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Specification

DESIGN AND TECHNOLOGY

H404–H406

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2e. Design Engineering (H404/01 and H404/02)

The subject content of this component is focused towards electronics and engineered products and systems and their analysis in respect of:

- materials and components, and their selection and uses in products/systems
- wider issues affecting design decisions.

It is essential that materials, components and systems are studied from the perspective of analysing modern engineered products. Learners should gain practical experience of using materials, components and systems and, where possible, the content which follows should be learned through applied practical activities, set within realistic design scenarios.

The aim of the component is to give learners a framework for analysing existing products/systems that enables them to make considered selections of appropriate materials, components, systems and manufacturing processes when designing.

The component brings together the knowledge, understanding and skills acquired in the NEA.

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1. Identifying requirements

DESIGNING PRINCIPLES

Considerations	*Maths & Science*
1.1 What can be learnt by exploring contexts that design solutions are intended for?	
a. Understand that all design practice is context dependent and that investigations are required to identify what makes a context distinct in relation to: i. environment and surroundings ii. user requirements iii. economic and market considerations iv. product opportunities.	
1.2 What can be learnt by undertaking stakeholder analysis?	
a. Demonstrate an understanding of methods used for investigating stakeholder requirements, such as: • user-centred design and stakeholder analysis • SWOT analysis • focus groups • qualitative observations • market research to identify gaps for new products or opportunities to update existing products.	
b. Demonstrate an understanding of how enterprise can help drive the development of new product ideas through routes to innovation such as: • entrepreneurship • commercial partnerships • venture capitalists and crowd funding websites.	

Considerations	*Maths & Science*
1.3 How can usability be considered when designing prototypes?	
a. Learners should be able to analyse and evaluate factors that may need consideration in relation to the user interaction of a design solution, including: i. the impact of a solution on a user's lifestyle ii. the ease of use and inclusivity of products iii. ergonomic considerations and anthropometric data to support ease of use iv. aesthetic considerations.	
b. Demonstrate an understanding of the ergonomic factors that may need considering when developing engineered products, including: i. anthropometric data to help define design parameters associated with the human body ii. user comfort, layout of controls, software user-interface.	

2. Learning from existing products and practice

Considerations	*Maths & Science*
2.1 Why is it important to analyse and evaluate products as part of the design and manufacturing process?	
a. Analyse and evaluate the features and methods used in existing products and design solutions to inform opportunities and constraints that may influence design decisions to offer product enhancement, including: i. the context of the existing product and the context of future design decisions ii. the multiple materials and components used iii. methods of construction and manufacture iv. how functionality is achieved v. the ease of use, including; ergonomic and anthropometric considerations vi. inclusivity of products and appropriate consideration of application to a wide variety of users vii. fitness for purpose viii. the impact on user lifestyles ix. the effect of trends, taste and/or style x. the effect of marketing and branding. xi. the considerations of how to get a product to market.	
2.2 Why is it important to understand technological developments in design engineering?	
a. Be able to critically evaluate how new and emerging technologies influence and inform the evolution and innovation of products and systems in both contemporary and potential future scenarios, including consideration of blue sky and incremental innovation.	

	Considerations	Maths & Science
	2.3 Why is it important to understand both past and present developments in design engineering?	
	a. Recognise how past and present design engineers, technologies and design thinking have influenced the style and function of products from different perspectives, including: i. the impact on industry and enterprise ii. the impact on people in relation to: lifestyle, culture and society iii. the impact on the environment iv. consideration of sustainability.	
	b. Understand how key historical movements and figures and their methods have had an influence on future developments.	
	2.4 What can be learnt by examining lifecycles of products?	
	a. Demonstrate an understanding of a product's marketing lifecycle, from initial launch to decline in popularity, including: i. consideration of initial demand, growth in popularity and decline over time ii. methods used to create more demand and maintain a longer product popularity iii. new models of marketing and the influence of social media.	

