thing to the product, before passing it on to the next one.

The cost of setting up a production line is very high, so you have to make large quantities of a product to pay for it. However, because so many products are made, the cost of each one is normally less than for batch production.

First mass produced car – **The Ford Model T**

4. Continuous Production

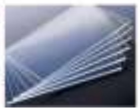
Continuous production is used to make products like steel, oil or chemicals.

Many of these products are used as the materials to make other products. Factories that operate continuous production often run 24 hours a day, seven days a week. The process needs to be continuous because it would be very expensive to stop it and then turn it on again.

An semi-automated production line is normally set up. Relying on computer control as well as human labour - production workers commonly work in rotating shifts.

Workers are less flexible than those working in batch production as the product rarely changes. There is a high level of investment in machinery and equipment.

Quality control is done at every stage of production. Sampling takes place at different stages of production.



Mass Customisation - International Mindedness

Mass customisation enables global products to become individual items. The clients are in control rather than companies answering to market expectations.

Mass customisation employs flexible manufacturing systems (often computer driven) to bring the efficiencies of mass production to short run jobs even down to single orders.

The advantages include

- Lost cost
- Fast production times

A good example of mass customisation is car manufacturing- car makers as BMW only produce cars that have an owner - made to it choices of colour, interiors, etc - takes 10 days to deliver from ordering.

http://www.youtube.com/watch?v=qJF51K7pQ80

Topic 4.9 - Production Systems

Essential Idea and Understanding

The development of increasingly sophisticated production systems is transforming the way products are made.

As a business grows in size and produces more units of output, then it will aim to experience falling average costs of production—economies of scale. The business is becoming more efficient in its use of inputs to produce a given level of output. Designers should incorporate internal and external economies of scale when considering different production methods and systems for manufacture.

Concepts and principles

- Craft production
- Mechanized production
- Automated production
- Assembly line production
- Mass production
- Mass customization
- Computer numerical control (CNC)
- Production system selection criteria
- Design for manufacture (DfM): design for materials, design for process, design for assembly, design for disassembly
- Adapting designs for DfM

Craft production

It involves the production of **single, unique, individual products**. A production process that is usually based **on manual skills.** It is a small-scale production. It's locally based and allows clients to discuss things with the manufacturer to produce customised items. These pieces exhibit both high quality and cost. Examples are haute couture fashion, jewellery and customised furniture.

Mechanised production

A **volume production process** where machines are controlled by humans. In other words machines are used to carry out some or all of the repetitive tasks in a production system.

Originally, small numbers of products were made by craftsmen in home workshops. The increasing demand for consumer goods following the industrial revolution, meant that larger numbers of products needed to be manufactured in a more efficient way.

Mechanisation might involve using jigs and templates to ensure quality. Also uses conveyor belts to keep components and parts flowing from one process to the other.

Craft production	Advantages	Disadvantages
Economies of scale		
Value of the product		
Labour		
Market forces		
Flexibility of manufacture		

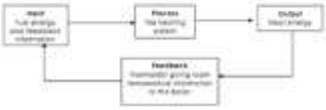
Mechanised production	Advantages	Disadvantages

Automated production

A volume production process which replaces human labour with mechanical, electronic or computer controlled machinery processes and systems that operate automatically or independently.

Today automation requires computer control. All automated systems depend of feedback to control their performance. The basic elements of feedback can be illustrated by a home heating system.

Devices then command the system to make adjustments to compensate for any feedback. Most modern industrial operations are too complex to be handled manually.



Automated production	Advantages	Disadvantages

Assembly line production

A volume production process where products and components are moved continuously along a conveyor. As the product goes from one workstation to another, components are added until the final product is assembled.

The origins of the Assembly line can be traced back to 1908, when Henry Ford invented and used for the first time the assembly line for the manufacturing of his Ford Model T - watch the video.

Mass customisation

It uses flexible manufacturing systems (often computer driven) that manufactures products to individual customer orders. The benefits of economy of scale are gained whether the order is for a single item or thousands. In somes ways it is consider the opposite of mass production - large numbers of identical products.

A clear example is Nike's ID program. Consumers can log on to the Nike website and customise the style, colour and any text addition to footwear while reviewing these changes on screen. The design can be purchased online and dispatched to the consumer directly from the factory.

Mass customisation

List other mass customisation products that you know.

Mass production versus Mass customisation

	Mass Production	Mass Customization
Goal	Delivering goods and services at prices low enough that nearly everyone can afford them	Delivering affordable goods and services with enough variety and customization that nearly everyone finds exactly what they want
Economics	Economies of scale	Economies of scope and customer integration
Focus	Efficiency through stability and control	Variety and customization through flexibility and responsiveness
Product	Standardized products built to inventory	Standardized modules assembled based on customer needs
Key Features	•Stable demand •Large homogeneous markets •Low-cost, consistent quality, standardized goods and services •Long product development cycles •Long product life cycles	•Fragmented demand •Heterogeneous niches •Low-cost, high-quality, customized goods and services •Short product development cycles •Short product life cycles
Organization	Mechanistic and hierarchical	Organic and flexible
Customer Involvement	Customers are passively involved in the value chain.	Customers are actively integrated into the value chain.

Computer Numerical Controlled (CNC)

(CNC) refers to the computer control of machines for the purpose of manufacturing complex parts. Machines are controlled by a programme commonly called a "G code". Each code is assigned to a particular operation or process. The codes control X, Y and Z movement and feed speeds.

Multi-tool CNC machines are used where the outcome requires more than one cutting process. Or example a CNC lathe is able to drill, ream, thread, cut and part-off components - watch the video how titanium dental implants are made using a CNC metal lathe.

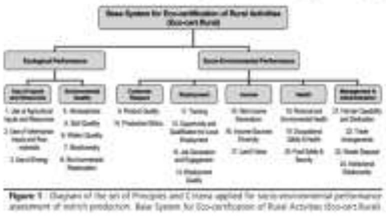
Glossary of terms

Craft production	
Mechanized production	
Automated production	
Assembly line production	
Mass production	
Mass customisation	
Computer Numerical Controlled (CNC)	

Production system selection criteria

Production system selection criteria include **time, labour, skills and training, health and safety, cost, type of product, maintenance, impact on the environment and quality management,** in order to create an effective, efficient and robust production system.

The use of Design for manufacture guidelines in the early stages of production system design is often adopted as a way of achieving these goals.



Production system selection criteria

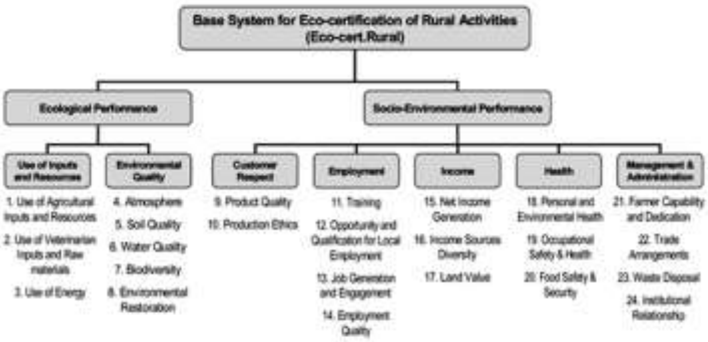


Figure 1 - Diagram of the set of Principles and Criteria applied for socio-environmental performance assessment of ostrich production. Base System for Eco-certification of Rural Activities (Eco-cert.Rural).

Design for Manufacture (DfM)

DfM is an important tool *in reducing production costs* through making the design as effective for ***design, manufacture and assembly***. DfM means designers design specifically for optimum use of existing manufacturing capability. There are four aspects of DfM:

- Design for materials
- Design for process
- Design for assembly
- Design for disassembly

Design for materials (DfM)

Design for materials means designers select material with the aim of reducing *toxic substances, hazardous waste, polluting emissions and the quantity of materials required*. Wherever possible single component materials are specified for moulding and recyclable materials are marked for later identification.

For example a green designer would consider the use of *recycled materials* in the design of the product, as well as ensure the paints used are water based so they aren't toxic and the card could be recycled easily at the end of its life. Also he will consider using the least amount of material possible, the availability of local recycled card, how it will affect the manufacturing process, etc.

Design for Process (DfM)

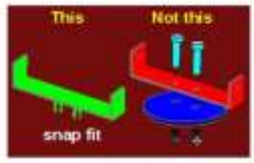
Design for process involves reductions in process related as the amount of **energy consumed, waste generated, emissions produced** and the reduction of the number of parts requiring additional operations such as plating, painting, printing, labelling, riveting and welding.

as well as ensuring the design is suitable for the specific manufacturing process, and used to its full potential.

Design for Assembly (DfM)

Design for assembly is an approach used by designers to analyse components and sub-assemblies with the goal of reducing costs through the **reduction in the number of parts** and maximizing the efficiency of assembly processes.

Design for assembly takes account assembly at various levels, for example component to component, components into sub-assembly and sub-assemblies into complete products.



DFA Design for Assembly Costs

Design for Disassembly (DfM)

Design for disassembly is a process that facilitates **easy repair, reuse, remanufacturing or recycling** of a product. It has become more popular with manufacturers as they strive to maintain profit as well the legislation requirements - such as the Waste Electrical and Electronic equipment (WEEE) and the reduction of hazardous substances of the European Parliament. Manufacturers also see the benefits of associated such to reduce production costs. Designing for disassembly happens if the criteria guidelines are followed such as

- Material selection - use recyclable materials and limit materials use
- Fastening techniques - minimise the use of permanent joints such as adhesives, welding, etc

- Standardise the fasteners used throughout the product.
- Reduce the number of components parts as much as possible. Consider modular designs.

International mindedness

The geographical distribution of different modes of production is an economic and political issue.

TASK
Read page 164 on the International Mindedness and make your own notes.
Use the fashion textile industry example used but try to identifying other examples of industries that have changed their production facilities to developing countries.

Theory of Knowledge

The increased dependency on automation and robots has affected craftsmanship. How has technology affected traditional ways of knowing?

2019 Exam style questions

1. Which of the following scales of production would be most appropriate for the Alpha Dog headphones?

A. Craft production
B. Mass production
C. Mass customization
D. Batch production

Figure 7: 3D printed headphone cup before the gloss paint finish is applied

2. Which of the following is most suited to the manufacture of a high-value niche product?
A. Continuous flow
B. One-off
C. Mass production
D. Batch manufacture

3. Which of the following best describes the ability to adapt a product to the needs of an individual?
A. Batch production
B. Mass customization
C. One-off production
D. Mass production

4. A recent study estimated that 239000 industrial robots were used globally in 2015, see
Figure 1. The study indicated that the growth was particularly rapid in China where the number of robots used increased by 16% from 2014 to 2015.

Figure 1: Worldwide supply of industrial robots 2000–2015

Rapid advances in robot technology bring both advantages and disadvantages. Another report stated that 45% of American jobs are at high risk of being taken by robots within the next twenty years.

4 (b) (i) List two advantages of using robotics in mass production. [2]

4 (ii) Outline how systems such as computer aided manufacturing (CAM) can contribute to improving the rate of production. [2]

4 (c) (i) Outline how design for disassembly can minimize waste. [2]

4 (ii) Explain the possible negative social effects of automation in a production system. [3]

5(c) Explain how injection moulding minimizes costs and waste during production of the Wakati power unit in Figure 9. [6]

Also relates to topic 4.2d plastics and 4.4 manufacturing processes

6. Which of the following considers materials, production, assembly and disassembly?
A. Mass production
B. Design for manufacture (DfM)
C. Assembly line production
D. Computer numeric control (CNC)

7. What is potentially the major ethical impact of an increase in the use of automation?
A. Decreased wages
B. Increased leisure time
C. Increased unemployment
D. Decreased manufacturing costs

8 Figure 11 shows a Butterfly Stool made of two identical pieces of plywood, joined in the centre with a single metal rod and connected under the seat by just two screws.

8 (a) List two ways that the principle of Design for disassembly influences the design development of the Butterfly Stool. [2]

9. Figure 6 shows a sports shoe on the Nike ID website, an online store where customers can order sports shoes manufactured to their own specific requirements. The website allows users to change the colours of different materials and swap between a predefined set of logos and soles.

What scale of production is illustrated by the product shown in Figure 6?
A. One-off
B. Continuous flow
C. Batch
D. Mass customization

10. Figure 2 shows ballpoint pens produced by injection moulding.

Which considerations would have been important in the design of the product shown in Figure 2?
I. Design for materials
II. Design for process
III. Design for disassembly
A. I and II
B. I and III
C. II and III
D. I, II and III

11. Which scale of production offers the most flexibility?
A. Craft
B. Mechanization
C. Automation
D. Mass customization

12. For which production approaches do customer requirements dominate?

	Mass customization	Craft production
A.	No	No
B.	No	Yes
C.	Yes	No
D.	Yes	Yes

13. Figure 4 shows the cardboard bicycle designed by Izhar Gafni an Israeli inventor and cycling enthusiast. He was inspired to design the bicycle when he learnt that another inventor had managed to design a canoe from cardboard. The cardboard for the bicycle has a special coating manufactured from organic materials which renders the material waterproof and fireproof. All components of the bicycle are made from recyclable materials and there are no metal parts. The bicycle only has a single gear. The bicycle can be manufactured for approximately £10 ($15) and sponsorship has been gained so it can be given away free to people in developing countries. Different sizes of the bicycle will be available and there are plans to use a similar technique to design a cardboard wheelchair.

(c) (i) Outline the scale of production for the cardboard bicycle. [2]

Figure 4: Cardboard bicycle

14. Figures 6 and 7 show the Teanest compact table and chairs set by designer Jody Leach. The two chairs tuck neatly under the table (Figure 7). The furniture is manufactured from composite timber (plywood) and is designed to be self-assembled (flat-pack). It is available in white, black or red with a protective finish (varnish).

a(ii) Outline the design for manufacture (DfM) strategy which has been a dominating constraint on the design brief for the table and chairs. [2]

a (iii) Outline how mass customization could improve the appeal of the table and chairs for consumers. [2]

c(ii) Discuss three considerations for the design of the table and chairs in relation to cost-effective manufacturing. [9]

Topic 4.10 - Robots and Automated Production

Essential Idea and Understanding

Idea - The development of increasingly sophisticated robotic manufacturing systems is transforming the way products are made

Understanding - Designers should consider the benefits of increased efficiency and consistency when using robots in production and be able to explore the latest advances in technology to ensure the optimum manufacturing process is used. However, a good designer will also understand their responsibility to consider the moral and ethical issues surrounding increased use of automation, and the historical impact of lost jobs.

Concepts and principles

- Primary characteristics of robots: work envelope and load capacity
- Single-task robots
- Multi-task robots
- Teams of robots
- Machine to machine (M2M)

Robots

Service robot

Personal care robot

A robot is defined as an actual mechanism programmable in 2 or more axes with a degree of autonomy, moving within its environment to perform intended tasks.

Robots are used for industrial use, for service, for personal care and for medical use.

In industrial use, robots are used for

- Quality control and inventory
- Fabrication and assembly operations
- Materials handling and transportation

Medical robot

Robots in industrial use

1 -Quality control Robot

Quality control robots use sensors to inspect product for defects. These robots might be stationed throughout the assembly line and may be independent or programmes as part of a multi-task robot operation.

2 - Manufacturing and Assembly robots

Fabrication or assembly robots work in a variety of ways such as single task, multi-task situations. Single task robots do one operation such as spot welding. Multi-task robots work together to place components, other drill or weld, etc.

AGV -Automated Guided Vehicle

Materials handling robots transport materials, components and the finished product throughout the plant. Above an example of an automated guided vehicle in an automated warehouse.
AGV follow sensors in the floor of a warehouse to carry out simple stock moving tasks. These are often linked into the JIT systems to deliver components to assembly lines just in time.

CIM Computer Integrated manufacture

Computer-integrated manufacturing (CIM) is the manufacturing approach of using computers to control the entire production process.

This integration allows individual processes to exchange information with each other and initiate actions.

Although manufacturing can be faster and less error-prone by the integration of computers, the main advantage is the ability to create automated manufacturing processes. Typically CIM relies on closed-loop control processes, based on real-time input from sensors

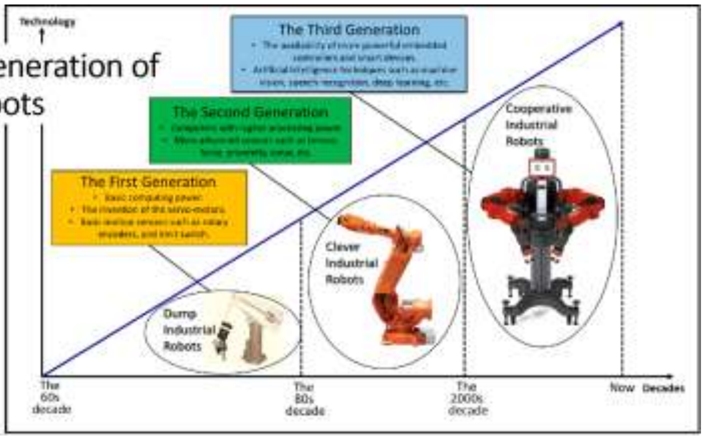
Some or all of the following subsystems may be found in CIM :

Computer-aided techniques:
CAD (computer-aided design)
CAE (computer-aided engineering)
CAM (computer-aided manufacturing)
CAQ (computer-aided quality)

Devices and equipment required:
CNC (Computer numerical controlled)
Robotics

Technologies:
FMS (flexible manufacturing system)
ASRS (automated storage and retrieval system)
AGV (automated guided vehicle)
Robotics

3 generation of Robots



1st Generation Robots


- Is a simple mechanical arm
- Ability to make precise motions at high speed, many times, for a long time.
- Such robots find widespread industrial use today
- First-generation robots can work in groups, such as in an automated integrated manufacturing system (AIMS), if their actions are synchronized.
- The operation of these machines must be constantly supervised, as these robots don't sense the world around them and can't respond to it.

2nd Generation Robots


http://www.youtube.com/watch?v=hMahhLE

- Has rudimentary machine intelligence.
- Such a robot is equipped with sensors that tell it things about the outside world. These devices include pressure sensors, proximity sensors, tactile sensors, radar, sonar, ladar, and vision systems.
- A controller processes the data from these sensors and adjusts the operation of the robot accordingly. These devices came into common use around 1980.
- Can stay synchronized with each other, without having to be overseen constantly by a human operator. Of course, periodic checking is needed with any machine.

3rd Generation robots

- Encompasses two major avenues of evolving smart robot technology: the autonomous robot and the insect robot.
- An autonomous robot can work on its own. It contains a controller, and it can do things largely without supervision, either by an outside computer or by a human being.
- A good example of this type of third generation robot is the personal robot about which some people dream. There are some situations in which autonomous robots do not perform efficiently. In these cases, a fleet of simple insect robots, all under the control of one central computer, can be used. These machines work like ants in an anthill, or like bees in a hive.While the individual machines lack artificial intelligence (AI), the group as a whole is intelligent.

AGV –Automated Guided Vehicle

Work envelope and load capacity

Work envelope: The 3D space a robot can operate within, considering clearance and reach. These distance are determined by the length of the robot arm and the design of its own axis.

Load capacity: Within this context, the weight a robot can manipulate.

Single/multi-task and teams of robots

Single-task robots – can only carry out one task at a time such as painting or welding.

Multi-task robots – can carry out more than one task at a time. They have flexible inputs and outputs, so they can be programmed to react to different stimulus such as sound or distance and they respond in different ways like movement or sound.

Teams of robots – groups of robots carry out similar tasks such as in a production line - teams of robots perform different tasks at different stages.

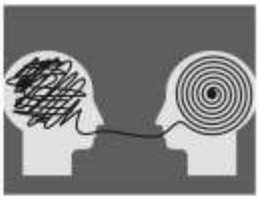
Machine to machine

Machine to machine is a broad label that can be used to describe any technology that enables networked devices to exchange information and perform actions without assistance of humans.

Key components of an M2M system include sensors, a wi-fi or cellular communications links and autonomic computing software programmed to help a networked device interpret data and make decisions.

Advantages and disadvantages of using robotic systems in production

Advantages	Disadvantages
• Improve health and safety of workforce. • High accuracy of work – reduced errors and waste - Quality of final product is up. • Perform repetitive and dangerous tasks • Work in confined spaces. • Perform functions 24/7 leading to higher production • Reprogrammability or flexible	• Expertise needed to operate such systems. • Training of workers required in both operation and maintenance. • High initial capital cost



Theory of knowledge

Technology in the form of robots currently serves man. Is man's place secure? Will the nature of man change due to technological enhancement? Will he be superseded altogether by technological developments?

Exam style questions 2019

16 - Robots can be used to replace humans in a number of production areas. Which of the following is a potential disadvantage of using robots in production?

A. Perform repetitive tasks
B. Work in confined spaces
C. Loss of jobs
D. Highly accurate

Figure 8: A smartwatch

Over the last five years there has been an increase in the number of people that own a smartwatch, see Figure 8. Users can listen to music, browse social media or find out about the weather on their smartwatch. Many smartwatches are assembled by robotic manufacturing systems.

7(c) Explain two ways how the use of robotic manufacturing systems can assist in the production of smartwatches. [6]

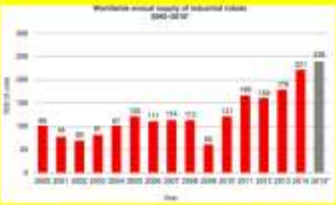


Figure 1: Worldwide supply of industrial robots 2000–2015

1. A recent study estimated that 239000 industrial robots were used globally in 2015, see Figure 1. The study indicated that the growth was particularly rapid in China where the number of robots used increased by 16% from 2014 to 2015.

Rapid advances in robot technology bring both advantages and disadvantages. Another report stated that 45% of American jobs are at high risk of being taken by robots within the next twenty years.

1 (a) (i) Define the term first generation robot. [1]

1 (ii) Describe the work envelope of a robot. [2]

15. A mechanical arm that can make precise motions at high speed belongs to which generation of robots?

A. First generation
B. Second generation
C. Third generation
D. Fourth generation

18. Discuss two considerations for a manufacturer when choosing CNC equipment. [6]

19. (a) Outline one way in which robots contribute to quality control in manufacture. [2]

(b) Outline one way in which robots facilitate waste reduction in manufacturing. [2]

(c) Outline one issue relating to replacing the human workforce with robots. [2]

Summary Notes
Q&A

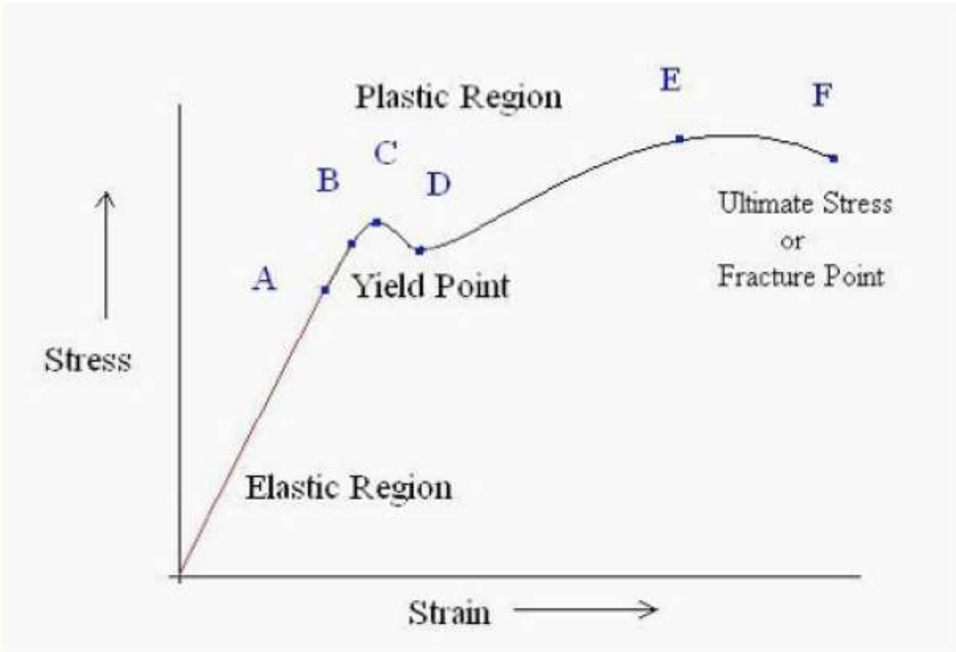
Topic 4 - Revision Notes

Topic 4
Raw material to final product

4.1 Properties of materials

Materials are selected for manufacturing products based primarily on their properties. The rapid pace of scientific discovery and new technologies has had a major impact on material science, giving designers many more materials from which to choose for their products. These new materials have given scope for "smart" new products or enhanced classic designs. Choosing the right material is a complex and difficult task with physical, aesthetic, mechanical and appropriate properties to consider. Environmental, moral and ethical issues surrounding choice of materials for use in any product, service or system also need to be considered.

