Kibworth Mead Design Technology

Polymers

Polymers (plastics) are one of the two main materials we focus on for this course. The other being Timbers. Whenever you see a question with multiple material options such as:

1 5 **Table 1** shows a range of specific materials.

Table 1

Aluminium	**Cartridge paper**	**High impact Polystyrene (HIPS)**	**Oak**	**Silk**

Choose **one** material from the table above.

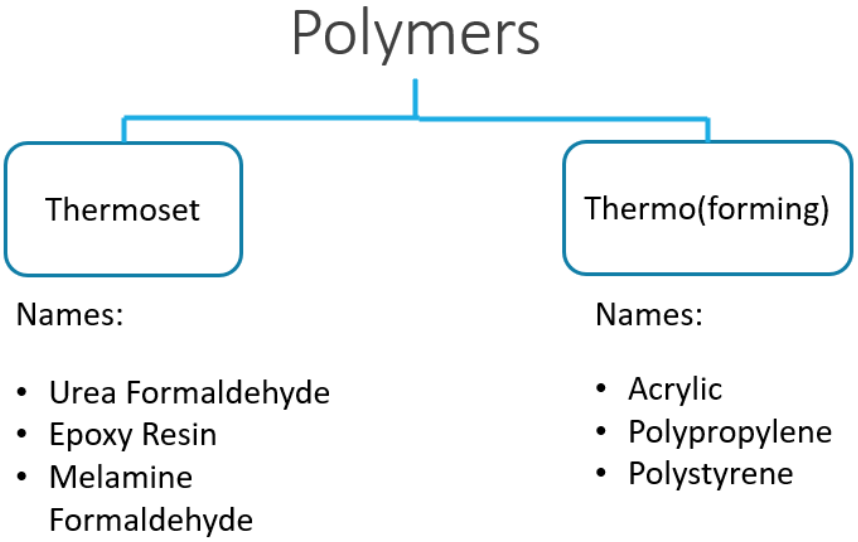
Then you are encouraged to pick Timbers of Polymers depending on how confident you are with the rest of the question.

In this guide it will cover:

- Types, Names and Conversion
- Properties
- Working with polymers
- Finishes

At the back the Do Nows from lessons (with answers) will be included as well as example exam questions. Your teachers will be happy to mark these exam questions for you or you can use the mark schemes on the AQA website to help you.

Types and Names



Timbers come from Crude Oil which is a finite resource and is a non-renewable material source. This means that we can't get more of it and once we have used it all up, then it is gone.

See the Sustainability Revision Guide for more information about how crude oil is processed and isn't sustainable.

The two main categories of polymers are Thermoset and Thermo, sometimes called Thermoforming. The Polymer types behave differently when reheated.

Polymers require heat to manufacture them into products (we will look at this in the next section), however once heated, only one type can be reheated.

Thermoset, as the name suggests, can be heated into shape but then that shape is set and can't be reheated.

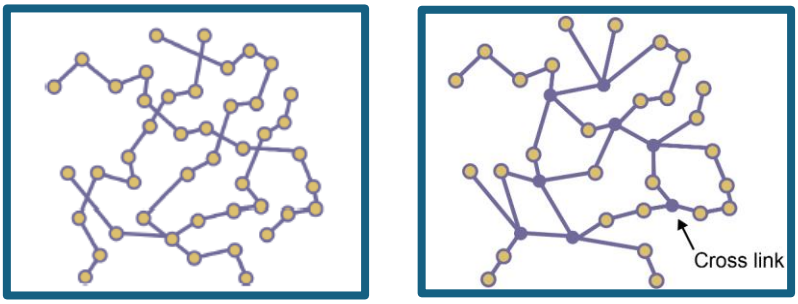
Thermo(forming) can be reheated either into a liquid again to be used or they will return back into a flat sheet.

First, let's look at how crude oil is made into usable plastic.