3. Implications of wider issues

Considerations	*Maths & Science*
3.1 What factors need to be considered when designing and manufacturing products to overcome possible conflicts between moral and commercial factors?	
a. Understand how social, ethical and environmental issues have influenced and been impacted by past and present developments in design practice and thinking, including: i. consideration of lifecycle assessment (LCA) at all stages of a product's life from raw material to disposal ii. the source and origin of materials and the ecological and social footprint of materials iii. the depletion and effects of using natural sources of energy and raw materials iv. planned obsolescence v. buying trends vi. environmental incentives and directives.	
3.2 What factors need to be considered when developing design solutions for manufacture?	
a. Awareness of the responsibilities and principles of designing for manufacture (DFM), including: i. planning for accuracy and efficiency through testing and prototyping ii. being aware of issues in relation to different scales of production iii. designing for repair and maintenance iv. designing with consideration of product life.	
b. Awareness of product lifecycle management and engineered lifespans considering; system compatibility, the need for maintenance of machinery, product support and end of life (EOL).	
c. Demonstrate an understanding of how environmental factors impact on: i. sourcing and processing raw materials into a workable form ii. the disposal of waste, surplus materials and components, by-products of production including pollution related to energy iii. cost implications related to materials and process.	
d. Demonstrate an understanding of sustainability issues relating to industrial manufacture, including: i. fair trade and the Ethical Trade Initiative (ETI) ii. economic issues and globalisation iii. material sustainability and optimisation, availability, recycling and conservation schemes, such as: ○ exploring the impact and use of eco-materials ○ exploring how materials can be up-cycled.	

TECHNICAL PRINCIPLES

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Considerations	*Maths & Science*
3.3 What factors need to be considered when manufacturing products?	
a. Demonstrate an understanding of how to achieve an optimum use of materials and components, including: i. the cost of materials and/or components ii. stock sizes and forms available iii. sustainability production.	
3.4 What factors need to be considered when distributing products to markets?	
a. Understand the issues related to the effective and responsible distribution of products, such as: • cost effective distribution • environmental issues and energy requirements • social media and mobile technology • global production and delivery.	
b. Demonstrate an understanding of the implications of intellectual property (IP), registered designs, registered trademarks, copyright, design rights and patents, in relation to ethics in design practice and consumer rights.	
3.5 What energy factors need to be considered when developing design solutions?	
a. Understand wider issues relating to the selection of energy sources, storage, transmission and utilisation in order to select them appropriately for use.	
3.6 How can skills and knowledge from other subject areas, including mathematics and science, inform decisions in design engineering?	
a. Demonstrate an understanding of the need to incorporate knowledge from other experts and subjects to inform design and manufacturing decisions, including the areas of science and mathematics.	
b. Understand how undertaking primary and secondary research and being able to interpret technical data and information from specialist websites and publications supports design development.	

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TECHNICAL PRINCIPLES

4. Design thinking and communication

Considerations	*Maths & Science*
4.1 How do designer engineers use annotated 2D and 3D sketching and digital tools to graphically communicate ideas?	
a. Demonstrate an understanding of how to use annotated sketching and digital tools to graphically communicate ideas and sketch modelling to explore possible improvements, in terms of physical requirements, such as: • function, usability, construction, movement, stability, composition, strength • aesthetic qualities • manufacturing processes • suitability of materials and components.	
b. Demonstrate an understanding of methods used to represent systems and components to inform third parties, including: i. constructional diagrams/working drawings ii. digital visualisations iii. circuit and system diagrams iv. flowcharts with associated symbols v. prototypes and models.	
4.2 How do industry professionals use digital design tools to support and communicate the exploration, innovation and development of design ideas?	
a. Demonstrate an understanding of how designers develop products using digital tools and online collaboration, such as: • discussing and exchanging ideas with specialists • developing designs concurrently with other designers • explaining and communicating their design decisions to stakeholders.	
b. Demonstrate an understanding of how digital design software, including CAD and CAE are used during product development, such as: • visual presentation, rendering and photo-quality imaging • product simulation and systems simulation • scientific analysis of real-world physical factors to determine whether a product will break or work the way it was intended.	