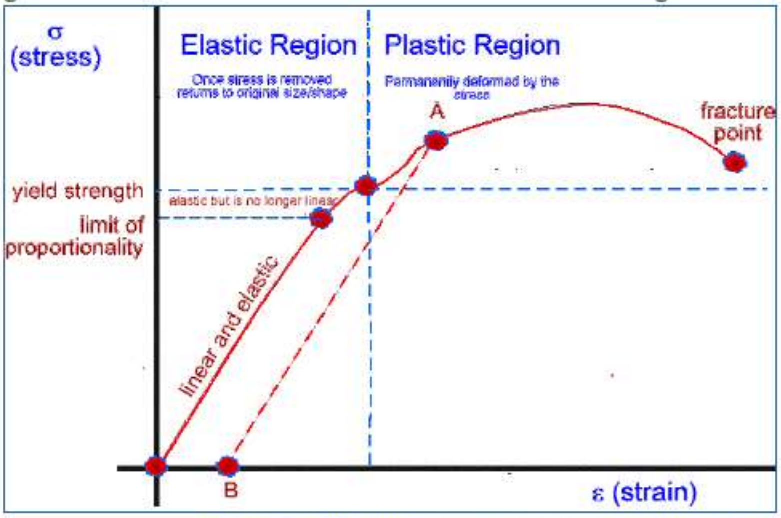
Define **Physical properties**	These properties tend to be the characteristic of materials that can be identified through testing that is considered to be **non-destructive**, although some deformation is required to test hardness. This exception is often why hardness is often catergorised as a mechanical property.
Definitions	**Mass-** relates to the amount of matter that is contained with a specific material. It is is often confused with weight understandably as we use Kg to measure it. Mass is a constant whereas weight may vary depending upon where it is being measured. **Weight-** relies on mass and gravitational forces to provide measurable value. Weight is technically measure as a force, which is the Newton, ie a mass of 1Kg is equivalent to 9.8 Newtons [on earth]. **Volume-** is the quantity of three-dimensional space enclosed by some closed boundary, for example, the space that a substance solid, liquid, gas, or shape occupies or contains. **Density-** is the mass per unit volume of a material. It's importance is in portability in terms of a product's weight and size. Design contexts include, pre-packaged food (instant noodles) is sold by weight and volume, packaging foams. **Electrical resistivity-** This is a measure of a material's ability to conduct electricity. A material with a low resistivity will conduct electricity well. It's particularly important in selecting materials as conductors or insulators. **Thermal conductivity-** A measure of how fast heat is conducted through a slab of material with a given temperature difference across the slab. It's important for objects that will be heated or must conduct or insulate against heat. **Thermal expansion** (expansivity)- A measure of the degree of increase in dimensions when an object is heated. This can be measured by an increase in length, area or volume. The expansivity can be measured as the fractional increase in dimension per kelvin increase in temperature. It's important where two dissimilar materials are joined. These may then experience large temperature changes while staying joined. **Hardness-** The resistance a material offers to penetration or scratching. Hardness is important where resistance to penetration or scratching is required. Ceramic floor tiles are extremely hard and resistant to scratching.

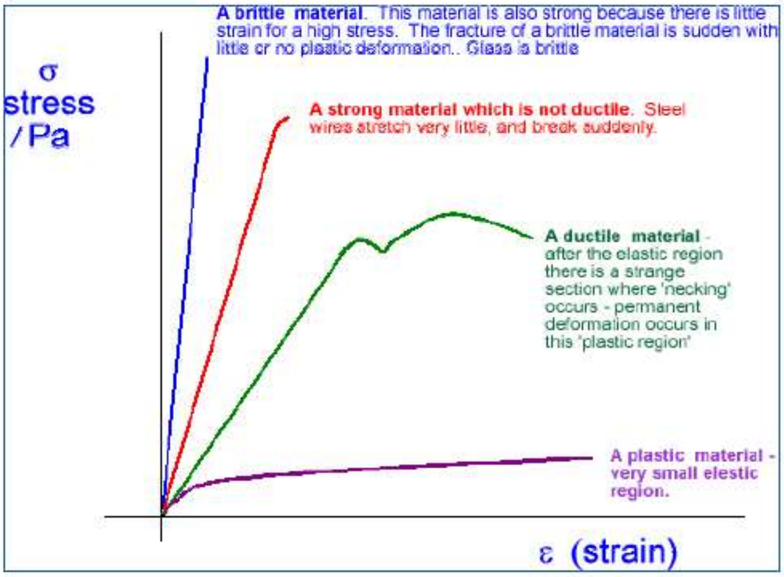
Mechanical properties	**Tensile strength**- The ability of a material to withstand pulling forces. **Tensile** strength is important in selecting materials for ropes and cables, for example, for an elevator. **Compressive strength-** Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, **Stiffness-** The resistance of an elastic body to deflection by an applied force. **Stiffness** is important when maintaining shape is crucial to performance, for example, an aircraft wing. **Toughness-** The ability of a material to resist the propagation of cracks. Good with resisting high impact of other objects- e.g. hammer **Ductility-** The ability of a material to be drawn or extruded into a wire or other extended shape. **Ductility** is important when metals are extruded (not to be confused with malleability, the ability to be shaped plastically). **Malleability** is the ability for materials to be shaped easily. The property of a substance that makes it capable of being extended or shaped by hammering or by pressure from rollers.
What is **Young's modulus**, stress and strain What is elasticity on the graph. Which part? What does it mean? Give an example. What is plasticity on the graph. Which part? What does it mean? Give an example.	**Young's Modulus** - also known as the tensile modulus or elastic modulus, is a measure of the stiffness of an elastic material and is a quantity used to characterize materials. It is defined as the ratio of the stress (force per unit area) along an axis to the strain (ratio of deformation over initial length) along that axis in the range of stress.  Stress = $\frac{\text{Force}}{\text{Cross Sectional Area}}$ Strain = $\frac{\text{Change in Length}}{\text{Original Length}}$ This straight line region is known as **elastic region** and the material can regain its original shape after removal of load. The stress and strain are directly proportional up to point A. Point B is known as the **Yield Point**. Once the material has crossed the Yield Point the material will not return to it's original shape, this is known as the plastic region. The line between AC is not a straight line and strain increases faster than stress. The material will change in length faster at these points than at any other point.

At this point C the cross sectional area of the material starts decreasing. At point D the workpiece changes its length with a little or without any increase in stress up to point E.

Point F is called **ultimate stress point** or fracture point. A material is considered to have completely failed once it reaches the ultimate stress.

Measuring when a material reaches it's Yield Point is called the Young's Modulus.





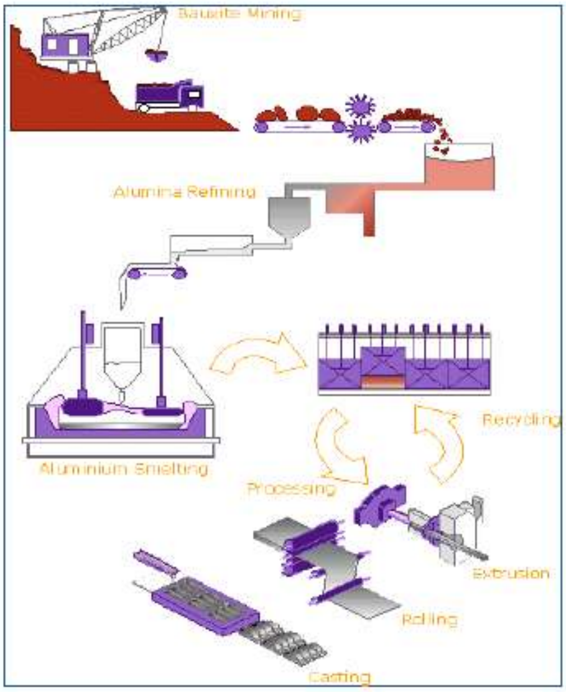
Aesthetic characteristics	Some aesthetic characteristics are only relevant to food, while others can be applied to more than one material group. Aesthetic characteristics of products make them interesting, appealing, likeable, or unattractive and are based completely on personal preferences. These personal views are affected by mood, culture, experience, activation of the senses, values, beliefs, etc. They are very difficult to quantify scientifically and people's **reactions to taste, smell, appearance and texture** are very different.
Definitions	**Taste** - the ability to detect the flavour of substances such as food and poisons. **Smell** - the ability of humans and other animals to perceive odors. Consider the scene in *Ratatouille (film)* where he experiences the taste of food in vibrant technicolor, think about how smells evoke memories, the smell of fresh bread when you enter a supermarket, food smells making you hungry, etc. **Appearance** - related to how something looks. What a product looks like. Is it colourful? masculine? feminin? funny? sexy? sleek? minimal? clean? busy? etc. The appearance of a product appeals to different demographics such as age, gender, culture, ethnicity, etc. Shopper place a large emphasis on colour, so does brand recognition IE Coca Cola **Texture** - the properties held and sensations caused by the external surface of objects received through the sense of touch. e.g. smoothness of kitchen work surfaces for reasons of hygiene, tiles around a swimming pool (i.e. roughened surface to prevent slipping when wet). Hard, Soft, Abrasive, Smooth. Wood has a grain pattern, metal has a cold texture. **Colour-** is the visual perceptual property corresponding in humans to the categories of colours. • Optical e.g. opaque, translucent, transparent • Colour e.g Hot, Cold, Warm, Mellow, Bright, Vivid, Cool • Effects on emotions. e.g. sense of 'warmth' and 'coldness' i.e. 'warm' red/orange/yellow 'cool' violet/green/blue. The use and application of such knowledge in the designed environment. e.g. decoration, symbols, artefacts.

Smart Materials	Smart materials have one or more properties that can be dramatically altered, for example, viscosity, volume, conductivity. The property that can be altered influences the application of the smart material.	
Type of Smart Material	**How it works/what it can do**	**Design contexts where properties of smart materials are exploited**
Piezoelectricity	is a term that is derived from the greek meaning for piezo, squeeze or pressure where electricity is generated when piezoelectric material is deformed, **The pressure acting upon the material it gives off a small electrical discharge.**	When a **piezoelectric** material is deformed, it gives off a small electrical discharge. When an electric current is passed through it, it increases in size (up to a 4% change in volume). These materials are widely used as sensors in different environments. Piezoelectric materials are used in the airbag sensor on a car as it senses the force of an impact on the car and sends an electric charge to activate the airbag.
Shape memory alloy (SMA's)	Metals that exhibit pseudo-elasticity and shape memory effect due to rearrangement of the molecules in the material. **Pseudo-elasticity occurs without a change in temperature or electrical voltage**. The load on the SMA causes molecular rearrangement, which reverses when the load is decreased and the material springs back to its original shape.	They can be used to make products for durable and harder to break. i.e. Glasses frames The shape memory effect allows severe deformation of a material, which can then be returned to its original shape by heating it.
Photochromicity	Material that can described as having a **reversible change of colour when exposed to light**. One of the most popular applications is for colour-changing sunglass lenses, which can darken as the sun light intensifies. A chemical either on the surface of the lens or embedded within the glass reacts to ultraviolet light, which causes it to change form and therefore its light absorption spectra.	welding goggles/ mask. cool tee shirts. "reactor light" sunglasses
Magneto-rheostatic **Electro-rheostatic**	**Electro-rheostatic** (ER) and **magneto-rheostatic** (MR) materials are fluids that can undergo dramatic changes in their viscosity. They can change from a thick fluid to a solid in a fraction of a second when exposed to a magnetic (for MR materials) or electric (for ER materials) field, and the effect is reversed when the field is removed.	MR fluids are being developed for use in car shock absorbers, damping washing machine vibration, prosthetic limbs, exercise equipment and surface polishing of machine parts. ER fluids have mainly been developed for use in clutches and valves, as well as engine mounts designed to reduce noise and vibration in vehicle
Thermoelectricity	**Thermoelectricity** is, at its simplest, electricity produced directly from heat. It involves the joining of two dissimilar conductors that, when heated, produce a direct current. Thermoelectric circuits have been used in remote areas and space probes to power radio transmitters and receivers.	Nest was co-founded by former Apple engineers Fadell and Rogers in 2010 and now produces a range of household monitoring devices. The temperature monitors uses thermocouples to drive the electrical signal to provide the data. Nest products form part of the interface to create smart systems that are remotely driven through smartphone apps.

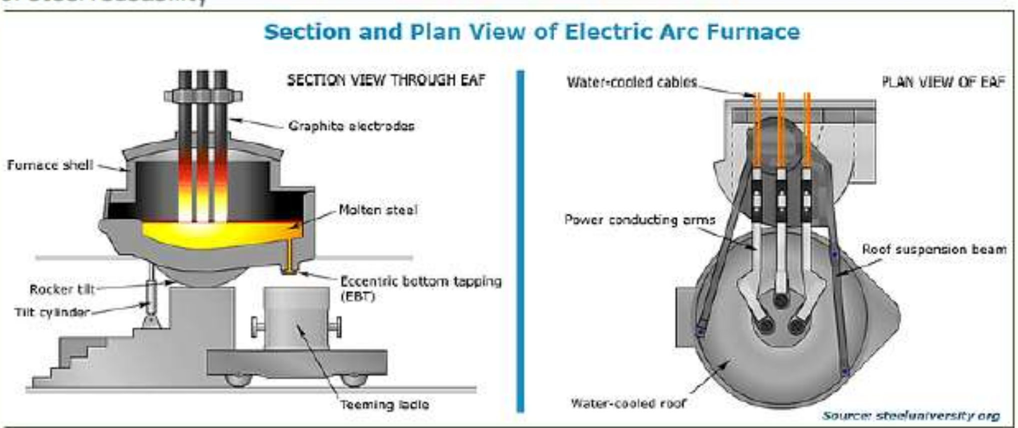
4.2a Metals and metallic alloys

Materials are classified into six basic groups based on their different properties. Typically hard and shiny with good electrical and thermal conductivity, metals are a very useful resource for the manufacturing industry. Most pure metals are either too soft, brittle or chemically reactive for practical use and so understanding how to manipulate these materials is vital to the success of any application.

<table>
<tr><td>Extracting metal from ore
The Earth's crust contains metals and metal compounds such as gold, iron oxide and aluminium oxide, but when found in the Earth these are often mixed with other substances. To be useful, the metals have to be extracted from whatever they are mixed with.</td><td>A metal ore is a rock containing a metal, or a metal compound, in a high enough concentration to make it economic to extract the metal. The method used to extract metals from the ore in which they are found depends on their reactivity. For example, reactive metals such as aluminium are extracted by electrolysis, while a less-reactive metal such as iron may be extracted by reduction with carbon or carbon monoxide. Thus the method of extraction of a metal from its ore depends on the metal's position in the reactivity series:</td></tr>
<tr><td>Aluminium Extraction</td><td>Aluminium ore, most commonly bauxite, is plentiful and occurs mainly in tropical and sub-tropical areas. Bauxite is refined into aluminium oxide trihydrate (alumina) and then electrolytically reduced into metallic aluminium.



</td></tr>
<tr><td>Steel</td><td>Blast Furnace using oxygen furnace and the electric arc furnace contribute to high rates of steel reusability



</td></tr>
</table>

Grain size	Metals are crystalline structures comprised of individual grains. The grain size can vary and be determined by heat treatment, particularly how quickly a metal is cooled. Quick cooling results in small grains, slow cooling results in large grains. Grain size in metals can affect the **density, tensile strength and flexibility.** The smaller the grains in the metal the higher density the metal is. Higher density means a lower flexibility and sometime tensile strength. The tensile strength and flexibility will also depend on how the metal is tempered normally. The rate of cooling and the amount of impurities in the molten metal will affect its grain size: • Gradual cooling - a few crystals are formed - large grain size • Rapid cooling - many crystals formed - small grain size. • Reheating a solid metal / alloy allows the grain structure to re-align itself. • Directional cooling in a structure is achieved by selectively cooling one area of a solid. The effect of impurities (or additives) in a molten metal can induce a large number of fine grains that will give a stronger and harder metal. This addition must be carefully controlled as too many impurities may cause an accumulation at the grain boundaries, which will weaken the material.
Modifying physical properties by alloying, work hardening and tempering	**Alloying** is an **alloy** is a mixture of two elements, of which one is at least a metal - e.g. Carbon and Iron is Steel. Copper and Zinc (two metals) create Brass - Adding in different (materials to) metals to ultimately create a harder and strong metal. **Work hardening** or cold working, is the strengthening of a metal by plastic deformation. As the name suggests the **metal becomes harder after the process**. The metal is not heated at all. The process involves the metal passing through a set of rollers to reduce its thickness, (compressed) grains are deformed. The shape is changed, but the volume remains constant. The defects of these structures reduce the ability for crystals to move within the metal structure, becoming more resistant to more deformation as they recrystallize. Processes include - • rolling, • bending • shearing • drawing **Annealing** is a heat treatment that alters the physical and sometimes chemical properties of a material to increase its ductility and to make it more workable. It involves heating, maintaining a suitable temperature, and then cooling by slowly reducing the temperature over time. Annealing is **softening the metal after work hardening**. **Case Hardening** is hardening are processes in which the surface of the steel is heated to high temperatures (by direct application of a flame, or by induction heating) then cooled rapidly, generally using water; this creates a surface of martensite on the surface. **Improves hardness on the surface** or case of the material while keeping the inner core untouched and so still processes properties such as **flexibility and is still relatively soft**. **Tempering** is a process of heat treating, which is used to **increase the toughness** of metals containing iron. Tempering is usually performed after hardening, to reduce some of the excess hardness, and is done by heating the metal for a certain period of time, then allowed to cool in still air. Tempering is reducing brittleness after quenching.
Superalloys	**Design criteria for superalloys:** - Excellent mechanical strength and creep resistance at high temperatures - Corrosion and oxidation resistance **Creep Resistance:** - Creep is the gradual extension of a materials under constant force. Dependant on temp. and pressure. - Occurs as a result of thermal vibrations of the lattice. Can result in fracture of superalloy due to development of cavities in the material

	Oxidation Resistance: - Presence of other metals such as chromium ensure that a tight oxide film is formed on the surface - This restricts access of oxygen to the metal surface so that the rate of oxidation is heavily reduced. **Applications of Superalloys:** Nickel Based Alloy - Jet Engine Components (Turbine blades operate at high temperature and under extreme stress conditions. In operation they will glow red hot, however they must be creep resistant, fatigue and corrosion resistant.

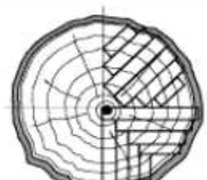
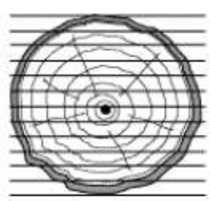
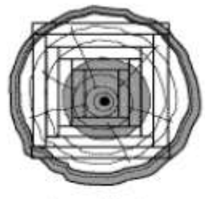
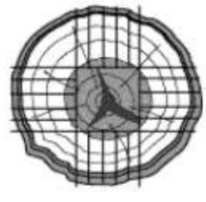
Recovery and **disposal** of metals and metallic alloys	- car bodies and steel reinforcing recovered from concrete can be recycled into new steel
	- modern technologies are causing a significant problem
	    - 20 million to 50 million tonnes of e-waste
	- new recycling schemes directed specifically for e-waste
	    - example; Samsung Washing Machine where broken parts can be taken apart and replaced with a new one
	    - Aluminium recycling a huge advantage as extraction process is so expensive/damaging to environment therefore we should encourage alu recycling

Contexts where different metals and metallic alloys are used

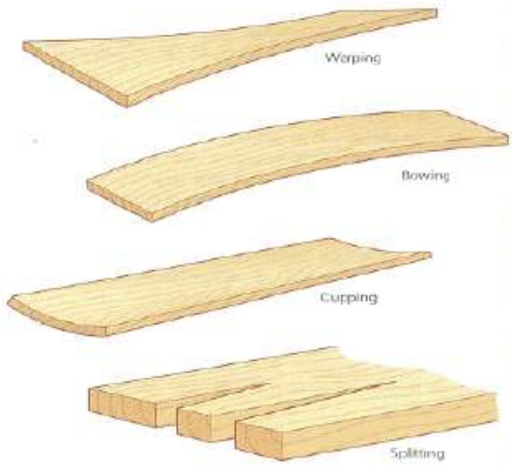
Classification and Type of Metal	Properties (pro's and con's)	Example of products
Ferrous metals: **Steel**	- Poor corrosion resistance - Tough - Ductile - Malleable - Good Tensile Strength - Can be recycled - Relatively Cheap	- Surgical tools - screw - nails - kitchen utensils - used in all purpose engineering
Ferrous metals: **Iron**	- very ductile - strong - malleable - Long lasting	- basic machinery - tools - building structures - manufacturing components of cars / automobiles
Ferrous metals: **Stainless Steel**	- high initial cost - difficult to fabricate - difficult to weld due to high carbon content?	- Pipes - cutlery - aircraft
Non Ferrous metals: **Aluminium**	- light weight - easily worked - Malleable and soft - Conducts heat and electricity - Corrosion resistant	- Aircraft manufacture - window frames and some kitchen ware
Non Ferrous metals: **Copper**	- conducts heat and electricity - Corrosion resistant - Tough, ductile	- Wiring - tubing - pipe work
Non Ferrous metals: **Tin**	- Soft - Corrosion resistant	- Tin cans
Non Ferrous metals: **Zinc**	- Layer of oxide, anti Corrosion - Easily worked with	- Makes brass - steel coating **(galvanising)** - tanks - anti rust
Non Ferrous metals: **Brass**	- Very corrosive - Tarnishes - Conducts electricity well	- Ornamental purposes - within electrical fittings

4.2b Timber

Timber is a major building material that is renewable and uses the Sun's energy to renew itself in a continuous cycle. While timber manufacture uses less energy and results in less air and water pollution than steel or concrete, consideration needs to be given to deforestation and the potential negative environmental impact the use of timber can have on communities and wildlife.

