Department for Education

Engineering

GCSE subject content

December 2015

Contents

The content for engineering GCSE

Introduction

1. GCSE subject content sets out the knowledge, understanding and skills common to all GCSE specifications in engineering.

2. They provide the framework within which the awarding organisation creates the detail of the specification.

Aims and objectives

3. GCSE specifications in engineering must require students to develop subject knowledge, skills and understanding that allow them to solve engineering problems in an informed way. Specifications will give students access to the use of new technologies, materials and processes in addition to established engineering practices. They must enable students to put theory into practice, solving engineering problems through the application of mathematical principles and computer modelling/simulation to produce carefully considered manufactured outcomes which showcase essential practical skills.

4. Students must apply their knowledge in a variety of contexts, developing systems that contribute to effective functional products that they build and test. Students must understand the contribution that engineering makes to society and the economy, and have the opportunity to make informed decisions about further learning opportunities and career choices.

5. GCSE engineering specifications must ensure that all students:

- engage in a range of intellectual and practical processes in order to solve problems through the production of engineered outcomes
- develop knowledge and understanding of materials, components and resources relating to engineering
- develop knowledge and understanding of engineering processes and be able to apply these where appropriate in order to produce a manufactured outcome
- draw on knowledge, skills and understanding of materials, processes and techniques in order to engineer products which provide a functioning solution in response to a given brief
- develop an understanding of how emerging technologies (in areas such as materials science, information technology (IT) and communications, energy, medicine and robotics) have changed and will continue to change the way in which engineered products are made and used
- develop an understanding of health and safety procedures and be able to carry out practical activities in a safe way

- develop an awareness and understanding of the impact of engineering on the environment and sustainable development
- develop skills, knowledge and understanding as a foundation for future learning and progression, in relation to engineering and other related disciplines
- apply their knowledge and understanding of mathematical concepts in an engineering related context

Subject content

6. GCSE specifications in engineering must enable students to make connections and draw conclusions based on the theoretical knowledge and understanding learnt, and the subsequent application of skills within a practical context.

7. GCSE specifications must require students to demonstrate the mathematical knowledge, understanding and skills set out in the appendix.

8. GCSE specifications must require students to study the following areas of content.

Engineering materials

9. Specifications must require students to know and understand, in relation to the following groups/classifications of engineering materials: metals, polymers, composites, timbers (structural grades) and ceramics:

- the properties, both physical and mechanical, of these groups of materials, including brittleness, ductility, malleability, hardness, strength/stiffness and toughness
- how to identify common materials from groups above, including carbon steel, cast iron, aluminium, copper and brass, based on physical appearance and behavioural characteristics when handling/machining
- how the mechanical properties of these groups of materials can change including:
    - in the case of metals, through the addition of other materials to form alloys and through methods which affect the grain size, cold working and quenching/hardening, corrosion and the addition/subtraction of carbon in the case of steels
    - in the case of composites (applied to glass-reinforced plastic (GRP), carbon fibre and structural concrete), through the direction/alignment of reinforcement, matrix in which the reinforcement is placed, amount of reinforcement used, and size and shape of reinforcement
- the cost, availability, form and supply of engineering materials from the groups above, including the comparative costs of different materials within and across these groups (for example, copper vs gold for use as electrical components, and cost of steel vs timber for structural components)

- the calculation of costs to manufacture/produce items based on available stock sizes/supply, using economies of scale and subsequent waste produced as a cost to inform the development of an engineered solution in industry
- that designs/solutions are sometimes inhibited by the availability and form of materials
- that design solutions need to consider energy production methods and engineered lifespans including planned obsolescence, the need for maintenance of machinery and end of life (EOL)
- the ability of engineering materials to be treated, shaped and recycled
- how user requirements affect material choice and the manufacturing process

Engineering manufacturing processes

10. Specifications must require students to demonstrate knowledge and understanding of the following manufacturing processes and techniques, including being able to describe which process is appropriate for specific materials and being able to explain how these processes would be carried out:

- additive manufacturing, including fused deposition and metal sintering
- material removal, including cutting, turning, milling, drilling and chemical etching
- shaping, forming and manipulation, including bending, folding, press forming, composite layup, punching and stamping
- casting and moulding, including pressure die-casting, sand casting and injection moulding
- joining and assembly, including methods of joining materials such as rivets, threaded fasteners, soldering, welding and brazing
- heat and chemical treatment, including normalising, annealing, hardening and quenching
- surface finishing, including painting, electroplating, galvanising and polishing

Systems

11. Specifications must require students to demonstrate knowledge and understanding of the use and role of the following systems within engineering settings and products:

Mechanical/electrical systems

- including linkages, gear trains, cam and follower, pulleys, including the use of pulleys as a means to reduce effort when lifting loads or transferring power within a system and the use of cams within an engine
- electrical/electronic/programmable systems
- including how to design and construct programs which monitor and control systems with the use of inputs, processes and outputs within an engineered

system (for example, pick and place machines used in the production of electronic circuits)

Structural systems

- how simple imposed, live and dead loads are applied and transmitted, including space frame and monocoque, leading to bending and torsion/buckling

Pneumatic/hydraulic systems

- including the use of and differences between pneumatic and hydraulic circuits in applications such as robotics, process and factory automation and machinery

Testing and investigation

12. Specifications must require students to demonstrate knowledge and understanding of testing and investigation methods, and be able to apply relevant mathematical calculations when engineering a solution. This should include:

