DT

GCSE (9–1) | AQA | 8552

Course Companion for GCSE AQA Design & Technology

3.2 Polymers

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POD 8910

Contents

Teacher's Introduction

> **Remember!**
> Always check the exam board website for new information, including changes to the specification and sample assessment material.

This resource has been written to cover **specification points 3.2 and 3.3.7–11** of the **AQA (8552) GCSE Design and Technology** specification (from 2017) in relation to the **Polymer** material category.

The course companion contains concise material which can be photocopied and distributed in class, or given as homework and self-directed revision. The resource features keywords, further knowledge boxes and engaging diagrams to appeal to visual learners. There are also exam style questions at the end of every section, designed to test and confirm knowledge. These questions are carefully constructed to familiarise students with the style of questions they can expect in the written exams.

This resource has been designed to help to build a solid understanding of the subject as well as encouraging recall-based knowledge. The text is broken into manageable sections, keywords in sections of text are highlighted and definitions are provided within each subject section. These features will help to support students in their revision, from lower-ability students right through to the most confident students.

How to Use
The course companion can be used in two main ways. Firstly, for a teacher, the resource is an invaluable tool to assist in the planning and delivery of the module. Secondly, for a student, this companion can be used alongside or as an alternative to the textbook.

Summary of Contents
This resource is designed to correlate clearly and accurately with the AQA (8552) GCSE Design and Technology specification (from 2017), covering the specification points 3.2 and 3.3.7–11, in relation to the **Polymer** material category.

The course companion is divided into sections following a narrative of plastic production, from sources and origins to surface treatments and finishes. Each section is clearly structured and interspersed with diagrams, keyword definitions, further knowledge boxes, end-of-section exam-style questions and a case study. Specification points 3.2 and 3.3.7–11 are fully covered within this resource, ensuring students are provided with the knowledge they will need to be successful within their exams. Refer to the table on the specification coverage page to see which section covers the specification points to help with lesson planning.

PS Our GCSE AQA Topic on a Page resource for the 3.2: Polymers category is the perfect accompaniment to this course companion. Used alongside the course companion, it provides highly visual revision mind maps to collate and illuminate the in-depth information covered in this pack. Additionally, consistent language, terms and diagrams are used across both resources to help reinforce knowledge.

Visit our website to preview and order Topic on a Page resources, and even more GCSE AQA DT resources.

October 2018

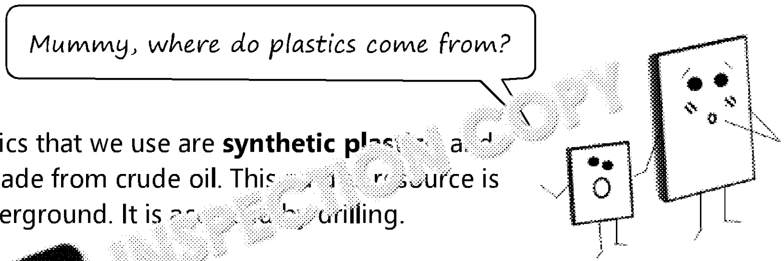
Specification Coverage

Section of Resource	Specification C
Sources and Origins	3.2.4 – Sources and origins
Selection of Materials or Components	3.2.1 – Selection of materials or comp materials and components
Ecological and Social Footprint	3.2.3 – Ecological and social footprint
Forces and Stresses	3.2.2 – Forces and stresses
Using and Working with Materials	3.2.5 – Using and working with mater
Stock Forms, Types and Sizes	3.2.6 – Stock forms, types and sizes
Scales of Production	3.2.7 – Scales of production
Specialist Techniques and Processes	3.2.8 – Specialist techniques and proc tools and equipment + 3.3.11 – Speci + 3.3.8 – Tolerances + 3.3.9 – Materi
Surface Treatments and Finishes	3.2.9 – Surface treatments and finish techniques and processes

Sources and Origins

What is a Polymer?

A polymer is a **chain of monomers** (a molecule that can be bonded to other identical molecules) that have joined end to end. Plastics have polymeric structures. For example, polythene (the plastic commonly used to make plastic bags) is a chain of ethene monomers and polypropylene (a plastic commonly used for packaging and plastic furniture) is a chain of propene monomers.



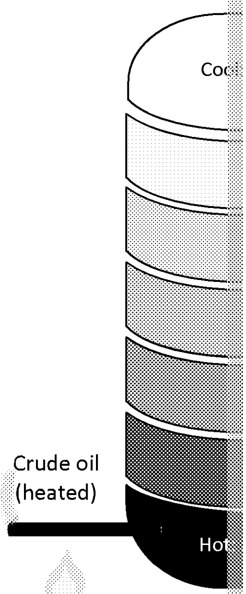
Most plastics that we use are **synthetic plastics**, and they are made from crude oil. This natural resource is found underground. It is accessed by drilling.

Drilling

Drilling is the process used to extract crude oil from 'oil fields' which are pockets o
These pockets can be in very remote areas, such as in the middle of an ocean. The
drilling down into the oil fields and then pumping the oil up to the surface of the
pipes under the sea or transporting it on ships or lorries to take it to **refineries**.

Crude oil is finite, which means that there is a limited amount of it. The crude oil w
products now will not be replaced, and the supply we are currently using is going
it necessary to recycle the plastics and crude oil products that we use when possib

Fractional Distillation

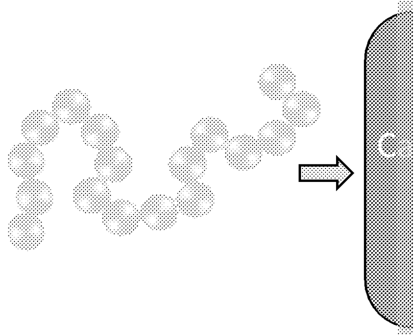


Fractional distillation is the **refining process** used to make crude oil into usable gases and oil that we use every day.

The process involves heating the crude oil in a distillation unit. The gas or oil products that need to be separated have different **boiling points**, which means that they can be syphoned off and condensed at different stages. The substances with low boiling points get syphoned off at the top of the distillation unit, and the substances that have a high boiling point, and that have larger molecules, are syphoned off at the bottom. A waste material called bitumen is left behind. Bitumen is used for resurfacing roads and roofs.

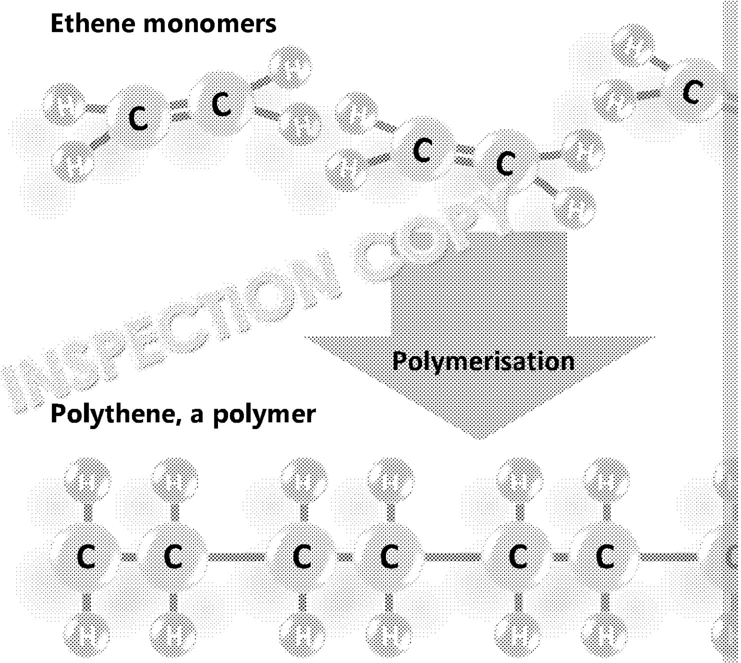
Cracking

To make the products left over from the fractional distillation process into plastics, larger hydrocarbon molecules need to be broken up into smaller versions that can be used to make plastics. Breaking up the large molecules involves using a hot **catalyst** to **break down the bonds within molecules**. This process is called cracking.



Polymerisation

The monomers created by the cracking process are placed in a polymerisation rea
and the **monomers link to create polymer chains**. Differences in how these mon
monomers are used, cause differences in the polymers. These differences cause di
longer polymer chains make stronger plastics.



Thermoplastics and Thermosetting Plastics

There are two main types of plastics. The main differences between them are **how**
exposed to heat. Thermoplastics can be **melted and reshaped** as many times as
and have relatively low melting points.

A thermosetting plastic creates more **bonds** within itself when it is first hardened. These bonds mean that it **doesn't melt but burns** instead. Therefore, thermosetting plastics cannot be melted to be recycled at the end of their life.

Thermoplastics and thermosetting plastics also exhibit other differentiating properties. Thermosetting plastics tend to perform better under heat and stress and are better heat and electrical insulators. This is because they have stronger bonds in the structure of the material.

Biopolymers

Plastics can also be made from **vegetable starches** and **plant resins**. Polylactic acid (PLA) is a thermoplastic usually made from cornstarch. It can be used for many applications including 3D printing. PLA is made by separating starch from corn. Starch is a natural polymer (chain of monomers) which is chemically broken apart to make the monomers required for PLA.

Rubbers can be **natural** too. Latex is taken from the rubber tree by '**tapping**'. Afte
used. It is often used to make balloons.

Biopolymers can break down in compost as well as be recycled. See **environment**

Questions: Sources and Origins

1. Using notes and/or sketches, explain the process of producing a synth source to granule stock form. (4 marks)
2. What is the difference between thermoplastics and thermosetting pla
3. Is latex natural or synthetic? (1 mark)

Keywords

Boiling point – The temperature at which a liquid turns into a gas.

Catalyst – A substance used to increase or accelerate chemical reactions.

Crude oil – A fossil fuel made from animals and plants that died millions of years and formed into crude oil under heat and pressure.

Monomers – single molecules that join to make polymers.

Natural – A material that occurs without human intervention.

Properties – What a material is or does and how it reacts to forces, use, UV ligh

Refinery – An industrial processing plant where crude oil is made into usable pro

Synthetic – A material that is not natural but that has been created by humans.

Tapping – The rubber tree's bark is cut and the latex drips out. The latex is colle

Selection of Materials or Compon

When selecting a material for a product, there are key factors that need to be con
material does not entirely fulfil the requirements, it is up to a designer to find the
requirements, or experiment to improve an existing material. The key factors that s
functionality and ease of use, aesthetics, availability, cost and environmental consi
prioritised by different designers and companies. Some companies might prioritis
whereas some companies will decide to pay more to use more environmentally fri
achieving a balance is usually the ideal situation.

Functionality

Different plastics have unique properties which make them appropriate for a **variety of functions**.

Plastics can be coloured or transparent which can add to their functionality. Being transparent, they can sometimes replace glass and be a stronger, less brittle alternative. This adds to the safety of the product because plastic will not shatter in the same way as glass.

Plastics are also resistant to weathering and corrosion. **Stabilisers** and other **addi**
durability and make plastics more resistant to **chemical** and **UV corrosion**. Additi
other properties like flexibility and scratch resistance; which improves the function

Plastic has a surface that can be sterilised or cleaned easily. This makes it function
equipment. It also means that it doesn't retain water or need time to dry out whic
products such as beach toys or camping equipment.

Plastic is also much **easier to work with** than traditional materials. Plastics can be
metal because they have comparable durability and strength properties. However,
to shape and form and use less-energy-intensive processes. This makes plastic an
option.

Aesthetics

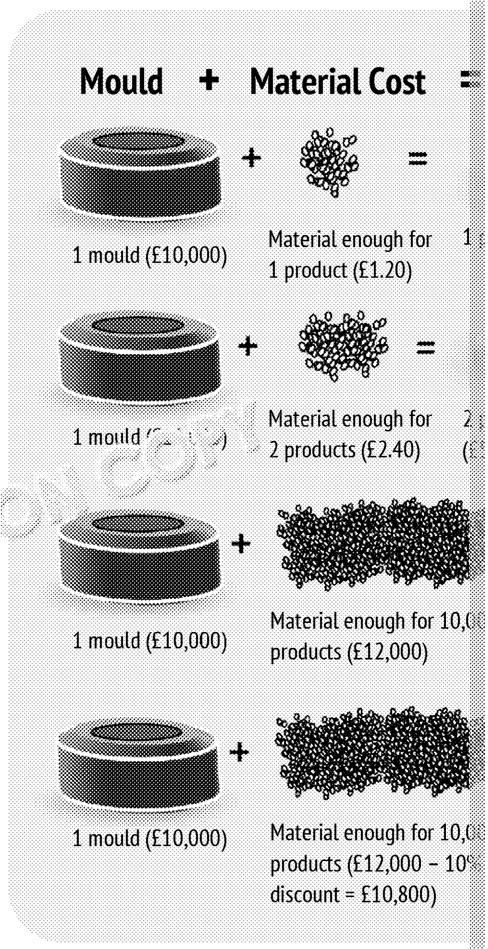
Plastic can be moulded, stamped and decorated in a variety of ways which means
its texture and shape. It can also be coloured in any colour or shade as well as be
in between. This means that it can be used for a variety of applications and can ha
required. It is also used to **mimic other materials**. For instance, vinyl is often prin
The texture of wood can also be added to make it a more convincing imitation. Pl
wood because it is cheaper to mass manufacture.

Being able to colour the material itself means that there is no need for additional fi
can't chip or scrape off from the material or product so is more resistant to fatig
The surface finish of plastics can also vary. The most common finish is a smooth, p
can be moulded with a highly textured finish and be treated further to create a hig
finishing techniques and treatments can also be used to create specific looks or ad

Availability

Plastic is readily available in a **variety of stock forms**. A lot of standard compone
More complex shapes and products will need to have bespoke moulds/dies/forms
of crude oil also means that plastics will eventually become less available. The sou
is recycled successfully or plastics become more commonly produced from sustai

However, currently plastic is very easily and cheaply available in a variety of forms, colours and finishes. More importantly, plastics have a wide range of properties which make them suitable for a lot of uses and products.



Cost

Plastic can also be easily moulded and cast which you can't do with wood and is harder to do with metal. This means that complex shapes can be produced faster and cheaply. Once one mould is made it can be used repeatedly. Products made from plastic often need less finishing than products made from wood or metal which can save costs.

Overall, plastic can be a very **cost-effective** material option. However, the more manufacturing and finishing processes that are involved, and higher quality and tighter tolerances, are all factors that can increase the cost of manufacturing.
Different types of plastics also cost more than others. Thermosetting plastics often However, when using thermoplastics, waste that incurs during the manufacturing and used again. This can't happen with thermosetting plastics, and therefore ther effective overall.

Another way to reduce the costs of manufacturing is to buy in bulk. **Bulk-buying** or material. A discount will often be applied to large amounts. This will mean that split over more products.

Questions: Selection of Materials or Components

1 Suggest how you could make plastic less likely to degrade in sunligh

2 Give **two** reasons why plastic might be used instead of wood. (2 mar

3 Explain why it is often cheaper per unit to mass produce a product c production. (2 marks)

Keywords

Additives – Chemicals, scents and colours added to plastics during the manufactu enhance, improve or add properties to the material.