Characteristics of natural timber:	Natural timber is timber that is used directly from the tree after being **seasoned** (a controlled drying process). It is actually a type of composite material because it is made up of cellulose (wood fibres) held together with a natural adhesive (lignin). The tensile strength of timber is greater along the grain (fibre) than across the grain (matrix). Natural timber is classified into two main categories: **Softwood** and **Hardwood**. • Softwood comes from *coniferous* trees. These have needles that are kept year-round. • Hardwood comes from *deciduous* trees. These are broad leaved and often shed their leaves during winter, depending on the climate. The world's forests can be divided into **temperate** and **tropical**: • Temperate forests are in the regions between the tropics and the polar areas, mainly in the northern hemisphere. *Both hardwoods and softwoods grow in temperate forests.* Tropical forests are in the region between the 2 tropics. *Generally only hardwoods are found in these forests.*
Seasoning of Timber	Two types of seasoning- Artificial (Kiln) or Natural **1) Air Seasoning** Advantages : No expensive equipment needed, Small labour cost once stack is made, Environmentally friendly-uses little energy Disadvantages :Takes longer than Kiln seasoning, large area of space required for a lot of wood, it is notable to produce timber not dry enough for use in the dry, centrally heated air of modern buildings **2) Kiln Seasoning** Advantages: Insects are killed during this process, Require little stacking space, Moisture content of the timber may be brought to any desired level, It is dries quickly, It can be controlled, Achieve a lower moisture content, Defects associated with drying can be controlled Disadvantage: It is expensive , It gives a little weaker timber when compared to air seasoning, requires supervision by a skilled operator, uses a lot of energy
Conversion of timber	After a tree has been **felled/cut down** and taken to a sawmill, it is converted ready for **seasoning.** After the timber dries out, it is cut into smaller sections.  quartered conversion, showing 2 different cuts (radial boards)  through and through conversion. (tangential and some radial board  tangential cuts (heart is boxed)  boxed heart

Faults with **natural timber**



Natural woods are also subject to movements such as **splitting, cupping, warping** and **bowing.** All of these would make the wood **unusable.**

Woods can also form **knots** which are formed where branches grow from the main trunk or where the bud was formed. Knots will make the timber weaker, but it can be used from an aesthetic point of view.

Characteristics of natural timber: **hardwood**

-Hardwood trees are mostly deciduous, and are characterised by their broad or large area leaves. hardwood trees also bear fruit, such as nuts, seeds or acorns, there name is often derived from the name of their fruits. They can 100 years to mature.
-Tropical hardwoods are not classified as deciduous but as *angiosperm.* but their timber has comparable mechanical properties of strength, hardness and durability. hardwood is mostly of a higher density and hardness than a softwood.
-Aesthetics of hardwoods is usually very appealing. This makes it very desirable and its often used in high-quality furniture. This also makes it very expensive.
-Hardwoods contain much more fibrous material than softwoods. The fibers are smaller and more compact, making it stronger and harder. In general, the greater the density of wood, the greater its mechanical strength.

Hardwood	Colour/texture	Uses
Beech - A straight-grained hardwood with a fine texture. Light in colour. Very hard so is ideal to be used where it is being bashed around and used often. Beech is also very easy to work with.		Used for furniture, children's toys, tool handles. Can be steam bent and laminates well.
Teak - A very durable oily wood which is golden brown in colour. Highly resistant to moisture as it contains natural oils.		A very durable oily wood which is golden brown in colour. Highly resistant to moisture and outdoor weather
Oak - A very strong wood which is light in colour. Open grain. Hard to work with. When treated it looks very classy and elegant.		A very strong wood which is light in colour. Open grain. Hard to work with. When treated it looks very classy and elegant.
Mahogany - An easy to work wood which is reddish brown in colour. This wood is very expensive. A hardwood.		An easy to work wood which is reddish brown in colour. This wood is very expensive.

Characteristics of natural timber: **softwood**

Softwoods

Softwood	Colour/Texture	Uses
Scots pine - A straight-grained softwood but knotty. Light in colour. Fairly strong but easy to work with.		Used for DIY and cheap quality furniture. Mainly used for constructional work and simple joinery.
Spruce - Creamy-white softwood with small hard knots. Not very durable.		Used for general indoor work, whitewood furniture used in bedrooms and kitchens.
European redwood - Quite strong, Lots of knots, durable when preserved.		Used for general woodwork, cupboards, shelves, roofs.

Softwoods come from **coniferous** trees which are evergreen, needle-leaved, cone-bearing trees, such as cedar, fir and pine.
Softwoods can often be harder than hardwood. Douglas Fir has a higher tensile and compressive strength than many hardwoods. Balsa wood, although technically a hardwood, is mechanical week, low tensile strength, low hardness and lacking in toughness.

Aesthetics : Softwoods such as pine are very resinous and at times this resin can leak out of the timber. Resin is really sticky and messy and will also come through painted surfaces (it makes a really bad stain).
Pine will change color if exposed to sunlight for long periods of time. Generally a pale yellow with brown streaks. Softwoods are also prone to decaying and warping, bowing, cupping and splitting.

Softwoods are usually made up of tube-like cells (similar to holding up a bunch of straws together). This would make the softwoods less dense and more prone to water damage. The timber absorbs water just like a sponge if the end grain is exposed.

Characteristics of **man-made timbers**

Man-made timbers are composite products that use wood lengths, fibres and veneers along with an adhesive binder and combined under heat and pressure to produce a product.

Highlight characteristics include tensile strength,resistance to damp environments, longevity, aesthetic properties

MDF	Plywood	Chipboard/Particleboard
		
Smooth, even surface. Easily machined and painted or stained. Also available in water and fire resistant forms.	A very strong board which is constructed of layers of veneer which are glued at 90 degrees to each other.	Made from chips of wood glued together. Usually veneered or covered in plastic laminate.
Used mainly for furniture and interior panelling due to its easy machining qualities. Often veneered or painted.	A very strong board which is constructed of layers of veneer which are glued at 90 degrees to each other.	Made from chips of wood glued together. Usually veneered or covered in plastic laminate.

Advantages and **disadvantages** of man-made timbers

Advantages	Disadvantages
available in **large** flat sheets- 2440 x 1220mm so can be used for large pieces of furniture without having to join pieces together	sharp tools required when cutting manufactured boards, and tools and easily blunted
good **dimensional stability**- they don't warp as much as natural timber	difficult to join in comparison with traditional construction methods- you cannot cut traditional woodwork construction joints such as finger or dovetail joints
can be decorated in a number of ways, eg, with **veneers** or paint	thin sheets do not stay flat and will bow unless supported
sheets of plywood and MDF are flexible and easy to bend over formers for laminating	cutting and sanding some types of board generates hazardous dust particles
waste from wood production can be used to make MDF, chipboard and hardboard.	edges must be treated and covered to hide unsightly edges and to stop water getting in, a process called concealing edges; this also helps to create an appearance of a solid piece of timber.

Treating and **finishing timbers**	Timber treatments & finishes are used to protect, enhance and improve the mechanical properties. **Timber treatments-** are an additive preservative to improve the timber's resistance to attack and improve its durability is enhanced to a level which is suitable for the intended use. - **Wood destroying fungi -** resulted from moisture - **Wood destroying insects** - borers, white ants eg. Wood preserver, creosote, stain preservers **Timber finishes-** are applied to the surface of the timber and is usually carried out to achieve one or both of the the following reasons: - **Aesthetics**- to improve the materials natural beauty - **Function**- to protect it from environmental impact, heat, moisture Finished timber requires sanding with abrasive paper to close up the grain leaving smaller gaps. eg. varnish/estapol, finishing oil, wood wax Timber is **seasoned** as part of it preparation for commercial use. This process reduces the moisture content so that it becomes workable. The remaining moisture, albeit small, means that the wood never really stabilises and continues to swell and shrink, with humidity and temperature variations.
Recovery and **disposal** of timbers	**Reforestation** is the process of restoring tree cover to areas where woodlands or forest once existed. If this area never returns to its original state of vegetative cover the destructive process is called deforestation. In order to maintain a sustainable forest industry reforestation is necessary. **Wood recycling** is the process of turning waste timber into usable products. Recycling timber is a practice that was popularized in the early 1990s as issues such as deforestation and climate change prompted both timber suppliers and consumers to turn to a more sustainable timber source. **Recycling timber** is the environmentally friendliest form of timber production and is very common in countries such as the UK, Australia and New Zealand where supplies of old wooden structures are plentiful. Timber can be chipped down into wood chips which can be used to power homes or power plants. **Uses for recycled waste wood** include traditional feedstock for the panel board industry, which still accounts for the majority of recycled wood. Other uses include animal beddings, equestrian and landscaping surfaces, play areas and filter beds.

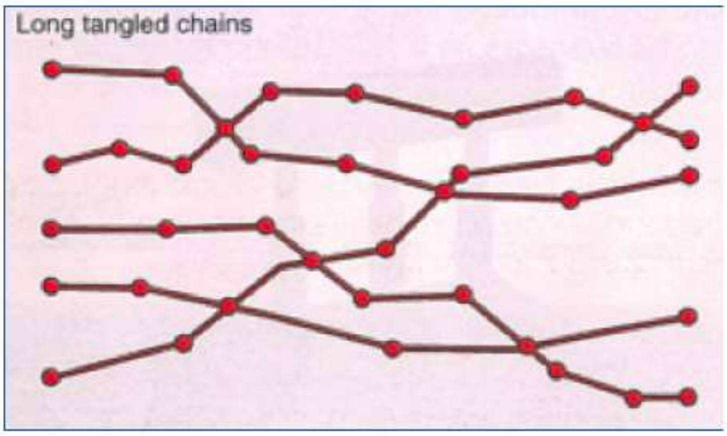
4.2c Glass

The rapid pace of technological discoveries is very evident in the manufacture and use of glass in electronic devices. Different properties have been presented in glass for aesthetic or safety considerations for many years but the future of glass seems to be interactivity alongside electronic systems. The structure of glass is not well understood, but as more is learned, its use is becoming increasingly prominent in building materials and structural applications.

Characteristics of glass	Glass is a hard, brittle and typically transparent amorphous* solid made by rapidly cooling a fusion of sand, soda and lime. **amorphous-** Glass is an amorphous substance (a solid that is not crystalline) made primarily of silica fused at high temperatures with borates or phosphates. **transparency**- Ability to allow light to be transmitted with minimal scattering allowing a clear view through material. **chemically inert**- Lack of reactivity with other materials. **non-toxic**- Absence of toxic breakdown products/lack of reactivity. **brittle**- Breaks into numerous sharp shards. **biocompatibility**- The product ensures the continued health of a biological environment. **hardness**- Scratch resistance. **aesthetic appeal**- Favourable in terms of appearance. **electrical insulator**- Reduces transmission of electric charge. **cheap-** Abundance of material and high volume production in comparison to production cost.
Applications of glass	**Laminated Glass**- 2 thin sheets of glass with an interlayer of plastic in between. It is very strong bonds, retains shards of glass when cracked **e.g. iPhone glass cover,car windshield, architectural use, bullet proof windows** **Toughened** or **Tempered Glass**- Outer face of glass in compression, inner side of glass in tension, it shatters in small pieces and **used for furniture e.g. staircases/floors, architectural use** **Soda Glass-** Has poor thermal shock (shatters when hot water put in glass), expands quickly, cheap to produce and **used in drinking bottles** **Pyrex** slow expansion/contraction and **used for cooking, test tubes, thermometers, over doors** **Gorilla Glass** is a brand of specialized toughened glass developed and manufactured by Corning for use with mobile devices, designed to be thin, light and damage-resistant.
Recovery and disposal of glass	-Faulty and broken glass products are broken up (cullet) and reused by mixing with virgin materials to make a batch. This can save energy and also materials (virgin). -No degradation of glass quality in the process so it can be repeated several times. There is very little wastage during manufacture. -Glass is 100% recyclable and can be recycled endlessly without loss of purity or quality 

4.2d Plastics

Most plastics are produced from petrochemicals. Motivated by the finiteness of oil reserves and threat of global warming, bio-plastics are being developed. These plastics degrade upon exposure to sunlight, water or dampness, bacteria, enzymes, wind erosion and in some cases pest or insect attack, but in most cases this does not lead to full breakdown of the plastic. When selecting materials, designers must consider the moral, ethical and environmental implications of their decisions.

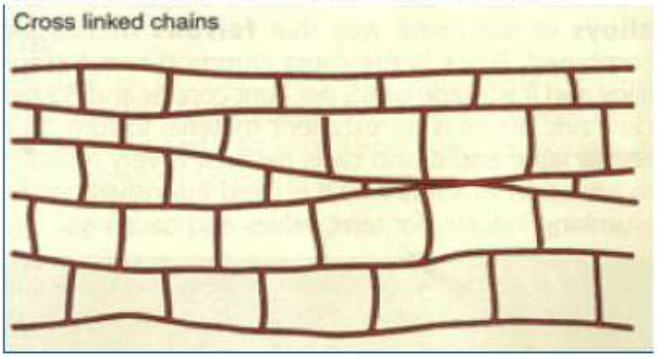
Raw materials for plastics	<table><tr><th>Natural plastics</th><th>Semi synthetic plastics</th><th>Synthetic plastics</th></tr><tr><td>these are naturally occurring materials that can be said to be plastics because they can be shaped and moulded by heat. An example of this is amber, which is a form of fossilised pine tree resin and is often used in jewellery manufacture.</td><td>these are made from naturally occurring materials that have been modified or changed but mixing other materials with them. An example of this is cellulose acetate, which is a reaction of cellulose fibre and acetic acid and is used to make cinema film.</td><td>these are materials that are derived from breaking down, or 'cracking' carbon based materials, usually crude oil, coal or gas, so that their molecular structure changes. This is generally done in petrochemical refineries under heat and pressure, and is the first of the manufacturing processes that is required to produce most of our present day, commonly occurring plastics.</td></tr></table>
Raw materials for plastics	Most modern plastics are derived from natural materials such as crude oil, coal and natural gas with crude oil remaining the most important raw material for their production. Polymers are substances which are made up from many molecules which are formed into long chains. The differences in the way the chains bond cause the different properties in the different types of polymers.
Structure of **thermoplastics**	Thermoplastics are linear chain molecules, sometimes with side bonding of the molecules but with weak secondary bonds between the chains. Between the long chain molecules are secondary bonds which are weak forces of attraction between the molecules. Thermoplastics can be heated and reformed. Their polymer chains **do not form cross links**. Thus, the chains can move freely each time the plastics are heated. 

Material	Properties	Applications
Polypropylene (PP)	Light, hard, tough, impact resistant, good chemical resistant, can be sterilised, good resistant to work fatigue	Used for medical and laboratory equipment, containers, chairs
Polyethylene (PE)	tough, resistant to chemicals, soft and flexible, good electrical insulator	
HIPS	Tough, high impact strength, rigid, good electrical insulator.	
ABS	High impact strength, tough, scratch-resistant, lightweight, durable, good resistance to chemicals, good electrical insulator	Kitchenware, GO Pro camera cases, Toys (Lego)
PET:	Chemical resistant, high impact resistance, tough, high tensile strength, durable, excellent water and moisture barrier	Plastic drinking bottles
PVC	Good chemical resistance, weather-resistant, lightweight, good electrical insulator, stiff, hard, tough, waterproof, durable	Pipes, Rainwater pipes and guttering, Window frames and fascias, Electrical cable insulation

Structure of **thermosetting plastics**

Thermosets are linear chain molecules but with **strong primary bonds between adjacent polymer chains (or cross links)**. This gives thermosets a rigid 3D structure.

On first heating, the polymer softens and can be moulded into shape under pressure. However, the heat triggers a chemical reaction in which the molecules become permanently locked together. As a result the polymer becomes permanently 'set' and cannot be softened again by heating. Examples of thermosetting plastics are polyurethane, urea formaldehyde, melamine resin and epoxy resin



Material	Properties	Applications
Polyurethane	strong electrical insulator (resistance) good tensile and compressive strength good thermal resistance can be fairly hard and tough can be easily bonded can be flexible and elastic	Wheels, foam, varnish, paint and glue

	<table><tr><td>**Urea-formalde hyde**</td><td>high tensile (tension) strength high heat distortion temperatures low water absorption high surface hardness weight/volume resistance</td><td>Tableware Worktop laminates Buttons Electrical casings</td></tr><tr><td>**Melamine resin**</td><td>high electrical resistivity very low thermal conductivity/ high heat resistance hard/ solid scratch resistant stain resistant available in a range of thicknesses and sizes</td><td>kitchen utensils plates, camping bowls (not microwave safe)kitchen utensils and plates, laminated benchtops</td></tr><tr><td>**Epoxy resin**</td><td>Tough Chemical resistance (also water) Fatigue and mechanical strength (Tensile strength and compressive strength) Electrical insulation Temperature resistant (maintains form and strength) (Though some are vulnerable to light) Can be used on metal (The adhesive)</td><td>Construction of aircraft boats and cars, also are used in electrical circuits and general purpose adhesive and with glass reinforced plastics</td></tr></table>
Temperature and recycling thermoplastics and thermoset plastics	-Thermoplastics soften when heated and harden and strengthen after cooling. -Thermoplastics can be heated, shaped and cooled as often as necessary without causing a chemical change, while thermosetting plastics will burn when heated after the initial molding. -Non-reversible effect of temperature on a thermoset contribute to it **not** being able to be recycled. Heating increases the number of permanent cross-links and so hardens the plastic, so therefore cannot be recycled
Recovery and **disposal** of plastics **Thermoplastics**: Heat, Reshape, Cool **Thermosetting** Plastics: Landfill, incinerate **Biodegradable** Plastics: Bury in the ground, landfill	Nearly all types of plastics can be recycled, however the extent to which they are recycled depends upon technical, economic and logistic factors. As a valuable and finite resource, the optimum recovery route for most plastic items at the 'end-of-life' is to be recycled, preferably back into a product that can then be recycled again and again and so on. The UK uses over 5 million tonnes of plastic each year of which an estimated 24% is currently being recovered or recycled. **Recycling:** Turning waste into a new substance or product. Includes composting if it meets quality protocols. • Provides a sustainable source of raw materials to industry • Greatly reduces the environmental impact of plastic-rich products which give off harmful pollutants in manufacture and when incinerated • Minimises the amount of plastic being sent to the landfill sites • Avoids the consumption of the Earth's oil stocks • Consumes less energy than producing new, virgin polymers • Encourages a sustainable lifestyle among children and young-adults **Bioplastics:** To reduce the problems of disposing of plastics they can be designed to be biodegradable, known as bioplastics. These are plastics derived from renewable sources, such as vegetable fats and oils, corn starch, pea starch or microbiota. Production of oil based plastics tends to require more fossil fuels and to produce more greenhouse gases than the production of biobased polymers (bioplastics). Some, but not all, bioplastics are designed to biodegrade. Biodegradable bioplastics can break down in either anaerobic or aerobic environments, depending on how they are manufactured. Bioplastics can be composed of starches, cellulose, biopolymers, and a variety of other materials.

4.2e Textiles

The continuing evolution of the textiles industry provides a wide spread of applications from high performance technical textiles to the more traditional clothing market. More recent developments in this industry require designers to combine traditional textile science and new technologies leading to exciting applications in smart textiles, sportswear, aerospace and other potential areas.

Raw materials for textiles

Fibres can be classified as being from a natural or synthetic source. A fibre is an elongated hair like strand or continuous filament. The length exceeds more than 200 times the diameter.

-Wool, linen and cotton are short fibres. silk is a long continuous filament fibre.
-Fibres can be twisted using the spinning process and converted into yarn or fibres can be used in their raw form and manufactured to create felt.
-Consider absorbency, strength, elasticity and the effect of temperature

- manufactured from fibres, the origin can be subdivided into two section
    - **natural** (organic)
        - either a plant or animal origin
        - ex. cotton, linen, wool and silk
    - **synthetic** (man-made)
        - created by chemical processes
        - polymer-based from oil and coal, others are from glass, metal ceramic and carbon.

Properties of **natural fibres**

Properties of wool, cotton and silk and Design contexts in which different types of textiles are used

- originates from plants, animals and minerals
- are usually short fibres (staple fibres)
- can absorb moisture (ex. sweat from skin) therefore fabrics are 'breathable.
- flammable, easy to dye, poor resilience, good conductor of electricity
- sources include cotton, wool, linen and silk

Fibres from Plants

- Cotton: Can be cool or warm to wear as fibres trap air, reducing convective heat loss. It is durable, creases easily, absorbent, dries slowly
- Linen: stiffer handle, dries quickly, durable, very absorbent

Fibres from Animals

- Wool: absorbent, dries slowly, warm to wear, not durable
- Silk: absorbent, durable, warm to wear, soft handle

Examples of **natural fibres**

Natural Fibre	Origin	End uses
Wool ANIMAL	Sheep fleece, goat, alpaca, camels	GOOD INSULATOR TRAPS AIR: sweaters, blankets, socks, coats, tailored suits etc
Cotton VEGETABLE	Cotton boll plant	HIGH ABSORBENCY: nightwear, summer clothes, shirts, underwear, jeans, bedsheets, socks, towels, etc
Silk ANIMAL	Silk cocoon.	HIGH LUSTRE: evening dresses, nightwear, ties, cushions, wedding dresses etc

<table>
<tr><td>Properties of synthetic fibres</td><td>

man made fibres (usually from chemical resources)
fibres produced are long and much smoother
most are thermoplastic and will soften and contract when exposed to heat.
have low affinity for moisture creating less ‘breathable’ fabrics.
sources include viscose, acrylic, nylon and polyester

</td></tr>
<tr><td>Examples of synthetic fibres</td><td>
<table>
<tr><th>Synthetic Fibre</th><th>End uses</th></tr>
<tr><td>Nylon</td><td>Rope, fishing filament, seatbelts, parachutes, luggage, conveyor belts, outerwear, tents.</td></tr>
<tr><td>Polyester (Dacron)</td><td>Outerwear, combined with other fibres to improve crease resistance, sportswear, hoses, sails, auto upholstery, carpets.</td></tr>
<tr><td>Lycra (Spandex)</td><td>Sportswear, combined with other fibres to improve stretch, disposable diaper, underwear.</td></tr>
</table>
</td></tr>
<tr><td>Conversion of fibres to yarns</td><td>

in the beginning, the strands are a tangle of loose fibres.
natural fibres, except silk, will be in different lengths to symbolise the maturity of growth.
natural fibres also require cleaning and refining, and some mixing in order to homogenise the batch
the fibres are then slightly twisted and thinned out in order to produce sufficient strength for handling
wrapping fibres around each other increases strength
the process is repeated, while lengthening the yarn.
the yarn that is formed is called a ‘single’ (single strand of yarn)

</td></tr>
<tr><td>Conversion of yarns into fabrics: weaving, knitting, lacemaking, and felting</td><td>
Weaving: undertaken on a machine called a loom with two distinct styles of thread which are interlaced together to form a fabric: warp and weft. Warp threads run lengthways on a piece of cloth and the weft runs across from side to side.

there are different kinds and ways to produce a weave; for example a thwill weave is by alternately passing under two and over one,
a smooth satin finish is achieved.

Knitting: process of forming fabrics by looping a single thread (by hand with slender wires or a machine provided with hooked needles)

made by making knots, however the destruction of one loop threatens the destruction of the entire web, unless the meshes are reunited (because of the interlocking nature of the yarn in knitted fabrics)
advantages include: fabric can stretch, low stress on the yarn, large number of stitch types are available

Lacemaking: lace-work is a stitched fabric patterned with holes, and is now commonly made from cotton.

it is made by hand with a needle (called needlepoint lace). by bobbins (along with a pins, pillow or a cushion, hence called ‘pillow lace’) or by a machine and is created by looping, plaiting one thread with another, without any backing material.
synthetic threads are often used for machine-manufactured lace and because of their high strength to weight circumstances, detailed and complex patterns are produced.

