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GCSE (9–1)

Delivery Guide

DESIGN AND TECHNOLOGY

J310
For first teaching in 2017

Topic Area 5: Material considerations – Polymers

Version 1

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Introduction

GCSE (9–1)

DESIGN AND TECHNOLOGY

A guide to approaching the teaching of the content related to Topic Area 5: Material considerations – Polymers

Delivery guides are designed to represent a body of knowledge about teaching a particular topic and contain:

- **Content:** A clear outline of the content covered by the delivery guide;
- **Thinking Conceptually:** Expert guidance on the key concepts involved, common difficulties learners may have, approaches to teaching that can help learners understand these concepts and how this topic links conceptually to other areas of the subject;
- **Thinking Contextually:** A range of suggested teaching activities using a variety of themes so that different activities can be selected which best suit particular classes, learning styles or teaching approaches.

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Link to qualification:

http://www.ocr.org.uk/qualifications/gcse-design-and-technology-j310-from-2017/

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Specification content (Sub Topic 1)

Sub Topic 1: Core consideration of polymer materials

Exam content

5.1 What are the main categories of materials available to designers when developing design solutions?

Understanding that products are predominantly made from multiple materials.

An overview of the **main categories** of materials as follows:

d. Thermo and thermosetting polymers, including:

- **i.** thermo polymers, e.g. PET, HDPE, PVC, LDPE, PS, PP, ABS, acrylic and TPE
- **ii.** thermosetting polymers, e.g. silicone; epoxy resin and polyester resin.

NEA content

a. Develop and apply in-depth knowledge by selecting and working with appropriate materials and components when developing their ideas, early models and producing their final prototype(s).

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Thinking conceptually

General approaches:

Learners should recognise that very few products are manufactured from just one material, and that the purpose of using multiple materials is that a product will benefit from the properties and characteristics of the individual material choices. In this way, products can be made in such a way that they can outperform products that previously were made with less considered choices of materials. However, they will also recognise that using fewer or even a single material for products makes them exceptionally easy to process at their end-of-life, and that wherever possible, the reduction of materials and methods used to join them will give a final product eco design characteristics.

It is important that learners are able to understand and identify the difference between thermo polymers and thermosetting polymers. Exploring both types in turn, rather than exploring both at the same time, certainly allows learners to understand and grasp the differences between both.

It is useful to explore the chemical composition of both thermo and thermosetting polymers but depending on the level of the teaching group, this may be explored at varying levels.

For learners only looking into the core content related to polymers, having knowledge of the two types of polymers and being able to exemplify some materials is all that is required at this point.

Those that are following and 'in-depth' pathway that incorporates polymers will need to be able to be more specific in their knowledge of polymers and be able to apply it to specific materials, processes and contexts. It is important for these learners to understand that thermo polymers have single polymer chains which allow for greater flexibility when forming and recycling. Whereas thermosetting polymers have a larger number of overlapping or intertwined polymer chains which, in turn, allow for a more rigid form that cannot be reformed.

Common misconceptions or difficulties learners may have:

Sometimes learners can be thrown by the introduction and exploration of "polymer chains" although they need to be aware of the differences between the two classifications and able to identify the chain structure, centres may wish to explore this concept at varying levels of complexity.

Thermosetting polymers are more difficult to recycle than thermo polymers but they are not impossible to recycle. Often learners state thermosetting polymers are not able to be recycled, whereas they are, it is just a more complex process.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

It is highly likely that many learners will choose to use, or at least explore the use of polymers in their NEA task; therefore a sound knowledge of different types of polymers and their uses will stand them in good stead when making appropriate suggestions and material choices. It is worth remembering that a centre may not have the facilities to manufacture a prototype(s) with the learners' desired polymer but the selection itself can be justified and presented in their supporting evidence.

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Thinking contextually

In every teaching space, polymers will be present in some way shape or form. Learners interact with a number of different polymers each day without necessarily realising it. A useful way of identifying different types of polymers and their use is to use an environment that the learner is familiar with and begin to deconstruct the products they interact with on a daily basis, what they are used for, what properties they require and what the most likely polymer would be for that application.

Allowing learners the opportunity to get hands-on with a number of different types of thermo and thermosetting polymers certainly reinforces learning objectives within this topic. The ability to identify a type of polymer through the markings and symbols on the product or packaging itself is a very useful way for learners to understand and begin to draw links between properties and application.

