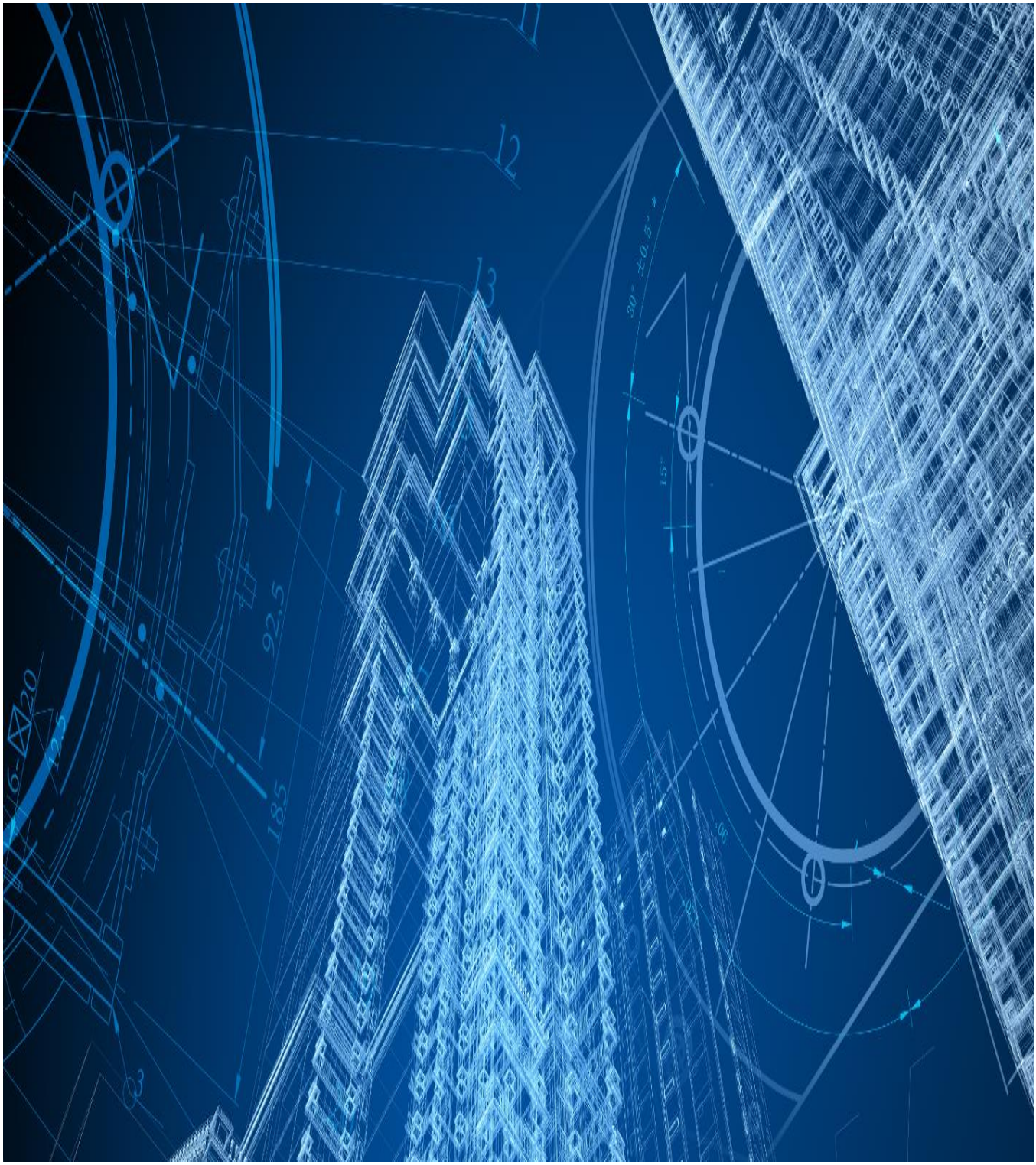
UNIVERSITY FOUNDATION PROGRAMME ENGINEERING SPECIFICATION

PREPARING STUDENTS FOR UNIVERSITY SUCCESS

FOR TEACHING FROM 2021



August 2021

CATS UFP

CATS UFP is a Level 3 course, specifically designed to help international students move successfully from secondary education to a UK University.