<u>Conversion - Polymerisation</u>

Plastics are produced by polymerisation. This is when molecules of simple compounds known as monomers join to other monomers to form polymers

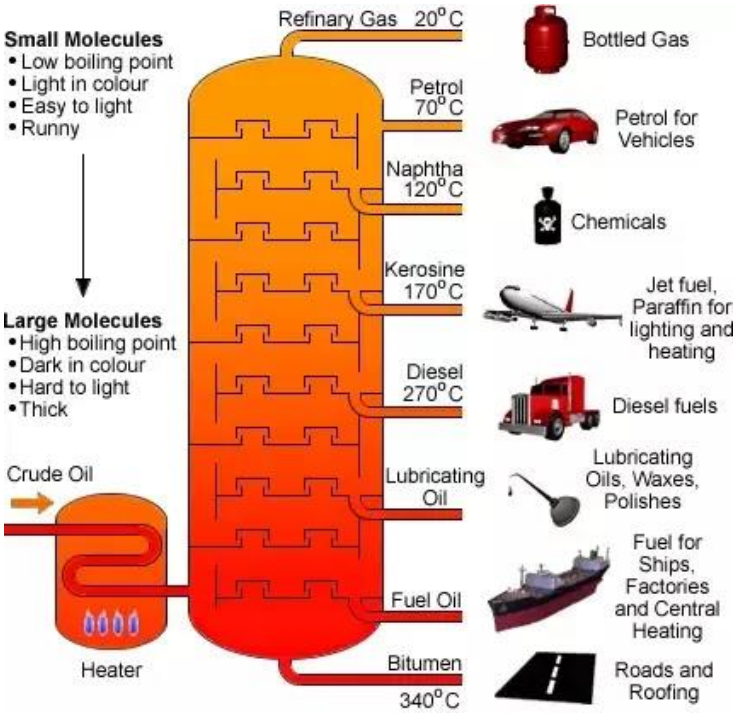
These atoms are joined end-to-end to form long chains. These chains are the building blocks of plastics that we use.



In the diagram above, Thermoset polymers have the cross links – these cross links are what prevent them from moving when heated and stop them melting.

Think back to the Sustainability revision guide and the 6Rs – if they can't melt, this means Thermoset polymers can't be recycled so are more harmful to the environment as they end up in landfill and more crude oil is needed to make more.

We also know from the Sustainability revision guide that crude oil is refined using a process called Fractional Distillation:

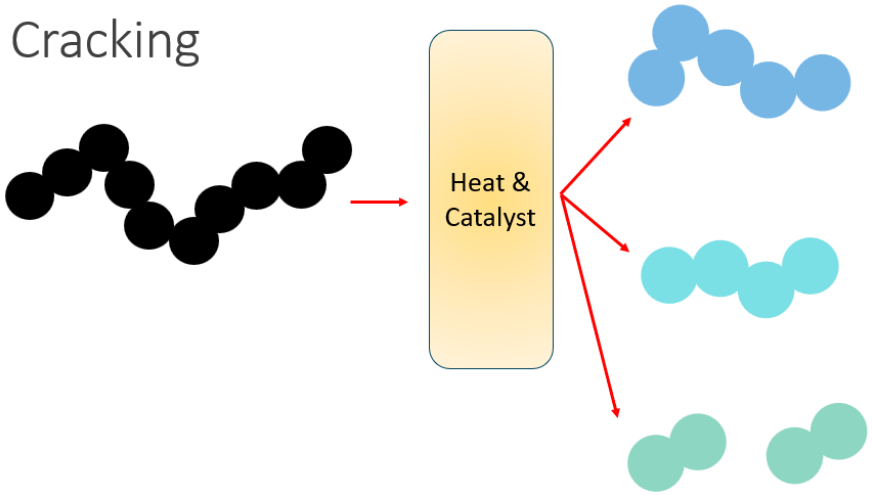


NOTE: You won't need to learn all the text on this diagram, however you might need to draw a basic diagram of the process, showing the different layers being separated.

This process separates the heated crude oil into many different compounds or fluids. Each compound has a different boiling point allowing them to be draw off separately at different stages.