Bulk-buying – Purchasing more supplies or materials at once to benefit from a d

Chemical corrosion – Damage to materials caused by exposure to chemicals.

Cost per unit – How much one product costs to make.

Cost-effective – Good value for money, getting more for the money.

Ease of sourcing – The level of difficulty in finding and purchasing a raw materi

Ease of working – How easy a material is to use and manufacture products from

Function – What a product does.

Requirements – What a material must do or be.

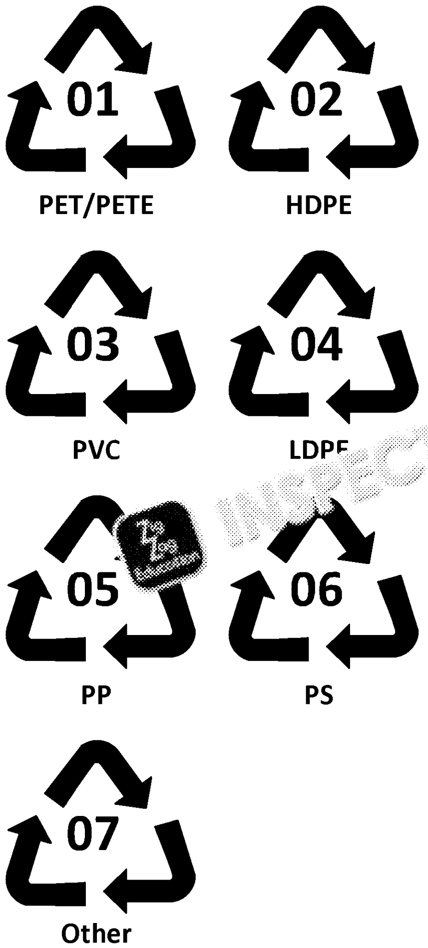
Stabilisers – Chemicals added to plastics during the manufacturing process that m and resistant to corrosion and UV degradation.

Stock form – The shape and sizes that plastics can be bought ready for manufac

Surface finish – The outside appearance of a product and how it has been treat

UV corrosion – Damage to materials caused by exposure to sunlight.

Versatile – The ability to be adaptable or used in a variety of ways.



Environmental Factors

Crude oil is needed to produce synthetic p
to extract the crude oil, is **highly energy c**
often involves burning fossil fuels which ca
production of greenhouse gases. Transpor
contributes to the energy consumption an
cause other environmental disasters. Leaki
habitats and kill wildlife. Birds are often es
they ingest the oil as they try to clean the

Durability is a key property of plastic. How
means that plastics **do not degrade** and s
undetermined amount of time. This also ca
sites. **Plastic pollution** in oceans is killing
which affects fish that are used for food.

The crude oil that is used to make plastic i
show that, at the current rate of consumpt
out in a matter of decades. This makes the
Recycling can help to extend the time we w
plastics are recycled correctly, then they ca
way as **virgin plastics**, and the properties

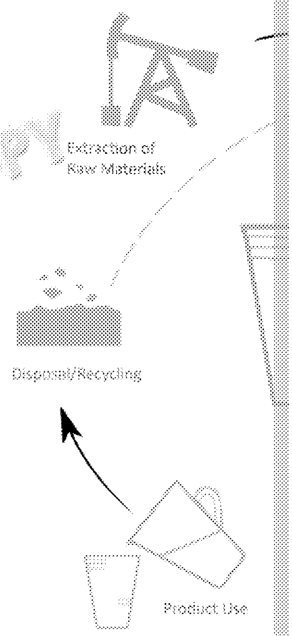
The different types of plastics should be **re**
the properties of the plastic are unaffected
the recycling symbols. The numbers on the
plastic the product or packaging is made o

Thermosetting plastics are especially difficult to recycle as they cannot be melted d
methods for them have only been developed recently. Most commonly thermosett
finely or grated and used as filling or insulation materials.

Bioplastics have many of the properties of synthetic plastics, but they can be com
compost. However, if even a small amount gets mixed in with thermoplastics in th
contaminate the batch of recyclable synthetic plastic and make it unusable.

Product Life Cycle

Products made from plastic have environmental impacts, from the extraction of the raw materials it is made of, to its eventual disposal. A **responsible designer** will try to reduce the amount of negative **environmental impacts** that their products incur.



The extraction of crude oil is a very energy-intensive process. Producing energy also involves sourcing and burning fossil fuels which release **greenhouse gases**.

The production of plastics is also energy intensive, as is the manufacturing. These energy-intensive processes require lots of electricity which is produced by burning fossil fuels. These processes can also create waste material which can cause environmental harm if not disposed of properly.

Transportation uses fuel which produces **carbon emissions**. Products and materia
different countries from where they are sourced or sold, which means that a lot of

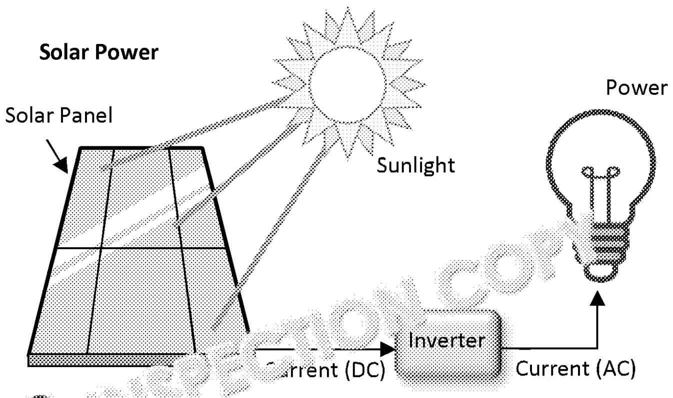
When the product reaches the consumer, it already has a large **carb**
product can also cause negative effects on the environment. If the pr
obsolescence, it will be discarded and easily replaced whereas **designe**
be repaired and possibly perceived at a higher value by the consumer,
used.

The disposal of the product is the final stage of the product life cycle, an
substantial negative impact on the environment if not disposed of properl
beneficial and means that new material doesn't need to be extracted from
still an energy-intensive process so is not without negative environmental impact.

At each stage of the life cycle, a product or the material used to make a product, will be transported; the distance it travels is known as the **product mileage**. A responsible designer will aim to reduce the amount of product mileage because the more mileage a product has, the more negative impact it has on the environment. The main way this can be achieved is to use suppliers and a manufacturer located in the same country as the retailer and final consumer.

There are ways to reduce the environmental impact. **Sustainable energy sources**
turbines or hydroelectric power could be used as an alternative to fossil fuels to cr
extraction, production, manufacturing and recycling. Responsible manufacturers w
manufacturing processes as efficient as possible; this can lead to saving money as
material wastage. A designer should use manufacturers who have environmentall
material sources and manufacturers can help to reduce the amount of fuel consum
and materials.

Designers can also help to reduce the negative environmental impact of the dispo
should be designed to be easily recycled, making sure parts that are made of diffe
easily for recycling is important. Clearly labelling the plastic avoids mixing types o
contaminates the whole batch and degrades the quality.



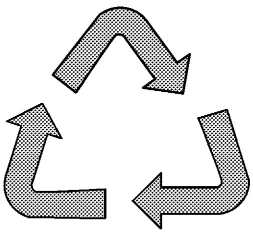
The Six Rs

The six Rs are ways that designers and consumers can **improve the ecologica**
our society and environment.

The six Rs are:

Reduce – Use **less** energy, material or products. Designers could make changes i
material is being used. Manufacturers can carefully consider how the material is u
material is a good way to minimise wasting. This can also be beneficial for reduci
less material. Consumers can also reduce the amount of products they buy, or cho
products that will last longer and are less likely to need to be replaced.

Reuse – Manufacturers could reuse moulds when possible and designers can find materials into their designs. For instance, companies who make bags from reused products or packaging to prolong the useful life. An example would be using emp holders, candle holders, etc.



Recycle – Recycling is made easier if the materials can be labelled. Designers can keep this in mind when deciding h different materials together. For example, using screws an glues. Manufacturers can recycle waste during the manuf wastage and also costs. Consumers can recycle products a nearest recycling facility and what can or can't be recycled designer's job to make it as straightforward as possible to easily and recycle the product they produce.

Rethink – Some products and practices that are accepted as normal now are reall designer should aim to challenge this and use **innovation** to create new products good products that look after the environment too. Manufacturers shoul make their processes more efficient. Consumers can rethink their product choices order to use them most efficiently.

Refuse – A designer and/or manufacturer can refuse to use materials or processes the environment. Consumers can also refuse to buy products that have a negative consumers are showing a trend of refusing to spend their money on products tha environment, the product design industry is more likely to move towards environm materials to fulfil consumer needs and encourage spending.

Repair – Instead of throwing something away when it breaks, a consumer can rep products that we currently used are not designed to be repaired. Sometimes it is i because the casing would have to be broken to get the piece that needs fixing. Al difficult by needing special tools for specific screws that are used. Designers and m easier for a consumer to repair a product when they are finished with it.

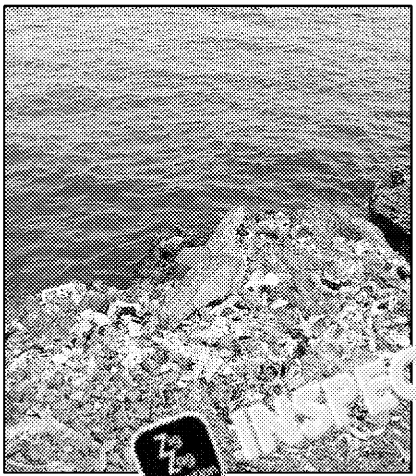
Social Factors

Products affect the lives of people in many ways. The products we use can make o easier and solve problems. The product life cycle also involves and affects a lot of Manufacturing, transport and sales of products all create jobs for people, from hig skilled designers, engineers and technicians to lower-skilled jobs such as factory w the responsibility of the designer and manufacturer to make sure that choices are throughout the product life cycle to **minimise any negative impact** that a produ not just on the environment but also on the people that are involved in the proce ideation to final disposal and beyond.

For the production of plastic, large amounts of oil have to be transported from so manufacturers. This oil is often transported by boat over oceans. If these ships are accident happens, it can cause the oil to spill onto water. If an oil spill does occur, in the area. The fishing industry in the area will halt as they are **not able to fish**, a **dwindles**. In places, these industries are the primary sources of income. This whole community significantly.

Pressure to reduce manufacturing costs means **lower wages** for people manufact lower quality of life. In some cases, where there are fewer government regulations provide a **quality of life** that is considered humane by the standards held in the U can combat this by using a higher proportion of the final product retail price to pa something that is reflected by the **Fairtrade** logo on some products.

Low manufacturing costs can also lead to **unsafe working conditions** for factory w
products is used to maximise profit instead of building safe premises to work in, p
clothing or providing safety training. Examples of this have been seen in recent yea
collapsing, killing workers.



If a product or manufacturing waste is not dis
problems. Plastic is particularly problematic b
fact that it does not degrade. Plastic-covered
the quality of life for local communities whic
Oceanic pollution can also affect the fish tha
fish can be affected by toxins, either dying fro
or animals that consume them. This affects th
and women that rely on the fishing indus
people who eat the fish that might be affecte
... to reduce this by choosing materials that
sure their products can easily be disposed of
recyclable plastics and reducing the amount o
produce will help the user to dispose of the p

Atmospheric pollution is also an issue. Fumes from plastic production, manufacturing, transport and even the production of electricity for all the production processes, all contribute to atmospheric pollution. This reduces air quality for workers and local communities but carbon dioxide fumes add to the greenhouse effect which is affecting our planet's climate and our ecosystem as a whole.

Social issues that surround plastic are not all negative. The need to produce and recycle plastics has **created a lot of jobs**. People are needed to drill for oil and transport it, to sort the different plastics at the end of life, and collect the discarded plastic from oceans and beaches. Discarded plastic is also being used as
sell by **community projects**. These goods are providing wages for people who hav
possibly no other ways to make money.

Plastic products can be produced very cheaply which means that products can be s
who have lower incomes because they can **buy more with less money**. This helps
living and their perceived social status.

All of these factors, positive and negative, create a product's **social footprint** – the
communities and people that it comes into contact with. As a designer and manuf
sure that the social footprint of a product is as positive as possible.

Cultural Factors

A designer needs to be aware of cultural factors when making material choices. Th
normal in one culture could be at best strange, or at worst offensive, to another cu
should be aware of the markets that their products will be sold in and undertake d
decisions that are **off-putting or offensive** to your target market can leave a lasti
could lead to **profit loss or lawsuits**.

Japanese culture is a good example of a culture that has noticeable differences fro
Japanese culture, **cleanliness** is considered to be of the utmost importance. Food i
wrapped in plastic packaging, far more than is considered necessary in England. Ja
high level of packaging and some companies and brands worry that by reducing th
might see their products as unhygienic.

Ethical Factors

A designer should aim to address ethical factors where possible. Ethical factors inc
and cultural factors. To make a product ethical, the products and materials shoul
the environment and the people involved in the manufacture and distribution of th
sensitive to the target market.

All these factors can be difficult to balance. For instance, how does a company app
expect consumables to be individually wrapped in plastic while also taking ecologic
This may be made even more difficult with time and budget restrictions in place as
materials and processes, and more consumers wanting to purchase ethical product
ethical practices.

Case Study

'Ghost fishing' is a term that refers to commercial fishing equipment that has bee
abandoned in the ocean. This equipment floats freely and **traps** marine animals as
drifts along. This causes the marine animals to die, usually of asphyxiation or event
starvation. This is increasingly becoming a problem. Whereas previously commercia
nets were made of cotton or hemp, which are biodegradable, they are now made o
plastic which will last for an undetermined amount of time.

Equipment is rarely discarded on purpose, but accidents happen that cause fishing
boats to have to cut their nets free, or sometimes nets or crab pots are lost due to
extreme weather conditions.

Solutions to this problem involve the fishing industry switching from **synthetic net**
to **biodegradable nets** such as nets made from coconut fibres. Incentives and
programs are also being put in place to collect any nets found when out at sea, or
least to report the locations of the lost nets.

Questions: Ecological and Social Footprint

1 Explain why different types of plastics need to be separated when th

2 Identify the six R's. (6 marks)

3 Explain what the term 'social factors' means. (4 marks)

4 Identify two ways that plastic pollution could be reduced. (2 marks)

Keywords

Bioplastics – Plastics that are made fr[illegible] sources and/or are biodegrad

Carbon emissions – The car[illegible] dio[illegible] produced during a process.

Carbon foot[illegible] [illegible] ct that a product/process has on the environment.

Designed [illegible]intenance – The practice of designing a product to last for a lo repaired.

Environmental impact – What effects a product, material or process has on the negative.

Finite – Limited or non-renewable.