The CATS UFP is delivered over 420 directed hours of teaching and learning, over 3 subjects, and utilises a rigorous style of study, within a pastorally supportive and culturally stimulating environment that enables students' learning to develop and progress successfully. Students are able to access a variety of assessment methods that are common in UK Universities, such as portfolios, presentations academic posters, and examinations combined with content specifically designed to build on prior learning from courses around the world.

English for Academic purposes is an essential part of CATS UFP, and all students will take an English course that supports their learning and prepares them for university life, as well as having access to many extracurricular activities that further reinforce their use of English. Assessment design within each subject carefully focuses on subject knowledge and skills, rather than the ability to cope with English as a second language.

CATS Colleges provide a stimulating intellectual and diverse environment with small classes; thus, enabling the best learning to happen. With CATS UFP, all learning happens with teachers who have excellent subject knowledge and are expert in creating a positive learning environment for students from a wide range of backgrounds.

CATS UFP has a successful record of accomplishment and is highly respected by UK universities. With this qualification, students with 12 years of schooling from their own country can make the progression that they want, to a wide range of UK universities, including those ranked most highly for both research and teaching. CATS UFP has strong advocates in its alumni, who display what a CATS UFP qualification can give them. Graduates report that they feel very well prepared for university study; often, better prepared than students from other Level 3 programmes. Universities have confirmed this, through testimonials and through extensive consultation with university based External Examiners it has gained excellent credibility with UK universities.

INTRODUCTION
Why Choose Engineering UFP?

Dynamic and engaging content:

For over 35 years CATS UFP has provided a high quality, successful qualification. Through consistent improvement using teacher and student feedback, classroom experience and by working closely with universities the Engineering UFP course is designed to engage international students through topics and issues that are relevant across the globe.

Real life skills:
In addition to learning standard principles, formulae and techniques, students will develop their critical thinking skills, logic and reasoning ability through the various problem-solving elements of the course. These skills are highly desirable in higher education and valued by employers. Students will also gain confidence in applying the ideas taught on the course in Engineering contexts, as assessed in the Controlled Assessment.

Assessment success:
UFP Engineering involves four methods of assessment: a multiple-choice assessment, a piece of coursework, a controlled assessment, and an examination paper.

- The poster coursework encourages students to develop important academic and scientific skills, including completing reflections, citing sources, and writing essays. Topics are contemporary, engaging and developed specifically for international students.

- The examination papers, both short-answer and multiple choice, cover the entirety of the course content. The style of these questions will involve a mix of applying standard techniques/formulae, interpreting/explaining and problem solving. However, these questions will be structured in a way that they are accessible for students with a lower level of English.

***AIMS OF THE COURSE**

The UFP encourages students to:

- 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
- Understand mathematical and scientific processes in a way that promotes confidence, fosters enjoyment and provides a strong foundation for progress to further study.
- Extend their range of mathematical and scientific skills and techniques.
- Understand coherence and progression in mathematics and science and understand how different areas of these are connected.
- Reason logically and recognise incorrect reasoning.
- Use their problem-solving abilities to approach challenging problems that require them to decide on the solution strategy.
- Recognise when mathematics can be used to analyse and solve a problem in context.
- Draw diagrams and sketch graphs to help explore situations and interprets solutions.
- Make deductions and inferences and draw conclusions by using logical reasoning.
- Interpret solutions and communicate their interpretation effectively in the context of the problem.
- Read and comprehend mathematical and scientific arguments, including justifications of methods and formulae, and communicate their understanding.
- Use technology such as calculators and computers effectively and recognise when their use may be inappropriate.
- Take increasing responsibility for their own learning and the evaluation of their own development.