For plastics, the crude oil is refined into large hydrocarbon molecules. These don't flow well however and need to be converted into more useful molecules of petrol, propane and ethene for example.

For this to happen we use a process called Cracking:



NOTE: You will need to learn this diagram and along with the basic fractional distillation diagram, use it to answer any questions about sourcing polymers.

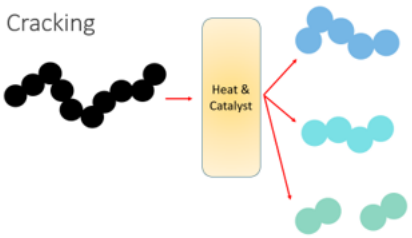
Here is an example GCSE question:

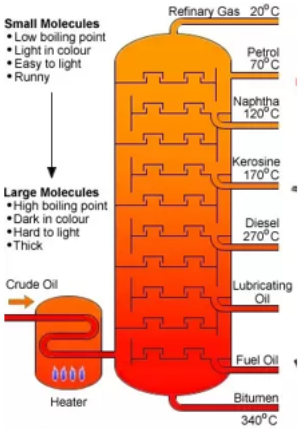
1 9 . 2	Name **one** process used to convert your chosen material category into a workable form. **[1 mark]**
1 9 . 3	Using notes and/or sketches describe the process you have named above. **[4 marks]**

To answer this question, you would answer 'fractional distillation' for 19.2. For 19.3 notice you need to use sketches. You would draw a basic diagram of fractional distillation AND THEN a basic diagram of cracking.

An answer like this would achieve all 4 marks:

1. Fractional distillation is used to convert the crude oil into workable chemicals we use to make polymers.
2. The heat separates the different chemicals in the crude oil as they all have different boiling points.
3. Next the chemicals are converted from long chain hydrocarbons into more usable ones.
4. This process is called cracking and involves heat and a catalyst for the reaction.





With the polymers now ready, we need to turn them into usable stock forms.

Stock Forms

Stock forms are standard shapes and sizes of a material that manufacturers can buy, ready to turn them into products. Stock forms make transportation of the material easier but also make the material easy to cost and sell as well as making it easier for designers to know what shape the material is available in.

Stock forms of polymers are:

- Pellets
- Powder
- Sheets
- Rods

Pellets and sheets are the most common stock form.

Polymer Properties

Firstly, let's look at working properties. These aren't just for polymers. The other materials revision guides (Timbers, Metals etc) will have this list too. Working properties are about how a material performs under a force. We analyse the working properties to see if a material would be suitable for the product and what the product needs to do.

Toughness	A materials ability to withstand fracture when a force is applied to it.
Hardness	A materials ability to withstand surface damage (dent or scratch) when a force is applied to it.
Malleability	A materials ability to be deformed under a force without fracture.
Ductility	A materials ability to be stretched without fracturing.
Elasticity	A materials ability to be stretched or compressed and then return back to its original shape.
Flexibility	A materials ability to be bent without fracture.

Polymers are used because of their ability to be manufactured into complex shapes very easily (explored further in the next section), however they do have some toughness (not as much as timber). They are a durable material they are also very lightweight compared with a material like metal or timber. Polymers also offer water resistance that the other materials don't.

So, when we are selecting polymers, we need to consider:

- Aesthetics – how they look – polymers come in a range of colours.
- Availability – polymers come in a range of different stock forms.
- Working properties
- Cost – polymers are a very cheap material.
- Sustainability – remember, only thermo(forming) polymers can be recycled.

Working with Polymers

In this section we will look at the manufacturing methods we use to shape polymers. As you will know from our polymer experiments, we don't hand craft polymers like we do timbers. They don't cut or finish well due to their

flexibility and in some cases, brittleness. Instead, we use polymers in commercial manufacturing processes:

- Injection moulding
- Blow moulding
- Extrusion
- Vacuum Forming

In the exam, you might be asked to explain a commercial manufacturing process in detail. These questions are usually worth 6 marks, so being able to remember the 5 steps we will look at below and draw a simple diagram of the process could make a big difference to your grade.