Felting: felt is made from animal fibres (sheep’s wool, rabbit fur), however today it can be made from man-made fibres (viscose)

felt-making process is dependent on the kinks in the fibres and the irregularities in the surface (to see if the fibres are able to interlock together) good wools, scales are perfect and numerous, while in inferior ones there are fewer serrations

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	(jagged edges) and are less perfect in structure - (from wool) progressively depositing layers of cleaned and combed fibers into a large tray, each 90 degrees from each other. - hot soapy water assists with lubrication and reduces friction and so the fibres can move and because entangles in the scales on the fibre surface. - they then bond to form a cloth. - (alternative) needle felting involves combining fibres using special felting needles.
Recovery and disposal of textiles	Many items of clothing are manufactured and produced in developing countries. Often working conditions that many people experience who do a repetitive, low skilled job. Other **ethical issues** connected to the production and manufacture of textiles are linked to environmental issues, chemical dyes, washing, finishes, use of pesticides to grow the crops and land usage for growing the crops and grazing for the animals. Development of new textiles and other related technologies needs to consider the sustainability issues such as recycling and disposal. • Wastage from textiles may be categorized as either pre- or post - consumer. Pre-consumer textile waste is mostly formed of materials that are generated as by-products of production processes. Post-consumer waste mentions to clothing or household textiles that is reused or recycled instead of being disposed. • Recycling involves the reprocessing of used materials (clothing, fabric scraps, etc) and waste from the manufacturing process. • Once all of the materials are collected, cleaned and sorted, recyclable textile may be processed; first mechanically where the fibres are separated before being re-spinned into yarn or chemically through repolymerizing fibres. to again spin into yarn. • With waste reduction, reuse and recycling results in: Lowering purchase prices, reducing use of virgin materials, reducing disposal costs and landfill, generating less air and water pollution, keeping materials out of the waste stream and preserving the 'embodied energy' used in manufacturing.

4.2f Composites

Composites are an important material in an intensely competitive global market. New materials and technologies are being produced frequently for the design and rapid manufacture of high-quality composite products. Composites are replacing more traditional materials as they can be created with properties specifically designed for the intended application. Carbon fibre has played an important part in weight reduction for vehicles and aircraft.

Form: fibres/sheet/particles and matrix

Composite materials (also called **composition materials** or shortened to **composites**) are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials. One material acts as the matrix, which can be in the form of fibres, sheets or particles with the other as the bonding agent.

Advantages	Disadvantages
• high strength-to-weight ratio • high tensile strength • weave of the cloth can be chosen to maximise strength and stiffness of final component • can be woven in different patterns to create aesthetically pleasing surface patterns	• very expensive • requires specialist manufacturing facilities • weak when compressed, squashed, or subject to a high shock or impact • small air bubbles or imperfections of the matrix will cause weak spots and reduce the overall strength

Fibres/sheets/particles: textiles, glass, plastics and carbon

- Laminar

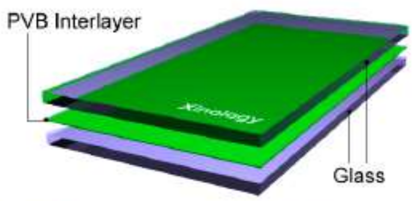
Consists of two or more layers of material bonded together usually with an adhesive to form a new composite material with improved properties
The most commonly recognized laminar material is plywood

Plywood

- → Manufactured from an uneven number of plys
- → Application where high quality, high strength, large sheet material is required
- → It is resistant to cracking, breaking, shrinkage, twisting and warping
- → Can be used as an engineering material for architecture or lightweight stressed skin applications (marine and aviation environments)

Laminated Glass

- → Consists of a sandwich of two layers of glass and a polymer interlayer of Polyvinyl butyral (PVB) joined under heat and pressure in a furnace called an autoclave



- → When broken the PVB interlayer hold the pieces of glass together (safer) avoiding the release of otherwise dangerous shards of glass
- → The fracture produces a pattern of radial and concentric cracks (spider-web mattern)
- → used for car windscreens

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Laminar composites

- ➔ Laminates of different material joined together in a sandwich structure
- ➔ Consists of layer of thin or bidirectional fibres or metal sheet held apart by a lightweight core (foam or honey-comb style structure)
- Fibre-reinforced
- Particle reinforced

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<td>Process: weaving, moulding, pultrusion and lamination</td>
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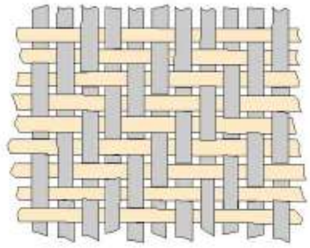
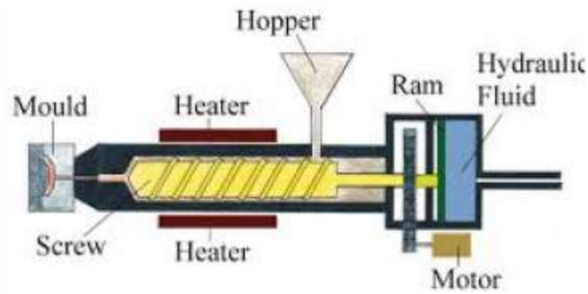
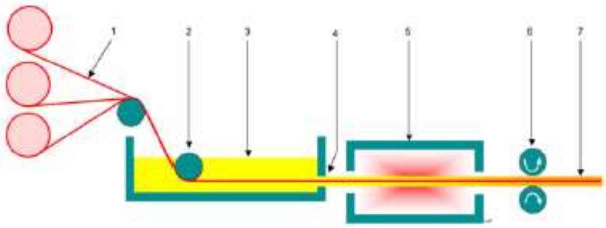
Weaving: to form (fabric or a fabric item) by interlacing long threads passing in one direction with others at a right angle to them.



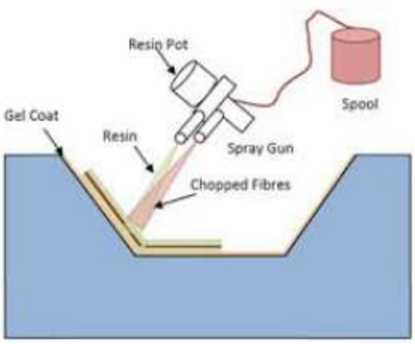


Moulding
Similar to injection moulding, using mix of materials. Or put under high pressure

Pultrusion is a continuous molding process whereby reinforcing fibers are saturated with a liquid polymer resin and then carefully formed and pulled through a heated die to form a part.



Lamination
One of the early materials that was used as part of a lamination process was called Formica. Formica originally consisted of layers of fabric bound together with resin; later, it was made with thick pieces of paper laminated with melamine. This tougher substance could resist heat and abrasion, while the paper opened up a wealth of possibilities for printing colours and patterns, which proved key to its success.



Spray-up
Spray-up is carried out on an open mould, where both the resin and reinforcements are sprayed directly onto the mould. The resin and glass may be applied separately or simultaneously "chopped" in a combined stream from a chopper gun. Workers roll out the spray-up to compact the laminate. Wood, foam or other core material may then be added, and a secondary spray-up layer embeds the core between the laminates (sandwich construction). The part is then cured, cooled and removed from the reusable mould.

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Composition and structure of composites	Matrix: thermoplastics, thermosetting plastics, ceramics, metals
Design contexts in this composite materials is used **Types and how used**	

Concrete: Sand, concrete, aggregate and water are mixed together, they form a fluid mass that is easily molded into shape. Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone-like material with many uses	Construction (reinforced with Steel) to make strong
Engineered wood: is made by binding or fixing strands, particles of fibres, veneers of boards of wood together with adhesives or other fixing methods to create composite materials.	-Medium Density Fibreboard -Particle or chipboard -Plywood -LVL- laminated veneered timer -I joists or I beams
Plywood: is a sheet material manufactured from thin layers or "plies" of wood veneer that are glued together with adjacent layers having their wood grain rotated up to 90 degrees to one another.	It may be used for wall panelling, flooring and furniture.
Particleboard : also known as particleboard and chipboard, is an engineered wood product manufactured from wood chips,sawmill shavings, or even sawdust, and a synthetic resin or other suitable binder, which is pressed and extruded. Oriented strand board, also known as flakeboard, waferboard, or chipboard, is similar but uses machined wood flakes offering more strength.	
Kevlar is a composite material similar to Carbon Fibre and is woven into a cloth which combined with Polyester resin can be moulded into a variety of complex shapes. It can also be woven into fabric cloth to protect the wearer almost like an indestructible net. Kevlar also has a high strength-to-weight ration and is five times stronger than steel.	Kevlar is used in a variety of applications because of its unique properties, including: -body protection, such as bullet-proof vests Military helmet where lightweight properties, comfort and flexibility are important -sports equipment, such as skis, helmets and racquets, where lightweight properties and strength are important -sails for windsurfing, where the material has to withstand high speeds
Carbon reinforced plastic (GRP) is a composite material made from plastic and fine fibres of glass. It is also known as Fibreglass.The strands are combined with resin (polyester or epoxy resin) to make GRP. Fibreglass and resin on their own are weak but when combined create a good strength-to-weight ratio material. It is very versatile and can easily be moulded into 3D shapes.	• Boat hulls • Canoes • Car body panels • Chemical storage tanks • Train canopies
Laminated veneer lumber (LVL) is an engineered wood product that uses multiple layers of thin wood assembled with adhesives. It is typically used for headers, beams, rimboard, and edge-forming material.	

Advantages and disadvantages of composite materials	**Advantages** They are much stronger than the original material used. Laminated glass for example is much tougher, and shatters less -Corrosion and Chemical Resistance Composites are highly resistant to chemicals and will never rust or corrode -High cost of fabrication of composites is a critical issue **Disadvantages** They can not be recycled. Most composites are thermosetting and so it is hard to separate and recycle

4.3 Scales of Production

The scale of production depends on the number of products required. Decisions on scale of production are influenced by the volume or quantities required, types of materials used to make the products and the type of product being manufactured. There are also considerations of staffing, resources and finance.

Scales of Production	**Description of why you would selecting an appropriate scale of production**	**Advantages**	**Disadvantages**
One-off	One - off production is where only one for a few specialist items are required. If a prototype is made then it usually part of the realisation of the product and so the next step after testing would be batch or volume production.	• Unique, high quality products are made • Workers are often motivated and take pride in their work	• Very labour intensive, so selling prices are usually higher • Production can take a long time and can be expensive as specialist tools are required • Economies of scale are not possible, often resulting in a more expensive product
Batch production	Limited volume production (a set number of items to be produced	• Since larger numbers are made, unit costs are lower • Offers the customer some variety and choice • Materials can be bought in bulk, so they are cheaper	• Workers are often less motivated because the work can be repetitive • Goods have to be stored until they are sold, which can be expensive
Mass	The production of large amounts of standardized products on production lines, permitting very high rates of production per worker.	• Labour Costs are usually lower/minimal • Materials can be purchased in large quantities so they are cheaper/provide excellent bargaining power • Large numbers of goods are produced	• Machinery is very expensive to buy and set up for production lines • Workers are not motivated • Not very flexible as a production line is difficult to adapt • Production process will have to stop when repairs are made
or **Continuous flow**	A production method used to manufacture, produce or process materials without interruption.		
Mass customization	A sophisticated CIM system that manufactures products to individual customer orders. The benefits of economy of scale are gained whether the order is for a single item or for thousands.	Mass customisation uses some of the techniques of mass production; for example, its output is based on a small number of platforms, core components that underlie the product. In the case of a watch, the internal mechanism is a platform to which can be added a wide variety of personalised options at later stages of production.	

4.4 Manufacturing processes

Different manufacturing processes have been developed to innovate existing products and create new products. Designers sometimes engineer products in such away that they are easy to manufacture. Design for manufacture (DfM) exists in almost all engineering disciplines, but differs greatly depending on the manufacturing technologies used. This practice not only focuses on the design of a product's components, but also on quality control and assurance.

Process	Manufacturing techniques
Additive techniques	**Paper-based rapid prototyping** (Layers of paper cut and glued together to create a 3D shape) **Laminated object manufacture (LOM)** (Layers of material cut and glued together to create a 3D shape) **Stereolithography** (Solidification of powder using 3D printing)
Wasting/ subtractive techniques To **remove** material by **cutting**, **machining**, **turning** or **abrading**.	**Cutting** (Laser, Saws, Chiseling, Drilling) **Machining** (Router or Milling machine) **Turning** (Metal or Wood Lathe) **Abrading** (Sanding, Filing, Grinding)
Shaping techniques To **change the shape** of the material without wasting	**Moulding** (Injection moulding, extrusion) **Thermoforming** (Heating plastics and vacuum forming, or using a strip heater to heat and bend acrylic) **Laminating** (Flexi-plywood by gluing layers together over a former/shaped mould) **Casting** (Sand casting, Die casting- usually solid to liquid then cooled **Knitting** (textiles) **Weaving** (textiles)
Joining techniques	**Permanent**- e.g. Welding, Brazing, Soldering, Pop riveting, **Temporary** (non-permanent fastening) Fastening or joining materials mechanically through the use of screws, rivets, bolts, pins, clips, nails, press studs and snaps. The advantage of this technique is the ease for disassembly at the expense of permanent damage to the materials used eg. installing screws **Adhering- Gluing** once formed, cannot easily be separated **Fusing (welding)** Permanent process involving the heating of the surfaces such as metals and plastics. This process isn't recommended when considering design for disassembly.

4.5 Production systems

The development of increasingly sophisticated production systems is transforming the way products are made. As a business grows in size and produces more units of output, then it will aim to experience falling average costs of production—economies of scale. The business is becoming more efficient in its use of inputs to produce a given level of output. Designers should incorporate internal and external economies of scale when considering different production methods and systems for manufacture.

Type	Description/Impact of different production systems on the workforce and environment	Advantages	Disadvantage
Craft production	This type of production makes a single, unique, product from start to finish. Labor intensive, highly skilled It is a small-scale production process centred on manual skills. eg. building ships, bridges, handmade crafts (furniture), tailored clothing	Locally based, allowing clients to converse directly with manufacture	This type of production is frequently slow May be required to have a variety of skills High cost.
Mechanized production	Volume production process involving machines controlled by humans.	Less labor intensive	
Automated production	Automated Production is the fasted way of mass producing goods and services. It is a volume production process involving machines controlled by computers. Pro's and con's of Automation include: -**Making complex decisions:** Automated systems can make decisions that are beyond the capacity of people to make. -**Speed of decision making.** Automated systems also can make decisions more quickly than people can. -**Routine, boring jobs.** Many people find repetitive, simple jobs, such as working on a factory assembly line, dull and degrading. They have difficulty maintaining the level of		
Assembly line production	Assembly line production is a volume production process where products and components are moved continuously along a conveyor. As the product goes from one workstation to another, components are added until the final product is assembled.		
Mass production	Mass production is the production of large amounts of standardized products on production lines, permitting very high rates of production per worker.		
Mass customization	Mass customization is a sophisticated CIM system that manufactures products to individual customer orders. The benefits of economy of scale are gained whether the order is for a single item or thousands.		
Computer numerical control (CNC)	CNC refers to the computer control of machines for the purpose of manufacturing complex parts in metals and other materials. Machines are controlled by a programme commonly called a "G code". Each code is assigned to a particular operation or process. The codes control X, Y and Z movement and feed speeds.		
Production system selection criteria	This is dependent on what type of production method that is selected for a product. Production system selection criteria include time, labour, skills and training, health and safety, cost, type of product, maintenance, impact on the environment and quality management E.g. Might be better to Injection mould a product case from 3 parts rather than 1 part as it might be easier and quicker to do final assembly.		

<table>
<tr><td rowspan="5">Design for manufacture (DfM)</td><td>Design for manufacture (DfM) means designers design specifically for optimum use of existing manufacturing capability. Designers need to consider designing products so they can be easily and efficiently manufactured with minimal impact on the environment. Design for Manufacture can be a constraint on the design brief. Design for Manufacture involves Design for Process, Design for Materials and Design for Assembly/Disassembly.
There are four aspects of DfM.</td></tr>
<tr><td>Design for materials: designing in relation to materials during processing.
The selection of materials is an important consideration for a designer. It can affect environmental at each stage of the Product Cycle, from pre-production to disposal. For example, the choice of a thermoplastic may mean an impact on the environment through the extraction of oil, however thermoplastics are highly recyclable meaning less of an impact at the disposal stage, providing they are recycled and not sent to landfill or incinerated. Minimising the amount of materials and using non-toxic or biodegradable alternatives can also reduce the impact on the environment.</td></tr>
<tr><td>Design for process: designing to enable the product to be manufactured using a specific manufacturing process, for example, injection moulding .
When designing or redesigning products, designers should consider how the manufacture of parts and components can be achieved efficiently and with minimal waste. For example injection moulding is an extremely energy efficient process with minimal waste produced.</td></tr>
<tr><td>Design for assembly: designing taking account of assembly at various levels, for example, component to component, components into sub-assemblies and sub-assemblies into complete products</td></tr>
<tr><td>Design for disassembly: designing a product so that when it becomes obsolete it can easily and economically be taken apart, the components reused or repaired, and the materials repurposed or recycle.
By minimising components, assembly can be made to be quicker and more efficient. In addition, using standard components can decrease manufacturing time. More and more designers are considering how their designs can be disassembled. This means that different materials can be separated for recycling or to make repair or reconditioning easier resulting in less products being sent to landfill.</td></tr>
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4.6 Robots in automated production

The development of increasingly sophisticated robotic manufacturing systems is transforming the way products are made. Designers should consider the benefits of increased efficiency and consistency when using robots in production and be able to explore the latest advances in technology to ensure the optimum manufacturing process is used. However, a good designer will also understand their responsibility to consider the moral and ethical issues surrounding increased use of automation, and the historical impact of lost jobs.

Primary characteristics of robots	A robot is defined as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications. The introduction of robots to an assembly line has had a major impact on the labour force, often making skilled workers redundant in favour of a technician who can maintain and equip a large number of robots.	
Work envelope	The 3D space a robot can operate within, considering **clearance** and **reach.** These distances are determined by the length of a robot's arm and the design of its axes. Each axis contributes its own range of motion. A robot can only perform within the confines of this work envelope. Still, many of the robots are designed with considerable flexibility. Some have the ability to reach behind themselves. Gantry robots defy traditional constraints of work envelopes. They move along track systems to create large work spaces.	
Load Capacity	Within this context, the weight a robot can manipulate	
	Advantages of using robotic systems in production	**Disadvantages of using robotic systems in production**
Single-task robots	-Reduces chance of error -Learnability for the operator	-Expensive relative to the outcome -Long process as little can be done with only single task robots
Multi-task robots	-Manufacture is sped up, more efficiency and -Inputs and outputs can be varied	-Increased chance of error
Teams of robots	-Increased efficiency and versatility -Need to hold parts in place while performing other tasks e.g. welding -Production line processes – require teams of robots to perform different tasks at different stages. Robots exhibit varying degrees of autonomy (ability to work independently, without human input. Some robots are programmed to faithfully carry out specific actions over and over again (repetitive actions) without variation and with a high degree of accuracy. These actions are determined by programmed routines that specify the direction, acceleration, velocity, deceleration and distance of a series of coordinated motions.	Other robots are much more flexible as to the orientation of the object on which they are operating or even the task that has to be performed on the object itself, which the robot may even need to identify. For example, for more precise guidance, robots often contain machine vision sub-systems acting as their "eyes", linked to powerful computers or controllers. Artificial intelligence or what passes for it, is becoming an increasingly important factor in the modern industrial robot.
Machine to machine (M2M)	(M2M) refers to wired and wireless communication between similar devices. In product restocking, for example, a vending machine can message the distributor when a particular item is running low. M2M communication is an important aspect of warehouse management, remote control, robotics, traffic control, logistic services, supply chain management, fleet management and telemedicine. It forms the basis for a concept known as the Internet of Things (IoT).	

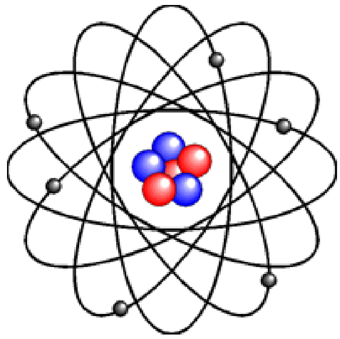
	Key components of an M2M system include sensors, a Wi-Fi or cellular communications link and autonomic computing software programmed to help a networked device interpret data and make decisions
First generation robots	First-generation robots are a simple mechanical arm that has the ability to make precise motions at high speed. They need **constant supervision by a human operator**. The operation of these machines must be constantly supervised, because if they get out of alignment and are allowed to keep working, the result can be a series of bad production units.
Second generation robots	Second-generation robots are equipped with sensors that can provide information about their surroundings. They can synchronize with each other and do not require constant supervision by a human; however, they are controlled by an external control unit. Second-generation robots can stay synchronized with each other, without having to be overseen constantly by a human operator. Of course, periodic checking is needed with any machine, because things can always go wrong; the more complex the system, the more ways it can malfunction.
Third generation robots	Third-generation robots are autonomous and can operate largely without supervision from a human. They have their own central control unit. Swarms of smaller autonomous robots also fit in this category. There are some situations in which autonomous robots do not perform efficiently. In these cases, a fleet of simple insect robots, all under the control of one central computer, can be used. These machines work like ants in an anthill, or like bees in a hive. While the individual machines lack artificial intelligence (AI), the group as a whole is intelligent.

END OF REVISION NOTES

Teacher Summary Notes and Q&A

4.1 Introducing and classifying materials

4.1.1 Define atom, molecule, alloy and composite.



An atom is the smallest part into which an element can be chemically divided. All atoms have the same basic structure but they vary in size and mass. Each atom has a positively charged nucleus at its centre containing positively charged protons and neutrons which together make up 99% of the atom. Electrons orbit around the nucleus. The number of electrons defines what element the atom is. For example, hydrogen has one electron and oxygen has eight.

When two or more atoms join together, they form a molecule. Hydrogen and oxygen combine to make water. Water is a compound because it is made up from two elements which are joined.

When two or more materials are combined, one of which is a metal, an alloy is formed. The properties of each element are still present in the alloy. For example, solder is an alloy of lead and tin.

Composites are made by bonding two or more materials. It is possible to make many composites with enhanced properties. For example, a milk carton is a composite of card and polyethylene. The card makes the carton rigid and the polyethylene makes it waterproof.

4.1.2 Describe a bond as a force of attraction between atoms.

Consider and differentiate between the three main types of bond: ionic, covalent and metallic.

Ionic Bonds: Ionic bonds occur between a metal and a non metal. All atoms strive for a full outer shell of electrons. Metals have an empty outer shell but a full shell beneath it while non metals have a few electrons on their outer shell. The metal becomes positively charged as it gives its extra electrons to the non-metal, which leaves them negatively charged. Opposite charges attract and so the atoms stay connected through electrostatic forces. The ionic bonds are fragile; small bumps can cause alterations in the position of the ions causing two like charges which then causes them to repel. When ions dissociate (separate), whether in a solvent such as water or through melting, they can conduct electricity.

Covalent Bonds: Covalent bonds are formed between two non-metals. It is characterized by the sharing of electrons between atoms. These bonds are the strongest type of bonds because the outer electron shell of two or more atoms overlap and create a completely new shell around both of them. There are two types of covalent bonds: molecular and network. A molecular bond, such as water, creates molecules that are weakly bonded to each other. They are usually in the gaseous or liquid state at room temperature. Network covalent bonds, such as diamond, can make crystals of virtually any size. Diamonds are known to be the toughest element. They are usually hard because of the strength between covalent bonds.

Metallic bonds: Metallic bonds are formed between metals. In a metallic bond, the valence electrons from each atom form a 'sea' of electrons that works as glue to keep the metals together. The sea of valence electrons gives the metals two important properties, the first being malleability: metals are malleable because the lattice ions are still attracted to the electrons even after being moved. The second property is conductivity. The electrons have enough freedom to move, which is exactly what electricity is. The electrons' freedom also means that they can start vibrating easily (and so can the lattice ions because they have quite a bit of freedom too) and that makes them good heat conductors because temperature is a measure of the average kinetic energy of the substance.