	Considerations	*Maths & Science*
	4.3 How do design engineers use different approaches to design thinking to support the development of design ideas?	
	a. Awareness of different strategies, techniques and approaches to explore, create and evaluate design ideas, including: • iterative designing • user-centred design • circular economy • systems thinking.	
	b. The importance of collaboration to gain specialist knowledge from across subject areas when delivering solutions in the design and manufacturing industries.	
	c. Understand how design engineers use system design processes to define and develop systems that satisfy specified requirements of users using the three sub-tasks of: i. user-interface design ii. data design iii. process design.	
	d. Understand how design teams use different approaches to project management when faced with large projects, such as critical path analysis, scrum and six sigma.	

TECHNICAL PRINCIPLES

5. Material and component considerations

Considerations | *Maths & Science*

5.1 What factors influence the selection of materials that are used in products?

a. Understand that the selection of materials and components is influenced by a range of factors, including:
   i. functional performance
   ii. aesthetics
   iii. cost and availability
   iv. properties and characteristics
   v. environmental considerations
   vi. social, cultural and ethical factors.

5.2 What materials and components should be selected when designing and manufacturing products and prototypes in Design Engineering?

a. Understand that most products consist of multiple materials and that design engineers are required to discriminate between them appropriately for their use, including:
   i. ferrous, non-ferrous and alloy metals, such as:
      - mild steel, aluminium and brass.
   ii. thermo softening and thermosetting polymers, such as:
      - HIPS, ABS and polyester resin, epoxy resin and polyimides.
   iii. timbers and manufactured boards, such as:
      - oak, plywood and MDF.
   iv. textiles used for reinforcement and coverings, such as:
      - geotextiles used in civil engineering and construction.
   v. composite materials, such as:
      - fibre-reinforced plastics, glass-reinforced plastics (GRP) and carbon fibre (CFRP).
   vi. smart materials, such as:
      - shape memory alloy, motion control gel, self-healing materials, thermochromic, photochromic and electrochromic materials.
   vii. modern materials, such as:
      - sandwich panels, e-textiles, rare earth magnets, high performance alloys and super-alloys, graphene and carbon nanotubes.

5.3 Why is it important to consider the properties/characteristics of materials when designing and manufacturing products?

a. Understand the characteristics and properties of materials that are significant in Design Engineering, such as:
   - density, tensile strength, strength to weight ratio, hardness, durability, thermal and electrical conductivity, corrosion resistance, stiffness, elasticity, plasticity, impact resistance, malleability and ductility, machinability.

b. Understand how the available forms, costs and properties of materials contribute to the decisions about suitability of materials when developing and manufacturing their own products.

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TECHNICAL PRINCIPLES

6. Technical understanding

	Considerations	*Maths & Science*
6.1 What considerations need to be made about the structural integrity of a design solution?		
a.	Learners should understand how and why some materials and/or system components need to be reinforced or stiffened to withstand forces and stresses to fulfil the structural integrity of products.	
b.	Learners should understand processes that can be used to ensure the structural integrity of a product, such as: • triangulation • reinforcing.	
6.2 How do mechanisms provide functionality to products and systems?		
a.	Demonstrate an understanding of the functions that mechanical devices offer to products, providing different types of motion, including: i. rotary ii. linear iii. reciprocating iv. oscillating.	
b.	Demonstrate an understanding of devices and systems that are used to change the magnitude and direction of forces and torques, including: i. gears, cams, pulleys and belts, levers, linkages, screw threads, worm drives, sprockets, chain drives and belt drives ii. epicyclic gear systems iii. bearings and lubrication iv. efficiency in mechanical systems.	
6.3 What forces need consideration to ensure structural and mechanical efficiency?		
a.	Demonstrate an understanding of static and dynamic forces in structures and how to achieve rigidity, including: i. tension, compression, torsion and bending ii. stress, strain and elasticity iii. mass and weight iv. rigidity v. modes of failure.	
6.4 How can electronic systems offer functionality to design solutions?		
a.	Demonstrate an understanding of how electronic systems provide input, control and output process functions, including: i. switches and sensors, to produce signals in response to a variety of inputs ii. programmable control devices iii. signal amplification iv. devices to produce a variety of outputs including light, sound, motion.	

