

CONDITIONS AND REQUIREMENTS

GCSE Subject Level Conditions and Requirements for Engineering (2021)

November 2020

ofqual

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Introduction

About this document

This document is part of a suite of documents which sets out the regulatory requirements for awarding organisations offering GCSE qualifications (graded from 9 to 1) in 2021.

We have developed these requirements with the intention that GCSE qualifications (graded from 9 to 1) should fulfil the following purposes:

- to provide evidence of students' achievements against demanding and fulfilling content;
- to provide a strong foundation for further academic and vocational study and for employment; and
- to provide (if required) a basis for schools and colleges to be held accountable for the performance of all of their students.

Requirements set out in this document

This document sets out the GCSE Subject Level Conditions for Engineering. These conditions will come into effect at 09:30 on 5 November 2020 for all GCSE qualifications (graded from 9 to 1) in Engineering for Learners completing the qualification in 2021, except where the GQCov Framework applies.

It also sets out our requirements in relation to:

- interpretation of subject content - awarding organisations must comply with these requirements under Condition GCSE(Engineering)1.1(c);
- assessment objectives - awarding organisations must comply with these requirements under Condition GCSE(Engineering)1.2; and
- assessment - awarding organisations must comply with these requirements under Condition GCSE(Engineering)2.3.

Appendix 1 reproduces the requirements in relation to [subject content for GCSE Engineering](#), as published by the Department for Education. Awarding organisations must comply with these requirements under Condition GCSE(Engineering)1.1.

With respect to GCSE qualifications (graded from 9 to 1) in Engineering in 2021, awarding organisations must also comply with:

- our [General Conditions of Recognition](#), which apply to all awarding organisations and qualifications; and
- our [GCSE Qualification Level Conditions](#); and
- all [relevant Regulatory Documents](#).

With respect to GCSE qualifications in Engineering taken by Learners completing the qualification in 2022 and after, an awarding organisation must continue to comply with the [GCSE Subject Level Conditions and Requirements for Engineering](#).

Subject Level Conditions

GCSE Subject Level Conditions for Engineering

Condition GCSE(Engineering) 1: Compliance with content requirements

GCSE (Engineering)1.1

In respect of each GCSE Qualification in Engineering which it makes available, or proposes to make available, an awarding organisation must -

- (a) comply with the requirements relating to that qualification set out in the document published by the Secretary of State entitled '[Engineering GCSE subject content](#)', document reference DFE-00196-2015,
- (b) have regard to any recommendations or guidelines relating to that qualification set out in that document, and
- (c) interpret that document in accordance with any requirements, and having regard to any guidance, which may be published by Ofqual and revised from time to time.

GCSE (Engineering)1.2

In respect of each GCSE Qualification in Engineering which it makes available, or proposes to make available, an awarding organisation must comply with any requirements, and have regard to any guidance, relating to the objectives to be met by any assessment for that qualification which may be published by Ofqual and revised from time to time.

Condition GCSE(Engineering) 2: Assessment

GCSE (Engineering)2.1

Condition GCSE4.1 does not apply to any GCSE Qualification in Engineering which an awarding organisation makes available or proposes to make available.

GCSE (Engineering)2.2

In respect of the total marks available for a GCSE Qualification in Engineering which it makes available, an awarding organisation must ensure that -

- (a) 60 per cent of those marks are made available through Assessments by Examination, and
- (b) 40 per cent of those marks are made available through assessments set by the awarding organisation that are not Assessments by Examination.

GCSE(Engineering)2.3

An awarding organisation must ensure that in respect of each assessment for a GCSE Qualification in Engineering which it makes available it complies with any requirements, and has regard to any guidance, which may be published by Ofqual and revised from time to time.

Interpretation of subject content

Requirements in relation to subject content for GCSE Qualifications in Engineering

The subject content for GCSE Qualifications in Engineering is set out in the document published by the Secretary of State entitled '[Engineering GCSE subject content](#)', document reference DFE-00196-2015 (the 'Content Document').

Condition GCSE(Engineering)1.1(c) requires awarding organisations to interpret the Content Document in line with any requirements published by Ofqual.

We set out our requirements for the purposes of Condition GCSE(Engineering)1.1(c) below.

Practical engineering skills

An awarding organisation must interpret paragraphs 4 and 15 of the Content Document as if -

- (a) the reference to practical engineering skills allows for Learners to produce clear and detailed intentions of prototypes rather than a finished product, and
- (b) a Learner may watch a demonstration of the use of a range of materials, parts, components, tools and equipment rather than use them him or herself.

Equations

The Appendix to the Content Document specifies a list of 'Equations in GCSE Engineering' that:

students should be able to recall correctly and apply [...] using standard SI units

In respect of each GCSE Qualification in Engineering which it makes available, or proposes to make available, an awarding organisation must -

- (a) interpret the above requirement in the Content Document as permitting the awarding organisation to set individual questions and/or tasks which require Learners to -
 - (i) recall one or more of those specified equations, and/or
 - (ii) recall, and then apply, one or more of those specified equations, and/or
 - (iii) apply one or more of those specified equations which is given in the question and/or task, and
- (b) design and set the assessments for that qualification such that, over the shortest period of time that is reasonably practicable, those assessments require Learners to demonstrate their ability to recall, and then apply, each of the equations listed in the Appendix to the Content Document.