Injection Moulding

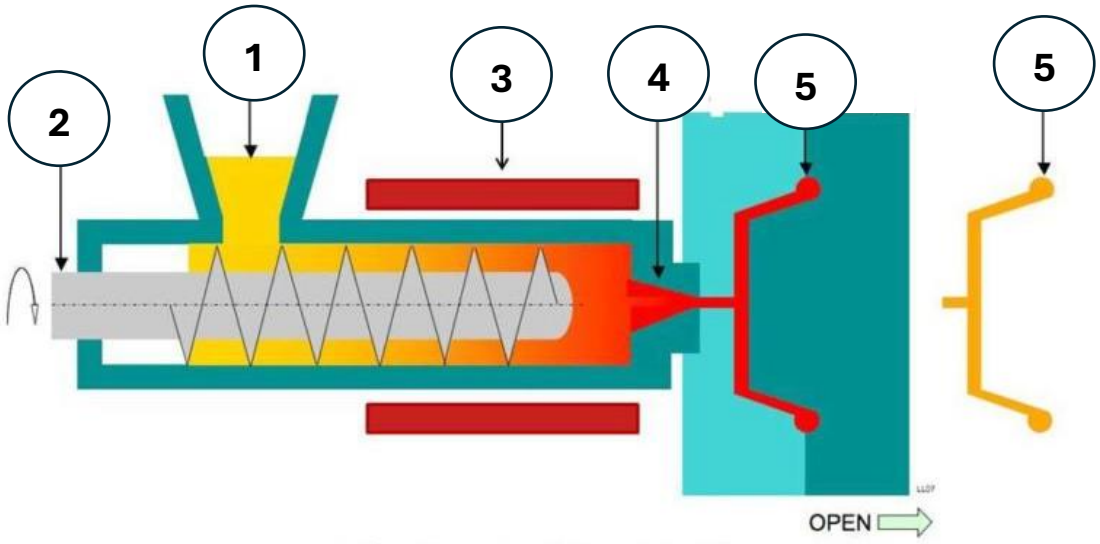
Most plastic products are made using injection moulding. It is used so commonly because of the following advantages:

Speed	Injection moulding can make products in seconds. Larger products can take minutes, but it is one of the fastest ways to make products in industry.
Range	Injection moulding can make lots of different types of products. Chairs, kettles, mobile phones… most plastic products are made using this method.
Complexity	Injection moulding can easily make complex shapes. Shapes that making by hand would take days or weeks can be made easily.
Amount	Injection moulding can make many products at once. Lego bricks can be made in batches of a hundred or so in the space of seconds.

Let's now look at the steps involved in injection moulding.

The process:

1) Plastic pellets are loaded into the hopper
2) The pellets are moved down the machine by a screw
3) Heat melts the pellets into a liquid
4) The liquid is injected into the mould cavity
5) The liquid polymer cools and is ejected to form the product



Injection Moulding Machine

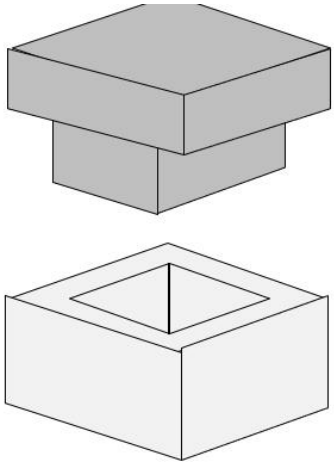
Why do we use pellets or powder though? We use them because they have a small surface area. Thinking about what you have learned in science, the smaller an object is, the less heat energy is needed to melt it. Having small pellets or powder means it requires less heat and will melt quickly so it can be injected into the mould.