Greenhouse gases – Gases that contribute to the greenhouse effect, causing glo

Innovation – New, or never done before. A new way of doing or presenting a me

Nesting – A technique used to make the most efficient use of a sheet of material cut out closely together so that the least material is wasted. See diagram on pa

Oil spillages – Oil being put into the sea as a result of an industrial accident, often Considered an environmental disaster which can have significant negative impacts o

Planned obsolescence – The practice of designing a product to last for a limited have to buy more / replace the item more often.

Plastic pollution – Plastic that has been disposed of improperly or that has ende where it may have a negative impact.

Product life cycle – The steps an item goes through, from design to disposal.

Product mileage – How many miles a product has travelled from where the raw final consumer.

Responsible designer – A designer that considers the environmental impact of a product life cycle.

Social footprint – The effect that a product/process h[illegible] e communities and

Sustainable energy sources – Energy sour[illegible] th[illegible] renewable or not limited. tidal power.

Virgin plastics – Newly [illegible]ed plastics. Plastics that have been produced from recycl[illegible]

Types of Forces and Stresses

Force and stress are different things.

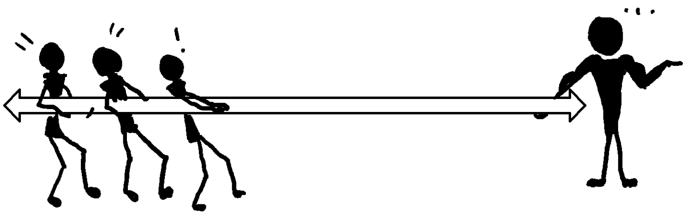
Force is the **interaction** which affects objects or bodies. For instance, friction, air re forces that act on a body or object. Whereas **stress** is the **amount of force** applied object. The maximum stress that a material or object can stand before it breaks is c **breaking stress**.

There are two types of forces, a dynamic load and a static load. **Dynamic loads** are falling, and **static loads** are **still**. Dynamic loads produce more force than static loa placed on a sheet of glass and not smash it, but dropping the brick onto the glass and The **magnitude** and **direction** of forces can be changed using **mechanisms**. Tools forces to create useful effects. For instance, scissors are used to create a shearing fo

There are lots of different types of forces. Materials can be more resistant to some important to know what type of forces a product will be expected to withstand so t material can be chosen.

Tension

When force is applied in opposite directions, pulling either end away from each ot



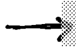
The tensile strength of a material is its ability to resist being pulled apart.

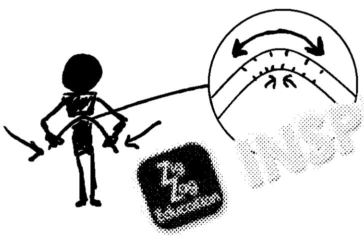
Torsion

Torsion is the force created by turning opposite directions, becoming twisted.
Torsion strength of a material is the ability to resist being permanently deformed b

Compression

When force is applied in opposite directions to push either end together. Compressive strength is the ability to resist being permanently deformed by being squashed or compressed.





Bending

Bending occurs when force is applied and creates The outside of the curve experiences tension whi experiences compression.

Stiffness is the ability of a material to resist bendi deformed by it.

Shear

When force is being applied to an object, perpendicular (at a 90° angle) to its length, it can cause a shear force. Shearing force can also occur when the forces are applied in opposite directions but on different planes, when objects are trying to slide past each other. For instance, the blades of scissors create a shearing force on paper and the paper 'fails' in shear when it is cut – it doesn't withstand the forc

Enhancing Materials to Improve Functionality

All materials and products have to withstand stress and forces, but it is up to a desi product can withstand the **maximum expected force and stress**. Making sure tha withstand more than it will typically experience is a way of keeping it **safe** and **relia** choosing the right materials and manufacturing processes. Another option is to **en** or **processes** to improve the functionality of a product.

Reinforce

A material can be reinforced by adding another **layer** of the same, or a different m directions may add more strength. Different layers can be fixed together, or combi **composite material**.

Fibreglass is a good example of reinforced material. It is a composite material most thermosetting plastics and glass fibres. The glass fibre adds to the strength of the it to be moulded into complex shapes and keeps the material lightweight.

Stiffen

Another way to improve the strength of a material is to make it stiff and **prevent** b stiffened by reinforcing it with enough layers to stop it being flexible, or by adding inherently stiff. Examples include PVA being added to newspaper to make it stiffer plaster being added to cotton bandages to make a stiff plaster cast. Laminated wo of the same material to make the material stiffer. Thin sheets of wood can be flexib reduces the flexibility and makes the laminated wood stiff and stronger. The differe stiffened is that a material can be reinforced without becoming stiff.

Improve Flexibility

A more flexible material can respond to stress by **bending** or twisting instead of br more flexible by adding chemicals called plasticisers. This will make a usually brittle likely to shatter.

Questions: Forces and Stresses

1 Explain what torsion is. Use an example of when it would occur. (2 ma

2 Identify and explain two ways that a material can be made stronger

Keywords

Composite material – A combination of one or more materials to make a materia the application it is intended for.

Direction – Which way the force is travelling.

Dynamic load – A force that is moving.

Force – The interaction between objects or bodies that create a push or pull.

Improve flexibility – Adding plasticisers to make a more flexible material which bending or twisting instead of breaking.

Magnitude – Size or amount of force.

Mechanism – Parts that work together to create a machine or tool. Used to tra applied force.

Reinforce – To make a material stronger by adding layers.

Static load – A force that is still / not moving.

Stiffen – Make less flexible to improve strength and make more appropriate for

Stress – The amount of force applied to an area of a material or object.

Ultimate tensile stress – The amount of force at which a material or object breα

Using and Working with Materi

The different properties of a material affect all the different stages of the product li
product will be made, how easy it is to work with, how it can be used and how it wi
Finally, it will affect disposal and recycling options.

It is essential to be aware of the properties of materials and how they will affect a p
product life cycle. This knowledge helps a designer to make the correct material ch
when producing a product for the mass market, as the amount of resources and im
a much wider scale.

Properties of Materials

Materials can have physical and working properties.

Physical properties are the ... of the product. They include properties like:

- **Thermal conductivity** – How well the material conducts heat. Low thermal co would be a good insulator, such as a flask used to keep something warm o
- **Electrical conductivity** – How well the material conducts electricity. Urea-for which means that it is a good material to use for plug sockets and other elect from coming into contact with a current.
- **Density** – How compact the material is per volume unit.
- **Fusibility** – High fusibility is used to describe materials that turn to liquid easi combine with material to make a joint which becomes permanent when the m
- **Absorbency** – The ability to soak up and hold liquid, light or heat.
- **Melting point** – The point a material turns from a solid to liquid state.
- **Opacity**- The ability of the material to let light through.
- **Colour**
- **Smell**
- **Magnetism** – The ability of a material to repel or attract other magnetic mate
- **Corrosion resistance** – The ability of a material to withstand chemical or UV d

Working properties describe how a material reacts to use or an environment.

- **Strength** – The ability of a material to withstand stress.
- **Toughness** – The ability of a material to absorb shock without breaking.
- **Hardness** – The ability to resist scratching or denting.
- **Elasticity** – The ability to be stretched and bent without deforming, and retur
- **Malleability** – The ability to deform and change shape without breaking.
- **Ductility** – The ability to be made into a thin strand without breaking.

The Modification of Properties

Properties of plastics can be modified and changed to suit the needs of the produc
makes the materials more versatile and appropriate for more applications. It can al
caused by using other materials. For instance, **additives** can be added to some pla
a time so that if and when they end up in landfill, they are not there indefinitely bu

Plastics can be mixed with other materials to create **composite materials** which ca
Stabilisers can also be used to enhance durability and resistance to **UV and chemi**
be increased by adding **plasticisers**.

Pigments can be used to add the desired colour, and fragrances can also be adde
desired smell.

Plastic Properties

Thermoplastics

Name	Symbol	Working Properties	Physical Properties
Polyethylene terephthalate (PETE)	01 PET/PETE	• Resistant to chemical corrosion • Fully recyclable • Tough and durable • Low cost	• Lightweight • Clear (transparent) • Can be easily coloured
High-density polyethylene (HDPE)	02 HDPE	• Hard • Stiff • Resistant to chemical corrosion	• Lightweight • Opaque, but can be translucent • Can be easily coloured
Polyvinyl chloride (PVC)	03 PVC	• Hard and tough • Resistant to chemical corrosion and weathering • Can be flexible or ridged • Low cost	• High-gloss finish • Coloured
Low-density polyethylene (LDPE)	04 LDPE	• Flexible • Tough • High strength to weight ratio • Resistant to chemical corrosion and weathering	• Clear (transparent) • Can be easily coloured
Polypropylene (PP)	05 PP	• Flexible • Tough • Resistant to heat, chemical corrosion and weathering • Fatigue resistant • Easily cleaned	• Can be translucent • Can be easily coloured • Lightweight
High impact polystyrene (HIPS)	06 PS	• Hard • Ridged • Tough • Impact resistant	• Can be translucent • Can be easily coloured • Lightweight
Acrylic / Poly-methyl methacrylate (PMMA)	07 Other	• Tough • Brittle when thin • Easily scratched	• Can be very clear (high optical qualities), translucent and opaque • Can be easily coloured • Lightweight • Smooth finish

Name	Symbol	Working Properties	Physical Properties
Acrylonitrile butadiene styrene (ABS)	07 Other	• Tough • Hard • Good chemical resistance	• Opaque • Smooth finish
Nylon polyamide	07 Other	• Durable • Low friction	• Opaque • Smooth finish • Can be easily coloured

Thermosetting Plastics

Name	Working Properties	Physical Properties	
Melamine formaldehyde (MF)	• Hard • Brittle • Heat resistant • Resistant to chemical corrosion	• Lightweight • Smooth finish • Can be easily coloured • Opaque	• Butto • Picni • Kitch • Lami
Urea-formaldehyde (UF)	• Hard • Brittle • Heat resistant • Very good electrical insulator	• Smooth finish • Limited colours available, usually white • Opaque	• Elect • Adhe • Ofte
Araldite®/ Epoxy resin (ER)	• Strong • Resistant to wear • Heat resistant • Good electrical insulator	• Smooth finish • Can be easily coloured • Very clear	• Circu • Surfa • Casti • Used • Adhe • Suppl hard hard
Phenol formaldehyde (PF) resin	• Hard • Ridged and brittle • Heat resistant • Very good electrical insulator • Resistant to chemical corrosion	• Can have a high-gloss finish • Limited colours • Opaque	• Elect • Pan h • Used • Ofte
Polyester resin	• Brittle • Tough when added to glass fibre • Heat resistant • Good electrical insulator	• Smooth finish • Can be easily coloured • Very clear	• Car b • Surfa • Casti • Used • Suppl hard hard

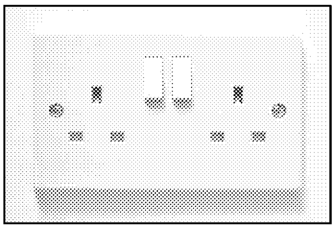
Biodegradable Plastics

Name	Made From	Working Properties	Physical Prop
Polylactic acid (PLA)	Corn kernels or cane sugar	• Fully biodegradable • Easily moulded	• Smooth or textured fi • Can be eas coloured
Polycaprolactone (PCL) Polymorph (62 °C) Coolmorph™ (42 °C)	Biodegradable polyester	• Fully biodegradable • Low melting point • Easily [illegible] at low temperature	• Off-white • Translucen
Biopol/ Polyhydroxybutyrate (PHB)	Fermented [illegible]	• Fully biodegradable • Easily processed and moulded • Can suffer from chemical corrosion	• Can be translucent • Can be eas coloured • Lightweigh

Case Study – Polymer Seating

This garden seat is made from polypropylene. It has been injection moulded (see S *Techniques and Processes* section) which means that the relatively complex shape h produced using only one method stage of manufacturing. This means that the pro process is simple, quick and high volumes can be produced. Polypropylene has be chosen because it is strong, durable and resistant to weathering and chemical cor All these properties are important for furniture that is going to be used outdoors. T manufacturer can also choose to add stabilisers to help make the plastic more res **UV degradation**. Polypropylene is also lightweight and can easily be coloured. Th the customer can easily handle and move the seat and they are able to reflect a p style or taste by choosing the colour they want.

Case Study – Electrical Fitting



This electrical fitting is made from urea-formaldehyd which means lots of the same unit can be produced smooth and it is white in colour and opaque. This m décor within a house. Most importantly, urea-forma **insulator** which means that it does not conduct elec electrical shocks.

How to Shape and Form

Forming and Reforming

Plastics can [illegible] heating them to a **softened** or **molten** state. They can t a **mould or** [illegible] The tools and processes that are used to do this are explained i *Techniques and Processes* section.

Thermoplastics can be **reheated and melted** and softened repeatedly which mea after they have been initially formed. Thermosetting plastics cannot be reformed. A thermosetting plastics will **burn** instead of softening or melting when exposed to h plastics are **hard to recycle**. New thermosetting plastics are being developed that **Casting** is an example of forming plastic. Plastic is heated until it becomes molten **mould** and then it is left to **cool and harden**. When the plastic is cooled, it is rele finished. Industrial forms of casting include injection moulding and rotational mou

Deforming plastic involves heating **sheets of plastic** to soften it and then **applyi** over a **form** to produce the desired shape. Deforming techniques and processes i forming, press moulding and blow moulding. In blow moulding, the force is applie to the walls of the mould.

Wastage and Addition

Wastage means to cut away material to get the desired form, whereas addition de adding material to make the form required.

Wastage methods include **perforation**, **cutting**, **milling**, **drilling**, **turning**, and **s** achieved with a variety of hand tools and machinery. They work best on plastics w thermosetting plastics. This is because the heat produced from the friction can me melting temperatures. This makes the process more difficult and less neat.

Addition techniques involve Rapid prototyping as well as **temporary** and **perma** for plastics can include screws, nuts and bolts which are all **standard component** **welding**. Plastic welding involves using a heat gun to liquefy a rod of plastic and u two surfaces together as it cools. Bonding plastic is achieved by using adhesives t plastics. It can involve adding chemicals which **dissolve** the surface of the plastics surfaces are held together, the dissolved surfaces become fused as they dry, this m foamed plastics as it dissolves the structure. Other adhesives include epoxy resin w product which when mixed, hardens and fuses plastic surfaces together.

Rapid prototyping is also a method of manufacture through addition. There are t prototyping which form plastics in different ways: **3D printing**, selective laser sinte These processes all use different methods of building a **3D object** from **layers**. Th using **CAD**. These files can be made anywhere in the world and sent to any rapid p These methods are often used for prototyping and testing but it costs too much a for industrial manufacturing.

3D printing involves heating a plastic filament and extruding it to create one layer built up to create the full 3D shape.

Selective laser sintering uses a bath of plastic in powder form, a laser is used to m create a layer of a 3D object. Another layer of powder is added and then the laser object. This process is repeated until the layers build up to create the 3D object. T it for different materials. Metals, glass and ceramics can also be printed using this

Stereolithography is similar to selective laser sintering but a photosensitive resin i plastic in powder form. The resin hardens when it is exposed to the laser beam, cr built up.