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Title	Organisation/ Company	Web link	Summary description	Additional description detail	Relevant chapter (i.e. Content, Thinking Conceptually, Thinking Contextually)	Mapping to specification level
Polymers	Peter Valdivia	http://www.petervaldivia.com/plastics/	This is a useful website to direct learners towards for further reading on the topic. The site also contains a 28 question activity which can be adapted to suit.		Thinking Conceptually	5.1 (d) , NEA a
Thermo vs Thermoset	Modor Plastics	http://www.modorplastics.com/thermoset-vs-thermoplastics	Simple comparison between the two types of polymers with examples provided.		Thinking Contextually	5.1 (d) , NEA a
Polymer Identification			Using the attached 'Polymer Cards', learners are required to match the sample materials to their associated classification, description, use and example products. All cards should be cut out and shuffled before learners are required to match them up.	Samples of each polymer will be required in order to make full use of the resource.	Thinking Contextually	5.1 (d) , NEA a

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Learner Activity

Identification of polymers and their uses

Introduction

This task is designed to allow you to begin to identify a number of different polymers and match their associated classification, description, use and example products where they are used.

The activity

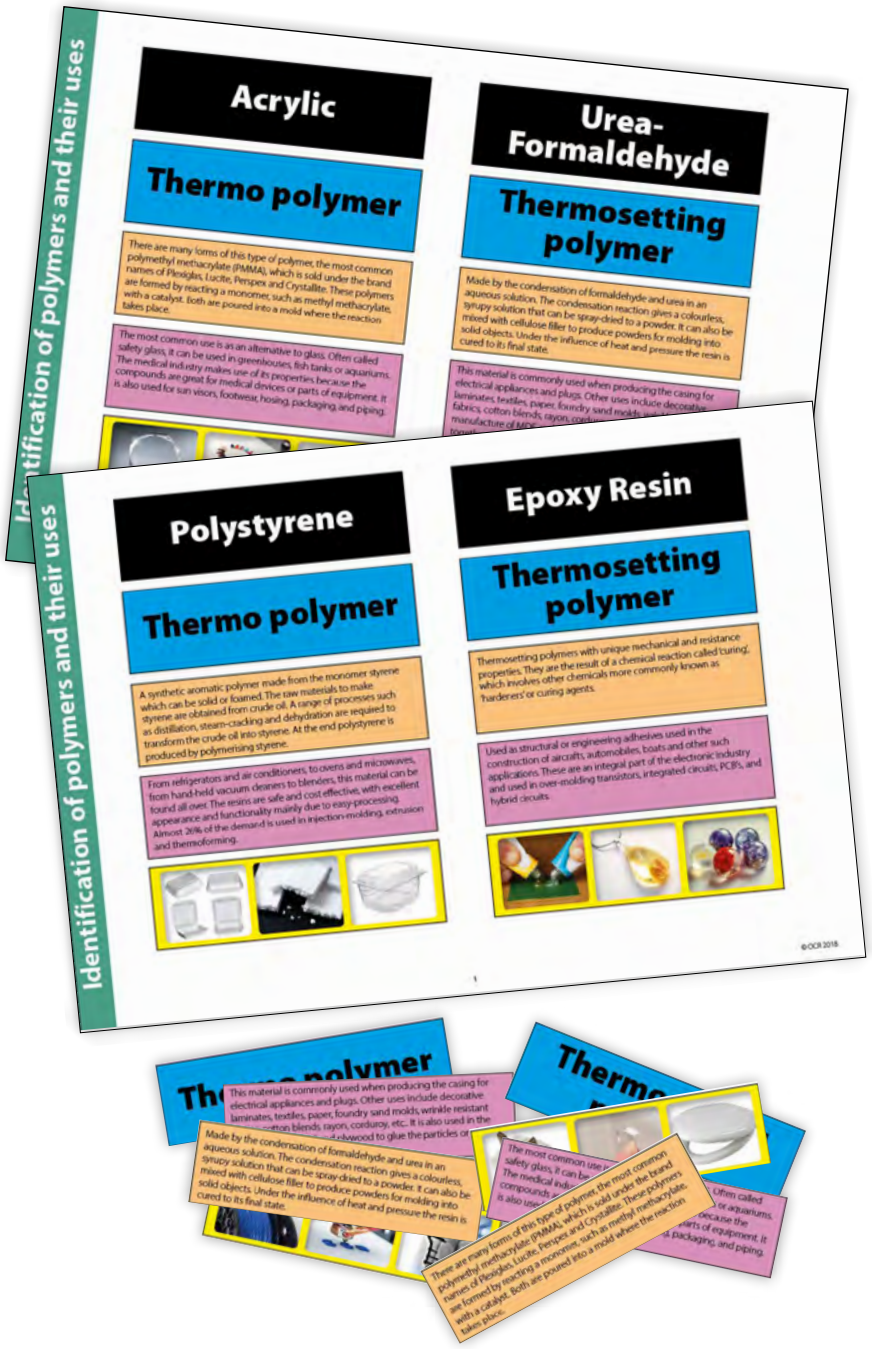
Try to match the material sample with its linked description cards, each material should have five different coloured cards linked to it.