Considerations	Maths & Science
b. Demonstrate an understanding of the function of an overall system, referring to aspects including: i. passive components: resistors, capacitors, diodes ii. inputs: sensors for position, light, temperature, sound, infra-red, force, rotation and angle iii. process control: programmable microcontroller iv. signal amplification: MOSFET, driver ICs v. outputs: LED, sounder, solenoid, DC motor, servo motor, stepper motor, piezo actuator, displays vi. analogue and digital signals and conversion between them vii. open and closed loop systems including feedback in a system and how it affects the overall performance viii. sub-systems and systems thinking.	
c. Demonstrate an understanding of what can be gained from interfacing electronic circuits with mechanical and pneumatic systems and components, such as: • the ability to add electronic control as an input to mechanical or pneumatic output • the use of flow restrictors to control cylinder speed • the use of sensors to measure rotational speed, strain/force, distance.	
d. Demonstrate an understanding of networking and of communication protocols, including: i. wireless devices, such as: RFID, NFC, Wi-Fi, bluetooth ii. embedded devices iii. smart objects iv. networking electronic products to exchange information.	
e. Demonstrate an understanding of the basic principles of electricity, including: i. voltage ii. current iii. Ohm's law iv. power.	
6.5 How can programmable devices and smart technologies provide functionality in system design?	
a. Demonstrate an understanding of how smart materials change the functionality of engineered products, such as: • colour changes, shape-shifting, motion control, self-cleaning and self-healing.	
b. Demonstrate an understanding of how programmable devices are used to add functionality to products, relating to coding of and specific applications of programmable components, such as: • how they incorporate enhanced features that can improve the user experience and solve problems in system design • how they use basic techniques for measuring, controlling, storing data and displaying information in practical situations • electronic prototyping platforms and integrated development environments (IDE) for simulation in virtual environments • the use of programmable components and microcontrollers found in products and systems, such as robotic arms or cars • creating flowcharts to describe processes and decisions within a process to control input and output components.	

7. Manufacturing processes and techniques

DESIGNING & MAKING PRINCIPLES

TECHNICAL PRINCIPLES

	Considerations	*Maths & Science*
7.1 How can materials and processes be used to make iterative models?		
a.	Understand that 3D iterative models can be made from a range of materials and components to create block models and working prototypes to communicate and test ideas, moving parts and structural integrity.	
b.	Demonstrate an understanding of simple processes that can be used to model ideas using hand tools and digital tools, such as rapid prototyping, or digital simulation packages.	
7.2 How can materials and processes be used to make final prototypes?		
a.	Understand how to select and safely use common workshop tools, equipment and machinery to manipulate materials by methods of: i. wasting/subtraction processes such as cutting, drilling, turning, milling ii. addition processes such as soldering, brazing, welding, adhesives, fasteners iii. deforming and reforming processes such as bending, vacuum forming.	
b.	Demonstrate an understanding of the role of computer-aided manufacture (CAM) and computer-aided engineering (CAE) to fabricate parts of a final prototype: i. additive manufacturing (3D printing) to fabricate a usable part ii. subtractive CNC manufacturing such as laser/plasma cutting, milling, turning and routing.	
c.	Demonstrate an understanding of measuring instruments and techniques used to ensure that products are manufactured accurately or within tolerances as appropriate.	
d.	Understand how the available forms, costs and working properties of materials contribute to the decisions about suitability of materials when developing and manufacturing their own products.	
7.3 How can materials and processes be used to make commercial products?		
a.	Demonstrate an understanding of the industrial processes and machinery used for manufacturing component parts in various materials, including: i. polymer moulding methods, such as injection moulding, blow moulding, compression moulding and thermoforming ii. metal casting methods such as sand casting and die casting iii. sheet metal forming methods using equipment such as punches, rollers, shears and stamping machines.	
b.	Demonstrate an understanding of the industrial methods used for assembling electronic products, including: i. surface mount technology (SMT) ii. PCB assembly using solder stencils, pick-and-place machines and reflow soldering ovens.	