Questions: Using and Working with Materials

1 Identify **two** physical properties of materials. (2 marks)

2 Identify **two** working properties of materials. (2 marks)

3 Identify how plastic can be modified to make it more resistant to UV

4 Which statements are **true** and which ones are **false**? (6 marks)

1. Polyethylene terephthalate (PETE) is often blow moulded
2. Polyvinyl chloride (PVC) can be flexible
3. Acrylic (PMMA) is a thermosetting plastic
4. Melamine formaldehyde (MF) is a thermosetting plastic
5. Epoxy resin is only available in opaque and white
6. Living hinges are typically made of polypropylene

5 Explain why polypropylene is an appropriate thermoplastic for seatin

6 Explain why urea-formaldehyde is an appropriate thermosetting plas (4 marks)

Keywords

Brittle – The tendency for a material to snap if bent.

Conductivity – A material's ability to let heat or electricity travel through it. Goo material easily lets heat of electricity travel through it. Bad conductivity means th travel through it and therefore it is a good insulator.

Fatigue – The effects on a material or product after it has been used, bent and s period of time.

Insulator – A material's ability to stop heat or electricity from travelling through i heat or electricity cannot travel through it. A bad insulator means that the materi travel through it, therefore it is a good conductor.

Molten – A material that is in a liquefied state due to being exposed to heat.

Opaque – The material doesn't let any light through, you cannot see through it.

Optical qualities – Good optical qualities means that the material is very clear a screens, safety glasses and other products that need to be seen through.

Permanent fixing – Fixings that cannot be opened after the materials have bee bonding and welding.

Physical properties – The nature of the product or material, how the product is, l

Pigments – Additives used to alter the colour of plastic material.

Plasticisers – Additives that can be used to improve the flexibility of plastic.

Resistant – A material that does not degrade or corrode.

Strength to weight ratio – Strong materials are usually heavier, like metals. How strong and lighter. This means they have a good strength to weight ratio.

Temporary fixing – Fixings that can be removed or undone, such as buttons, Vel

Translucent – The material is cloudy or only lets some light through.

Transparent – The material is clear.

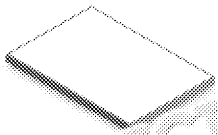
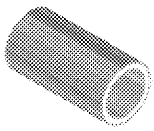
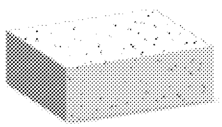
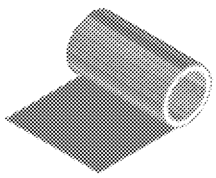
UV degradation – Some plastics degrade when exposed to UV light over time. T colour, become brittle and eventually break down.

Weathering – The effects on a material or product when it is left in the elements f

Working properties – How a material reacts to use or an environment.

Stock Forms

Stock forms are how plastics can be bought for manufacture. Plastics come in man shows all the different stock forms that are commonly available, which dimensions are used for. Having many different stock forms readily available makes it easier a products.

Stock Form	Appearance	Dimensions Sold By	
Sheet		length × width × thickness	The bui
Rod		length × diameter (ø)	Buil stru com
Tube		length × diameter (ø) × wall thickness	Buil com
Powder		weight	Pla
Granules		weight	Pla
Foam		length × width × thickness	Fille
Films		length × width × gauge thickness	Pro

Standard Components

Standard components are parts of a design that can be bought **'off the shelf'**. Usi design helps to keep costs down and make the design easier to assemble. This is b have to be designed or manufactured and existing tools can be used to assemble t type/style of screw is devised, a corresponding screwdriver has to be designed and

Screws

Plastic components are often designed to snap together, or they can be glued tog bond. Plastics can also be fixed using screws. There are different types of **screw**, th **screws**, **wood screws** and **self-tapping screws**. Machine screws and self-tapping s plastic. Machine screws require a hole to be made in the plastic which is tapped in must have screw threads (the grooves to hold the screw in place) inside it. Self-tapping screws don't require the hole to be drilled first because the threads on the screw are sharp and carve out its own thread as it is screwed into the material. A **pilot hole** may still be drilled to help guide in the screw. Another difference between machine and self-tapping screws is that the self-tapping screws have a sharp point and machine screws don't. The sharp point on the self-tapping screws helps to pierce the plastic it is being screwed into.

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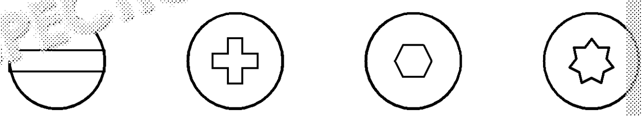
The type of screw head can vary. The main types include Slotted, Phillips, Allen and Torx®.

Screws can also have different shaped heads. Round head screws will sit proud on top of the material while flat head screws will sit flush to the surface providing a countersink hole is drilled first.



Slotted   Phillips   Allen   Torx®

Nuts and Bolts
Nuts and bolts can also be used to fix plastic components. A bolt has a thread like a screw but often has a thicker shaft and a hexagonal head, sometimes with a slot. This is so they can be fixed with a wrench or spanner. A bolt must be paired with a nut. The nut is threaded on the inside and secures the bolt.

Hinges
There are many types of hinge. Some hinges are made of plastic, while some are m commonly made of metal. Some are purely practical, while others have decorative

Hinges are used to attach one component to another while allowing a range of mo often 180°.

Hinges can be attached to plastic using screws, nuts and bolts, or adhesive.

A butt hinge is a standard, purely functional hinge. There are variations on this styl which is a longer hinge intended to span the length of the hinged component.

A flush hinge is another practical style of hinge which has a thin profile because th closed, creating only one layer of thickness when the hinge is closed instead of tw

A plastic or glass door hinge allows the material to be clamped into place instead c hinge in place. This is beneficial for brittle materials which might lose strength or c Butterfly hinges are purely decorative. It works in the same way as a butt hinge, bu used for decorative effect.

Living hinges are unique to plastic, specifically polypropylene. This is a hinge that Polypropylene is very flexible and resistant to wear, and so it can be bent and unfo showing wear. Living hinges **are not standard components** because they are par extruded separately and then attached to plastic components, these are called pla

Questions: Stock Forms, Types and Sizes

1 Identify **two** stock forms of plastic. (2 marks)

2 Identify **two** standard components. (2 marks)

3 Which stock form is used for vacuum forming? (1 mark)

Keywords

Diameter – The measurement across a circle.

Gauge – The thickness of plastic film.

Length – The measurement of the longest side of a product, component or materi

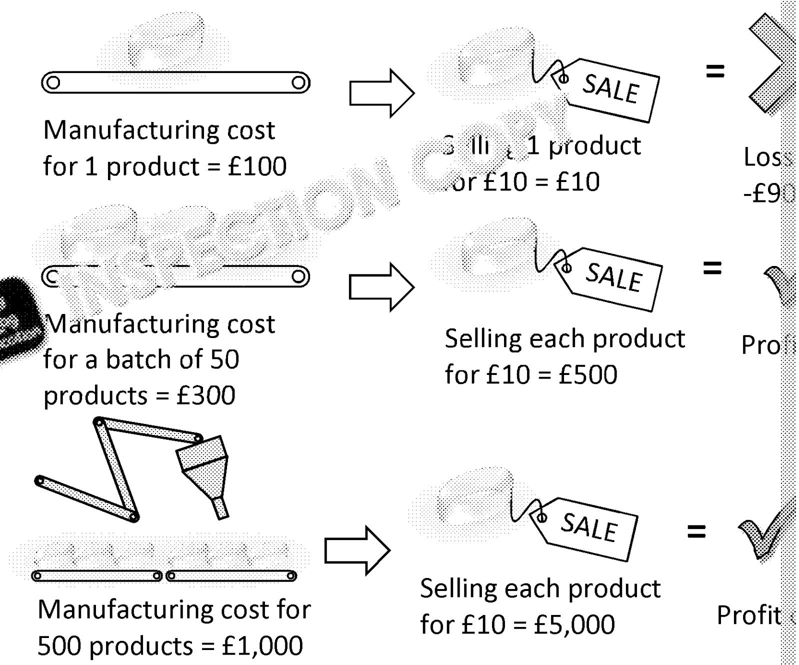
Off the shelf – Something that can be bought or sourced somewhere else, as opp scratch. This includes standard components such as screws, nuts and bolts which wi manufactured and used to make a product.

Pilot hole – A hole that is drilled to help guide a screw into the correct position a

Width – The measurement from side to side of a product, component or material.

Scales of Production

The **amount of units** being manufactured is called the scale of production. The te materials can differ if one product is being manufactured compared to thousands affected by scale of production. As more products are produced, the cost per unit margins per unit.



The scale of production should be taken into consideration when designing a prod manufacture should be made in a way that reduces the amount of assembly requi

Another benefit of mass production is bulk-buy discounts. When buying materials offered when buying large amounts. This reduces the cost per unit for the materia manufacturing costs.

Prototype

A prototype is a **functioning** and **aesthetically correct** version of a design. Proto design ideas and to demonstrate the product to manufacturers, clients and invest important part of the design process. There are many design problems and oppor when a physical version of a design is realised. To be the most useful, a prototype product as possible. This means using the right materials, processes, measuremen sometimes this is not possible; for instance, if a product is designed to be mass m injection moulding is chosen as the manufacturing method. Making a mould and i will cost a huge amount. alternative materials and techniques like **3D** prototype to ... possible to the design while still being **viable**.

Prototypes are made to **identify problems** and help with the design process. This prototype will probably be produced during the design process. Prototypes are m and altered, and then another prototype is produced until the product is ready fo

The prototyping process might not be hugely expensive but the cost per unit will highly labour intensive.

One-off Production

One-off production is when a single product is made and it is unique. It can either
specific client preference. This type of production is normally reserved for high-en
dresses, jewellery or **bespoke** furniture. This type of production is very expensive b
time-consuming and requires a skilled craftsperson to create it. This high cost tran
However, the client or customer can usually expect an entirely unique, high-quality

Batch Production

When a number of products are made for a certain amount of time it is called a ba
have to be a small amount but it will be a **specified amount**, usually dictated by e
limitations or ability to store stock.

Batch production also means that products that are similar or the same, but with d
produced. For example, a travel coffee mug might come in yellow and blue. The ba
produced first and then the blue mugs would be produced using the same moulds
material.

Production aids such as templates, moulds, patterns, jigs, and formers are used in
produce identical and consistent products. Batch production can be completed by
batches. For bigger batches, automation can be used. Automation helps to create
Machines cost less to run than paying human workers for the same amount of wo

The production lines producing batches of products need to have the ability to be
change to allow for changing product colours, making changes to production or t
produce a completely different product. The aim is to be able to **quickly change** a
the production line is not making products. **CNC** (computer numerically controlle
time it takes to change over.

Mass Production

Large quantities of products being produced over a **long period** of time is calle
production products are usually products that are not likely to change much and t
more permanent than in batch production. Mass production can also involve asse
standard components. Mass-produced products can include packaging, cars and m

A lot of **automation** is used to produce large quantities of **identical products** in t
effective way. Any workforce that is used is often low skilled and low paid, with the
required to operate and maintain the machinery.

Processes like injection moulding, blow moulding and rotational moulding are ofte
This is because these methods incur a lot of initial costs; for instance, making the m
high cost becomes affordable when it is spread over lots of units.

Vacuum forming, line bending, press forming and die cutting are also used in mas
these processes are automated to make them more efficient.

Continuous Production

Continuous production is similar to mass manufacturing but the production line is
day, **every day**. The production line is very rarely halted at all and it is highly, if no
aim of continuous production is to produce a **high volume** of products for the **lo**
continuous production line would be very expensive initially, but by producing suc
are minimal and profit margins will be high.

It is normally stock forms of material that are produced through continuous produ
sheets, plastics granules. Extrusion is a commonly found manufacturing process in
This is because material can be continuously fed into the extruder and the approp
having to stop the process (see *Specialist Techniques and Processes* section).

Questions: Scales of Production

1 Which scale of production is 3D printing often used for? (1 mark)

2 Explain why automation is often used in mass or continuous producti

3 Identify **two** things that a prototype can be used for. (2 marks)

Keywords

Automation – Processes and functions being per[illegible] y robots and machinery

Batch – A specified amount of products [illegible] roduced for a limited time.

Bespoke – A product that is [illegible] e to [illegible] der, for a specific customer, client or use.

Computer numeri[illegible] rolled – Tools that automated and operated by mac

**Continuo[illegible] roduction process that is constant. It operates 24/7 producing h possible c[illegible]

Mass – A large amount of products produced over a long period of time.

One-off – A single product that is unique and is not recreated.

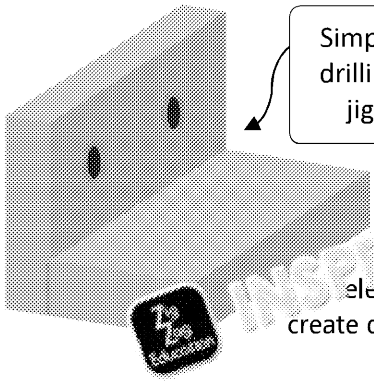
Profit margins – How much money is left after all the costs have been taken out.

Prototype – A functioning and aesthetically correct version of a design used to te

Viable – A product that will be successful and will make enough money to cover i

The Use of Production Aids

Production aids such as templates, jigs and forms can all be used during plastic production processes. Production aids help to keep **consistency** and ensure **accuracy** during the production processes.



Simple drilling jig

Jigs are used to help shape plastics into the desired shape. They are often used when line bending acrylic to achieve the correct angle or curve. Jigs are often made from wood, they can be a simple form that the material is clamped onto or they can have a fixed element and an adjustable element to create different angles accurately.

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Templates are used to translate and recreate shapes and dimensions accurately w repeatedly. When drawing round a template onto plastic, chinagraph pencils and s These methods of making marks are preferable because they can be easily remove

Forms are essential for thermoforming techniques such as vacuum forming. The fo final shape will be. The form should be made from a material that is unaffected by wood, metal or clay. The forms used for processes like vacuum forming should hav is because the finish will translate into the plastic forms. The forms used for vacuu holes drilled into any recesses to ensure that the vacuum can pull the plastic shee

Tools, Equipment and Processes

The following pages outline the processes used for manufacturing plastics. These p **reforming** techniques. All of these processes use specific machinery. Moulds, form use these processes, producing these also requires the use of tools and equipmen

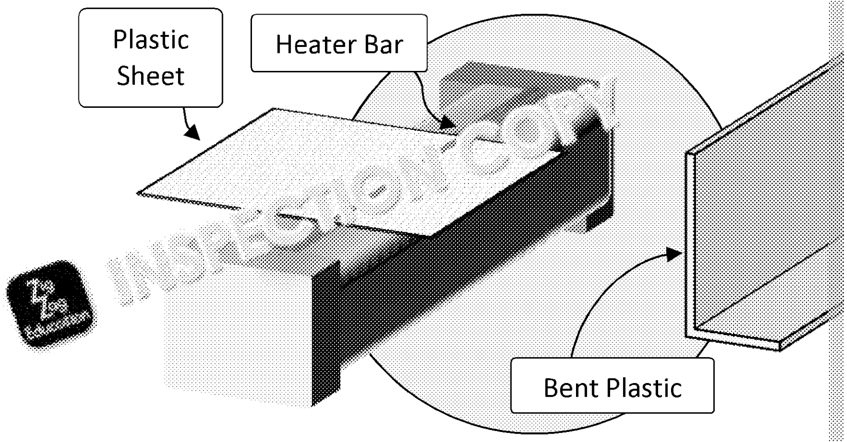
The **commercial processes** include Blow Moulding, Injection Moulding, Extrusion processes are performed commercially as opposed to in the workshop because th equipment and creating metal moulds to use to make plastic parts is very expensi costs can be justified is by mass-producing products and splitting the high tooling

These processes are usually automated to make them as efficient and cost-effectiv require a few qualified technicians to maintain and load the machines with materi

Line Bending

A wire is heated (heater bar) and plastic sheeting is held over it. This softens the pl enabling it to bend. The plastic is then often fixed into jigs (see above) to cool to e and shape.

