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GCSE (9–1)

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DESIGN AND TECHNOLOGY

J310
For first teaching in 2017

Topic Area 5: Material considerations – Design Engineering

Version 1

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Contents

TOPIC AREA 5: MATERIAL CONSIDERATIONS – DESIGN ENGINEERING

Introduction

GCSE (9-1)

DESIGN AND TECHNOLOGY

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

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/

Specification content (Sub Topic 1)

Sub Topic 1: Core consideration of materials in system components

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.

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).

Thinking conceptually

General approaches:

It is important for learners to understand that there are a wide variety of materials available to designers when developing products and selecting the appropriate materials to both prototype and produce a final product is a very important factor. Often prototyping will utilise either samples of materials or similar materials to reduce costs and ease of prototyping and it is important that this is considered when forming design decisions and recommendations. Designers often use multiple materials within their products to enhance certain qualities, increase efficiency and be more environmentally friendly to name just a few.

When considering materials used in Design Engineering products and systems, these will come from across the range, but will definitely include consideration of metals and some polymers. Application of materials for this in-depth area goes beyond the core learning of materials required by all learners.

Common misconceptions or difficulties learners may have:

When prototyping, it is important to consider the affect that material choice may have on the function of the prototype, especially when modelling to scale. Often materials will behave differently if they are smaller, thinner, supported by smaller components etc., and therefore will possibly present skewed outcomes that may not be realistic when compared to the full scale product. However, this is all part of the prototyping process and full scale testing of components can be included throughout the iterative design process using both physical and CAD means.

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 the foundation for further exploration of 5.2, 5.3 and 5.4.

Thinking contextually

It is important for learners to be able to identify and justify why a range of products are produced using different materials. For instance, why the materials used to produce a standard water bottle differ from those used to produce a thermal insulated flask. A useful way for learners to begin to explore material selection is for them to select an everyday product which they have regular interaction with and then identify the materials used and why. Learners could also evaluate the effectiveness of the identified material and suggest and justify the use of different materials. Learners may often agree with the material choice, which should be expected, therefore, identifying why the product is not produced using a different material is also an important factor.

Title	Organisation/ Company	Web link	Summary description	Additional description detail	Relevant chapter (i.e. Content, Thinking Conceptually, Thinking Contextually)	Mapping to specification level
Online repository full of materials resources	CORE Materials	http://core.materials.ac.uk/index.php	The CORE-Materials repository contains 1670 open educational resources (OERs) in Materials Science and Engineering, all freely available. These are great resources to link to SOWs and to build into lesson plans.	Of particular interest is the PowerPoint based on materials selection which provides a number of examples (www.materials.ac.uk/resources/fe/materialsselection.ppt). There are also a number of technically demanding resources that would be more suited to learners that want stretch and challenge.	Thinking Contextually	5.1 5.2
Material selection	Advanced Metallic Systems Centre	https://www.youtube.com/watch?v=g1BpNasM-os	Materials selection is a fundamental part of Materials Science and is explained through a number of examples in this short video clip.		Thinking contextually	5.1 5.2
Aluminium - The material that changed the world	Real Engineering	https://www.youtube.com/watch?v=yn9qhQSMCRk	This short video clip explores the discovery of aluminium and how important it was in the development of early aircraft.		Thinking contextually	5.1

Learner Activity

Material Selection

Introduction

We encounter hundreds of different products in our daily lives both directly and indirectly, but have you ever considered why these products are produced from particular materials?

The activity

Pick an everyday product that you use or interact with regularly, this could be the water bottle that you drink from, the pens or pencils that you use, or even the pencil case or bag that you store them in, it could even be the bicycle you rode to school on this morning.

- What material(s) is it made from?
- What makes that material suitable for a particular product?
- Which manufacturing methods have been used in the production of your chosen product?
- Could that product be improved by utilising a different material?

Extension activities/questions:

If you were going to produce a prototype of your chosen product in the school workshop, how would you do it and what materials would you use?

Sub Topic 2: In-depth consideration of materials in system components

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 **system components**, 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).

Thinking conceptually

General approaches:

It is important that learners are able to understand and correctly describe the properties of a material using terms 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. Using these terms correctly will add depth and clarity to both examined answers and analysis within their NEA projects. It is important for learners to consider the use of materials within system components such as levers, linkages and gears. The properties will need to link to the application of these system components and full consideration must be given to the environment in which they will be used. Exploring properties through experimental workshop testing is a good way to further enhance learning and retention.

Common misconceptions or difficulties learners may have:

Learners often describe the properties of materials using the terms "strong" and "lightweight", however, this does not offer any real technical insight into the properties of the material in question. Learners should be encouraged to use terms such as 'strength-to-weight ratio', 'hardness', 'impact resistance' to name just a few in order to provide greater explanation and depth to their answers.