Assessment objectives

Assessment objectives - GCSE Qualifications in Engineering

Condition GCSE(Engineering)1.2 allows us to specify requirements relating to the objectives to be met by any assessment for GCSE Qualifications in Engineering.

The assessment objectives set out below constitute requirements for the purposes of Condition GCSE(Engineering)1.2. Awarding organisations must comply with these requirements in relation to all GCSE Qualifications in Engineering they make available.

	Objective	Weighting
AO1	Demonstrate knowledge and understanding of engineering principles and processes	25%
AO2	Apply knowledge, understanding and skills in different contexts, including through the use of a range of tools, equipment, materials, components and manufacturing processes ¹	50%
AO3	Analyse and evaluate evidence in relation to a range of engineering contexts	25%

¹ To be interpreted in line with the requirements on practical engineering skills published under Condition GCSE(Engineering)1.1(c).

Assessment requirements

Assessment requirements - GCSE Qualifications in Engineering

Condition GCSE(Engineering)2.3 allows us to specify requirements in relation to assessments for GCSE Qualifications in Engineering.

We set out below our requirements for the purposes of Condition GCSE(Engineering)2.3. Awarding organisations must comply with these requirements in relation to all GCSE Qualifications in Engineering they make available.

Assessment of mathematical content

Pages 8 and 9 of the Content Document specify the mathematical skills, knowledge and understanding which Learners will be required to use in GCSE Qualifications in Engineering (the 'Mathematical Skills').

In designing and setting the Assessments by Examination for a GCSE Qualification in Engineering which it makes available, or proposes to make available, an awarding organisation must ensure that -

- (a) questions and tasks rewarding the use of Mathematical Skills assess those skills within the context of other areas of the subject content, and not in isolation,
- (b) at least 20 per cent of the marks in those Assessments by Examination reward the use of Mathematical Skills at a Level of Demand which is not lower than that which is expected of Learners at Key Stage 3 as outlined in the Department for Education's document 'Mathematics programmes of study: key stage 3', document reference DFE-00179-2013, and
- (c) without prejudice to the above requirements and those outlined in the Content Document, in each set of assessments² Mathematical Skills are assessed across a range of Levels of Demand which supports effective differentiation in relation to the qualification.

Non-examination Assessment

Condition GCSE(Engineering)2.2(b) states that an awarding organisation must ensure that, of the total marks available for a GCSE Qualification in Engineering, 40 per cent of those marks are made available through assessments set by the awarding organisation which are not Assessments by Examination.

In respect of that 40 per cent, an awarding organisation must ensure that the marks are comprised as follows -

- (a) 30 per cent of the total marks for the qualification through marks made available in respect of assessment objective AO2, and

² For the purposes of these requirements, a 'set of assessments' means the assessments to be taken by a particular Learner for a GCSE Qualification in Engineering. For clarity, the assessments taken by Learners may vary, depending on any possible routes through the qualification.

- (b) 10 per cent of the total marks for the qualification through marks available in respect of assessment objective AO3.

In respect of the assessments which are not Assessments by Examination, an awarding organisation must ensure that each Learner is required to complete a single task which -

- (a) is designed and set to -
 - (i) allow the Learner to demonstrate the practical engineering skills specified in paragraph 15 of the Content Document as interpreted in line with the requirements published under Condition GCSE(Engineering)1.1(c), and
 - (ii) be completed by the Learner during periods of assessment totalling approximately 30 hours,
- (b) requires the Learner to produce the following evidence -
 - (i) Either -
 - (A) a single engineered product based on a brief set by the awarding organisation, or
 - (B) a prototype and/or clear and detailed intentions in relation to a prototype,
 - (ii) Such additional evidence as is necessary to enable the consideration of that Learner's level of attainment in respect of all of the relevant criteria against which Learners' performance in that assessment will be differentiated, and
- (c) must be taken under conditions specified by the awarding organisation, including, in particular, conditions which -
 - (i) ensure that the evidence generated by each Learner can be Authenticated, and
 - (ii) require each Learner to produce the evidence set out in paragraph (b) above under Immediate Guidance or Supervision.

In respect of the brief(s) it sets for the assessments which are not Assessments by Examination, an awarding organisation -

- (a) must design and set those brief(s) in a way which -
 - (i) minimises the predictability of non-examination assessment tasks in any given set of assessments, and
 - (ii) facilitates comparability of non-examination assessment tasks, both within a set of assessments, and over time, and
- (b) must not communicate the brief(s) that it has set before 1 June in the calendar year preceding the year in which the qualification is to be awarded.

Marking of non-examination assessments

Evidence generated by a Learner in an assessment for a GCSE Qualification in Engineering which is not an Assessment by Examination may be marked -

- (a) by the awarding organisation or a person connected to the awarding organisation,
- (b) by a Centre, or
- (c) through a combination of (a) and (b).

In any event, the awarding organisation must demonstrate to Ofqual's satisfaction in its assessment strategy that -

- (a) it has taken all reasonable steps to identify the risk of any Adverse Effect which may result from its approach to marking the assessments (and to Moderation where appropriate); and
- (b) where such a risk is identified, it has taken all reasonable steps to prevent that Adverse Effect or, where it cannot be prevented, to mitigate that Adverse Effect.

Appendix 1 – Subject content (published by Department for Education)



Department
for Education

Engineering

GCSE subject content

December 2015

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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 $=$, $<$, \leq , \geq , $>$, \pm , ∞ and \sim
- 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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