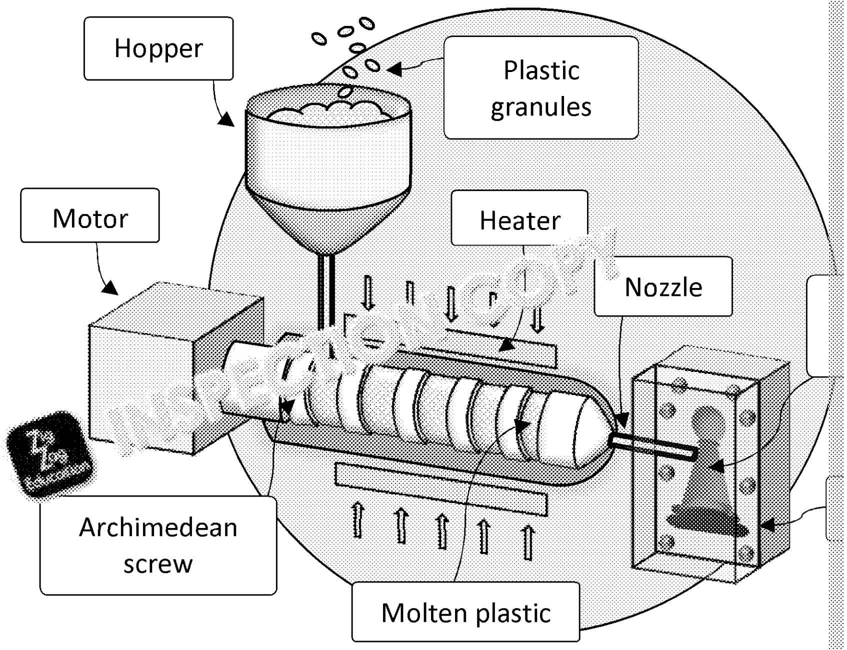
Examples of Products	Tooling Cost	Production Volume
Trays, stands, displays.	Low	Prototype/Batch



Injection Moulding

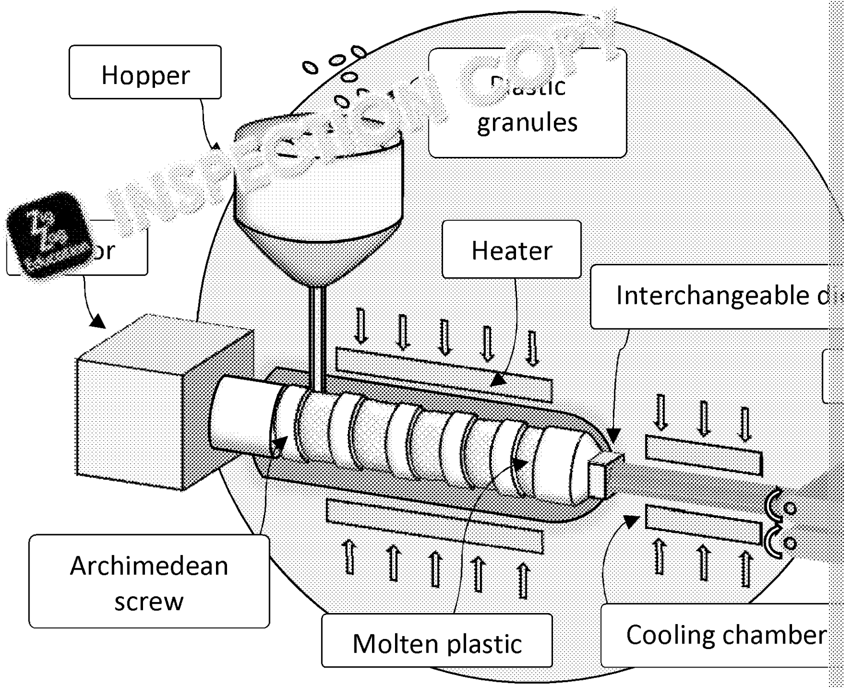
Plastic granules are poured into a hopper, the hopper feeds the plastic into a heate Archimedean screw. This screw pushes the melting plastic through the heating cha (sprue gate), into the mould. When the plastic fills the mould it is rapidly cooled, th finished plastic form is trimmed and finished.

Examples of Products	Tooling Cost	Production Volume
Complex shapes such as LEGO®, chairs, phone cases, etc.	High	Mass/Continuous



Extrusion
Initially this process is similar to injection moulding (see above). The difference bei into a mould, the molten plastic is forced through an interchangeable die. A die is shape that is being formed, for example if you want a circular tube the die has a ro pulled as it emerges from the die to stop it from bending. The plastic is then rapid desired length.

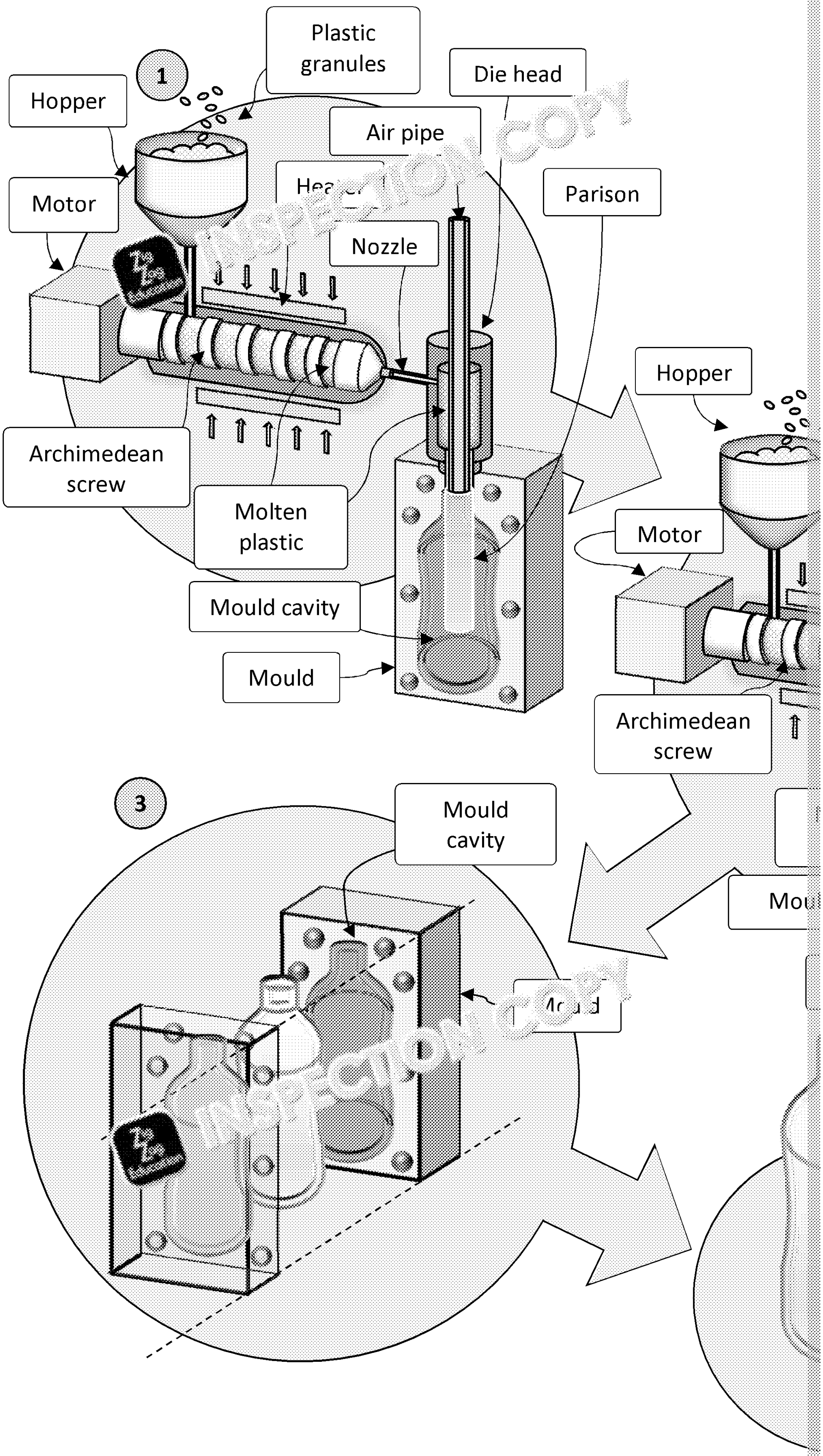
Examples of Products	Tooling Cost	Production Volume
Pipes, gutters, films, sheets, tubing, etc.	Moderate	Mass/Continuous



Blow Moulding

Initially the process is similar to injection moulding and extrusion. However, after t the nozzle (sprue gate), it is formed into a tube of semi-molten plastic (a parison) a (1). Air is pumped into the tube to expand it and make it fill the mould (2). The two separated and the moulded plastic is released (3), cooled and trimmed (4).

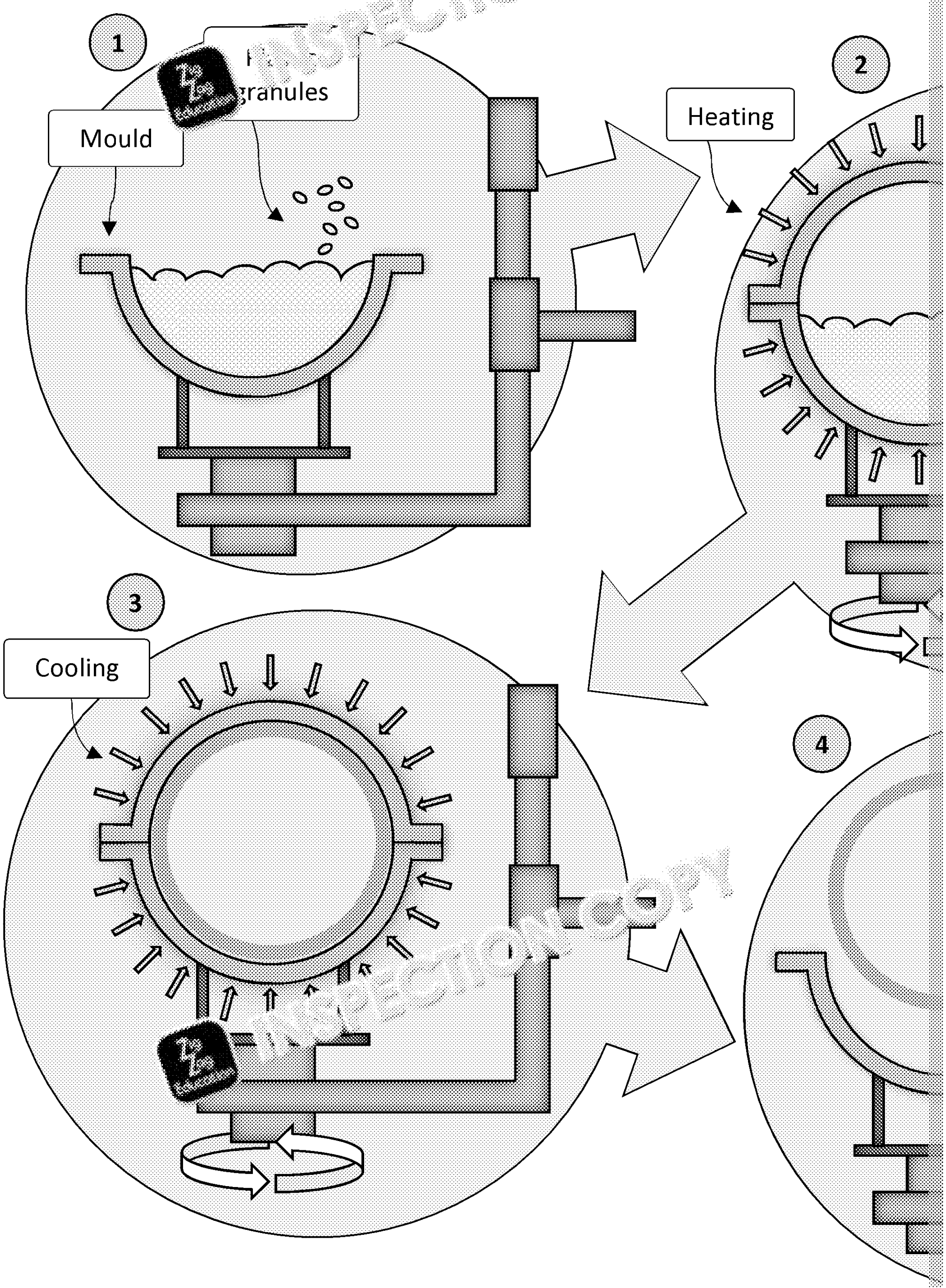
Examples of Products	Tooling Cost	Production Volume
Plastic water bottles	High	Mass/Continuous



Rotational Moulding

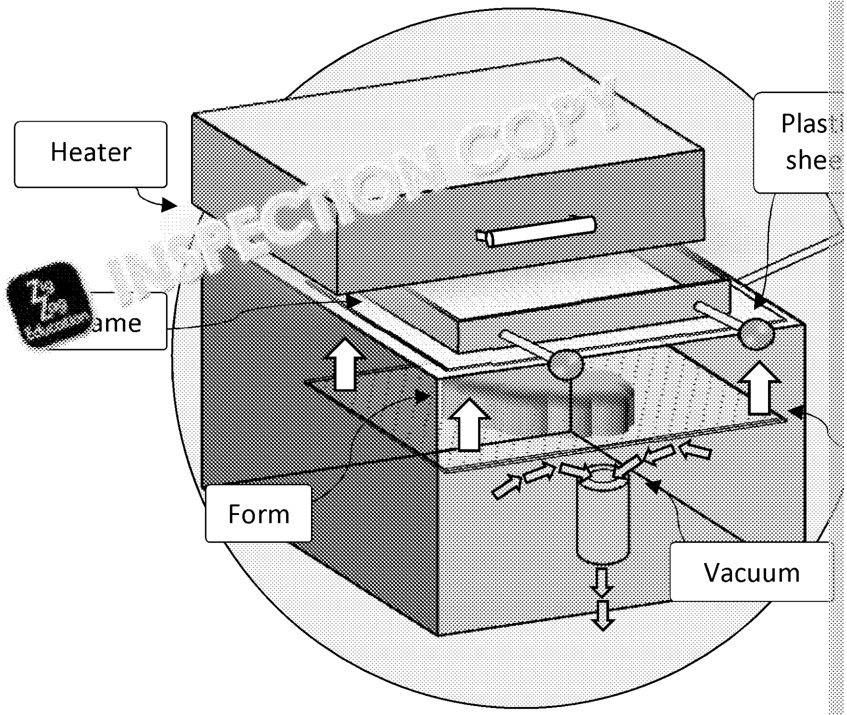
A little bit of plastic is poured into a mould (1). The mould is then closed, put into a
on two axes while being heated (2). This melts the plastic and distributes it around
mould is cooled while it is still rotating to ensure an even coverage (3) and then th
the mould and finished. (4)