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 builds on prior knowledge gain studying topic area 5.1 and provides a foundation for further exploration of 5.4.

Thinking contextually

A useful way to approach this topic is to disassemble and analyse sample products while paying particular attention to the materials used for each component. Sample products that include relatively simple mechanisms such as a stapler, provide a number of investigative avenues. Quite often the casing of the product will consist of at least one polymer which is combined with and attached to metallic components. Through disassembly and simple testing procedures, learners are able to identify or suggest potential materials and then justify their use based on their knowledge of the product and its function. It is also important to consider why the product is not produced with other materials due to working properties, aesthetics etc.

Title	Organisation/ Company	Web link	Summary description	Additional description detail	Relevant chapter (i.e. Content, Thinking Conceptually, Thinking Contextually)	Mapping to specification level
Materials testing	Real Engineering	https://www.youtube.com/watch?v=BHZALtqAjeM	This is a very good video that explains how material selection can be informed through a number of testing and analysis techniques.		Thinking contextually	5.2
Tensile strength testing	University of Liverpool	http://classroom.materials.ac.uk/tensile.php	This is an interactive resource based around the tensile strength of steel. Learners select the carbon content of the steel and then click through the animation as the tensile strength test is carried out. Real time information and a graph for analysis are provided.	Flash player is required.	Thinking contextually	5.2
Material selection – Environmental influences	Autodesk Sustainability Workshop	https://www.youtube.com/watch?v=I3tfQeIzofE	Environmental properties of materials are an important part of making smarter choices in selecting green building materials. When looking for sustainable materials, the first step is to understand where their ecological impacts come from.	Learn about material scarcity and abundance, rapidly renewable materials, embodied energy, recycled materials, and toxicity in this video overview.	Thinking contextually	5.2

Learner Activity

Tensile Strength

Introduction

During this task, you will learn about how the carbon content of steel can have an impact on its tensile strength. The interactive simulation will allow you to carry out multiple tests and then analyse your findings.

The activity

Start off by selecting a low carbon content and observe the results whilst considering the following factors:

- What do you notice about the shape of the graph produced?
- What does this mean?

Now select a mid-range carbon content but, before you start, what do you expect to happen? Now consider the following as the simulation begins:

- What do you notice about the shape of the graph produced?
- What does this mean?
- Is this what you expected to see?

Now select higher carbon content, but before you start, what do you expect to happen this time? Now consider the following as the simulation begins:

- What do you notice about the shape of the graph produced?
- What does this mean?
- Is this what you expected to see?

What conclusions are you able to draw from your observations?

Extension activities/questions:

How would this test be useful when determining material selection for a specific product? Try and name your product and support your answer using your previous findings.

Sub Topic 3: Sources and origins of system components

Exam content

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

- **a.** The sources and origins of **system components**.
- **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 **system components** to convert them into workable forms, such as:
  - mining, harvesting, manufacturing, transporting.
- **d.** The lifecycle of **system components** when used in products.
- **e.** Consideration of recycling, reuse and disposal of **system components**, 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).

Thinking conceptually

General approaches:

Understanding the sources and origins of system components is essential for learners to make informed choices on the materials that they use or suggest. As explored later in the topic the stock form of a material or system component will provide the basis for the system component itself. For instance, gears or other components may be cast or stamped as part of the process of becoming their final form, but this will be produced from their stock form. In order to produce a stock form, the material will need to extracted or converted into a workable form. Understanding the origins of materials will help learners understand the environmental impact a product may have. It is not always immediately obvious as a product may appear to be "eco-friendly" through the task that it performs, but it may have been produced or derived by means that are less eco-friendly and undermine the overall environmental impact of the product.

When considering the lifecycle of system components, it is important to consider the impact of interchangeable or replaceable components, such as mechanism parts which can be repaired or replaced if the product becomes defective. This will allow the lifespan of the product to be increased and reduce the burden on landfill and recycling centres. Often mechanical components will wear down due to the nature of the product and it is important for learners to understand how material selection can play a part in balancing the durability and efficiency of parts in a system.

Common misconceptions or difficulties learners may have:

Often learners are able to identify stock forms of products but overlook the origin of those stock forms and the impact the extraction or conversion process may have on the product. The carbon footprint of a product is often linked to the efficiency of the product itself, for instance, a car when considering exhaust emissions. However, the carbon footprint is traced all the way back to the extraction of the raw materials, production, transportation and eventual end of life or recycling of the product.

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 well with 5.2, 5.4 and 8.

Conducting a full lifecycle analysis of products right the way from material extraction, manufacturing, transportation, use and eventual recycling or end-of-life, is great way to put these topics into context. Take for instance, a PET water bottle; exploring the raw materials that are required and combined to produce the polymer, the stock form the polymer would be produced into, the manufacturing processes used to produce the bottle, the transportation method, use and finally reuse/recycling of the bottle. Exploring each of these stages with a focus on this topic area will provide learners with contextual knowledge of the different elements of this topic area.