- the use of quality control methods to ensure successful outcomes, including working within tolerance
- the methods of testing and evaluating materials, and structural behaviour under load, including determining tensile/compressive strength and calculating forces within/applied to a component/system
- understanding the difference between destructive and non-destructive testing, and the advantages of each of these methods
- predicting performance in any of the systems referred to above, using calculations, simulations and modelling either manually or with Computer Aided Design (CAD), (for example using CAD to design and test electronic circuits or using formulae to calculate hydraulic/pneumatic forces)
- calculations of area, volume, stiffness, density, and Young's Modulus and Factors of Safety, and converting load/extension to stress/strain when investigating tensile strength of a material
- calculations using Ohm's law and resistance in series and parallel when building circuits
- testing control programs for programmable devices through modelling and enactment, modifying the program to improve performance

13. Specifications must also require students to know what is meant by lift, drag and thrust, in the context of aerodynamics.

The impact of modern technologies

14. Specifications must require students to demonstrate knowledge and understanding of:

- the use of new and emerging technologies, including an understanding of their impact upon production, society and the environment
- the impact (positive and negative) of engineering industries upon the social and economic infrastructure

Application of practical engineering skills

15. Specifications must require students to draw upon their knowledge and understanding of engineering in order to apply key practical skills to create engineering solutions to a given problem. They will be required to produce an engineered product from a given brief. In doing so, they will need to:

- solve problems through a logical, systematic approach using block diagrams and flowcharts
- produce and work to a series of engineering drawings or schematics (both mechanical and electrical/electronic), which must be drawn using current conventions, such as drawings in orthographic (3rd angle), 3D representation (Isometric), assembly and section view as appropriate
- use CAD to assist in the creation and Computer Numerical Control (CNC)/Computer Aided Manufacture (CAM) in the manufacture of a solution
- test materials and their structural behaviour under load in order to ascertain suitable material for a chosen component/application
- predict performance using calculations and modelling
- perform calculations relating to area, volume, stiffness and density and converting load/extension to stress/strain including the conversion of units as appropriate in the production of their engineered product
- produce and follow a production plan
- select and use a range of appropriate materials, parts, components, tools and equipment in order to manufacture a working solution
- select and use appropriate processes such as measuring, marking, turning, milling, drilling, forming, bending, casting, joining, fastening, folding, shaping and finishing in order to manufacture a working solution
- apply quality control methods and techniques during manufacture of the solution, including working to necessary tolerances and demonstrating the ability to check these through the use of tools and equipment, including Vernier calipers, micrometers and depth gauges, as well as within software – specifically in conjunction with CNC/CAM to ensure that all parts/components fit together allowing the solution to function
- design a range of tests to assess the fitness for purpose and performance of a completed product, taking into account how areas for improvement/modification could be identified and alternative solutions clearly shown

Appendix - mathematical understanding

Through their work in engineering, students will be expected to apply relevant knowledge, skills and understanding from key stage 3 and 4 courses in mathematics. Students will be required to use the following mathematical skills, knowledge and understanding in their engineering course.

Equations in GCSE engineering

In developing engineering solutions, students should be able to recall correctly and apply the following formulae using standard SI units:

Area of a rectangle	$A = L \times W$
Volume of a cuboid	$V = L \times W \times H$
Area of a circle	$A_c = \pi r^2$
Volume of a cylinder	$V_c = A_c \times L$
Area of a triangle	$A_t = \frac{1}{2}(B \times H)$
Density = mass/volume	$\rho = \frac{m}{v}$
Stress = force/cross-sectional area	$\sigma = \frac{F}{A}$
Strain = change in length/original length	$\varepsilon = \frac{\delta l}{l}$
Young's modulus = stress/strain	$E = \frac{\sigma}{\varepsilon}$
Pressure = force/area	$P = \frac{F}{A}$
Factor of safety = material strength/yield stress	$FoS = \frac{\sigma_y}{L}$
Ohm's law: current = voltage/resistance	$I = \frac{V}{R}$

Units in engineering

Students should recognise, carry out calculations and be able to communicate using the following SI units: millimetres (mm), metres (m), kilograms (Kg), tonnes (T), newtons (N), volt (V), ohm (Ω); and the following SI multipliers: m, k, M, G and T

Students should also have knowledge and understanding of the conversion of units, including:

- mm to cm

- cm to m
- litres to ml, to cm^3, and to mm^3
- kg to tonnes
- weight to mass

Mathematical skills required for GCSE engineering

Arithmetic and numerical computation

- recognise and use expressions in decimal form
- recognise and use expressions in standard index form
- perform calculations using time and cost
- use ratios, fractions and percentages
- calculate squares and square roots
- calculate angles of a triangle using trigonometry
- use Pythagoras' theorem

Handling data

- use an appropriate number of significant figures
- find arithmetic means
- make order of magnitude calculations
- collection, organisation and presentation of data

Algebra

- understand and use the symbols =, <, ≤, ≥, >, ±, ∝ and ~
- change the subject of an equation
- substitute numerical values into algebraic equations using appropriate units for physical quantities
- solve simple algebraic equations

Graphs

- translate information between graphical and numeric form
- plot two variables from experimental or other data
- draw an appropriate trend line onto plotted data
- determine the slope of a graph
- interpret data presented in graphical form

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Reference: DFE-00196-2015

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