Examples of Products	Tooling Cost	Production Volume
Products that have a uniform wall thickness, such as containers, tanks, kayaks and ping-pong balls	Moderate to Low	Batch/Mass



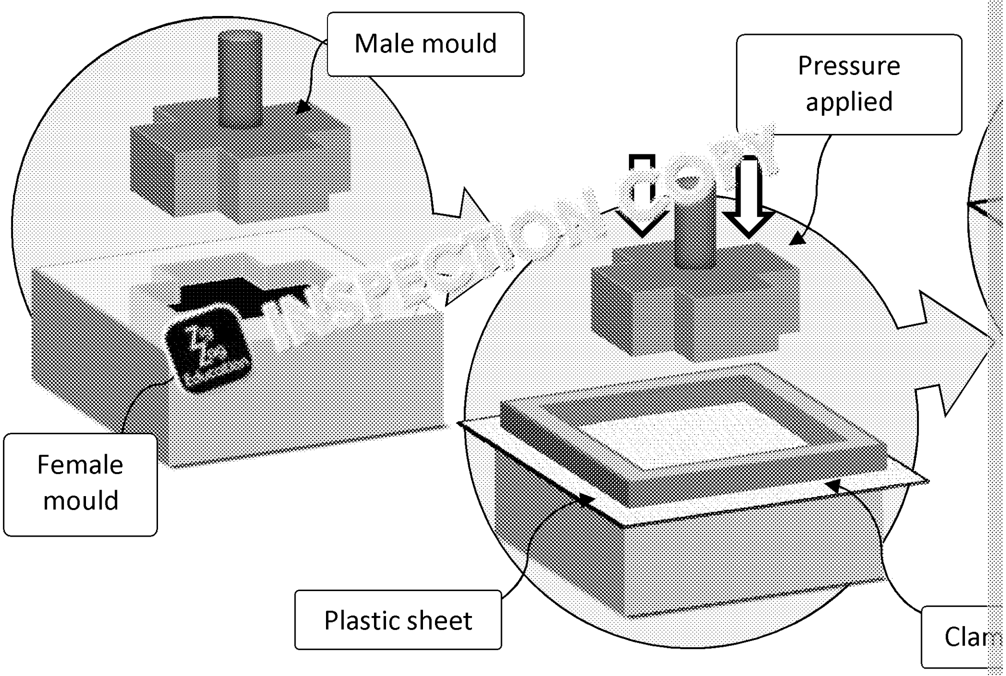
Vacuum Forming
A form is prepared which is the inverse of the shape that the plastic will be. A plas machine, clamped by a frame to make sure it doesn't move and heated to soften i form is raised so that the plastic drapes over it and then a vacuum is applied to pu form. The plastic is then cooled and the form is removed. The plastic is then trimm

Examples of Products	Tooling Cost	Production Volume
Trays, pots and packaging	Low	All



Press or Compression Forming
Similar to vacuum forming but is used to form thicker plastics and simpler shapes. parts, a male and female mould. These parts sandwich around a softened sheet of of the form.

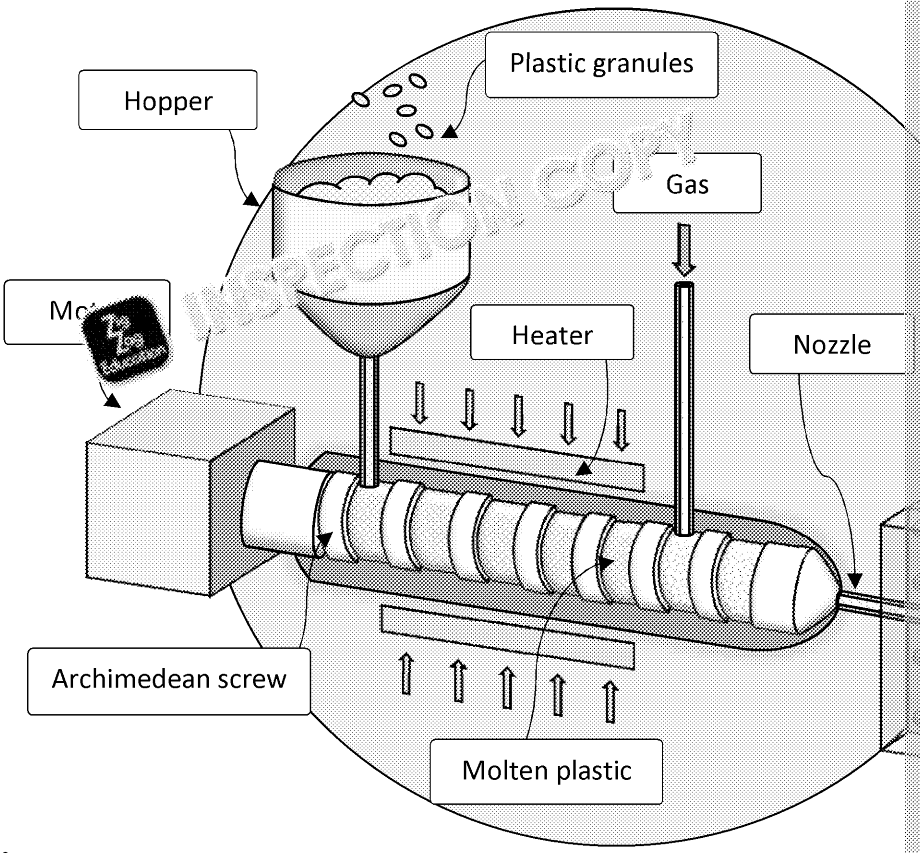
Examples of Products	Tooling Cost	Production Volume
Trays, pots and packaging	Low	All



Foaming

A very similar process to injection moulding with the exception that gas is injected Archimedean screw and mixes into the molten plastic before it is forced into the m the plastic which turn into spaces when the plastic cools.

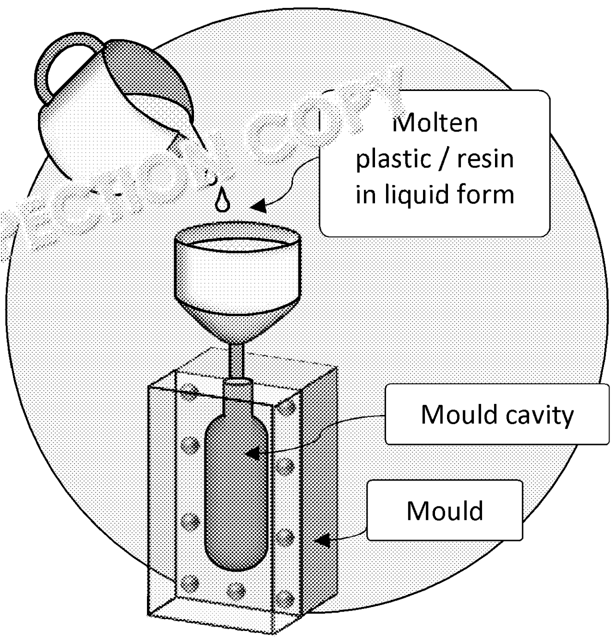
Examples of Products	Tooling Cost	Production Volume
Polystyrene packaging	Medium	Mass/Continuous



Casting

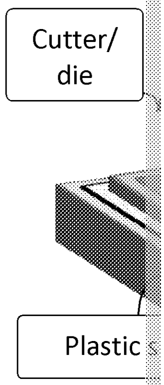
Plastic in liquid form is poured into a mould and left to set.

Examples of Products	Tooling Cost	Production Volume
Silicone or resin products/ parts, jewellery, etc.	Low	Prototype/Batch



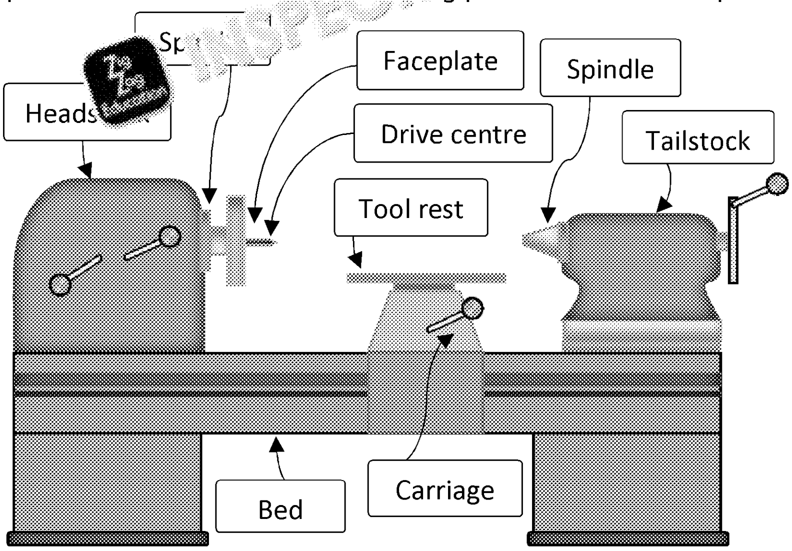
Wastage techniques for plastic materials include:

- **Die cutting** is a commercial cutting process that presses a metal shape into the materials to cut it out (much like a cookie cutter). The machine is called a 'cutting press' and the shaped blade is called a 'cutting die' or 'tool'.



- **Perforating** just means lots of small holes to help the user tear a line. Think the join between bin bags on a roll or between sheets of cling film. Perforation machines can be automated or operated by hand. They can look like paper guillotines but instead of a blade, there is a wheel with teeth to cut the perforations.

- **Turning** is not only for wood! Plastics can be turned too. Thermosetting plast they don't soften and deform under the heat of the friction that is created. Th process is called a lathe. When turning plastics, it is often helpful to cool the m



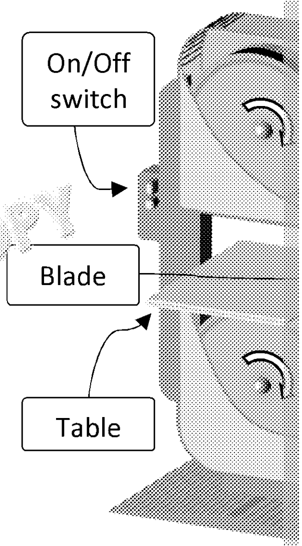
To use a roughly mounte materia The bla and/or d two spi clampe headsto spins). A lathe, a into the shape. T and fini sandpa the mat

- **Milling** is the process of using milling 'bits' (the cylindrical cutting blades tha material, often used to make grooves and slots. There are two types of millin vertical. The difference is the direction of the cutting bits. The horizontal bits cut wide channels and mill full surfaces. They spin on the horizontal axis whereas the vertical bits spin on the vertical axis. Vertical bits can create holes like a drill bit and also carve out material, channels and slots. The material is clamped into the bed of the milling machines. The machine bed can be adjusted on the x-axis (side to side) and y-axis (back to front). The spindle, which holds the cutting tool, can be moved along the z-axis (up and down). The bit can also be moved up and down using a lever (just like on a pillar drill), which means that the mill can be used to drill holes too. Milling machines are often computer numerically controlled (CNC). These machines can automatically move and change tools.

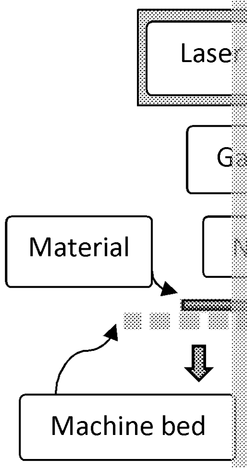
- **Drilling** is the process of making holes in a material. It can be done using hand tools, an electric drill or a pillar drill. A pillar drill is a drill, mounted to a pillar, which has a table to hold the material. The material is clamped securely to the table and the table can be adjusted to meet the drill. The drill can be pulled directly down with a lever. Using a pillar drill ensures that the hole will be drilled vertically. The material can also be clamped to the table using a jig to ensure consistency and accuracy in the measurements. A jig can also be used when using an electric or manual drill.

- **Cutting and sawing** can be achieved using many tools depending on the thi plastic being cut. Hand tools such as scalpels, craft knives and even scissors c of plastics and plastic films. Thicker plastic sheets, tubes, pipes and foams can machine saws such as a bandsaw or rotary saw. Laser cutting can also be used Acrylic and PETG. However, it can melt some types of plastics and therefore d

- **Bandsaws** are the most commonly used machine saw in the workshop. It has a long strip of metal with teeth on one side. The strip of metal is made into a band which is fed into a pulley system. The pulley system is attached to the motor which turns the pulley, feeding the blade down and round, inside the machine and then down again to cut the material. The guard that covers the exposed blade should always be adjusted to the correct height, goggles should always be worn, hair and loose clothing should be tied back and material should always be fed in a controlled way to avoid it jumping against the blade. All bandsaws are also fitted with an emergency stop button which applies a break to the blade, so that in the event of an accident the blade can be stopped immediately.



- **Laser cutters** are machines that use a laser to cut and engrave sheet materials. The material needs to be loaded onto the materials bed. The laser should be told where the edges of the material is so that the laser does not go off the edge. A set of cutting instructions are loaded into the laser cutter in the form of a drawing produced using CAD. Different colours are used to tell the machine which line should be cut and which lines should be engraved. Engraving is achieved by moving the laser along the line at the fastest speed with the least power. Full cuts will need a slower speed at a higher power. However different materials will need different power and speed settings, these can vary from machine to machine.



  When laser cutting plastic, the machine should be well ventilated and the len laser should be cleaned to increase accuracy.

  Kerf allowance should be taken into consideration when drawing the cutting l will remove some material as it cuts, the material that is removed is called the different amounts of material to be removed, from 0.1 mm to over 1 mm. Wh the kerf allowance for the machine that will be used should be found out and the parts might be cut too small. The kerf can become wider if the laser is no cutters have auto focus fitted but they might still need to be adjusted to achie etch.