4.1.3 Describe how materials are classified into groups according to similarities in their microstructures and properties.

The microstructure of a material is its structure when perceived through a microscope. Materials are classified depending on their crystal structure, their size, composition, orientation, formation and interaction. Materials will be classified in terms of their physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high / low temperature behaviour, durability, etc… In the case of metals, the microstructures must be viewed with a microscope. Each polygon, usually hexagons, represents a single crystal of zinc. Metals are classified by their microstructures and properties (ex. this is why steel is different from iron).

4.1.4 Explain that several classifications are recognised but that no single classification is "perfect".

It is convenient to be able to classify materials into categories (albeit crude in nature) that have characteristic combinations of properties.

4.1.5 Describe that, for this course, materials are classified into groups: timber, metals, plastics, ceramics, food and composites; and that some of these groups have subdivisions.

In each group there can be subdivisions, for example, for timber (natural wood and man-made), metals (ferrous and non-ferrous), plastics (thermoplastics, thermosets), ceramics (earthenware, porcelain, stoneware, glass), textile fibres (natural or synthetic), food (vegetable or animal origin) and composites (difficult to classify due to variability and continual development of new composite materials). Food is included here for completeness, although it is dealt with in detail as an option.

4.2 Properties of materials

4.2.1 Define density, electrical resistivity, thermal conductivity, thermal expansion and hardness.

Density: The mass per unit volume of a material.

Electrical resistivity: This is a measure of a material's ability to conduct electricity.

Thermal conductivity: A measure of how fast heat is conducted through a slab of material with a given temperature difference across the slab.

Thermal expansion (expansivity): A measure of the degree of increase in dimensions when an object is heated. This can be measured by an increase in length, area or volume. The

expansivity can be measured as the fractional increase in dimension per kelvin increase in temperature.

Hardness: The resistance a material offers to penetration or scratching.

4.2.2 Explain a design context where each of the properties in 4.2.1 is an important consideration.

Density is important in relation to product weight and size (for example, for portability). Prepackaged food is sold by weight or volume, and a particular consistency is required. Electrical resistivity is particularly important in selecting materials as conductors or insulators. Thermal conductivity is important for objects that will be heated or must conduct or insulate against heat. Thermal expansion (expansivity) is important where two dissimilar materials are joined. These may then experience large temperature changes while staying joined. Hardness is important where resistance to penetration or scratching is required. Ceramic floor tiles are extremely hard and resistant to scratching.

4.2.3 Define tensile strength, stiffness, toughness and ductility.

Tensile strength: The ability of a material to withstand pulling forces.

Stiffness: The resistance of an elastic body to deflection by an applied force.

Toughness: The ability of a material to resist the propagation of cracks.

Ductility: The ability of a material to be drawn or extruded into a wire or other extended shape.

4.2.4 Explain a design context where each of the properties in 4.2.3 is an important consideration.

Tensile strength is important in selecting materials for ropes and cables, for example, for an elevator. Stiffness is important when maintaining shape is crucial to performance, for example, an aircraft wing. Toughness is important where abrasion and cutting may take place. Ductility is important when metals are extruded (not to be confused with malleability, the ability to be shaped plastically).

4.2.5 Outline the characteristics of taste, smell, appearance, texture and colour.

Taste: the sensation that results when taste buds in the tongue and throat convey information about the chemical composition of a soluble stimulus.

Smell: the ability to perceive odours such as sweet, acrid or fragrant.

Texture: it is how something feels or looks, it can be rough or smooth.

Colour: can be warm (eg browns) or cool (eg blues) can have psychological affects (eg greens are claming).

Appearance: the design of appearance in a product must be aesthetically pleasing to attract a customer, unless it is for a certain market.

(Student Task: Investigate the subject area of the Tensile Strength. Prepare a short paragraph detailing the main points and then as a class group discuss your findings.)

4.2.6 Explain a design context where each of the characteristics in 4.2.5 is an important consideration.

Some of these properties are only relevant to food, while others can be applied to more than one material group. Although these properties activate people's senses, responses to them vary from one individual to another, and they are difficult to quantify scientifically, unlike the other properties.

4.3 Timber

4.3.1 Describe the structure of natural timber.

Natural timber is a natural composite material comprising cellulose fibres in a lignin matrix. The tensile strength of timber is greater along the grain (fibre) than across the grain (matrix).

Wood is a fibrous material. The structure of wood similar to a bunch of parallel straws (the cellulose fibres), which are bonded together with a glue (lignin matrix). The fibres are long and slender and are aligned with the long axis of the trunk which gives it an interesting property behaviour.

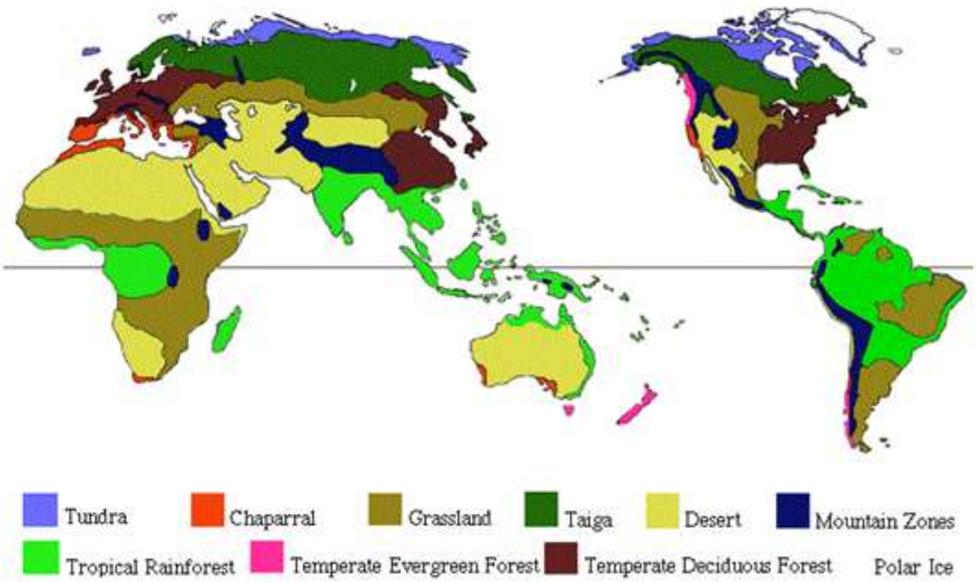
When load is applied parallel to the axis of the fibres, they are very strong in tension and have reasonably good compressive strength until they start to buckle.

When the load is applied perpendicular to the axis of the fibres, they will tend to crush under compression and are weakest in tension, where the "glue" bond fails and the straws literally tear apart.

4.3.2 Outline that timber can be classified according to the conditions needed for tree growth.

Consider temperate and tropical conditions. (A general knowledge of the geographical distribution of world timber resources is required)

Study the distribution of forest map of the world below. Temperate forests tend top be in cooler regions and tropical tends to be between the Tropic of Cancer and Capricorn. Visit the Missouri **botanical garden** website.



4.3.3 Outline that conifer trees are referred to as softwoods and that these grow only in temperate regions.

Recognise the characteristics of softwood trees.

Characteristics of softwood trees are:

- Softwood trees have several characteristics that make them different from hardwood trees.
- The wood from these trees is generally softer. (That's where the name comes from.)
- Softwoods reproduce* by cones.
- Softwoods have needles.
- They do not lose their needles in the fall. They are sometimes called evergreens because the needles are green year round.
- Examples included are pine, cedar, and cypress.

(Student Task: Investigate the subject area of Softwoods. Prepare a short paragraph detailing the main points and then as a class group discuss your findings.)

4.3.4 Outline that deciduous trees are referred to as hardwoods and that these grow in both temperate and tropical regions.

Recognise the characteristics of hardwood trees.

Characteristics of hardwood trees are:

- Hardwood trees have several characteristics that make them different from softwood trees.
- The wood from these trees is generally harder. (That's where the name comes from.)
- Hardwoods reproduce* by flowers.
- Hardwoods have broad leaves.
- Many lose their leaves every autumn and are dormant* in the winter.

Some examples of hardwood trees include: eucalyptus, elm, maple, oak, and beech.

4.3.5 Discuss the issues relating to the consideration of timber as a renewable resource.

Consider time to reach maturity, soil erosion, greenhouse effect and extinction of species. The issues should be placed in local, national and international contexts.

- time to reach maturity, e.g. Mahogany trees takes about 100 years to mature
- soil erosion ... the roots of the tree hold the soil in
- greenhouse effect ... less trees to remove the greenhouse gases
- extinction of species ... destroying animal, insect and plant life

4.3.6 List two examples of composite timbers.

Consider particle board (chipboard) and plywood.

4.3.7 Compare the characteristics of particle board, laminated woods (for example, plywood), pine wood (a softwood) and mahogany (a hardwood).

Consider composition, hardness, tensile strength, resistance to damp environments, longevity and the aesthetic properties of grain, colour and texture. The ability to produce sketches showing cross-sectional views of the structure of the materials is expected.

4.3.8 Outline criteria for the selection of timber for different structural and aesthetic design contexts.

Consider timber for buildings, furniture and children's toys.

Buildings - often the timber rafters, studs, beams are hidden from view so there is no need for wonderful looking hardwoods but rough sawn pine is fine. If within a house there is flooring then aesthetics plays a role and a hardwood would be selected.

Furniture and children's toys need to withstand some amount of wear and therefore need to be durable. In furniture aesthetics plays an important role as well. In toys the wood may be painted or stained.

4.3.9 Describe the reasons for treating or finishing wood.

Consider reducing attack by organisms and chemicals, enhancing aesthetic properties and modifying other properties.

4.3.10 Explain three differences in the selection of timbers for flooring if it were made of a hardwood, softwood or a composite material.

Consider durability, ease of maintenance and aesthetics.

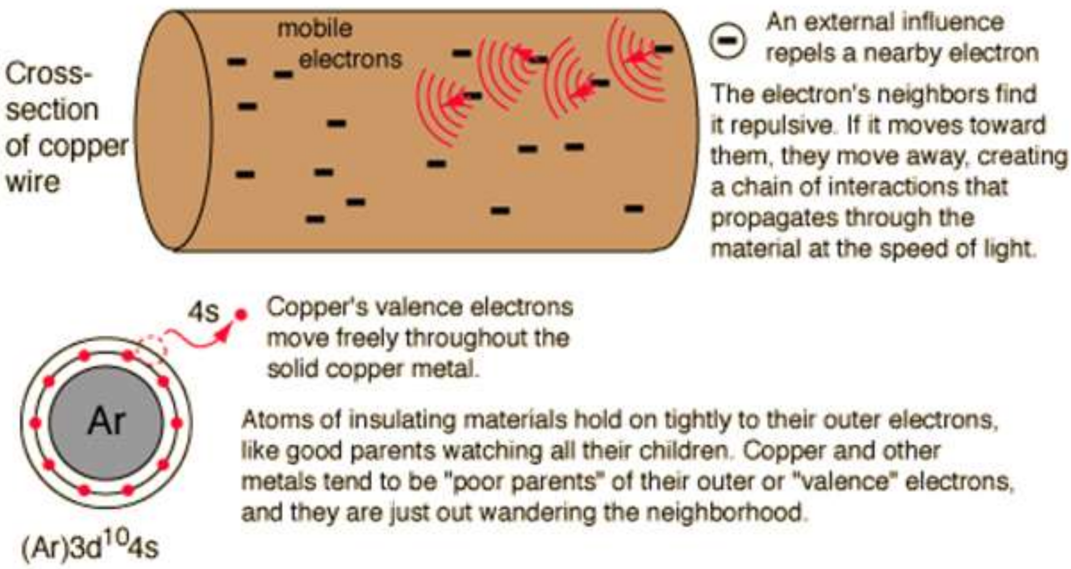
Hardwood	Softwood	Composite (flooring) material	
Durability	Very suitable in high traffic areas like kitchens due to its higher hardness	Not suitable in high traffic areas like kitchens due to its lower hardness. May need a special plastic finish to improve hardness.	Highly durable
Ease of maintenance	When finished very easy to clean. Will need to have a finished reapplied over time.	When finished very easy to clean. Will need to have a finished reapplied over time.	Very easy to clean.
Aesthetics	Usually darker colours.	Usually pines are white or yellowy in colour. People like the feeling of warmth it gives.	Colour and features can be designed in, may have a cool feeling to it

4.4 Metals

4.4.1 Draw and describe a metallic bond.

Metals are often described as positively charged nuclei in a sea of electrons. The outer electrons of the metal atom nuclei are free and can flow through the crystalline structure. The bonding is caused by attraction between the positively charged metallic atom nuclei and the negatively charged cloud of free electrons. Specific arrangements of metal atoms are not required.

4.4.2 Explain how the movement of free electrons makes metals very good electrical and thermal conductors.



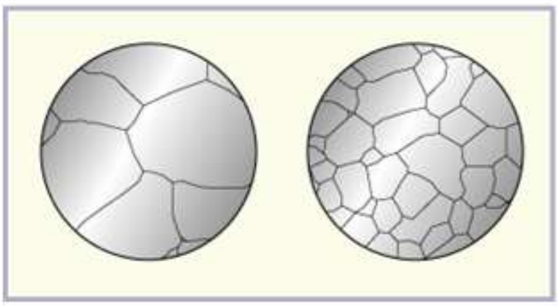
4.4.3 State that metals (pure or alloyed) exist as crystals.

Crystals are regular arrangements of particles (atoms, ions or molecules). (Details of types of crystals are not required)

****(Student Task: Investigate the subject area of Atoms. Prepare a short paragraph detailing the main points and then as a class group discuss your findings.)****

4.4.4 Draw and describe what is meant by grain size.

In metallurgy this refers to any of the small randomly distributed crystals of varying sizes that compose a solid metal. The grains contact each other at surfaces called grain boundaries. The structure and size of the grains determine important physical properties of the solid metal.



Forming modifies the grains of a metal ingot to improve the mechanical properties in the direction of grain length. Internal stresses at grain boundaries may be relieved by annealing to restore ductility in certain alloys or to harden other alloys.

4.4.5 Explain how grain size can be controlled and modified by the rate of cooling of the molten metal, or by heat treatment after solidification.

Reheating a solid metal or alloy allows material to diffuse between neighbouring grains and the grain structure to change. Slow cooling allows larger grains to form; rapid cooling produces smaller grains. Directional properties in the structure may be achieved by selectively cooling one area of the solid.

The rate of cooling and the amount of impurities in the molten metal will affect grain size:

1. Gradual cooling - a few nuclei are formed - large grain size

2. Rapid cooling - many nuclei formed - small grain size.

3. Reheating a solid metal / alloy allows the grain structure to re-align itself.

4. Directional cooling in a structure is achieved by selectively cooling one area of a solid.

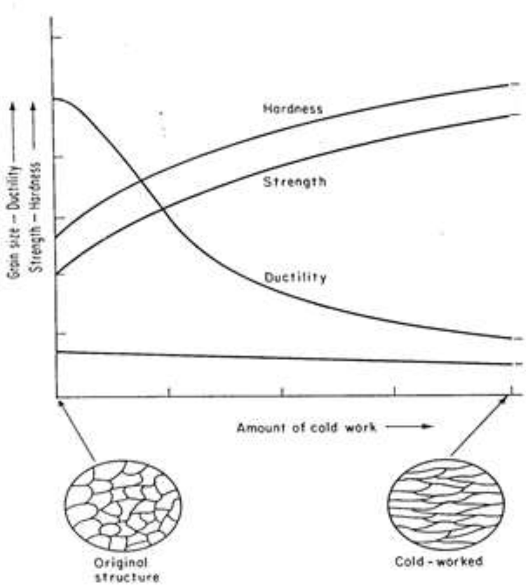
5. The effect of impurities (or additives) in a molten metal can induce a large number of fine grains that will give a stronger and harder metal. This addition must be carefully controlled as too many impurities may cause an accumulation at the grain boundaries, which will weaken the material.

4.4.6 Define plastic deformation.

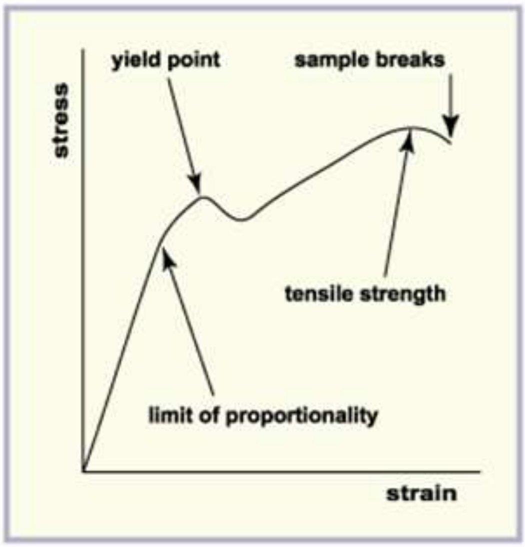
The permanent deformation of a solid subjected to a stress.

4.4.7 Explain how metals work-harden after being plastically deformed.

Beyond the yield stress metals and alloys harden when plastically deformed.



Effect of cold working



Properties Vs Hardening

4.4.8 Describe how the tensile strength of a metal is increased by alloying.

The increased strength and hardness, and reduced malleability and ductility, of alloys compared to pure metals is due to the presence of "foreign" atoms which interfere with the movements of atoms in the crystals during plastic deformation (see above diagram on plastic deformation).

Examples of Alloys: An alloy is a metal compound produced by combining a metal with one or more other elements to change its properties:

Change the melting point , Increase strength, hardness & ductility , Change colour (e.g. brass from copper), Give rise to better casting, Change electrical and thermal properties

4.4.9 Explain the effect of alloying on malleability and ductility.

The presence of "foreign" atoms in the crystalline structure of the metal interferes with the movement of atoms in the structure during plastic deformation.

Iron and carbon: Iron is soft and ductile in its pure state; carbon is brittle. The addition of carbon to iron gives three different grades of steel:

Low (> 0.3%) medium (0.3 - 0.6%) high (0.6 - 1.7%) carbon steels.

When the carbon content is below 0.2% steel remains ductile and malleable. As the level of carbon increases so does hardness but ductility & malleability decrease. This change is due to the introduction of impurities (carbon atoms).

4.4.10 Describe a superalloy.

The strength of most metals decreases as the temperature is increased. Superalloys are metallic alloys that can be used at high temperatures, often in excess of 0.7 of their absolute melting temperature.

"When forces are applied to a metal, its deformation, whether plastic or elastic, usually takes place very rapidly, and then no further deformation takes place however long the force continues to act. This is not true, though, at temperatures greater than about half of the melting point (in Kelvin) of the metal.

At these higher temperatures, a metal continues to deform slowly whilst the stress on it is maintained – a process called creep. In machine parts which are stressed at high temperatures, such as turbine blades, creep is a very serious problem. Soft metals such as lead will creep at room temperature, so creep is a problem in lead pipes and white metal bearings. Creep may occur under static tension, compression, shear, torsion and bending loads."

A superalloy is an alloy that is designed to be used at high temperatures that can resist creep and oxidisation. Superalloys are based on iron, cobalt or nickel. Nickel based superalloys are particularly suitable for use in aircraft engines and other applications that require high performance at high temperatures.

4.4.11 List two design criteria for superalloys.

Consider creep and oxidation resistance.

- Creep is the tendency of a metal (or material) to slowly move or deform permanently due to the long term exposure of stress that are below the yield strength or ultimate strength of the metal. Creep is more severe when metals are subjected to near the melting point heat for long periods of time. (Wikipeadia 2007)
- Oxidation is the interaction between oxygen and different substances when they make contact, such as rust Fe_2O_3
- Oxidation resistance is the ability of a material to resist the direct and indirect attack of oxygen (oxidation).

4.4.12 Identify applications for superalloys.

Superalloys can be based on iron, cobalt or nickel. Nickel-based superalloys are particularly resistant to temperature and are appropriate materials for use in aircraft engines and other applications that require high performance at high temperatures, for example, rocket engines, chemical plants.

Superalloys are used where there is a need for high temperature strength and corrosion/oxidation resistance.

Other uses of superalloys are: aircraft and industrial gas turbines, space vehicles, submarines, nuclear reactors, military electric motors and heat exchanger tubing.

4.5 Plastics

4.5.1 Describe a covalent bond.

In a covalent bond the outer electrons of some atoms come close enough to overlap and are shared between the nuclei, forming a covalent bond. Each pair of electrons is called a covalent bond. Mention of sigma (σ), pi (π), double or triple bonds is not required. Covalent bonds are strong bonds and examples of primary bonds (as are metallic and ionic bonds).

Plastics are made up of long chains of molecules called 'macromolecules'. The 'links' in the chains are covalent bonds. They are strong and are also known as primary bonds. However, each chain is linked to the next with only weak bonds known as secondary bonds. When heat is applied to a thermoplastic, these secondary bonds become weaker, allowing the plastic to be formed (bent and moulded). The chains become more flexible but the strong primary bonds keep each chain firmly linked together. This is one of the reasons why plastics are such useful materials: They can be formed into complex shapes without weakening their tensile strength.

There are a few other general reasons why plastic is such a useful material:

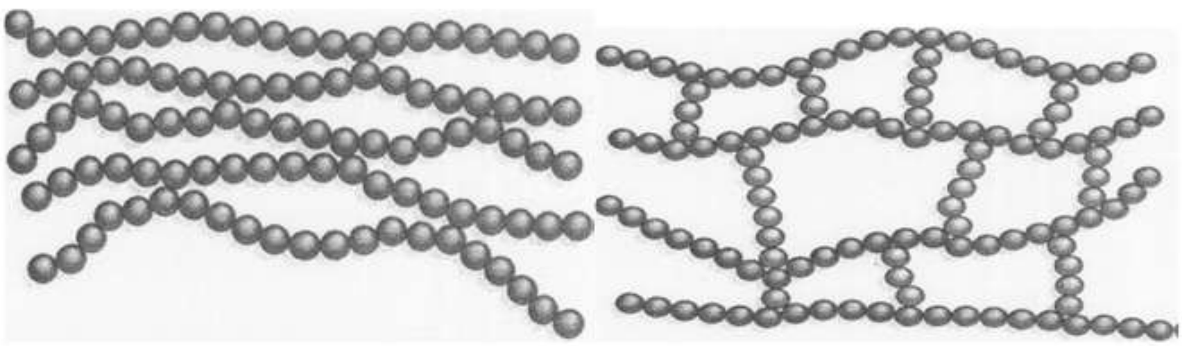
1. Its density is similar to water so we can develop plastics that float and sink.
2. It is water resistant and inorganic so it doesn't biodegrade. This makes it very durable.
3. It can be coloured.

Remember though that these points are general. Some plastics are organic and do biodegrade. Durability can become an environmental problem if plastics aren't disposed of responsibly. Bear this in mind when you discuss the benefits and drawbacks of the plastics group of materials.

There are two main types of plastic: Thermoplastics and Thermosets.

The difference between them is that thermoplastics can be softened when heated and solidified when cooled. This can be repeated indefinitely provided the plastic is not overheated.

Thermosets actually harden when heated. They begin as a liquid plastic or putty. When it is heated, it becomes solid. It cannot be softened again. This is because the secondary links between the chains are primary bonds (very strong) so the chains cannot flex.



Left hand diagram above – thermoplastic macromolecules

Right hand diagram above – thermoset macromolecules with strong primary between between the chains.