- Black = Material name
- Blue = Classification
- Orange = Description
- Purple = Use
- Yellow = Example products.

*Answers are as the cards are originally produced in the reference document prior to trimming and shuffling.

Extension activities/questions:

Try and create your own polymer cards for other different polymers that you know, remember to try and use as much detail as possible. A blank set of cards have been provided. These could be used as a great revision tool.



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Specification content (Sub Topic 2)

Sub Topic 2: In-depth consideration of polymer materials

Exam content

5.2 What factors are important to consider when selecting appropriate materials and/or system components when designing?

a. The characteristic properties of the main categories of materials (5.1 a–e, not the specific materials) and why this makes them appropriate for different uses, such as:

- density, strength, hardness, durability, strength to weight ratio, stiffness, elasticity, impact resistance, plasticity, corrosive resistance to chemicals and weather, flammability, absorbency, thermal and electrical conductivity.

b. The physical and working properties of specific materials, with consideration of:

i. how easy they are to work with

ii. how well they fulfil the required functions of products in different contexts.

c. Other factors that influence the selection of materials and/or components, including;

i. required functionality of the design solution

ii. aesthetic attributes

iii. environmental considerations

iv. availability and cost of stock forms v. social, cultural and ethical considerations

NEA CONTENT

a. Develop and apply in-depth knowledge by selecting and working with appropriate materials and components when developing their ideas, early models and producing their final prototype(s).

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Thinking conceptually

General approaches:

Beginning to develop a learner's understanding of the characteristic properties of materials before delving further into the uses and advantages/disadvantages of specific materials allows for greater appreciation of material selection. It is important to understand that the characteristic properties are to be understood as generic core content, i.e. the resistant properties of most polymers, how much lighter they are in weight to most alternatives that could be used for similar uses etc.

When moving into content 5.2b onwards, we have the opportunity to discover greater depth of the properties and attributes of polymers with those learners covering this area in preparation for the 'in-depth' sections of the exam.

There are a number of simple workshop tests that can be carried out to evaluate the working properties in a practical situation, such as a simple, controlled drop test for hardness. A simple workshop test or CAD simulation can add further clarity to the definitions and provide learners with practical experience which may prove invaluable in both the exam and NEA. Consideration of the use of polymers in context will also help to understand why their working properties make them suitable for use or how best to work with them.

Common misconceptions or difficulties learners may have:

Learners often confuse the terms 'strength' and 'hardness', therefore, it is recommended to reinforce the difference between the two. The same principle applies to 'elasticity' and 'plasticity'. Learners often find it difficult to grasp the difference between the characteristic properties in a purely theoretical sense and then apply that knowledge in through practical application. If possible, demonstrating each force adds clarity to each definition. It is also important for learners to understand that 'trade-offs' between characteristics may be required in order to select an appropriate material for a product/task. It is not always possible to select a material which 100% satisfies all design criteria and a balance of characteristics may need to be achieved.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

Understanding the selection and application of specific materials used in load- or force-bearing mechanisms will provide an enhanced understanding of forces and motion. If a learner is able to justify the application of a material within a mechanism, this will add further clarity and evidence of understanding in both the exam and NEA.

When understanding the working properties of polymers, this also links directly to Topic Area 7 where manufacturing processes and techniques are considered.

The material characteristics identified are also not solely linked to polymers and can be applied to a wide range of materials covered in other areas of the specification.