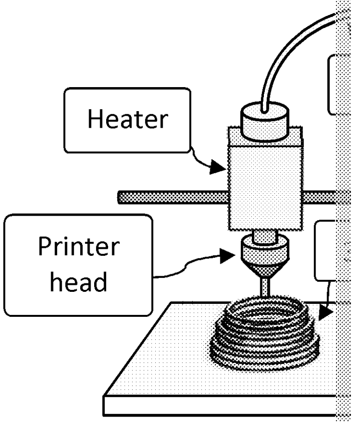
- **Sanding** helps to create a smooth finish to a material or component. To sand grits of sandpaper should be used. The coarsest sandpaper should be used fi Sandpaper has a number to indicate how coarse it is. The higher the number, Wet and dry sandpaper is a sandpaper that can also be used with water. The and material that is removed during sanding, this helps to prevent build-up o cause deep scratches which ruin the sanded surface.

  A belt sander can be used to remove more material, faster. A belt sander is a standing machine that has a belt made of sandpaper, which is attached to a p attached to a motor. The result is a fast-moving surface of sandpaper that ca material when it is held against it. Take all the relevant safety precautions wh machinery, especially wearing goggles, masks and tying up loose clothing and machine is good for taking down the surface of a material quickly but to get a on a prototype hand sanding is the best technique.

- **Files** can also be used to smooth the surface of plastics. Files are a tool, often looks like a rod with a handle. They also have a rough surface and can be used away small amounts of material from another surface. They come in many siz profiles to help create the surface finish required. The fact that files are ridged create cleaner, straighter finishes.

Addition techniques for plastic materials include:

- **Rapid prototyping** is a term that can be used to mean 3D printing, stereolithography printing and laser sintering.



  These processes involve creating one layer of a 3D object. The layers are built up to create the full 3D shape. Rapid prototyping is often used for prototypes, custom-fit prosthetics and dental retainers. This manufacturing technique has high costs, both in time and money, per unit, so is only used for manufacturing one-off or small quantities. However, it is a very useful tool for producing prototypes in plastic for testing.

- **Welding** plastic can refer to two different processes. Plastics can be chemical adhesive such as Tensol cement (dichloromethane). The solvent melts the sur are held together until the solvent dissipates and the plastics will fuse togeth a hot air gun to melt two plastic surfaces and holding them together at which together. Only thermoplastics can be joined using heat welding plastics usin commercially. In a school workshop, chemical welding and other adhesives ar

- **Bonding** refers to using adhesives to join plastic components together. Whe surfaces need to be prepared by cleaning and degreasing. The surface should sandpaper this will create a stronger bond.

Health and Safety

Health and safety precautions should always be followed when operating machine
but also for the **safety of others** in the workshop. Each machine and tool will have
follow including emergency stop buttons, adjustable guards and safety equipmen
identified and followed before using the machine or tool.

Common health and safety precautions that should always be followed include:

- Tying long hair back to avoid it getting caught or obstructing vision.
- Wearing goggles when needed to avoid particles getting into eyes.
- Wearing breathing protection including dusk mask to avoid breathing in part
- Ensuring that the appropriate ventilation is switched on. This is especially imp which can release toxic fumes during manufacture.
- Securing loose clothing and protecting clothing with aprons or workshop ove
- Wearing appropriate shoes in the workshop to avoid injuring feet. This means should be covered and trip hazards should be avoided.
- Being aware of emergency procedure and location of first aid kits and trained

> **Top Tip!**
> Risk assessments are a great thing to include in your design projects. They are evidence that you consider health and safety within your projects.

It is important to carry out **risk assessm** environments. You should identify the ri is at risk, decide how risky the situation/ rating is a good, clear way to do this), re risks throughout the process / working i

A good way to identify the possible risks are using is to **read the instructions an** product/tool. This will inform you of the need to use the product/tool in a well-ventilated area, what personal protection yo have an accident. If you are unsure how to use something or what you should do t then avoid using it until you can ask a responsible adult and confirm the precautio

If you feel uncomfortable or under confident while using a machine/tool or substa **Do not put yourself or others at unnecessary risk.** It is also good practice to kno power shut off, exit and first aid kits are located.

Material Management

It is important to use material as **efficiently** as possible. Using materials efficiently will **minimise waste**, reduce costs and be more environmentally friendly. This can be done using material management techniques.

These techniques include **nesting**, recycling waste materials and trimming and sanding oversized parts. Nesting is used when shapes are being cut from material. The shapes should fit together, or be nested, to make the best use of the material and to make sure there are the fewest gaps possible between the shapes.

During manufacturing of products using thermoplastics, the waste material from the manufacturing processes can be gathered, melted and fed back into the production processes. This reduces the overall waste and costs of the manufacturing.

Products or parts that are slightly too big for purpose can be trimmed, sanded or filed to fit within the **tolerances** *(see quality control and tolerances section)* of the design. Trimming or sanding to make it work is often more efficient than remaking a part of product from scratch.

All of these techniques should be used during the manufacturing process to ensu in the most efficient way possible.

Quality Control and Tolerances

Tolerances are the **minimum** and **maximum** sizes that a product or component c sometimes to be functional.

Tolerances are usually expressed like this: **+/-2 mm**. This example means that the r under by up to 2 mm – no more, no less. If the measurements fall within this tolera used or sold. If not, it will have to be fixed or remade. Tolerances are implemented method, this means it can be measured.

A designer and manufacturer will decide what the acceptable tolerances are. Some older equipment can lead to having to allow for higher tolerances. Or if you are ma might want to have higher tolerances because, mostly, you will be less accurate tha manufacturing is now fully automated which means that tolerances are often very s

Quality control is an important part of the manufacturing process. It helps to iden the manufacturing process and materials. It also ensures that the customers receiv happy with, and that is safe to use and will not break prematurely. Quality control s and should have **quantitative** and **measurable** outcomes, such as testing tolera

For plastic products that are cut using a laser cutter, dimensional accuracy can be i correct laser settings are used. The laser cutter also needs to be kept clean and mai

If the wrong laser settings are used it can lead to engraving marks being cut throu surface or cuts only being etched. There might also be a higher amount of kerf, an plastics, the edges could melt or distort, and burn if using thermosetting plastics. T tolerances and creating an unusable part.

Questions: Specialist Techniques and Processes

1 Give **three** examples of products produced using extrusion. (3 marks)

2 Write step-by-step instructions for vacuum forming. (8 marks)

3 Explain why injection moulding is used as a commercial process and
(2 marks)

Keywords

Accuracy/accurate – Correct or precise.

Addition techniques – To make so... ...ng by adding material as opposed to re... bonding components togeth... ...r rapid prototyping techniques.

Archimedes screw – A screw system inside a cylinder that is turned by a moto... to travel ... the cylinder.

Commercial processes – Manufacturing processes that are used in an industrial s... tooling costs and capable of producing high volumes of products.

Consistency – The same or similar. Products in the same batch should have consis...

Deforming – Take a stock form, such as sheet material, and use thermoforming m... forming, to make it into the required shape.

Extrusion – A manufacturing process where molten plastic is then pushed through required shape, and then cooled and cut to length.

Injection moulding – A manufacturing process in which granules of plastic are p... chamber to melt them. Molten plastic is then forced into a mould.

Measurable – An action or object for which a size or amount can be recorded.

Quality control – The process used to determine whether a product is up to the s... that don't meet the standard are discarded.

Quantitative – Actions, objects or data that are measured or the amount counted quality of it.

Reforming – Reshaping an existing material/product by softening them (using he... to harden.

Tolerances – The minimum or maximum measurement that a component or part c... the design.

Wastage techniques – To make something by removing material as opposed to a... or carving.

Surface Treatments and Finish

Most plastics are **self-colouring** and are resistant to weathering and corrosion. M
used for plastic products are purely **aesthetic** choices. However, there are finishes
functions for products. For example, a rubberised spray finish can help provide a g
vinyl decals or printing techniques can be used to apply labels or signs to help the

Preparing the Surface

Before finishing plastic, the surface should be prepared. The surface should always
remove dirt, dust, oil and fingerprints. If the surfaces are not cleaned, the finish wi
smooth as it could be, and will not be as durable or protective.

The smooth reflective surface of plastic can sometimes hinder the durability of a fi
are applied, like paint, it can be important to slightly sand the surface in preparatio
surface that the paint will stick to and be less likely to chip off.

Polishing

Polishing is used to produce a high-shine finish and **high-quality** appearance. Hig
shine surfaces are achieved by **sanding** the surface with a series of sandpaper grit
from harsh to a superfine grit, to completely smooth the surface. Then the surface
buffed, often using a cotton wheel and cutting compound to create the desired fin

Health and Safety Requirements

- Wear gloves/mask and eye protection when sanding to avoid coming into co
- Protect clothing.
- Tie up loose hair and clothing when using the cotton wheel.

Printing

Heat transfer printing / sublimation printing and **hydrographic printing** are b
techniques for printing onto plastics. Heat transfer printing involves printing an im
onto **special paper**, placing the image face down onto the surface and applying h
the reverse which transfers it to the surface of the plastic. This technique can also b
to print designs onto fabric.

Hydrographic printing allows a graphic design to be applied to a **three-dimensio**
printed onto water-soluble film which is floated on a **water bath**. The film dissolve
applied and leaves the image on the surface of the bath. The product is **dipped** in
bath, the image is wrapped onto the surface.

For both of these printing techniques the printing surface should be prepared and
process begins, to ensure the highest quality results.

Health and Safety Requirements

- Use precautions when using heat to prepare the surface and transfer graphics
- Wear gloves/mask and eye protection when handling chemicals.
- Protect clothing.

Painting

Plastics are usually **spray-painted** to create an even finish. The finish can also be
improved by cleaning and preparing the surface of the plastic and applying a few c
of **primer** before adding the paint finish. The primer should be left to completely d
then sanded to a fine finish before adding the next layer. The paint should also be
applied in multiple even coats to create a fine surface.

Paint can be delivered using a spray can or via an **air gun** which gives greater con

Health and Safety Requirements

- Use a face mask to avoid breathing in particles.
- Use in a well-ventilated area.
- Keep paint and aerosol cans away from naked flames.
- Protect clothing.

Vinyl Decals

Vinyl decals are shapes and designs that are cut out of a **film** made of vinyl.

To use, the vinyl film is added to a backing paper to keep one side clean from dus often cut out of the vinyl film and backing. The designs ... cut using a CNC cut or hand cut. The backing is peeled off the vinyl film and the design is applied o part or surface. These decals are **self-adhesive** so do not require any extra glue to be applied and smoothed down carefully to avoid forming air bubbles.

Health and Safety Requirements

- Use a safety rule when cutting by hand.
- Take appropriate precautions when using a die cutter / CNC cutting machine

Other Finishing Techniques

Electroplating / Electroless Plating

This creates a **metal layer** over the plastic product, providing the aesthetics of a m weight and manufacturing limitations.

Rubberising Spray

A finish applied in the same way as spray paint but it provides a **textured**, matt fin **grip** on handles or buttons.

Engraving

A **laser cutter** can be used to engrave plastics by cutting into the plastic but not a writing can be engraved onto plastic to create a subtle difference in **texture** and t

Frosting

Frosting can be achieved by adding **texture** to a transparent plastics surface or by plastic more opaque and can **diffuse light** to give a softer glow.

Flocking

Plastic strands are electrostatically charged and adhered to a surface, creating the **texture** of fur.

? *Questions: Surface Treatments and Finishes*

1 Identify two ... graphic printing. (2 marks)

2 Explain the process of spray-painting plastic. (4 marks)

3 Give a reason that flocking might be used. (1 mark)

Glossary

Accuracy/accurate	Correct or precise.
Addition techniques	To make something by adding material as opposed to r bonding components together or Rapid Prototyping tec
Additives	Chemicals, scents and colours added to plastics during th enhance, improve or add properties to the material.
Archimedean screw	A screw system inside a cylinder that is turned by a mo to travel along the cylinder.
Automation	Processes and functions being performed by robots and
Batch	A specified amount of products to be produced for a li
Bespoke	A product that is made to order for a specific customer
Bioplastics	Plastics that are made from natural sources and/or are
Boiling point	The temperature at which a liquid turns into a gas.
Brittle	The tendency for a material to snap if bent.
Bulk-buying	Purchasing more supplies or materials at once to benef
Carbon emissions	The carbon dioxide produced during a process.
Carbon footprint	The effect that a product/process has on the environme
Catalyst	A substance used to increase or activate chemical react
Chemical corrosion	Damage to materials caused by exposure to chemicals.
Commercial processes	Manufacturing processes that are used in an industrial s costs and capable of producing high volumes of produc
Composite material	A combination of one or more materials to make a mat application it is intended for.
Computer numerically controlled (CNC)	Tools that are automated and operated by machines in
Conductivity	A material's ability to let heat or electricity travel throu that the material easily lets heat of electricity travel thr that heat or electricity cannot travel through it and ther
Consistency	The same or similar. Products in the same batch should b
Continuous	A production process that is constant. It operates 24/7 p lowest possible cost.
Cost-effective	Good value for money, getting more for the money.
Cost per unit	How much one product costs to make.
Crude oil	A fossil fuel made from animals and plants that died mi buried deeper and formed into crude oil under heat an
Deforming	Take a stock form, such as sheet material, and use therm vacuum forming, to make it into the required shape.
Designed for maintenance	The practice of designing a product to last for a long ti repaired.
Diameter	The measurement across a circle.
Direction	Which way the force is travelling.
Dynamic load	A force that is moving.
Ease of sourcing	The level of difficulty in finding and purchasing a raw m
Ease of working	How easy a material is to use and manufacture produc
Environmental impact	What effects a product, material or process has on the e negative.
Extrusion	A manufacturing process where molten plastic is then pu cut-out of the required shape, and then cooled and cut t
Fatigue	The effects on a material or product after it has been u prolonged period of time.