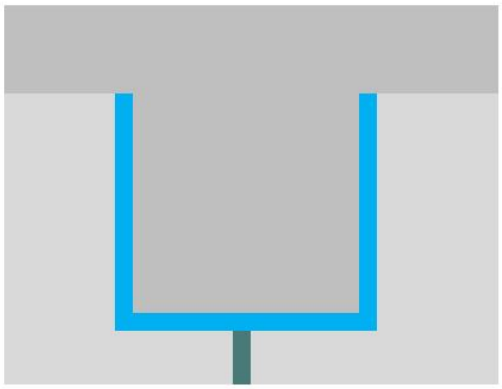
We mentioned before about injection moulding being able to make complex shapes. This is because it uses a liquid! A liquid can get into all the small and fine details of the mould to make those complex shapes.

Injection Moulding - Two Part Moulds

Injection moulding uses a special mould called a Two-Part Mould. As the name suggests, it is made up of two different parts that when they are put together, have a gap inside. That gap is called a cavity, and it is the shape of the product wanting to be formed.

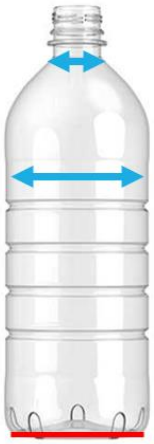
Here is an example of a plastic box made using injection moulding and the two-part mould that might be used to make it:





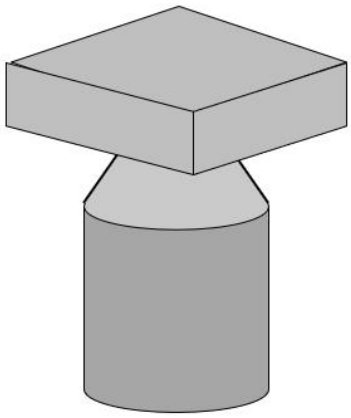
Blow Moulding

Blow moulding is used when injection moulding can't be. Let's have a look at why:



Products such as bottles have a closed bottom and then a top that is narrower than the body… a narrowed top! This means that the Two-Part Mould couldn't be removed if it was injection moulded as that process requires a mould to fill all empty space EXCEPT where the liquid plastic will be injected into.

A Two-Part Mould for blow moulding would look like this:

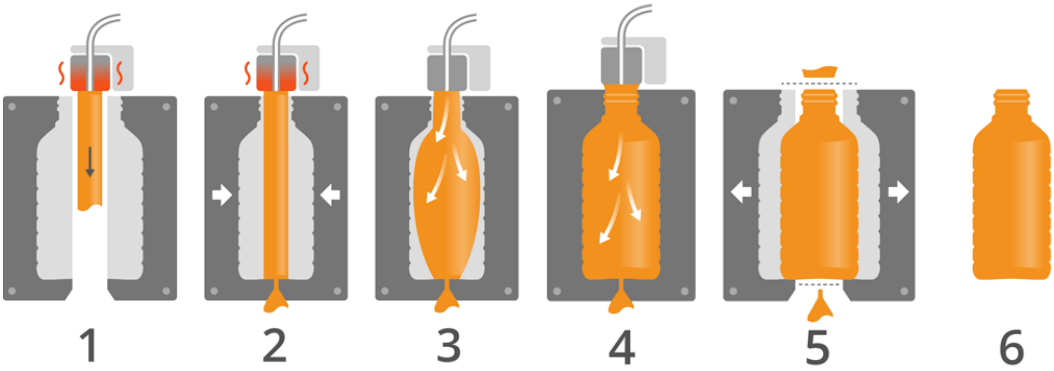


You can clearly see here why it wouldn't work and would be impossible to remove without breaking the plastic bottle – think about when you freeze water inside a bottle… you can't get it out!

Therefore, we need to use blow moulding, and it has the following advantages:

Speed	Blow moulding can make products quickly. It isn't as fast as injection moulding as the parison needs to be made first.
Complexity	Blow moulding can make complex bottle shapes. Shapes that would not be able to be made using injection moulding.