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Thinking contextually

Analysing existing products is a great way of adding context to this topic. Selecting products with numerous components that can each be explored in varying levels of detail provide learners with the opportunity to practically evaluate and apply the knowledge they have gained in the previous topics. Often products with moving parts combine a number of different materials that can also be analysed and provide links between the different topic areas covered within the specification. Children's toys and also kitchen products often make use of a range of polymers and are a good place to start when it comes to selecting products to analyse.

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Learner Resources – Activities

Title	Organisation/ Company	Web link	Summary description	Relevant chapter (i.e. Content, Thinking Conceptually, Thinking Contextually)	Mapping to specification level
Material Characteristics Testing	Royal Society of Chemistry	http://www.rsc.org/learn-chemistry/resource/res00001792/the-properties-of-materials?cmpid=CMP00005337	This resource contains a number of experiments that can be safely carried out in a classroom/workshop environment. PDF file is downloadable from the RSC website.	Thinking Contextually	5.2 (a, b)
Properties, Applications & Examples of Polymers	Study.com	http://study.com/academy/lesson/what-are-polymers-properties-applications-examples.html	This is a very useful video which explains polymerisation process and different applications of a number of polymers.	Thinking Contextually	5.2 (a, b, c)
Plastic Properties Table	Curbell Plastics	https://www.curbellplastics.com/Research-Solutions/Plastic-Properties	An interactive properties table below to explore by property group, sort, or compare two or more plastic materials. Also provides links to a "Plastic Material Selection Guide" to assist with the material selection process based on application requirements.	Thinking Conceptually	5.2 (a, b, c)

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Specification content (Sub Topic 3)

Sub Topic 3: Sources and origins of polymer materials

Exam content

5.3 Why is it important to understand the sources or origins of materials and/or system components?

a. The sources and origins of **specific materials**.

b. An overview of the processes used to extract and/or convert the source material into a workable form.

c. Consideration of the ecological, social and ethical issues associated with processing **specific materials** to convert them into workable forms, such as:
- mining, harvesting, manufacturing, transporting.

d. The lifecycle of **specific materials** when used in products.

e. Consideration of recycling, reuse and disposal of **specific materials**, such as:
- recycling and sustainability schemes
- eco-materials
- upcycling.

NEA CONTENT

a. Develop and apply in-depth knowledge by selecting and working with appropriate materials and components when developing their ideas, early models and producing their final prototype(s).

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Thinking conceptually

General approaches:

In order for learners to understand the sources and origins of polymers, they must understand the concept of synthetic and naturally occurring. The majority of synthetic polymers are derived from fossil fuels, such as coal, oil and gas which are obviously in limited supply. This has led to the development of more environmentally friendly polymers such as PLA, which is derived from corn starch. Rubber and amber are examples of naturally occurring sources and origins of polymers.

A product's lifecycle, such as a water bottle is a great way to link content points 5.3a to b and c and also to content point 5.3e. Each stage of the product lifecycle can be explored in-depth to consider the extraction/conversion of the raw material, the wider issues surrounding the manufacture, transportation and use of the product and finally the recycling or eventual end-of- life for the product. This approach would allow for multiple topic areas to be considered whilst exploring the product lifecycle.

Common misconceptions or difficulties learners may have:

Learners often overlook the carbon footprint produced by products, as they only consider the carbon produced by the factory or the product itself. It is important to highlight factors such as the fuel required for extraction/conversion/transportation and recycling stages.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

This topic provides useful links to new and modern materials, especially where recycling initiatives are involved. The Adidas and Parley collaboration is a great example of how waste plastic is being collected and removed from the ocean, recycled and reused to produce high performance footwear.

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Thinking contextually

As previously mentioned a useful way to look deeper into sub-sections a, b, c and e is to explore the lifecycle of a product. It is recommended to explore a sample product such as an everyday item and conduct lifecycle analysis as whole-class group before setting individual products for smaller groups of learners or individuals. This approach allows learners to explore each stage of the product lifecycle and link it directly to a product, rather than just a theoretical based approach.

Learners often find it useful to be able to directly relate processes to a product in order to full understand the how and why they have been produced, transported and eventually recycled. The symbols found on a product packaging and the product itself will provide useful clues and insights into the material used and how it should be disposed of in order to minimise the environmental impact. Therefore, it would be recommended to discuss and explore a range of product/packaging symbols and markings prior to conducting a lifecycle analysis.