Title	Organisation/ Company	Web link	Summary description	Relevant chapter (i.e. Content, Thinking Conceptually, Thinking Contextually)	Mapping to specification level
All about PET	PETRA	http://www.petresin.org/index.asp	This is a really useful website that details everything that you need to know about PET. The website contains an FAQ section which fully details common questions and misconceptions covering recycling, use and how the material is produced. This is very useful when conducting a lifecycle assessment of PET products.	Thinking contextually	5.3 5.1
How gears are made	How it's Made	https://www.youtube.com/watch?v=836V8bytgLU	This short video clip details how a gear is produced from its stock form.	Thinking contextually	5.3
Design for disassembly	Autodesk Sustainability Workshop	https://sustainabilityworkshop.autodesk.com/products/disassembly-and-recycling	This is an extremely useful website when considering design for disassembly and also features a detailed video that further informs the key points featured.	Thinking contextually	5.3

Sub Topic 4: Available forms of system components

Exam content

5.4 Why is it important to know the different available forms of systems components?

a. Awareness of commonly available forms and standard units of measurement of **system components** 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:

- system components, e.g. resistors, capacitors, diodes, transistors and drivers, microcontrollers o mechanical components, e.g. gears and cams, pulleys and belts, levers and linkages.

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).

Thinking conceptually

General approaches:

It is important for learners to understand the stock forms of system components as this will be of vital importance when calculating weight, cost and amount required to produce the components. For instance, if a product contains a number of linkages that can all be produced from a single sheet, the designer will need to be able to calculate the surface area required (tessellation may take place) and translate this to the number of lengths or sheets of the material required. The designer can then divide the cost of the stock form between the number of parts to calculate part cost and a similar calculation can be used to calculate weight.

Electronic components are often available to consumers in single units or larger quantities depending on the requirements. Often a unit cost is provided with relative price breaks as quantities increase, although this is usually dependent on the supplier. Most electronic components are available in a number of different capacities or sizes, for instance, common resistor values of 220, 330 and 1K ohms are readily available.

Mechanical components such as gears, chains, pulleys and belts are also available in a range of standard sizes which allow for easy identification and replacing of worn components in a system such as bicycle. As explored in previous topics, designers are encouraged to use standard components rather than bespoke to allow product parts to be replaced easily extending the products lifecycle.

Common misconceptions or difficulties learners may have:

Learners often confuse stock form and standard components. Stock form relates to the form in which a product is available such as lengths, sheets, pellets, reels, rolls, rods. Standard components relate to the size or capacity for instance resistance/capacitance or diameter/teeth of gears and length of belts.

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 area links very well with and can be delivered alongside 5.1 and 5.2 to inform and justify design decisions.

The best way for learners to grasp this topic is to get hands-on with the stock forms and understand that a stock form is the state/shape/size a material is formed into once extracted/manipulated. Around your department there will be numerous examples of stock forms even if the product itself is no longer in its "raw" stock form it can still be recognised and identified.

When it comes to system components, these can be a little trickier as there are numerous capacities/types within the same form. However, a sample of the most common resistor and capacitor values, standard sized gears, cams and pulleys etc. are useful teaching aids when exploring this topic. It is not necessary for each learner to have their own example to look at so long as the stock forms can be explored in small groups.

Title	Organisation/ Company	Web link	Summary description	Relevant chapter (i.e. Content, Thinking Conceptually, Thinking Contextually)	Mapping to specification level
Standard components	BBC Bitesize	http://www.bbc.co.uk/schools/gcsebitesize/design/systemscontrol/productiontechniquerev1.shtml	This resource covers the standard stock forms of components and how and when they are used.	Thinking contextually	5.4
How a mountain bike is made	How it's Made	https://www.youtube.com/watch?v=V8HAsLURWyo	This short video shows how a mountain bike is manufactured which will assist with the accompanying 'identifying raw materials' task.	Thinking contextually	5.4
Types of gears	Engineers Edge	http://www.engineersedge.com/gears/gear_types.htm	This is a useful website for highlighting the different types of gears available and their uses.	Thinking contextually	5.4

Identifying stock forms

Introduction

During this task, you will identify the stock forms and components used in the manufacture of a bicycle.

The activity

Identify a suitable material and its stock form for the following parts of the bicycle:

- main frame
- handle bars
- handle bar grips
- pedals
- sprockets (spur gears)
- tyres
- wheels
- brake/gear cables.

Extension activities/questions:

Pick three different parts of the bicycle and explain how each part would be manufactured in as much detail as possible.

The small print

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