Plastic deformation occurs when a force permanently deforms a material even after the force is removed. If you bend a paper clip a little, it will spring back to its original position. However, if you bend it too far (beyond its elastic limit) it stays bent. This is plastic deformation. It also hardens as it is being 'worked'. A material which can undergo plastic deformation in all directions is said to be malleable e.g. lead.

Symbol	Acronym	Full name and uses
1	PET	Polyethylene terephthalate - Fizzy drink bottles and frozen ready meal packages.
2	HDPE	High-density polyethylene - Milk and washing-up liquid bottles
3	PVC	Polyvinyl chloride - Food trays, cling film, bottles for squash, mineral water and shampoo.
4	LDPE	Low density polyethylene - Carrier bags and bin liners.
5	PP	Polypropylene - Margarine tubs, microwave-able meal trays.
6	PS	Polystyrene - Yoghurt pots, foam meat or fish trays, hamburger boxes and egg cartons, vending cups, plastic cutlery, protective packaging for electronic goods and toys.
7	Other	Any other plastics that do not fall into any of the above categories. For example melamine, often used in plastic plates and cups.

Like all materials, plastic has elastic properties. It can be stretched and it will return to its original dimensions. If it is stretched beyond its elastic limit, plastic deformation occurs and the plastic's structure will be permanently changed.
It is important to remember this when designing a plastic product that will be under tension (a stretching force). The force should not take the plastic beyond its elastic limit.

Load (stretching force). If this is within the elastic limit, the secondary bonds can return to their original position.

Load (stretching force). If this is beyond the elastic limit, the secondary bonds weaken and the chains slide between each other, weakening the plastic. It can not return to its original position.

Some plastics also suffer from creep in the same way as metals. It is an important consideration in the design of plastic products that operate at relatively high temperatures and where large forces are exerted.

Summary:

Thermoplastics can be heated, softened cooled and hardened in a continuous cycle.

This is not the same for thermosetting plastics.

This is why thermoplastics are easy to recycle. However, this is only possible if you know what type of plastic it is. More about this later.

Thermosets do not soften when heated. This makes them useful for applications where heat resistance is important. i.e. saucepan handles, kitchen work tops and electrical fittings like plugs, sockets and light housings.

4.5.2 Describe secondary bonds as weak forces of attraction between molecules.

Hydrogen is positively charged and the Oxygen (one side) is negatively charged.

****(Student Task: Investigate the subject area of Molecules. Prepare a short paragraph detailing the main points and then as a class group discuss your findings.)****

4.5.3 Describe the structure and bonding of a thermoplastic.

Thermoplastics are linear chain molecules, sometimes with side bonding of the molecules but with weak secondary bonds between the chains.

4.5.4 Describe the effect of load on a thermoplastic with reference to orientation of the polymer chains.

Deformation occurs in two ways:
• elastic, in which initially coiled chains are stretched and the material returns to its original size and shape when the load is removed.
• plastic, when at higher loads the secondary bonds between the chains weaken and allow the molecular chains to slide over each other, and the material does not return to its original size and shape when the load is removed. Creep and flow are important. No quantitative details are required.

4.5.5 Explain the reversible effect of temperature on a thermoplastic, with reference to orientation of the polymer chains.

Increase in temperature causes plastic deformation:

- The weak secondary bonds
- That can easily broken by heat
- Thus the long chains can slide over each other.
- When plastically deformed and cooled at the same time new secondary bonds are made.

4.5.6 Explain how the reversible effect of temperature on a thermoplastic contributes to the ease of recycling of thermoplastics.

- The Increase in temperature causes the weak secondary bonds to break (The heat is sufficient enough to break the secondary bonds but not the primary, covalent, bonds)
- allows the long molecular chains to slide over each other, i.e. be reshaped into a new product.
- when a plastically deformed and allowed to cool it will remain in the new shape
- due to new secondary bonds being formed

4.5.7 Draw and describe the structure and bonding of a thermoset.

Thermoplastics are linear chain molecules but with strong primary bonds between adjacent polymer chains. This gives thermosets a rigid 3D structure.

4.5.8 Explain the non-reversible effect of temperature on a thermoset.

Heating increases the number of permanent crosslinks and so hardens the plastic.

4.5.9 Discuss the properties and uses of polypropene and polyethene thermoplastic materials.

Polypropene: Properties: is resistant to fatigue, durable, higher melting point than other thermoplastics (160 Celsius), high impact strength or toughness, high tensile strength, low density, corrosion resistant, retains stiffness at very high temperatures, can be easily coloured

Uses: in carpeting, ropes, dishwasher safe housewares, plastic containers that have hinges, bumpers on cars

Polyethene (Polyethylene) - Properties: high hardness, high stiffness, strong, corrosion resistant, high transparency and colourless. Uses: footwear, houseware, insulation, luggage.

4.5.10 Discuss the properties and uses of polyurethane and urea---formaldehyde (methanal) thermoset materials.

Polyurethane - Properties: "Polyurethanes can be manufactured in an extremely wide range of grades, in densities from 6kg/m3 to 1220kg/m3 and polymer stiffnesses from very flexible elastomers to rigid, hard plastics." from Huntsman.com

4.5.11 Discuss the issues associated with the disposal of plastics, for example, polyvinyl chloride (PVC).

Although PVC disposal is problematic, PVC is still widely used as a structural material, for example, in windows and for guttering and drainpipes.

4.6 Ceramics

4.6.1 Describe the composition of glass.

Glass is composed primarily of silicon dioxide together with some sodium oxide and calcium oxide and small quantities of a few other chemicals.

4.6.2 Explain that glass is produced from sand, limestone and sodium carbonate, and requires large quantities of energy for its manufacture.

Scrap glass is added to new raw materials to make the process more economical.

Glass is produced from all these elements and needs a lot of energy. This is because the in order to produce glass the first thing is to melt all elements, this takes a tremendous amount of energy due to the very high melting points of the materials.

Glass furnace temperatures reach up to 1675°C adding scrap glass leads to savings not only in the raw materials, but also in the energy consumption of the glass furnace.

4.6.3 Describe the characteristics of glass.

Consider brittleness, transparency, hardness, unreactivity and aesthetic properties.

Glass is a ceramic that is very hard on the surface, though brittle on the side. It is usually highly transparent, does not conduct electricity and is therefore an electrically insulating material. Since Its transparency, glass absorbs light, partly reflecting it at the surface. Glass however does not transmit neither ultra-violet nor infra-red radiation. It is a material that can easily be coloured.

4.6.4 Explain that the desired characteristics of glass can be accurately determined by altering its composition.

Consider soda glass and Pyrex®.

Soda glass is made of oxides of silicon (SiO2), calcium (CaO) and sodium(Na2O). It is the most common type of glass which is used for windowpanes, glass containers for beverages and food.

- Colour altering chemical compounds can be added that change the colour of the soda glass

Soda glass has a medium resistance to high temperatures and sudden changes of temperature (low thermal shock) and a high resistance to corrosive chemicals. To improve the low thermal shock one can alter the chemical composition which to make Pyrex.

- Pyrex is made of soda-lime glass and(with 60–80% SiO_2, 10–25% B_2O_3, 2–10% Na_2O and 1–4% Al_2O_3) are added. Pyrex is a brand name and company manufacturing kitchen glassware.

NB: For IB no need to know the chemical compounds just FYI

4.6.5 Outline the differences between toughened and laminated glass.

Consider their responses to being deflected and to impact.

The desired characteristics of glass can also be altered in way to produce toughened *and* laminated glass which respond differently when being deflected and to impact.

Laminated Glass

Is layers of glass and plastic sheet. When impacted the glass fragments are held in place. This prevents cracks from growing it can even be made bullet proof eg windscreens or bank teller windows

Toughened Glass

Is heated up to the point of melting, blasted with cold air, when it is impacted shatters into little pieces rather than sharp shards, eg. windscreens of cars. In toughened glass, the applied tensile load must overcome the compressive stress at the surface before the surface can go into tension and fail.

4.6.6 Explain why glass is increasingly used as a structural material.

Consider the use of plate glass and glass bricks as wall and flooring materials. Consider material properties, for example, resistance to tensile and compressive forces, thermal conductivity and transparency. Consider aesthetic properties and psychological benefits: allows natural light into buildings and can visually link spaces, creating more interesting interiors.

Plate glass, glass bricks and flooring are used as a structural material due to the:

- Aesthetic properties. Glass is can a transparent or translucent material, allowing light to pass through, thus allowing users to see in or out. It will also allow light to it can fill dark areas of building or office. Natural lighting has positive affects on people and well as health reasons. In flooring can add appeal by having lights shine through (dance floors) or over things of interest (aquariums).
- Thermal Conductivity. Glass can insulate a building thus keeping it cool/warm which in turn be a benefit to the environment (reduced energy consumption) and owner(reduced energy costs).
- Hardness Compressive strength. Resists scratching and indentation of peoples' shoes or chairs etc. Easily maintained as well since it is non-reactive.

4.7 Composites

4.7.1 Describe composites.

Composites are a combination of two or more materials that are bonded together to improve their mechanical, physical, chemical or electrical properties.

Very often two or more materials are combined to obtain different properties than those available in the original substances.

Concrete, plywood and fibreglass and these are known as composite materials.

Composites are usually formed to increase strength-to-weight ratio, ductility, temperature and shock resistance.

A metal-ceramic composite of cemented carbide is used to make cutting tools that are shock resistant, hard enough to maintain their cutting edge and will continue to produce a quality finish when they become very hot.

Composites can be any combination of metal, ceramic and polymer, be in particle, fibre or laminated form.

Concrete is a mixture of cement and gravel and is a particle composite of two ceramics.

'GRP' or glass fibre reinforced polyester is a ceramic reinforced polymer composite. The polyester resin polymer is brittle with low strength but when fibres of glass are embedded in the polymer it becomes strong, tough, resilient and flexible enough to use for building boat hulls, car bodies, roofing and furniture.

Steel reinforced concrete is a ceramic-metal fibre reinforced composite that provides enhanced properties suitable for constructional purposes.

Plywood with layers of wood and adhesives is a laminar composite of two polymers whereas chipboard is a particle composite of the same materials.

Specific examples of composite materials:

Wood or timber:

A natural fibre-reinforced polymer that has been used for many centuries.

All timbers are essentially composed of a large number of close packed tubular filaments of cellulose bonded together with an organic resin, lignin.

Weight for weight, wood can be as strong as steel but steel is about fourteen times as dense.

Cellulose, the main structural element of all plants, is contained in the xylem cells end gives trees their strength and stiffness.

Cellulose is a long chain condensation polymer of ring-shaped glucose (sugar) molecules with its axis parallel to the direction of the fibre and hence the tree trunk.

Cellulose fibres in a lignin matrix— the tensile strength is greater along the grain (fibre) than across the grain (matrix).

The cellulose molecule is about 30% crystalline and about 70% amorphous and it is the amorphous section that can absorb water.

Softwoods and hardwoods have a similar structure but the main difference is the thickness of the tubular cell walls. This results in differing densities and mechanical properties for different types of wood.

Using a specific product example of your choice, explain how a composite material has properties that are different to raw materials. Describe how these properties have been exploited to meet to the requirements of the product.

4.7.2 Define fibre.

A class of materials that are continuous filaments or are in discrete elongated pieces, similar to lengths of thread with a length to thickness ratio of at least 80.

4.7.3 Describe the matrix composition of composites.

It is where one material acts as a glue 'matrix' holding the other material in place, such as Glass reinforced fibre (fibreglass). This is where the glass fibres are held by a plastic such as resin. The resin is the 'Glue'.

4.7.4 Explain that new materials can be designed by enhancing the properties of traditional materials to develop new properties in the composite material.

It is possible to enhance the properties of a material by adding another material with the properties that are wanted, an example would be improving the toughness of concrete by adding steel rods. concrete is hard (high compressive strength) and weak in tension but steel is tough and has high tension but not too hard, therefore by adding steel to concrete, we get a hard and tough composite material that is ideal for building. Something important to consider when making composites is thermal expansivity as two materials with different rates of expansion would break each other.

4.7.5 Describe a smart material.

Smart materials have one or more properties that can be dramatically altered, for example, viscosity, volume, conductivity. The property that can be altered influences the application of the smart material.

Science and technology have made amazing developments in the design of electronics and machinery using standard materials, which do not have particularly special properties (i.e. steel, aluminium, gold). Imagine the range of possibilities, which exist for special materials that have properties scientists can manipulate. Some such materials have the ability to change shape or size simply by adding a little bit of heat, or to change from a liquid to a solid almost instantly when near a magnet; these materials are called smart materials.

(Student Task: Investigate the subject area of Smart Materials. Prepare a short paragraph detailing the main points and then as a class group discuss your findings.)

4.7.6 Identify a range of smart materials.

Smart materials include piezoelectric materials, magneto-rheostatic materials, electro-rheostatic materials, and shape memory alloys. Some everyday items are already incorporating smart materials (coffee pots, cars, the International Space Station, eye-glasses), and the number of applications for them is growing steadily.

4.7.7 Describe a piezoelectric material.

When a piezoelectric material is deformed, it gives off a small electrical discharge. When an electric current is passed through it, it increases in size (up to a 4% change in volume). They are widely used as sensors in different environments. Specific details of crystalline structure are not required.

The piezoelectric effect describes the relation between a mechanical stress and an electrical voltage in solids. It is reversible: an applied mechanical stress will generate a voltage and an applied voltage will change the shape of the solid by a small amount (up to a 4% change in volume). In physics, the piezoelectric effect can be described as the link between electrostatics and mechanics. The piezoelectric effect occurs only in non-conductive materials. Piezoelectric materials can be divided in 2 main groups: crystals and ceramics. The most well known piezoelectric material is quartz (SiO_2).

4.7.8 Outline one application of piezoelectric materials.

Piezoelectric materials can be used to measure the force of an impact, for example, in the airbag sensor on a car. The material senses the force of an impact on the car and sends an electric charge to activate the airbag.

Piezoelectric materials are also useful for guitar pickups, converting the vibrations on an acoustic guitar into an electric signal sent to an amplifier. Because they are only affected by vibration of the guitar, unwanted sounds do not affect the quality much. They can also be used for guitar tuners, also with the same advantage as piezoelectric pickups.

4.7.9 Describe electro-rheostatic and magneto-rheostatic materials.

Electro-rheostatic (ER) and magneto-rheostatic (MR) materials are fluids that can undergo dramatic changes in their viscosity. They can change from a thick fluid to a solid in a fraction of a second when exposed to a magnetic (for MR materials) or electric (for ER materials) field, and the effect is reversed when the field is removed.

Electro-rheostatic (ER) and magneto-rheostatic (MR) materials are fluids, which can experience a dramatic change in their viscosity. These fluids can change from a thick fluid (similar to motor oil) to nearly a solid substance within the span of a millisecond when exposed to a magnetic or electric field; the effect can be completely reversed just as quickly when the field is removed.

MR fluids experience a viscosity change when exposed to a magnetic field, while ER fluids experience similar changes in an electric field.

The composition of each type of smart fluid varies widely. The most common form of MR fluid consists of tiny iron particles suspended in oil, while ER fluids can be as simple as chocolate milk or cornstarch and oil.

4.7.10 Outline one application of electrorheostatic materials and one application of magneto-rheostatic materials.

MR fluids are being developed for use in car shock absorbers, damping washing machine vibration, prosthetic limbs, exercise equipment, and surface polishing of machine parts. ER fluids have mainly been developed for use in clutches and valves, as well as engine mounts designed to reduce noise and vibration in vehicles.

4.7.11 Describe shape memory alloys (SMAs).

SMAs are metals that exhibit pseudo-elasticity and shape memory effect due to rearrangement of the molecules in the material. Pseudo-elasticity occurs without a change in temperature. The load on the SMA causes molecular rearrangement, which reverses when the load is decreased and the material springs back to its original shape. The shape memory effect allows severe deformation of a material, which can then be returned to its original shape by heating it.

SMA's are metals with special properties that enable them to bend and deform, yet go back to their original shape when put in a medium with a certain pressure or "load" is put on the molecules. These composites have a shape memory, which enable them to go back to their initial shape very easily. SMA's are a remarkably new composite, and will open up new capabilities and opportunities for their use in anything ranging from fixable glasses to helping build an underwater hotel.

After a sample of SMA has been deformed from its original crystallographic configuration, it regains its original geometry by itself during heating (one-way effect) or, at higher ambient temperatures, simply during unloading (pseudo-elasticity or superelasticity).

These extraordinary properties are due to a temperature-dependent martensitic phase transformation from a low-symmetry to a highly symmetric crystallographic structure. Those crystal structures are known as martensite (at lower temperatures) and austenite (at higher temperatures). The three main types of SMA are the copper-zinc-aluminium-nickel, copper-aluminium-nickel, and nickel-titanium (NiTi) alloys. NiTi alloys are generally more expensive and possess superior mechanical properties when compared to copper-based SMAs.

Shape memory alloys (SMA's) are metals, which exhibit two very unique properties, pseudo-elasticity, and the shape memory effect. The most effective and widely used alloys include NiTi

(Nickel - Titanium), CuZnAl, and CuAlNi. In most shape memory alloys, a temperature change of only about 10°C is necessary to initiate this phase change.

4.7.12 Identify applications of SMAs.

Applications for pseudo-elasticity include eye-glasses frames, medical tools and antennas for mobile phones. One application of shape memory effect is for robotic limbs (hands, arms and legs). It is difficult to replicate even simple movements of the human body, for example, the gripping force required to handle different objects (eggs, pens, tools).

SMAs are strong and compact and can be used to create smooth lifelike movements. Computer control of timing and size of an electric current running through the SMA can control the movement of an artificial joint. Other design challenges for artificial joints include development of computer software to control artificial muscle systems, being able to create large enough movements and replicating the speed and accuracy of human reflexes.

Shape memory alloys can be applied in many different products and situation: Nokia has recently developed a technology that utilizes SMAs to make the process of recycling easier. Normally, when phones are reclaimed, it takes several minutes to take a phone apart to recycle its components. This tech would do it, hands-off, in two seconds, using heat. . The application of high heat (between 60-150C) causes the SMA to "actuate" and release the parts

One of the commercial uses of shape memory alloy involves using the pseudo-elastic properties of the metal during the high temperature (austenitic) phase.

- The frames of reading glasses have been made of shape memory alloy as they can undergo large deformations in their high temperature state and then instantly revert back to their original shape when the stress is removed.
- Another application is using SMAs to construct aircraft engines which reduces aircraft's engine noise greatly.
- SMAs have also been widely used in dental work, used most commonly in braces, in the case where they are broken or bent, thus temperature can be changed to send them back to their original shape.

END OF NOTES

Topic Questions & Exam Practice

Activities and Quizzes

E	D	F	B	V	A	Q	C	T	Q	Z	W	E	L	R
S	M	X	D	M	F	P	S	H	T	V	C	V	C	I
N	O	W	S	F	S	L	P	E	P	Y	A	Z	Z	G
O	T	P	U	L	H	Y	Q	R	M	E	T	A	L	S
R	A	J	P	G	R	T	S	M	A	Q	F	F	S	L
T	T	D	E	E	D	I	U	O	V	P	R	Z	E	P
C	E	W	R	F	J	L	O	P	O	L	R	R	T	S
E	P	H	A	T	R	I	U	L	W	A	F	J	I	C
L	H	E	L	B	U	T	D	A	P	S	U	E	S	I
E	D	V	L	X	O	C	I	S	X	T	O	R	O	M
E	P	S	O	W	X	U	C	T	P	I	W	B	P	A
C	Z	Z	Y	J	Q	D	E	I	V	C	N	I	M	R
X	F	V	S	C	E	M	D	C	X	S	W	F	O	E
H	R	C	A	R	E	B	M	I	T	Q	H	Q	C	C
L	I	D	O	T	V	Z	C	P	B	I	O	A	T	C

TIMBER
CERAMICS
THERMOPLASTIC
DECIDUOUS

METALS
COMPOSITES
SUPERALLOYS
DUCTILITY

PLASTICS
FIBRE
ELECTRONS
ATOM

Unscramble the words below:

1. EITBRM________________	13. LAERAMTSI________________
2. AMCRCEIS________________	14. TAMO________________
3. PMAEILTRSTOCH________________	15. TDYINSE________________
4. SUEDUIOCD________________	16. OUOLCR________________
5. LTSAME________________	17. EYRITSLNLCA________________
6. OTMESIPOCS________________	18. GASSL________________
7. SPSULAORELY________________	19. CPV________________
8. CDLITIYUT________________	20. YMOMRE________________
9. SLITACSP________________	21. IRETZEPCIOCLE________________
10. RIEBF________________	22. LYOAL________________
11. SOENCRLTE________________	23. LMCEEULO________________
12. OMAT________________	24. SFOTOOWD________________

Complete the missing word(s) from the text below. Each of these sentences has been taken from Topic 4 / Materials:

(1) Explain that new ______ can be designed by enhancing the properties of traditional materials to develop new properties in the ______ material.

(2) An ______ is the smallest part into which an element can be chemically divided. All atoms have the same basic structure but they vary in size and ______.

(3) Ionic ______ occur between a metal and a non metal. All atoms strive for a full outer shell of electrons.

(4) Thermal ______: A measure of how fast heat is conducted through a slab of material with a given temperature difference across the slab.

(5) ______ is important in relation to product weight and size (for example, for portability). Prepackaged food is sold by weight or volume, and a particular ______ is required.

(6) Colour: can be ______ (eg browns) or cool (eg blues) can have psychological affects (eg greens are ______).

(7) Wood is a ______ material. The structure of wood similar to a bunch of parallel straws (the cellulose fibres), which are bonded together with a glue (______ matrix).

(8) Metals are often described as ______ charged nuclei in a sea of electrons. The outer electrons of the metal atom nuclei are free and can flow through the ______ structure.

(9) An ______ is a metal compound produced by combining a metal with one or more other elements to change its properties.

(10) Soda ______ has a medium resistance to high temperatures and sudden changes of temperature (low thermal shock) and a high resistance to ______ chemicals.

(11) Glass can insulate a ______ thus keeping it cool/warm which in turn be a benefit to the environment.

(12) Although ______ disposal is problematic, PVC is still widely used as a structural material, for example, in windows and for ______ and drainpipes.

(13) ______ are linear chain molecules, sometimes with side bonding of the molecules but with weak secondary bonds between the ______.

(14) ______ materials can be used to measure the force of an impact, for example, in the airbag sensor on a car.

(15) ______ alloys (SMA's) are metals, which exhibit two very unique properties, pseudo-elasticity, and the shape ______ effect

Topic 4 Design Technology Terminology

(Add in the missing words at the start of each sentence)

______ When two or more materials are combined, one of which is an metal, an alloy is formed.

______ An atom is the smallest part into which an element can be chemically divided.

______ A mixture composed of two or more substances (materials) with one substance acting as the matrix or glue.

______ The mass per unit volume of a material.

______ This is a measure of a material's ability to conduct electricity.

______ A class of materials that are continuous filaments or are in discrete elongated pieces, similar to lengths of thread with a length to thickness ratio of at least 80.

______ The resistance a material offers to penetration or scratching.

______ When two or more atoms join together they form a molecule.

______ The permanent deformation of a solid subjected to a stress.

______ A measure of how fast heat is conducted through a slab of material with a given temperature difference across the slab.

______ (expansivity) A measure of the degree of increase in dimensions when an object is heated. This can be measured by an increase in length, area or volume. The expansivity can be measured as the fractional increase in dimension per kelvin increase in temperature.

______ Deciduous trees (meaning leaf losing) have broad leaves and covered seeds, often enclosed in fruits or nuts. Examples are: Beech, Elm, oak, Ash, mahogany, Meranti, Teak, Iroko, Walnut and Obeche

______ Coniferous (meaning cone bearing) trees are commonly classified as softwoods. Examples are: Scots pine, Western Red Cedar, Parana Pine and Spruce.