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Learner Resources – Activities

Title	Organisation/ Company	Web link	Summary description	Additional description	Relevant chapter (i.e. Content, Thinking Conceptually, Thinking Contextually)	Mapping to specification level
Lifecycle of a plastic bottle	Residential Waste Systems	http://residentialwastesystems.com/blog/the-life-cycle-of-a-plastic-water-bottle/	This is a very useful website for explaining the lifecycle of a standard water bottle. This resource can used as a starting/reference point for learners to create their own info graphic on the products lifecycle.	An example PLC info graphic can be viewed by clicking on the link within the text. This would be useful to show as an example, if required.	Thinking Contextually	5.3 (a, b, c)
Waste plastic recycling	Adidas	http://www.adidas.co.uk/parley	Adidas are working with Parley to transform marine plastic pollution into high performance sportswear, spinning the problem into a solution. The threat into a thread.	This website is a really useful resource that details the Adidas and Parley collaboration aimed at reducing ocean waste and transforming it into high performance footwear.	Thinking Contextually	5.3 (a, b, d, e)
From threat to thread	Adidas	https://www.youtube.com/watch?v=iisMyJdkyqg	This short video clip details the Adidas and Parley collaboration aimed at recycling ocean waste into high performance products.		Thinking Contextually	5.3 (a, b, d, e)

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Specification content (Sub Topic 4)

Sub Topic 4: Available forms of polymer materials and components

Exam content

5.4 Why is it important to know the different available forms of specific materials and/or systems components?

a. Awareness of commonly available forms and standard units of measurement of **specific materials** when calculating costs and quantities, including:

i. Weights and sizes

ii. stock forms, such as:
- lengths, sheets, pellets, reels, rolls, rods.

iii. Standard components, such as:
- timber, e.g. hinges, brackets, screws

NEA CONTENT

a. Develop and apply in-depth knowledge by selecting and working with appropriate materials and components when developing their ideas, early models and producing their final prototype(s).

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Thinking conceptually

General approaches:

Learners often have a limited knowledge of the term 'stock form' prior to exploring this topic, and when considering 'stock', they often relate to a product being in stock or not in a retail outlet. Building an understanding of what forms polymers are manufactured into at the factory site, before being transported to a retailer or stockist is a good way for learners to begin to understand the term. Considering how and why stock forms take on the shape and size they do for both transportation and universal sizing means begins to develop understanding. Also, considering what stock forms are used in order to manufacture certain elements of products or for specific production techniques gives context to a product. For instance, if a product is injection moulded, the stock form of the polymer would be in pellet form, however, vacuum forming would require a sheet. 3D printing requires spools or reels of material, known as filament and so on.

Common misconceptions or difficulties learners may have:

The term "stock form" can often confuse learners as they may not have experienced or seen the polymer in a store room or retail outlet and considered the form that it has taken. It is common for learners to submit cutting lists and such like to teachers and technicians and they will receive their order without consideration as to how their order has been sourced or cut from for instance. Learners are often able to identify sheets as a stock form of polymers as they generally have experience of working with the form or have seen this form in the workshop but omit the other stock forms available.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

This topic links to all other material areas as there are common overlaps between the two, especially with regards to standard sizing and stock forms.

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Thinking contextually

As with the previous topics, exploring existing products and analysing the stock form required to produce it provides a great platform from which learners can build and apply their knowledge. This can be explored at varying depths of complexity: a product could be analysed and found to be injection moulded, stock form of pellets identified, weighed, cost-calculated due to weight and stock form etc.

When considering forms of components, it is important to consider why components such as nuts and bolts or snap rivets would be required or utilised in polymer form. Exploring samples and uses will identify the reasoning's behind their selection, such as their lightweight properties compared to other forms which may make them more suitable for use in products that need to shed weight to work more efficiently i.e. model aircraft/quadcopters.

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Learner Resources – Activities

Title	Organisation/ Company	Web link	Summary description	Relevant chapter (i.e. Content, Thinking Conceptually, Thinking Contextually)	Mapping to specification level
Cast versus extruded acrylic	TAP Plastics	https://www.youtube.com/watch?v=hiJft-LUAXI	This video compares cast acrylic with extruded acrylic sheet.	Thinking Conceptually	5.4 (a)
How plastic is made		http://www.plasticseurope.org/en/about-plastics/what-are-plastics/how-plastics-are-made	On this website, there is a very informative and interactive element explaining how plastics are produced and formed in a variety of different ways.	Thinking Conceptually	5.4 (a)

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