Let's now look at the steps involved in blow moulding:



1) A heated parison is made and put into the mould
2) The mould closes, sealing the parison at one end

3) Air is blown into the parison
4) The parison expands, filling the shape of the mould
5) The product is trimmed to remove waste
6) The product is complete

Blow Moulding - Parison

A parison is simply a heated cylinder of plastic used in blow moulding. The cylinder is made using a process called Extrusion but is then heated to make it soft.

Before a plastic melts into a liquid, it becomes soft and very flexible. This is what we need the parison to be so that it will expand when air is pushed inside it… a bit like a balloon!

Blow Moulding Limitations

Blow moulding can make a range of different shaped bottles; however, it can't make products that are too big!

The bigger the object, the more air is needed to expand the parison and there is a limit to how much air can be pumped in and how much the parison expands.

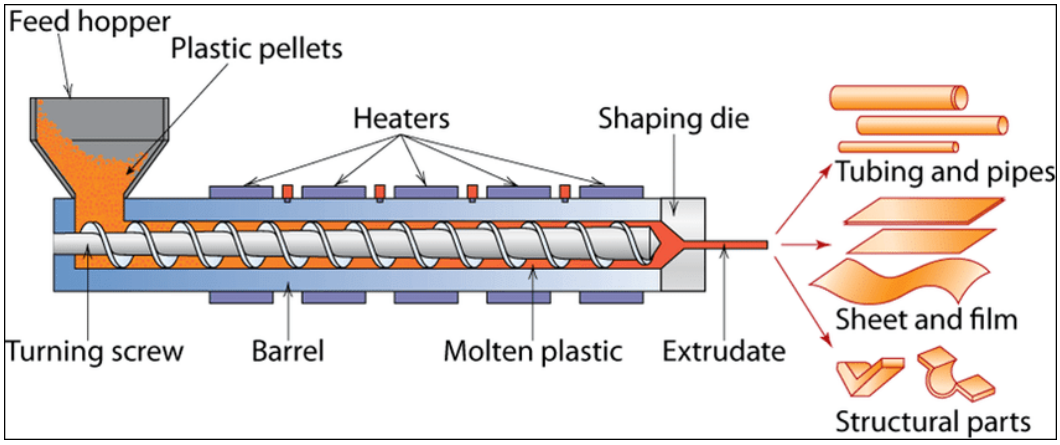
Think about what happens is you blow up a balloon too much. It will burst! The more the parison expands, the thinner it becomes. Eventually it will become too thin and just break.

Blow moulding requires a parison to be made before the product can then be shaped so why make a parison when you can just make a product with injection moulding? That saves time and money!

Extrusion

This polymer manufacturing process is very similar to injection moulding; however, it doesn't use a two-part mould, it uses a die! This is because it is used to make consistent shapes such as tubes, rods, pipes etc.

Here is how extrusion works:



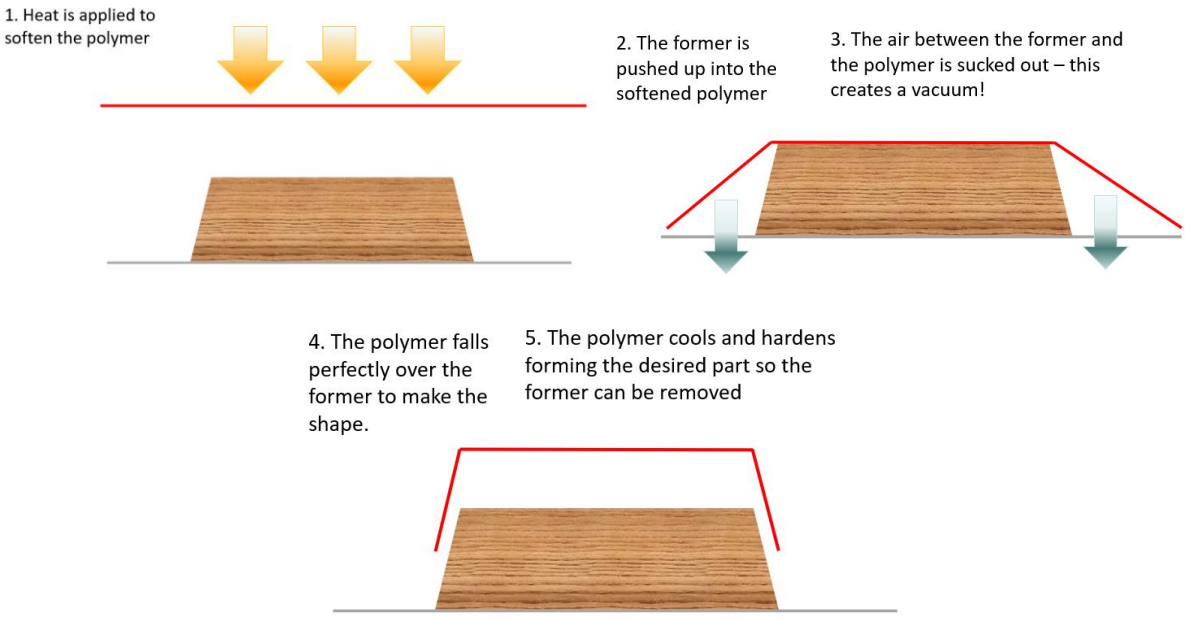
1) Plastic pellets are loaded into the hopper
2) The pellets are moved down the machine by a screw
3) Heat melts the pellets into a liquid
4) The liquid is pushed through a shaping die
5) The extrudate (shaped polymer) cools and is then cut into the desired length

As you can see, the first three points are exactly the same as injection moulding so this will help with your revision!

<u>Vacuum Forming</u>

Not as common in industry as the first three processes, however we use it a lot in school. It creates a 'shell' out of plastic using a former. The most common use of Vacuum forming is in packaging, especially chocolate boxes!

In vacuum forming, the polymer sheet is heated up causing it to soften (not melt!). A former (made from either timber or metal) is pushed up into the polymer sheet and the air between the former and sheet is removed so the polymer falls perfectly over the mould.



If you can remember these 5 steps and draw diagrams like this, you will be able to achieve the 6 marks if you are asked about vacuum forming.

Polymer Finishes

Polymers are very different to timbers. They don't require 'finishes' like paint, varnish etc.

Polymers are made into products using heat so when softened or melted, any scratches in the plastic disappear and polymers have what is called a 'self-finish from the mould'.

A big advantage of polymers is that they are available in a range of colours. This is because different coloured **pigments** are added to the polymer when it is being made (after the cracking process).

Polymers are very resistant materials, they don't react to much, however they do break down in UV light (sunlight). UV (ultraviolet light) can make polymers brittle and lose colour.

Stabilisers can be added into the polymer when it is being manufactured to help prevent how it reacts with UV light.

Adding these and the pigments make polymers available in a range of colours and helps them last longer, especially if the polymer is going to be used outside.

Do Now Questions

What are the two main categories of polymers?

Thermoset and Thermo(forming)

What is the name of the polymer used for plug sockets?

Urea Formaldehyde

Where do we get polymers from?

Crude Oil

Which polymer type can be recycled?

Thermo

Name a stock form of polymer?

Sheet, powder, rod, pellet, tube

What can be added to polymers to stop them reacting to UV light?

Stabilisers

What is the process called when large hydrocarbon molecules are split into usable chemicals?

Cracking

What is the process of turning oil into usable chemicals called?

Fractional Distillation

What do pigments do for polymers?

Add colour

Name a thermos(forming polymer)

Acrylic, Polypropylene, Polystyrene

Why are thermoset polymers not able to be recycled?

Once they have been heated into shape they don't melt down, they just burn.

What polymer manufacturing process is used to make rods, tubes or bars of plastic?

Extrusion

What type of mould is used in injection moulding?

Two part

What type of polymer is Acrylic?

Thermo(forming)

If I wanted to make a sheet of plastic, what polymer manufacturing method would I use?

Extrusion

If I wanted to make a water bottle, what polymer manufacturing method would I use?