______ Examples are: Blockboard, Lamin Board, Veneered Plywood, Marine Plywood, Chipboard and Medium Density Fiberboard (MDF)

______ The chemical bonding that holds the atoms of a metal together. Metallic bonds are formed from the attraction between mobile electrons and fixed, positively charged metallic atoms. Whereas most chemical bonds are localized between specific neighboring atoms, metallic bonds extend over the entire molecular structure.

Is a process in which enough stress is placed on a metal or plastic to cause the object to change its size or shape in a way that is not reversible. In other words, the changes are permanent; even when the stress is removed, the material will not go back to its original shape.

or high-performance alloy, is an alloy that exhibits excellent mechanical strength and creep (tendency for solids to slowly move or deform under stress) resistance at high temperatures, good surface stability, and corrosion and oxidation resistance.

Is a form of chemical bonding that is characterized by the sharing of pairs of electrons between atoms. The stable balance of attractive and repulsive forces between atoms when they share electrons is known as covalent bonding.

Is a type of plastic made from polymer resins that becomes homogenized liquid when heated and hard when cooled. When frozen, however, a thermoplastic becomes glass-like and subject to fracture.

Thermoset, or thermosetting, plastics are synthetic materials that strengthen when heated, but cannot be successfully remolded or reheated after their initial heat-forming. Thermosetting plastics have a number of advantages. Unlike thermoplastics, they retain their strength and shape even when heated.

In comparison to conventional materials, smart materials are functional, that is, they are required to undergo purposeful and reversible changes, playing an active part in the way the structure or device works. Their degree of smartness is measured in terms of their "responsiveness" to environmental stimuli and their "agility". Responsiveness implies a large amplitude change while agility implies a fast response. Their classification is based on the relationship between the stimulus and response.

These are crystals which acquire a charge when compressed, twisted or distorted. Piezoelectric materials have two unique properties which are interrelated. When a piezoelectric material is deformed, it gives off a small but measurable electrical discharge. Alternately, when an electrical current is passed through a piezoelectric material it experiences a significant increase in size (up to a 4% change in volume).

End of Topic Questions

Advanced Manufacturing Techniques

Joining, Moulding, Casting and Forming /74

1 Describe Friction Welding

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2 Describe Plastic Welding

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3 Define Permanent Joining techniques

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4 How can permanent techniques lead to planned obsolescence and influence environmental issues?

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....4

5 Identify one suitable for each of the following;

I Timber..1
Ii Acrylic..1
Iii Thermoplastics...1

6 Explain how an Injection Moulded product is made.

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7 Outline the advantages of Injection Moulding.

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8 Describe Blow Moulding

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9 What is rotational moulding?

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10 Explain how a compression moulded product is made.

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11 Describe the process of vacuum forming.

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12 Describe the process of Lost wax casting.

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13 What is meant by High pressure Die casting?

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14 Outline 2 advantages and 2 disadvantages of High pressure Die Casting

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15 Describe the process of Spray-up

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16 What is Filament Winding

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17 Describe the process of Vacuum Bagging

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18 Outline the benefits of using vacuum Bagging

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19 What is LVL material?

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20 How have forming techniques enabled designers to be more flexible towards product design?

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DT – Materials 1

1 List the three classifications of Timber

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………3

2 What is do we mean by Grain in timber?

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……2

3 Identify the three Tropical hardwoods?

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………3

4 Identify 3 Temperate hardwoods

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………3

5 Name 3 Softwoods

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………3

6 Name the two classifications of metals

……

………2

7 Metals that contain Iron are called……………………………………………………………………………………………………1

8 Metals that don’t contain iron are called…………………………………………………………………………………………1

9 What is an Alloy?

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………1

10 What is the material that causes a metal to become harder?

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………

………1

11 Name 3 metals that contain iron

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………3

12 Name 3 metals that don't contain iron

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13 What are the main differences between a thermoset and a thermoplastic material?

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………2

14 Name 3 thermoplastic materials

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………3

15 Name 3 thermoset materials?

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………3

16 Why is a thermoset material used for the casing of an electrical plug?

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………

………3

DT Materials 2

1 Describe Work hardening

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……3

2 Describe Annealing

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……3

3 What causes metal to break through constant working/bending?

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………

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………

……3

4 Draw the grains that appear in metal – label your diagram

3

5 What are the main differences between a thermoset and a thermoplastic material?

………

……2

6 Draw a generic Stress/Strain graph. Clearly label all sections.

3

7 Draw a representation of a stress/strain graph of timber - label and explain your answer.

3

8 Strain is;

A Change in length over original length

B The force pressing down on a structure

C Deflection of material

D Work Hardening 1

9 Stress involves:

A Compressive forces

B Tensile Forces

C Turning forces

D Shear forces 1

DT Test 3 Materials/Wood/Metal /Plastics

1 Explain;
Tensile
Strength……
………
………
………
……3

Plasticity………
………
………
………
……3

Toughness……
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………
………
……3

Ductility
………
………
………
………
……3

2 Explain

Density……
………
………
………
……3

Electrical Resistivity
………
………
………
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……3

Thermal
Conductivity……
………
………

Thermal Expansion

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....3

Hardness..
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....3

3 Explain a design context where Plasticity is an important design consideration.

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....3

5. Raw timber needs to be seasoned to

A. cut it into useful sizes.
B. reduce the size.
C. reduce moisture content.
D. increase quality.

6. What is a characteristic of hardwood trees?

A. Needle like leaves
B. Fast growing
C. Grow only in temperate regions
D. Lose leaves in winter

7. Which statement is **not** true?

A. Carbon monoxide from carbon reduces iron oxide to iron metal in a blast furnace.

B. Calcium oxide from limestone removes the impurity silicon dioxide from iron in a Blast furnace

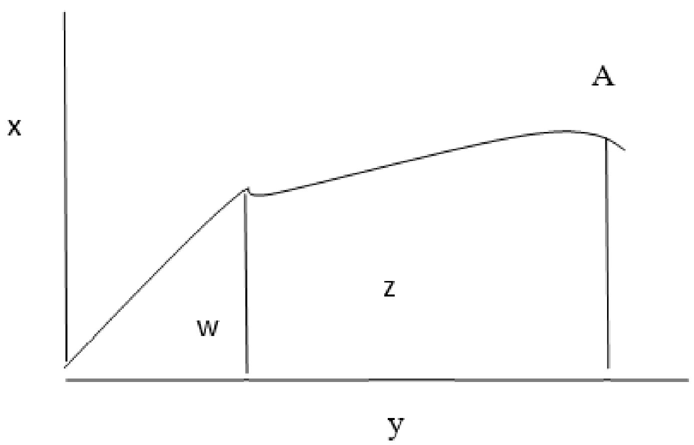
C. Wrought iron has a higher carbon content than pig iron.

D. The product of a blast furnace is an alloy called pig iron.

8. Which of the following are thermoplastics?

A. Acrylic
B. Polystyrene
C. Urea Formaldehyde
D. Melamine Formaldehyde

9. Name the parts labelled A, x, y, w, z of the graph below.



10. Selective cooling of metal allows

A. material to diffuse between neighbouring grains.
B. smaller grains to form.
C. directional properties to be developed in the metal.
D. larger grains to form.

11. Which statements are true?

I. Thermosets have strong secdondary bonds between adjacent polymer chains.

II. Thermosets cannot be reshaped repeatedly with heat.

III. Polyester is a thermoset.

A I and II only
B II and III only
C I and III only
D All 3

12 Which of the following is **NOT** a ferrous metal?

A Silver
B Mild Steel
C Aluminium
D Brass

13 Which of the following is a manufactured Board?

A Plywood
B Oak
C Spruce
D Mahogany

14 The most common treatment for mild steel used in car bodies is

A. anodizing.
B. painting.
C. plastic coating.
D. vitreous enamelling.

15 What is meant by the term Ergonomics

………
………
………
………
………
…………………………………… 3

16 State a context where the 5th-95th percentile range has been used

………
………
………
……………………………….3

17 What is meant by the term Anthropometrics

………
………
………
……
………
…………………………………….3

Multiple Choice Questions

(1)

In which design context is material density an important consideration?: **(1)**

A. Electrical insulation

B. Wooden toys

C. Winter clothing

D. Food Packaging

(2)

What material has very high electrical resistivity, very low thermal conductivity, very low thermal expansivity and is very hard?: **(1)**

A. Ceramic

B. Plastic

C. Textile

D. Food

(3)

What mechanical property of a material is its ability to resist the propagation of cracks?: **(1)**

A. Stiffness

B. Toughness

C. Hardness

D. Ductility

(4)

Which is a composite timber?: **(1)**

A. Plywood

B. Pine wood

C. Hardwood

D. Softwood

(5)

How is particleboard made more acceptable as a material for modular furniture?: **(1)**

I. Veneered
II. Untreated
III. Varnished or painted

A. I and II

B. II and III

C. I and III

D. I, II and III

Multiple Choice Questions

(6)

What material comprises 60-80% SiO_2, 10-25% B_2O_3, 8% Na_2O_2 and 3% $A1_2O_3$?: **(1)**

A. Toughened glass

B. Soda glass

C. Laminated glass

D. Borosilicate (pyrex) glass

(7)

What is an alloy?: **(1)**

A. A mixture that contains al least one metal

B. A substance made of two or more other substances that can be separated

C. A mixture of two or more substances

D. A substance formed by the combination of elements

(8)

What material has very low solubility in water, very low electrical resistivity, a wide hardness range and is very stiff?: **(1)**

A. Ceramic

B. Food

C. Metal

D. Textile

(9)

What are "weak forces of attraction between molecules"?: **(1)**

A. Ionic bonds

B. Metallic bonds

C. Covalent bonds

D. Secondary bonds

(10)

What is true of a thermoset?: **(1)**

A. Reversible effect of temperature

B. Strong primary bonding between adjacent chains

C. Weak secondary bonding between adjacent chains

D. Easily recyclable

Multiple Choice Questions

(11)

What defines plastic deformation?: **(1)**

A. The ability of plastics to be moulded

B. The ability of a material to resist deformation

C. The permanent deformation of a solid due to stress

D. The ability of a material to be drawn into a wire

(12)

The material used to manufacture steel suspension cables for a bridge should have: **(1)**

A. Hardness

B. Tensile strength

C. Stiffness

D. Toughness

(13)

Which material group has very low electrical resistivity and very high toughness?: **(1)**

A. Timber

B. Metals

C. Ceramics

D. Plastics

(14)

The ability of a material to resist penetration or scratching defines: **(1)**

A. Hardness

B. Stiffness

C. Density

D. Toughness

(15)

Which property is most likely to be evaluated using qualitative data?: **(1)**

A. Electrical resistivity

B. Hardness

C. Smell

D. Tensile strength

Multiple Choice Questions

(16)

Which material group usually has very high thermal conductivity, high density and very high toughness?: **(1)**

A. Metals

B. Timber

C. Ceramics

D. Plastics

(17)

Which property is difficult to quantify scientifically?: **(1)**

A. Tensile strength

B. Density

C. Aesthetics

D. Stiffness

(18)

Which material group is difficult to classify due to its variability and the continual development of new materials?: **(1)**

A. Timber

B. Metals

C. Composites

D. Food

(19)

In order to resist the propagation of cracks a material used to manufacture a tennis racquet should have high: **(1)**

A. Toughness

B. Hardness

C. Electrical resistivity

D. Stiffness

(20)

Which material group is subdivided into natural and composite?: **(1)**

A. Plastics

B. Food

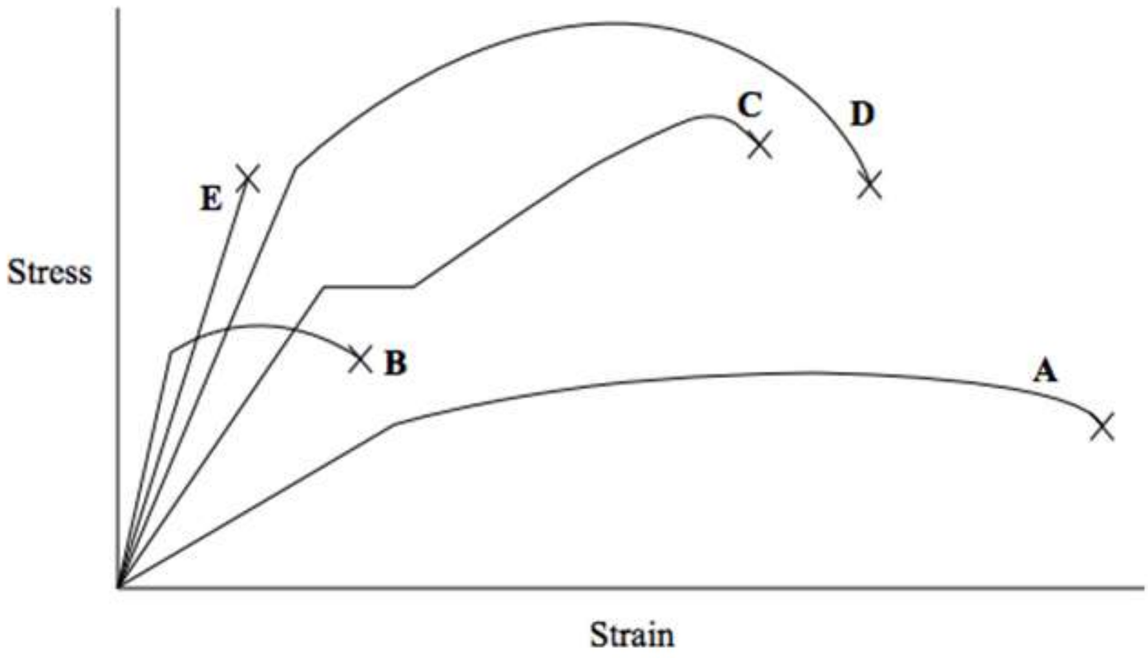
C. Metals

D. Timber

Exam Practice Questions

Figure 5 shows the stress/strain graph for five different materials A–E.

Figure 5: Stress/strain graph for five different materials A–E



[Source: © International Baccalaureate Organization 2014]

(a) Outline which material is the strongest. *[2]*

(b) Outline which material is the stiffest. *[2]*

(21)

Outline **one** reason why thermoplastics are suitable for vacuum forming. **(2)**

....

Answer: Award **[2]** for:
cost effective;
low melting point/easily moulded;

(22)

Figure 4 shows a hammock manufactured by the company Sedi. It has a hardwood frame and a bed made from woven cotton (canvas). The hammock is self-assembly and the canvas bed is easily detachable from the frame.

Figure 4: The Sedi Hammock

[Source: www.sedifurniture.com]

Outline one reason for the choice of hardwood for the frame of the hammock. **(2)**

....

Award **[2]** for one reason:
hardwood is a dense wood/has a close grain;
it will hold fittings more securely;

hardwood is a durable timber;
so promotes a longer product life;

aesthetics;
attractive grain pattern/texture;

(23)

The cardboard building for Westborough Primary School shown in **Figure 1** is Europe's first permanent cardboard structure, providing a much-needed educational space anticipated to last 20 years. The building is 15 metres long and 6 metres wide. Cardboard tubes support the roof. The roof and walls are made from 90 % recycled cardboard.

The card panels for the walls are made up of three 50 mm thick layers of honeycomb and one 15 mm solid card. This provides strength from the solid card, and insulation from the honeycomb. A finish is applied to the panels.

Figure 1: Westborough Primary School

[Source http://i.treehugger.com/files/cardboardschool.jpg]

Buildings often have a layer of material coating the outside of the building to protect it. **Table 1** shows the thermal conductivity ratios of various materials often used in buildings. The ratios relate to how quickly heat is conducted through each material.

Table 1: Thermal conductivity ratio of materials used in buildings

material	ratio
brick	1.5
cardboard	0.5
cement	1.7

Expressed in gram–calories/second/square centimeter/centimeter/°C

State **one** disadvantage of using cardboard as a building material. **(1)**

....

Answer: Award **[1]** per distinct point in a description along the lines of:
the honeycombing and solid panel cover;
trap the air and form a barrier;

Suggest **one** reason why cardboard has been used for the building even though it has a lower thermal conductivity rating than other materials. **(3)**

....

Award **[3 max]** for one reason.

cost;
- cheaper to buy than most construction materials;
- cheaper to manufacture;

ease of manufacture;
- can be formed into any shape;
- can be easily cut/joined;
- lightweight so easy to handle;

maintenance;
- easy to replace panels;
- easy to apply a finish;

(24)

Figure 2 and **Figure 3** show a table designed by Ingo Maurer. The table has 278 light emitting diodes (LED) which are connected by tiny transparent wires embedded between two sheets of toughened glass. The LEDs are energy efficient and extremely bright. Ingo Maurer has decided to produce a limited amount of LED tables.

Figure 2: Ingo Maurers' LED Table

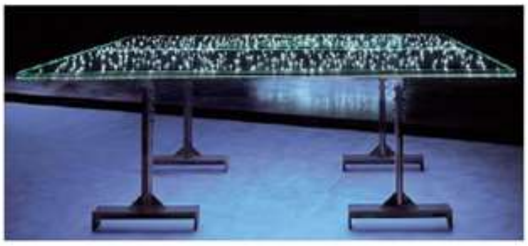


Figure 3: Close up of the LED table

[Source: http://www.inhabitat.com/2005/05/15/led-glass-table/]

Define composite. **(1)**

Answer: Award **[1]** for:
a mixture composed of two or more substances (materials) with one substance acting as the matrix or glue;

Outline **one** physical property of glass that makes it suitable for the Ingo Maurer table. **(2)**

Answer: Award **[2]** for:
hardness;
will not scratch easily;

Outline **one** reason why toughened glass was used for the Ingo Maurer tabletop. **(2)**

Answer: Award **[1]** for one reason and **[1]** for a point in a description.
safety;
the glass will not shatter;
strength;
improve impact strength;

Figure 6 shows two coffee tables designed by John Green in the "Embrace" range. The tables can be used individually or fitted together to form a multi-purpose coffee table and storage unit. The tables are manufactured from plywood with a choice of three different surface veneers.

Figure 6: Embrace coffee tables

[Source: www.ariashop.co.uk/1288/embrace-table-by-john-green

(a) (i) Describe the structure of plywood. *[2]*

(ii) Outline **one** physical property required for the surface finish of the Embrace coffee table. *[2]*

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(b) (i) Outline **one** reason for designing the coffee tables with a choice of surface finishes. *[2]*

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3. (a) State the type of materials which can change from a fluid to a solid in a fraction of a second when exposed to an electric field. *[1]*

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....

(b) Explain what is meant by *smart materials*. *[3]*

(c) (i) Outline the scale of production for the Embrace coffee tables. *[2]*

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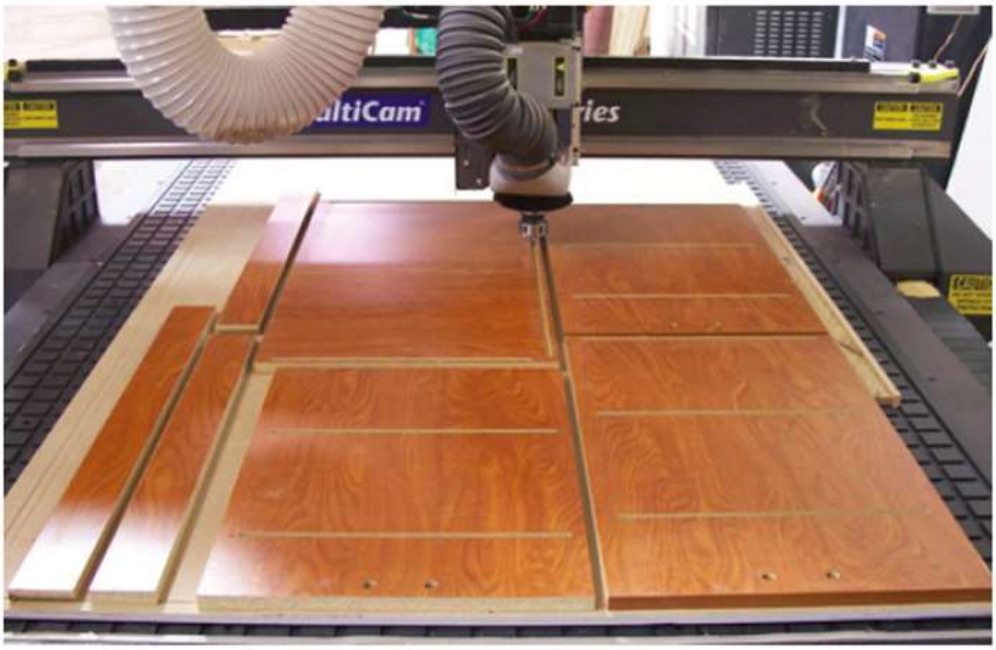
....

C4. **Figure C3** shows a CNC router being used in the manufacture of components for flat pack furniture.

Figure C3: CNC router used in manufacturing flat pack furniture



[Source: http://www.cncmillwork.com/img/CNC_machine_01.jpg]

Discuss **two** benefits for the manufacturer of using the CNC router to manufacture the flat pack furniture in Figure C3. *[6]*

C5. (a) Outline **one** way in which robots can be used in the assembly of cars. *[2]*

(b) Outline **one** reason why robots work in teams when assembling cars. *[2]*

(c) List **two** ways in which robots help to conserve resources. *[2]*

C6. **Figure C4** (a) – (c) shows three stages in the production of a white gold ring. Image (a) shows a CAD design of the ring. Image (b) shows a wax model of the ring. Image (c) shows the final ring.

Figure C4: White gold ring produced using ArtCAM

(a) (b) (c)

(b) Compare the process of CAD/CAM and craft production to make the ring in relation to value for money for the consumer. *[3]*

Figure 7 shows a treated steel wire table and stool. They were designed by Stephen Burks and are available in white, black or red. The furniture is craft produced by weaving the steel wire onto a rigid steel frame. The 90 cm diameter table is available for approximately US$550 and the stool for US$172.

Figure 7: Treated steel wire table and stool

Outline the technique used for joining the components of the steel frame. *[2]*

Outline the manufacturing technique used for creating metal wires. *[2]*

(ii) Discuss how the designer has taken into account the properties of tensile strength, stiffness and toughness in the design of this type of furniture. *[9]*

(i) Outline **one** potential safety issue for the use of this type of furniture in a family home. *[2]*

(b) Explain why a glass bottle dropped on a hard surface smashes, but a metal drink can dropped from the same height, dents. [3]

Figure 6 shows an expansion joint on a bridge.

Figure 6: Expansion joint on a bridge

(a) Define *thermal expansion*. [1]

(b) Explain **one** reason why the expansion joint shown in Figure 6 is an important consideration in the design of the bridge. [3]

3. (a) Define *assembly-line production*. [1]

....

....

(b) Explain the impact of assembly-line production on the workforce for a mechanized production process. [3]

Figure 7 shows the Isokon Penguin Donkey. It was originally designed in 1939 by Egon Riss and was quickly adopted for use at that time by the head of Penguin book publishers who realized that its shelves were the perfect size for the company's paperbacks – hence the name "penguin" was incorporated into the title for the book/magazine rack along with "donkey" because of its four legs and two "panniers". The Penguin Donkey is made from laminated birch plywood.

Figure 7: The Isokon Penguin Donkey Magazine/book rack

[Source: www.isokonplus.com. Used with permission.]