	Considerations	Maths & Science
TECHNICAL PRINCIPLES	c. Demonstrate an understanding of the benefits and flexibility of using computer-controlled machinery during industrial production, such as: • automated material handling systems • robot arms to stack, assemble, join and paint parts.	
	d. Understand the necessity for manufacturers to optimise the use of materials and production processes, such as: • economical cutting and costing, ensuring cost effective production for viability • working to a budget through efficient manufacture and making the best use of labour and capital throughout the design and manufacturing process.	
	7.4 How is manufacturing organised and managed for different scales of production?	
	a. Understand how and why different production methods are used when manufacturing products, dependent on market demand, including: i. one-off and bespoke, batch and high volume production systems ii. modular/cell production systems iii. lean manufacturing iv. just-in-time manufacture v. fully automated manufacture.	
	b. Understand how ICT and digital technologies are changing modern manufacturing: i. customised manufacture systems ii. rapid prototyping iii. additive and digital manufacture methods iv. stock control, monitoring, purchasing logistics in industry.	
	7.5 How is the quality of products controlled through manufacture?	
	a. Understand the processes that need to be undertaken to ensure products meet legal requirements and are high quality: i. quality control ii. quality assurance iii. ‘Total Quality Management’ (TQM) iv. European† and British standards.	

† The reference to European standards remains unmodified since it informs pupils knowledge that when designing products, they need to adhere to the standards of the region to be marketable.

8. Viability of design solutions		
	Considerations	*Maths & Science*
DESIGNING & MAKING PRINCIPLES	**8.1 How can design engineers assess whether a design solution meets its stakeholder requirements?**	
	a. Critically evaluating how a design solution has met its intended requirements, including: i. functionality ii. ease of use and inclusivity of the solution iii. user needs.	
	b. Demonstrate an understanding of the needs and methods for testing design solutions with stakeholders throughout the design development, and when testing the success of a product or system.	
	c. Demonstrate an understanding of the importance of testing the feasibility of getting a product to market including considerations of cost, packaging and appeal.	
	d. Understanding the relevant standards that need to be meet and how to ensure these are delivered, including: i. those published by the British Standards Institute (BSI) ii. those published by the International Organisation for Standardisation (ISO) specific to the subject.	
TECHNICAL PRINCIPLES	**8.2 How can design engineers assess whether a design solution meets the criteria of technical specifications?**	
	a. Demonstrate an understanding of the methods and importance of undertaken physical testing on a product to ensure it meets the criteria it is meant to fulfil, including: i. functionality ii. accuracy iii. performance.	
	b. Recognise how physical testing systems are integrated into the manufacturing process to test functionality, including: i. destructive and non-destructive methods ii. testing of materials for durability iii. testing models and prototypes for performance and fitness for purpose iv. testing products in use through different methods, such as: ○ consumer testing ○ virtual testing.	

Considerations		*Maths & Science*
8.3 How do design engineers and manufacturers determine whether design solutions are commercially viable?		
a.	Demonstrate an understanding of the value of feasibility studies to determine the likely factors that influence the commercial viability of a product to market, such as: • the design solution's impact on user lifestyles • how well a product performs • technical difficulty of manufacture • stock availabililty of materials and components • costs and profit • timescales involved • promotion, brand awareness and advertising potential • balancing supply and demand • market analysis of similar products.	

9. Health and safety

Considerations		*Maths & Science*
9.1 How can safety be ensured when working with materials in a workshop environment?		
a.	Demonstrate an understanding of safe working practices in the workshop situation, including: i. understanding the need for risk assessments ii. identifying hazards and implementing control measures to minimise risks.	
b.	Demonstrate an understanding of how to work safely with specialist tools, techniques, processes, equipment and machinery during the design and manufacture of products.	
9.2 What are the implications of health and safety legislation on product manufacture?		
a.	Demonstrate an understanding of how the regulatory and legislative framework in the Health and Safety at Work Act (HASAW) sets out duties of employers and employees in the product manufacturing industries, including: i. Control of Substances Hazardous to Health (COSHH) ii. Personal Protective Equipment at work regulations (PPE) iii. ensuring machinery is well maintained.	
b.	The responsibility of manufactures to appropriately label products and offer warranties to their consumers to deliver the correct levels of product assurance related to safety.