Blow moulding

What is the difference between how blow moulding and vacuum forming use air?

Blow moulding blows air into the polymer to make it expand into and fill the mould.

Vacuum forming sucks the air out from between the polymer sheet and the former, so the polymer falls perfectly over it, creating the shape.

What adds colour to polymers?

Pigments

What machine can I use to bend plastic in a straight line?

Line bender

When drilling plastic, what can happen if the drill is pressed too hard?

The plastic can crack under the pressure

What happens when plastic is cut by hand with a saw?

It leaves an untidy finish as the plastic softens and becomes brittle so breaks off easily.

What happens when plastic is sanded using the belt sander?

It begins to melt and leaves an untidy finish.

Why are polymers considered unsustainable when analysing their source?

They come from crude oil, and this is a finite resource. A lot of heat is also needed to turn crude oil into usable polymers and this heat will come from coal (a fossil fuel).

Which polymer type can't be recycled?

Thermoset

What happens to a product when it is recycled?

The product is broken down into its different materials. If those materials can be recycled, then they are heated up and melted so they can be made into more products.

GCSE Exam Questions

June 2023 Paper (Mark scheme - Mark scheme: Paper 1 - June 2023 (sanity.io))

0 4 Which **one** of the following is a thermoforming polymer?

A Epoxy resin (ER) ⬭

B High density polythene (HDPE) ⬭

C Melamine formaldehyde (MF) ⬭

D Polyester resin (PR) ⬭

[1 mark]

1 6 Give **two** aesthetic considerations when selecting materials and/or components to make prototypes.

[4 marks]

Consideration 1 _____

_____

_____

_____

Consideration 2 _____

_____

_____

_____

1 8 Choose **one** commercial process from the table below.

Paper and board die cutting	Wood turning	Metal casting	Polymer extrusion	Textile weaving	Electronic pick and place assembly

My chosen process is _____

1 8 . 1 Name a **specific** main material used with this process.

[1 mark]

_____

1 8 . 2 Name a stock form of the material used in your chosen process.

[1 mark]

_____

1 8 . 3 Give **two** reasons that make your chosen process suitable for commercial manufacture.

[4 marks]

June 2022 Paper (Mark scheme - Mark scheme: Paper 1 - June 2022 (sanity.io))

1 2 High density polyethylene (HDPE) is widely used in the manufacture of household bottles and containers.

Give **two** detailed reasons why HDPE is suitable for this type of packaging.

[2 x 2 marks]

2 1 Materials frequently have to be deformed and reformed.

Choose **one** product from **Table 3**.

Table 3

		
Metal toy car	**Birthday card**	**Polymer toothbrush**
		
Cotton skirt	**Plywood chair**	

My chosen product is _____

2 1 . 1 Name a specific deforming or reforming process used in the manufacture of your chosen product.

[1 mark]

_____

_____

2 1 . 2 Explain why this process is used in the manufacture of your chosen product.

[2 marks]

_____

_____

_____

_____

November 2021 Paper (Mark scheme - [Mark scheme: Paper 1 - November 2021 (sanity.io)])

1 4 **Table 2** shows a range of products.

Table 2

		
Mail packaging	**Baseball bat**	**Screwdriver blade**
		
Baby's drinking cup	**Gym wear**	**Electronic device with display**

Choose **one** product from **Table 2**.

1 4 . 1 Name the specific main material/component of your chosen product.

[1 mark]

_____

1 4 . 2 Name **one** property of the material of your chosen product.

[1 mark]

_____

_____

1 4 . 3 Describe why the property is needed for the product to function properly.

[2 marks]

_____

_____

_____

_____

1 7 **Table 4** shows examples of manufacturing processes.

Table 4

Offset lithography	**Turning**	**Casting**	**Injection moulding**	**Weaving**	**Flow soldering**

Choose **one** of the manufacturing processes from **Table 4**.

Use notes and/or sketches to describe how your chosen process is used to make products.

[6 marks]

My chosen manufacturing process is _____