(i) List **two** advantages of using an adhesive to join together the components of the Penguin Donkey. *[2]*

(ii) Describe a suitable adhesive for joining together the component parts of the Penguin Donkey. *[2]*

Figure 7 shows the Isokon Penguin Donkey. It was originally designed in 1939 by Egon Riss and was quickly adopted for use at that time by the head of Penguin book publishers who realized that its shelves were the perfect size for the company's paperbacks – hence the name "penguin" was incorporated into the title for the book/magazine rack along with "donkey" because of its four legs and two "panniers". The Penguin Donkey is made from laminated birch plywood.

Figure 7: The Isokon Penguin Donkey Magazine/book rack

(ii) Evaluate the importance of strength and stiffness in the design of the Penguin Donkey. *[3]*

(c) (i) Describe the importance of the technique of abrading to the manufacture of the Penguin Donkey. *[2]*

(ii) Explain **three** advantages of using laminated timber to produce the Penguin Donkey. *[9]*

7. **Figure 6** shows two coffee tables designed by John Green in the "Embrace" range. The tables can be used individually or fitted together to form a multi-purpose coffee table and storage unit. The tables are manufactured from plywood with a choice of three different surface veneers.

Figure 6: Embrace coffee tables

(ii) Explain **three** advantages of manufacturing the coffee tables with the technique of lamination. *[9]*

(ii) Discuss **one** ergonomic consideration for the design of the handholds in the smaller version of the tables. *[3]*

(ii) Outline **one** physical property required for the surface finish of the Embrace coffee table. *[2]*

Figure 7 and **Figure 8** show a Robin Day stackable chair manufactured by Hille. The original design was developed so that it was available in a range of seat heights and colours to make it suitable for use in schools. The chairs are made in two sections: the polypropene seat (which is injection moulded) and the legs (which are made from enamelled bent tubular steel).

Figure 7: Robin Day's stackable polypropene chair

Figure 8: Robin Day chairs stacked

(b) (i) Describe the concept of break-even in relation to the manufacture of the chair. *[2]*

(ii) Explain how injection moulding contributes to cost-effectiveness for the chair manufacturer in relation to the manufacture of the chair in a range of sizes. *[3]*

Explain how each of three design for manufacture (DfM) strategies (design for materials, design for process and design for assembly) are dominating constraints on the design of the chair. *[9]*

(a) Describe how the structure of LVL timber makes it a suitable choice of material for roof beams spanning a roof 25 m long. [2]

....

....

....

....

(b) Describe why LVL beams are often made to resemble beams made from solid natural timber. [2]

(b) (i) Outline which category of Design for Manufacture (DfM) was a dominating constraint on the design brief for the keyboard and mouse. [2]

....

....

....

....

25. Compare mass customization with craft production in relation to value-for-money for a consumer wishing to purchase a one-off item of clothing. [6]

Figure 6: Panton S-shaped chair

[Source: © Vitra. Used with permission]

(a) (i) Describe how plastic deformation contributes to the manufacture of the chair in **Figure 6**. [2]

....
....
....
....

(ii) Describe how elastic deformation contributes to the performance of the chair in **Figure 6**. [2]

(iii) Describe the structure and bonding of a thermoplastic. [2]

....
....
....
....

(a) Describe the structure and bonding of thermoset plastic materials. *[2]*

....

....

....

....

(b) Outline why thermosetting plastics are suitable for compression moulding. *[2]*

3. (a) State the manufacturing technique used to create glass bottles. *[1]*

....

....

(b) Explain how the composition of Pyrex® glass has been determined in order to make it successful in the marketplace. *[3]*

(a) State **one** function of the glue in a composite matrix. *[1]*

....

....

(b) Explain why the technique of weaving is appropriate to manufacture composite materials. *[3]*

C6. **Figure C6** shows a team of robots working together to weld the main frame (shell) of a vehicle.

Figure C6: Welding robots in automotive production ABB Robotics AB, Västeras, Sweden

[Source: www.abb.com/robotics]

(a) Discuss **one** advantage of using robots to weld the vehicle in **Figure C6** in relation to quality control. *[3]*

(b) Discuss **one** reason why it may be cost effective for a company to replace the human workforce with robots. *[3]*

4. Injection-moulded preforms and caps (see **Figure 9**) can be purchased in standard sizes for the production of bottles for water and soft drinks (see **Figure 10**).

Figure 9: Standard preforms and caps

Source: www.teachersource.com. Used with the permission of Educational Innovations.

Figure 10: PET water bottles

Source: www.get-inc.com/BottleMfgBlowMolding.htm. Used with the permission of Global Water & Energy Ltd.

(a) State the process which would be used for the production of PET water bottles from the preforms shown in Figure 9. *[1]*

....

(b) Discuss **one** advantage of purchasing standard preforms and caps for the production of PET water bottles for the manufacturer. *[3]*

6. (a) Describe a superalloy. [2]

. . . .

. . . .

(b) Outline **one** reason why nickel-based superalloys are appropriate materials for application in aircraft engines. [2]

. . . .

7. **Figure 12** shows the Tandem Sling Chair. It was originally designed by husband and wife design team Charles and Ray Eames for airports in Washington and Chicago. It is now widely used in airports and other public buildings around the world. The brief was to develop a multiple-seating system which facilitated security checks, looked good (aesthetics) and was easy to maintain (see **Figure 13**). The aluminium frame is produced by high-pressure die casting.

Figure 12: Tandem Sling Chair

www.hermanmiller.co.uk. Used with permission

Figure 13: The chair is widely used in airports and other public access areas

www.hermanmiller.co.uk. Used with permission

(a) (i) Describe the process of high-pressure die casting. [2]

. . . .

. . . .

. . . .

(ii) Outline **one** advantage of using high-pressure die casting to produce the metal frame. [2]

4. (a) State the manufacturing technique which uses a parison. *[1]*

....

(b) Explain why compression moulding is an appropriate technique to manufacture plastic saucepan handles. *[3]*

....

7. **Figure 2** shows a bag manufactured from an obsolete fire hose and fasteners. The company Fire-hose.co.uk makes bags and belts from hoses discarded by the fire brigade. The hoses are made from a thermoplastic material. Half the profits for products made from the hoses go to the Fire Fighters charity.

Figure 2: fire-hose.co.uk bag

(ii) Explain why the type of bonding structure of the plastic material aids recycling of the Fire-hose.co.uk bag at the end of its life. *[3]*

(c) (i) Outline **one** advantage of the use of rivets to attach the straps to the Fire-hose.co.uk bag. *[2]*

8. **Figure 3** shows the Eames Armchair RAR designed by Charles and Ray Eames and considered to be a classic design. The seat is made from a thermoplastic, the frame from steel and the rockers from a hardwood.

(a) (i) Outline **one** reason why hardwood is an appropriate material to make the rockers of the Eames Armchair RAR. *[2]*

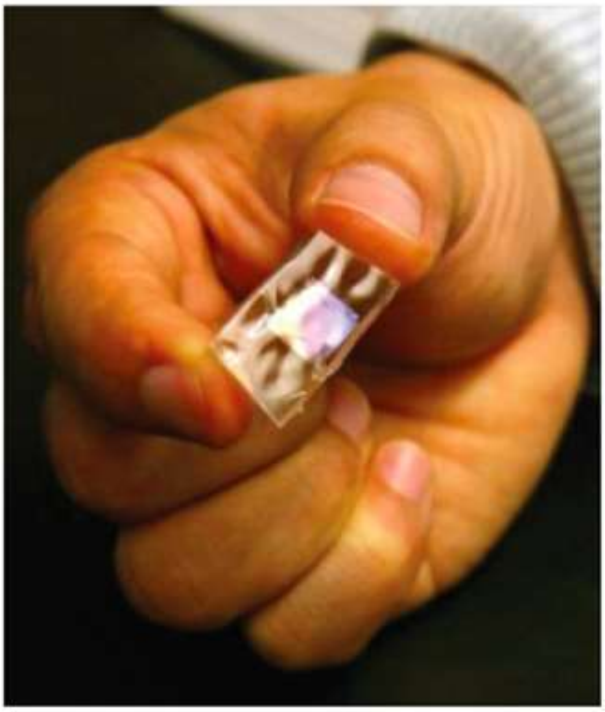
(ii) Outline **one** advantage of making the rockers of the Eames Armchair RAR from laminated timber instead of a hardwood. *[2]*

(b) (i) Outline **one** benefit of using plastic to make the seat of the Eames Armchair RAR. *[2]*

(ii) Explain the most likely technique for joining the metal frame to the wooden rockers. *[3]*

9. **Figure 4** shows a device called the Human Dynamo being worn by a runner. The Human Dynamo is still at the research and development stage of its design. The device is made of tiny ribbons of a piezoelectric material which produce an electric current when flexed such as by the movement of the runner in **Figure 4**. The piezoelectric material is encased in silicon rubber which makes the device bio-compatible with the human body. The technology is being developed by a team of academics in the US backed by government funding. It is expected that within a short space of time, improved electronic chips will be developed so that enough electricity can be produced to power products such as mobile phones and iPods.

Figure 4: Illustration of the Human Dynamo in action



(a) (i) Outline the importance of density to the choice of material for the Human Dynamo. *[2]*

(ii) Outline the materials group to which piezoelectric materials belong. *[2]*

Petra Furniture Store specializes in the manufacture of solid wood furniture like the coffee table (**Figure C3**).

Figure C3: Solid wood coffee table

[Source: www.zientte.com]

(a) Outline **one** disadvantage for manufacturers who replace a human workforce with robots for the production of the solid wood coffee table shown in **Figure C3**. *[2]*

. . . .
. . . .
. . . .
. . . .

(b) Outline **one** advantage of robots in batch production. *[2]*

4. (a) Define *Young's modulus*. *[1]*

(b) Explain how knowledge of the *Young's modulus* of a material affects the selection of materials for a tennis racquet. *[3]*

(ii) Explain how permanent joining techniques lead to planned obsolescence and associated environmental issues. *[3]*

NOTE: This question also covers topics 5,2 and 8

Figure D3 shows two cyclists wearing garments made from Lycra®.

Figure D3: Cyclists wearing Lycra®apparel

[Source: http://en.wikipedia.org/wiki/File:Barney_Storey_and_Neil_Fachie.jpg]

Explain **two** ways in which Lycra® has contributed to the enhanced performance of racing cyclists. *[6]*

(a) State **one** reason for adding scrap glass to new raw materials in the manufacture of glass. *[1]*

....

....

(b) Explain why glass is a suitable structural material for making bricks. *[3]*

(a) State what is meant by *work hardening* a metal. *[1]*

....

....

(b) Compare work hardening and alloying in terms of increasing the strength of a material. *[3]*

Explain why a glass bottle dropped on a hard surface smashes, but a metal drink can dropped from the same height, dents. *[3]*

) Describe how the rate of cooling of a metal controls grain size. *[2]*

(a) State **one** way in which the use of robots in a manufacturing system has helped to reduce material waste. *[1]*

....

....

(b) Outline how the use of robots allows for flexibility in a manufacturing system in relation to scale of production. *[2]*

Figure C4 shows a Morgan motor car. **Figure C5** shows a stage in the assembly of Morgan motor cars which are produced using traditional manufacturing methods. The company produces about 675 cars per year to order. Customers have to wait between one and two years before they receive their car.

Figure C4: A Morgan motor car

[Source: http://www.morgan-motor.co.uk/mmc/hiresimages.html#!prettyPhoto. Used with permission.]

Figure C5: A stage in the assembly of a Morgan motor car

[Source: http://rides.webshots.com/photo/2221698510098837763IWoqYr. Used with permission.]

(a) Suggest **one** reason why the Morgan Motor Company continues to use traditional methods to make the car rather than use CAM. *[3]*

Explain **one** social implication of maintaining traditional manufacturing techniques in the Morgan Motor Company. *[3]*

Explain how mass customization has improved the scope for designing for people with disability. *[3]*

Figure 3 shows the Odin chair which is part of the Nordic (Scandinavian) range of furniture and is manufactured in central China. The chair is made from plywood and steel with a chrome finish. The plywood is veneered with a hardwood (beech or walnut). The seat and the backrest are joined to the tubular steel frame with fasteners.

Figure 3: Odin chair

Outline the importance of ductility to the choice of material for the frame of chair. *[2]*

Explain **three** advantages of using plywood to produce the chair seat and backrest. *[9]*

C1. **Figure C1** shows a CAD image of the design of a new sign for a Design Technology department. The letters for the sign will be cut from a thermoplastic sheet using a CNC laser cutter (**Figure C2**). Laser cutting is a subtractive process. Initially, a prototype of the sign will be cut from thin card.

Figure C1: CAD image of sign

Figure C2: Laser cutter machine

(a) State **one** disadvantage of using a subtractive process. *[1]*

Glossary of Terms

Glossary of Terms

Topic 4: Raw material to final product

Term	Definition
Absorbed moisture	The moisture within timber that is contained in the cells walls.
Additive techniques	Manufacturing techniques that add material in order to create it.
Aesthetic appeal	Favourable in terms of appearance.
Aesthetic characteristics	Aspects of a product that relate to taste, texture, smell and appearance.
Air-drying	Air- drying places the stacks of sawn timber in the open or in large sheds hence there is little control over the drying process.
Alloy	A mixture that contains at least one metal. This can be a mixture of metals or a mixture of metals and non-metals.
Assembly line production	A volume production process where products and components are moved continuously along a conveyor. As the product goes from one work station to another, components are added until the final product is assembled.
Automated production	A volume production process involving machines controlled by computers
Batch production	Limited volume production (a set number of items to be produced).
Bio-compatibility	The product ensures the continued health of a biological environment.
Bowing	A warp along the length of the face of the wood.
Brittle	Breaks into numerous sharp shards.
Chemically inert	Lack of reactivity with other materials.
Composite	A material comprised of two or more constituent materials that have different properties.
Compressive strength	The ability of a material to withstand being pushed or squashed.
Computer numerical control (CNC)	Refers specifically to the computer control of machines for the purpose of manufacturing complex parts in metals and other materials. Machines are controlled by a program commonly called a "G code". Each code is assigned to a particular operation or process. The codes control X, Y, Z movements and feed speeds.
Continuous flow	A production method used to manufacture, produce or process materials without interruption.
Craft production	A small-scale production process centred on manual skills.
Creep	The slow, permanent deformation of a solid material under the influence of a mechanical stress.
Creosote	A material that penetrates the timber fibres protecting the integrity of the wood from attack from borer, wood lice and fungal attack.
Cupping	A warp across the width of the face of wood, in which the edges are higher or lower than the centre.
Density	The mass per unit volume of a material. Its importance is in portability in terms of a product's weight and size. Design contexts include, pre-packaged food (instant noodles) is sold by weight and

	volume, packaging foams.
Design for assembly	Designing taking account of assembly at various levels, for example, component to component, components into sub-assemblies and subassemblies into complete products.
Design for disassembly	Designing a product so that when it becomes obsolete it can easily and economically be taken apart, the components reused or repaired, and the materials recycled.
Design for manufacture	Designers design specifically for optimum use of existing manufacturing capability.
Design for materials	Designing in relation to materials during processing.
Design for process	Designing to enable the product to be manufactured using a specific manufacturing process, for example, injection moulding.
Dry rot	When timber is subject to decay and attack by fungus.
Ductility	The ability of a material to be drawn or extruded into a wire or other extended shape.
Elasticity	The extent to which a material will return to its original shape after being deformed.
Electrical insulator	Reduces transmission of electric charge.
Electrical resistivity	The measure of a material's ability to conduct electricity. A material with low resistivity will conduct electricity well.
Electro-rheostatic	This smart property relates to a fluid that can undergo a dramatic change in its viscosity when exposed to an electric field.
Equilibrium Moisture Content (EMC)	EMC is at which the moisture content of wood achieves an equilibrium with the environment which can be affected by humidity and temperature.
Felting	A method for converting yarn into fabric by matting the fibres together.
First generation robots	A simple mechanical arm that has the ability to make precise motions at high speed. They need constant supervision by a human operator.
Free moisture	The moisture within timber that is contained within the cell cavities and intercellular spaces.
Glass	A hard, brittle and typically transparent amorphous solid made by rapidly cooling a fusion of sand, soda and lime.
Grain size (metals)	Metals are crystalline structures comprised of individual grains. The grain size can vary and be determined by heat treatment, particularly how quickly a metal is cooled. Quick cooling results in small grains, slow cooling results in large grains. Grain size in metals can affect the density, tensile strength and flexibility.
Hardness	The resistance a material offers to penetration or scratching.
Hardwood	The wood from a deciduous (broadleaved) tree.
Joining techniques	Methods that are used to join two similar or dissimilar materials together.
Kiln drying	Kiln-drying places the stacks of sawn timber in a kiln, to reduce the moisture content in wood, where the heat, air circulation, and

	humidity is closely controlled.
Kiln seasoning	Thermally insulated chamber, a type of oven, which produces temperatures sufficient to complete some process, such as hardening, drying, or chemical changes.
Knitting	A method for converting a yarn into fabric by creating consecutive rows of interlocking loops of yarn.
Knots	Imperfections in timber, caused by the growth of branches in the tree that reduces its strength.
Lacemaking	A method for creating a decorative fabric that is woven into symmetrical patterns and figures.
Laminated boards	Sheets of material made from layers of veneers (e.g. plywood).
Laminated object manufacture (LOM)	A rapid prototyping systems that creates a 3D product by converting it into slices, cutting the slices out and joining the slices together.
Lamination	Covering the surface of a material with a thin sheet of another material typically for protection, preservation or aesthetic reasons.
Load capacity (Robots)	The weight a robot can manipulate.
Machine to machine (M2M)	Wired and wireless communication between similar devices.
Magneto-rheostatic	This smart property relates to a fluid that can undergo a dramatic change in its viscosity when exposed to a magnetic field.
Man-made timber	Also known as engineered wood or composite wood, these are wood products that are made by binding or fixing strands, particles of fibres, veneers of boards of wood together with adhesives or other fixing methods to create composite materials. Typical examples include MDF, plywood and chipboard.
Mass	Relates to the amount of matter that is contained with a specific material. It is often confused with weight understandably as we use Kg to measure it. Mass is a constant whereas weight may vary depending upon where it is being measured.
Mass customization	A sophisticated CIM system that manufactures products to individual customer orders. The benefits of economy of scale are gained whether the order is for a single item or for thousands.
Mass production	The production of large amounts of standardized products on production lines, permitting very high rates of production per worker.
Material selection charts	A chart used to identify appropriate materials based on the desired properties.
Mechanical properties	Properties of a material that involve the relationship between stress and strain or a reaction to an applied force.
Mechanized production	A volume production process involving machines controlled by humans.
Multi task robots	A type of robot that can perform more than one task in a manufacturing environment.

Natural fibres	Materials produced by plants or animals that can be spun into a thread, rope or filament.
Non-toxic	Absence of toxic breakdown products/lack of reactivity.
One-off production	An individual (often craft-produced) article or a prototype for larger-scale production.
Oxidization resistance	A property of a metal that means that it does not readily react with oxygen and degrade.
Paper-based rapid prototyping	Often the first step in a rapid prototyping process, paper prototyping is widely used in UCD for designing and testing interfaces.
Particle boards	A material made from different sizes of wood chips and joined with glue.
Photochromicity	A property of a smart material. A photochromic material changes colour in response to an increase in light. When the light source is removed, it returns to its original colour.
Physical properties	Any property that is measurable that describes a state of materials, for example, mass, weight, volume and density. These properties tend to be the characteristic of materials that can be identified through non-destructive testing (although some deformation is required to test hardness).
Piezoelectricity	A property of a smart material. A piezoelectric material gives off a small electrical discharge when deformed.
Plasticity	The ability of a material to be changed in shape permanently.
Pultrusion	A continuous manufacturing process used to create composite materials that have a constant cross-section. Reinforcing fibres are saturated with a liquid polymer resin and then pulled through a heated die to form a part.
Reforestation	Reforestation is the process of restoring tree cover to areas where woodlands or forest once existed. If this area never returns to its original state of vegetative cover the destructive process is called deforestation.
Seasoning	Seasoning is the commercial drying of timber which reduces the moisture content of wood.
Second generation robots	Robots that are equipped with sensors that can provide information about their surroundings. They can synchronize with each other and do not require constant supervision by a human; however, they are controlled by an external control unit.
Shape memory alloys	Shape memory alloys are metals that when deformed, can spring back into its original shape once released.
Shaping techniques	Manufacturing methods for modifying the shape of a material.
Single task robots	Robots that can perform one task only.
Smart material	Materials that have been designed to have one or more properties that can be modified when subject to an external stimuli in a way that the output can be controlled.
Softwood	The wood from a coniferous (evergreen) tree.

Stiffness	The resistance of an elastic body to deflection by an applied force.
Strain	The response of a material due to stress, defined as the change in length divided by the original length.
Stress	A force on a material divided by the cross-sectional area of that material.
Super alloys	An alloy that exhibits excellent mechanical strength, resistance to thermal creep deformation, good surface stability and resistance to corrosion.
Synthetic fibres	Fibres made from a man-made material that are spun into a thread; the joining of monomers into polymers by the process of polymerisation. Examples include polyester, acrylic, nylon, rayon, acetate, spandex, and Kevlar.
Tempering	A heat treating process designed to increase the toughness of an iron-based metal by heating it and allowing it to cool in air. Tempering decreases the hardness of the material, which usually increases the ductility and decreases the brittleness.
Tensile strength	The ability of a material to withstand pulling forces.
Thermal conductivity	The measure of how fast heat is conducted through a slab of material with a given temperature difference across the slab.
Thermal expansion	A measure of the degree of increase in dimensions when an object is heated. This can be measured by an increase in length, area or volume. The expansivity can be measured as the fractional increase in dimension per kelvin increase in temperature.
Thermo-electricity	This refers to a smart material that when heated can produce an electric current. A thermoelectric material is comprised of two dissimilar conductors.
Thermoplastic	A type of plastic that can be heated and formed into a new shape repeatedly.
Thermosetting plastic	A type of plastic that once formed into a shape, cannot be reformed into a different shape.
Third generation robots	Autonomous robots that can operate largely without supervision from a human. They have their own central control unit. Swarms of smaller autonomous robots also fit in this category.
Toughness	The ability of a material to resist the propagation of cracks.
Transparency	Ability to allow light to be transmitted with minimal scattering allowing a clear view through material.
Twisting	A distortion in which the two ends of a material do not lie on the same plane.
Volume	The quantity of three-dimensional space enclosed by a boundary, for example, the space that a substance solid, liquid, gas, or shape occupies or contains.
Warping	A distortion in wood caused by uneven drying, which results in the material bending or twisting.
Wasting/subtractive techniques	Manufacturing techniques that cut away material in order to create a component.

Weaving	The act of forming a sheet like material by interlacing long threads passing in one direction with others at a right angle to them.
Weight	Relies on mass and gravitational forces to provide measurable value. Weight is technically measure as a force, which is the Newton, i.e. a mass of 1 Kg is equivalent to 9.8 Newton [on earth].
Wood recycling	Wood recycling is the process of turning waste timber into usable products. Recycling timber is a practice that was popularized in the early 1990s as issues such as deforestation and climate change prompted both timber suppliers and consumers to turn to a more sustainable timber source.
Wood treatment	Treatment of wood can involve using solutions, which make the wood poisonous to insects, fungus, and marine borers as well as protecting it from the weather.
Work envelope	A fixed 3D space where work activities take place, considering clearance and reach.
Work hardening	Also known as strain hardening or cold working, this is the process of toughening a metal through plastic deformation.
Yarn	A long continuous length of interlocked synthetic or natural fibres.
Young's Modulus	A measure of the stiffness of an elastic material and defined by stress/strain.

DP DESIGN TECHNOLOGY

WITH

Mr Moneeb

TOPIC 1: Guidance and Notes Booklet
2020 - 2022