Finite	Limited or non-renewable.
Force	The interaction between objects or bodies that creates
Function	What a product does.
Gauge	The thickness of plastic film.
Greenhouse gases	Gases that contribute to the greenhouse effect, causing
Improve flexibility	Adding plasticisers to make a more flexible material w bending or twisting instead of breaking.
Injection moulding	A manufacturing process in which granules of plastic are chamber to melt them. Molten plastic is then forced into
Innovation	New, or never done before. A new way of doing or pr product or idea.
Insulator	A material's ability to stop heat or electricity from travel means that heat or electricity cannot travel through it. A material ... heat or electricity travel through it,
Length	The measurement of the longest side of a product, comp
Magnitude	The size or amount of force.
Mass	A large amount of products produced over a long peri
Measurable	An action or object for which a size or amount can be r
Mechanisms	Parts that work together to create a machine or tool. U enhance an applied force.
Molten	A material that is in a liquefied state due to being exp
Monomers	The single molecules that join to make polymers.
Natural	A material that occurs without human intervention.
Nesting	A technique used to make the most efficient use of a she that need to be cut out closely together so that the leas diagram on page 10.
Off the shelf	Something that can be bought or sourced somewhere el scratch. This includes standard components such as screw bought in by a manufacturer and used to make a prod
Oil spillages	Oil being put into the sea as a result of an industrial ac transport of oil. Considered an environmental disaster w negative impacts on the environment and wildlife.
One-off	A single product that is unique and is not recreated.
Opaque	The material doesn't let any light through, you cannot s
Optical qualities	Good optical qualities means that the material is very c screens, safety glasses and other products that need to
Permanent fixing	Fixings that cannot be opened after the materials have bonding and welding.
Physical properties	The nature of the product or material, how the product
Pigments	Additives used to alter the colour of plastic material.
Pilot hole	A hole that is drilled to help guide a screw into the corr
Planned obsolescence	The practice of designing a product to last for a limited have to buy more / replace the item more often.
Plastic pollution	Plastic that has been disposed of improperly or that ha environment where it may have a negative impact.
Plasticisers	Additives that can be used to improve the flexibility of
Product life cycle	The steps an item goes through, from design to disposa
Product mileage	How many miles a product has travelled from where th the final consumer.
Profit margins	How much money is left after all the costs have been ta
Properties	What a material is or does and how it reacts to forces,

Prototype	A functioning and aesthetically correct version of a des a design.
Quality control	The process used to determine whether a product is up t Products that don't meet the standard are discarded.
Quantitative	Actions, objects or data that are measured or the amou looking at the quality of it.
Refinery	An industrial processing plant where crude oil is made i
Reforming	Reshaping an existing material/product by softening th and cooling to harden.
Reinforce	To make a material stronger by adding layers.
Requirements	What a material must do or be.
Resistant	A material that does not degrade or corrode.
Responsible designer	A designer that considers the environmental impact of a product [illegible]
Social footprint	The effect that a product/process has on the communitie
Stabilisers	Chemicals added to plastics during the manufacturing p more durable and resistant to corrosion and UV degra
Static load	A force that is still / not moving.
Stiffen	Make less flexible to improve strength and make more
Stock form	The shape and sizes that plastics can be bought ready
Strength to weight ratio	Strong materials are usually heavier, like metals. Howe and lighter. This means they have a good strength to w
Stress	The amount of force applied to an area of a material o
Surface finish	The outside appearance of a product and how it has b enhanced.
Sustainable energy sources	Energy sources that are renewable or not limited. For e power.
Synthetic	A material that is not natural but that has been created
Tapping	The rubber tree's bark is cut and the latex drips out. Th
Temporary fixing	Fixings that can be removed or undone, such as buttons,
Tolerances	The minimum or maximum measurement that a compone as part of the design.
Translucent	The material is cloudy or only lets some light through.
Transparent	The material is clear.
Ultimate tensile stress	The amount of force at which a material or object brea
UV corrosion	Damage to materials caused by exposure to sunlight.
UV degradation	Some plastics degrade when exposed to UV light over colour, become brittle [illegible] break down.
Versatile	The ability to be adaptable or used in a variety of wa
Viable	A product that will be successful and will make enough
Virgin plastics	Newly manufactured plastics. Plastics that have been p and not from recycled materials.
Wastage techniques	To make something by removing material as opposed t or carving.
Weathering	The effects on a material or product when it is left in th period of time.
Width	The measurement from side to side of a product, compo
Working properties	How a material reacts to use or an environment.

Mark Scheme

Sources and Origins

1. Up to **4 marks** for explaining the process of producing a synthetic plastic, from prima

3–4 marks	A detailed explanation that shows a good level of understanding of synthetic plastic, from crude oil to the granule stock form of synthet correct and demonstrate the right order of the processes.
1–2 marks	A basic explanation of the process of turning crude oil into a granul explanation should show a basic understanding of the processes an made.
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers, including images and sketches.

- Crude oil extracted from the ground by drilling.
- Crude oil transported to an oil refinery.
- Crude oil is separated into useable products using the process of fractional distil
- Large hydrocarbon molecules are cracked to make monomers.
- Polymerisation happens, monomers are linked together to create polymer chain
- Plastic is then extruded and cut into small granules.

2. Up to **2 marks** for explaining the difference between thermoplastics and thermosettin

2 marks	Identifying two valid differences between thermoplastics and thermo
1 mark	Identifying a single valid difference between thermoplastics and ther
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.

- Thermoplastics can be remelted and reformed if exposed to heat, whereas therm
- Thermoplastics are easier to recycle whereas thermosetting plastics are difficult t
- Thermosetting plastics have more bonds between the molecules.

3. Up to **1 mark** for identifying if latex is natural or synthetic.

1 mark	A valid answer.
0 marks	Nothing worthy of credit.

Answer:
Natural

Selection of Materials or Components

1. Up to **1 mark** for stating how you could make a plastic less likely to degrade in sunligh

1 mark	A valid answer.
0 marks	Nothing worthy of credit.

Answer:
Add UV stabilisers into the plastic.

2. Up to **2 marks** for giving **two** reasons why plastic might be used instead of wood.

2 marks	Identifying two valid reasons that plastic might be used instead of w
1 mark	Identifying a single valid reason that plastic might be used instead c
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.

- Plastics are faster and cheaper to produce than wood.
- Plastic is more durable than wood.
- Plastic is more resistant to weathering than wood.
- Plastic has functional benefits while mimicking the aesthetic of wood.
- Plastic is easier to sterilise than wood.

3. Up to **2 marks** for explaining why it is often cheaper per unit to mass produce a produ production.

2 marks	A valid reason and explanation as to why it is often cheaper per uni opposed to one-off production.
1 mark	A valid reason as to why it is often cheaper per unit to mass produc off production. An explanation is lacking.
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.
It is cheaper per unit to mass produce a product than create a one-off product becaus spread over the units. [1] For example, the fixed costs for production, like producing a units instead of just the one. [1]

Ecological and Social Footprint

1. Up to **2 marks** for explaining why different types of plastics need to be separated whe

2 marks	A valid reason and explanation as to why different types of plastics they are recycled.
1 mark	A valid reason as to why different types of plastics need to be sepa explanation is lacking.
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.
If different types of plastic are mixed during the recycling process then the resulting p plastic and therefore the properties of the plastic might be compromised. [1] If the pr might make the recycled material unusable or only fit for applications that don't requi

2. Up to **6 marks** for correctly identifying the six R's.

1 mark for each correct answer.
Answers:
Reduce
Reuse
Recycle
Rethink
Refuse
Repair

3. Up to **4 marks** for explaining what the term 'social factors' means.

3–4 marks	A detailed explanation that shows a good level of understanding o factors'. The explanation should also demonstrate an understandin possibly by providing examples.
1–2 marks	A basic explanation that shows an understanding of the meaning o
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.
Social factors describe the way in which a product affects the people and communitie [1] This includes looking at if the people involved in the manufacturing and supply ch wage. [1] This is important because some countries do not have strict regulations abo should be paid. [1] In some cases, people involved in the manufacturing of products c their quality of life extremely poor. [1]

4. Up to **2 marks** for identifying **two** ways that plastic pollution could be reduced.

2 marks	Identifying two ways that plastic pollution could be reduced.
1 mark	Identifying a single way that plastic pollution could be reduced.
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.

- Plastics could be more clearly marked to help consumers recycle the plastic corr
- Biodegradable plastics could be used to reduce the amount of plastic waste that
- A designer could reduce the amount of plastics used in a product.
- Incentives could be put in place to encourage people using plastic fishing gear t to retrieve lost fishing gear when possible.
- The products containing plastics could be designed for maintenance as opposed

Forces and Stresses

1. Up to **2 marks** for explaining what torsion is, using an example of when it would occu

2 marks	A valid explanation of torsion and an example of when it would oc
1 mark	A valid explanation of torsion.
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.
Torsion is the force that is caused by turning in opposite directions, causing a twist. [1] a towel. [1]

2. Up to **4 marks** for correctly identifying and explaining two ways that a material can b

3–4 marks	Identifying two valid ways to make a material stronger. A detailed e [illegible] understanding of how the material is made stronger.
1–2 marks	Identifying two valid ways to make a material stronger but the expl way of making a material stronger is identified. 2 marks should be a provided.
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.

- A material can be reinforced by adding layers of the same material or different m stronger by adding thickness, alternating grain to avoid splitting and by combini to strengthen a material. [1]
- Materials can be mixed to create composite materials that are stronger than the fibreglass is a composite material. The material is made stronger by reinforcing i the material lightweight and gives it the ability to be cast. [1]
- Materials can be stiffened by fixing or bonding layers together to create a stiffer more resistant to bending, distorting or ripping. [1]
- Materials can be made more flexible. [1] This makes the material stronger becau by bending and twisting instead of snapping or breaking. [1]

Using and Working with Materials

1. Up to **2 marks** for identifying **two** physical properties of materials.
   1 mark per correct answer.

   Allow all valid answers.
   Answers:
   - Thermal conductivity
   - Electrical conductivity
   - Density
   - Fusibility
   - Absorbancy
   - Melting point
   - Opacity
   - Colour
   - Smell
   - Magnetism
   - Corrosion resistance

2. Up to **2 marks** for identifying **two** working properties of materials.
   1 mark per correct answer.

   Allow all valid answers.
   Answers:
   - Strength
   - Toughness
   - Hardness
   - Elasticity
   - Malleability
   - Ductility

3. Up to **1 mark** for identifying how plastic can be modified to make it more resistant to
   1 mark for correct answer.

   Answer:
   Add stabilisers to the plastic.

4. Up to **6 marks** for identifying which statements are **True** and which ones are **False**.
   1 mark per correct answer.

Statement
Polyethylene terephthalate (PETE) is often blow moulded
Polyvinyl chloride (PVC) can be flexible
Acrylic (PMMA) is a thermosetting plastic
Melamine formaldehyde (MF) is a thermosetting plastic
Epoxy resin is only available in opaque and white
Living hinges are usually made of polypropylene

5. Up to **4 marks** for explaining why polypropylene is an appropriate thermoplastic for s

3–4 marks	A detailed explanation that shows a good level of understanding o polypropylene. The explanation should also demonstrate an unders methods that could be used.
1–2 marks	A basic explanation that shows an understanding of the properties
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.
Polypropylene is an appropriate thermoplastic for plastic seating because it is very durab This means that the seat can be used outside without being damaged by weather or use be injection moulded. [1] This means that identical prod... mass manufactured number of units, making the seating cost-effective to produce. [1]

6. Up to **4 marks** for explaining why urea-formaldehyde is an appropriate thermosetting

3–4 marks	A detailed explanation that shows a good level of understanding o formaldehyde. The explanation should also demonstrate an unders methods that could be used.
1–2 marks	A basic explanation that shows an understanding of the properties
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.
Urea-formaldehyde is an appropriate thermosetting plastic for electrical fittings becau insulator. [1] This means that electricity can't travel through it, protecting the user from formaldehyde can also be injection moulded. [1] This means that identical products ca cost is spread over the number of units, making the electrical fittings cost-effective to

Stock Forms, Types and Sizes

1. Up to **2 marks** for identifying **two** stock forms of plastics.
   1 mark per correct answer.

   Allow all valid answers.
   Answers:
   - Sheet
   - Rod
   - Tube
   - Powder
   - Granules
   - Foam
   - Films

2. Up to **2 marks** for identifying **two** standard components.
   1 mark for correct answer.

   Allow all valid answers.
   Answers:
   - Screws
   - Nuts
   - Bolts
   - Hinges

3. Up to **1 mark** for identifying which stock form is used for vacuum forming.
   1 mark per correct answer.

   Answer:
   Sheet

Scales of Production

1. Up to **1 mark** for identifying which scale of production 3D printing is often used for.
   1 mark for correct answer.

   Answer:
   Prototyping

2. Up to **2 marks** for explaining why automation is often used in mass or continuous pro

2 marks	Identifying a valid reason with an explanation demonstrating a goo
1 mark	Identifying a valid reason only.
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.
Automation is often used in mass or continuous production because it is more efficie
Automation is more reliable than a human workforce – it does not call in sick or need t
mistakes and can work faster. Therefore, it can make more products in a shorter amo

3. Up to **2 marks** for identifying **two** things that a prototype can be used for.

2 marks	Identifying two things a prototype can be used for.
1 mark	Identifying only one thing a prototype can be used for.
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.
- Testing a design idea
- Testing a manufacturing process
- Demonstrating a product idea to investors and clients
- User testing
- Using in a focus group

Specialist Techniques and Processes

1. Up to **3 marks** for identifying **three** products produced using extrusion.
   1 mark per correct answer.

   Answers could include:
   Allow all valid answers.
   - Pipes
   - Gutters
   - Cable casings
   - Drinking straws
   - Plastic sheets
   - Silicone shower door/window trim
   - Plastic tubes

2. Up to **8 marks** for writing step-by-step instructions for vacuum forming.

7–8 marks	Detailed instructions that show an excellent level of understanding forming. The instructions should be correct and demonstrate the ri correct technical terminology should be used.
5–6 marks	Mostly detailed instructions that show a good level of understandin forming. The instructions should be correct and demonstrate the ri correct technical terminology used.
3–4 marks	Simple instructions that show a good level of understanding of the instructions should be mostly correct. Some errors made.
1–2 marks	Basic instructions that show an understanding of the process of va made.
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.
1. Make a form that meets the specifications required for a vacuum forming form. recesses to ensure the vacuum will pull into the recesses.
2. Set up the machine as per machine requirements. Check settings.
3. Put form on platen / machine bed. Make sure the form is centred.
4. Clamp sheet material into machine. Make sure all the edges of the material are c
5. Heat sheet material until soft. Sheet material shouldn't be over heated. The plast
6. Raise platen / machine bed to push form up into plastic sheet.
7. Activate vacuum to suck plastic sheet tightly around the form.
8. Leave the form to cool until it is cool to the touch.
9. Release plastic from machine and form from the plastic.
10. Trim and finish plastic form.

3. Up to **2 marks** for explaining why injection moulding is used as a commercial process

2 marks	A valid reason and explanation as to why injection moulding is used not used in the workshop.
1 mark	A valid reason as to why injection moulding is used as a commerci workshop.
0 marks	Nothing worthy of credit.

Indicative content:
Allow all valid answers.
Injection moulding is used as a commercial process and not used in the workshop be associated with the process. [1] A mould made of metal is needed to make plastic pro machine itself, the costs of housing and operating the machine, as well as the materia process. All these costs have to be spread over a high volume of units to make them v moulding process is only used comnmercially. [1]

Surface Treatments and Finishes

1. Up to **2 marks** for identifying **two** types of graphic printing.
   1 mark per correct answer.

   Answers:
   - Hydrographic printing
   - Heat transfer printing

2. Up to **4 marks** for explaining the process of spray-painting plastic.

3–4 marks	A detailed explanation that shows a good level of understanding o[f] plastic. The explanation should be correct and demonstrate the rig[ht]
1–2 marks	A basic explanation that shows a good level of understanding of th[e] plastic. Some errors made.
0 marks	Nothing worthy of credit.

   Indicative content
   Allow all valid answers, including images and sketches.
   1. Clean and smooth the surface using sandpaper.
   2. Apply one or two coats of primer, letting it completely dry in between. Sand any [...] finish.
   3. Apply multiple coats of spray paint evenly, holding the spray can at a distance fr[om]
   4. Let dry completely, for 24 hours if possible, for it to set properly.

3. Up to **1 mark** for giving a reason that flocking might be used.
   1 mark for correct answer.

   Answer:
   Allow all valid answers.
   To create the look of fur on a miniature scale.