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[1] Elements taken from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/510751/gcse-subject-level-conditions-and-requirements-for-engineering.pdf

KEY SKILLS

Students taking this course will be encouraged to develop into independent learners with the ability to think critically, understanding the key importance of research and presentational skills. The course covers these key skills in the following ways:

Reasoning and critical thinking:

- Use problem solving skills to solve problems effectively in situations where more than one approach is possible.
- Select, organise and communicate relevant information in a variety of forms
- Use mathematical techniques in a multitude of situations applicable to the real world
- Understand how principles of science and mathematics can be applied practically in different fields of Engineering.

Independent Learning:

- Organise own learning through management of time and material
- Work on own initiative to prioritise tasks
- Work independently to support understanding of material
- Carry out self-directed learning tasks.

Research Skills:

- Research an area of interest and produce a summary of what was learned
- Ensure all research is referenced and not plagiarised
- Use ICT to develop information literacy skills, to communicate and collaborate with others.

Presentational Skills:

- Systematic documentation of finding and analysis
- Use of word processing and other forms for ICT for communication
- Organise information clearly and coherently, using specialist vocabulary when appropriate

***ASSUMED PRIOR KNOWLEDGE**

UK Government recommendations for Level 3 qualifications[2] states that:

"…specifications must build on the skills, knowledge and understanding set out in the whole GCSE subject content for mathematics for first teaching from 2015."

We appreciate that UFP students come from a diverse range of cultures and backgrounds, so necessary Level 2 content and terminology will be covered in UFP teaching.

It is assumed that students will be conversant with the following subject content before the start of the UFP Engineering course. Note that since students taking UFP Engineering will also study UFP Mathematics there will be more mathematical content needed for UFP Mathematics than the content listed below. All GCSE content that overlaps with the UFP Mathematics course content has been removed from the list below. No prior knowledge is expected for modules 1 to 5.

Number

- order positive and negative integers, decimals and fractions; use the symbols =, ≠, , ≤, ≥
- apply the four operations, including formal written methods, to integers, decimals and simple fractions (proper and improper), and mixed numbers – all both positive and negative; understand and use place value (e.g. when working with very large or very small numbers, and when calculating with decimals)
- recognise and use relationships between operations, including inverse operations (e.g. cancellation to simplify calculations and expressions; use conventional notation for priority of operations, including brackets, powers, roots and reciprocals
- use the concepts and vocabulary of prime numbers, factors (divisors), multiples, common factors, common multiples, highest common factor, lowest common multiple, prime factorisation, including using product notation and the unique factorisation theorem
- apply systematic listing strategies including use of the product rule for counting
- use positive integer powers and associated real roots (square, cube and higher), recognise powers of 2, 3, 4, 5; estimate powers and roots of any given positive number
- work interchangeably with terminating decimals and their corresponding fractions (such as 3.5 and $\frac{7}{2}$ or 0.375 or $\frac{3}{8}$); change recurring decimals into their corresponding fractions and vice versa
- identify and work with fractions in ratio problems
- interpret fractions and percentages as operators
- use standard units of mass, length, time, money and other measures (including standard compound measures) using decimal quantities where appropriate
- estimate answers; check calculations using approximation and estimation, including answers obtained using technology
- round numbers and measures to an appropriate degree of accuracy (e.g. to a specified number of decimal places or significant figures); use inequality notation to specify simple error intervals due to truncation or rounding

Algebra

- use and interpret algebraic notation, including:
    - ab in place of a × b
    - 3y in place of y + y + y and 3 × y

[2] Taken from http://qna.files.parliament.uk/ws-attachments/171767/original/GCE%20AS%20and%20A%20level%20subject%20content%20for%20mathematics.docx

    - a^2 in place of a × a, a^3 in place of a × a × a, a^2b in place of a × a × b
    - $\frac{a}{b}$ in place of a ÷ b
    - coefficients written as fractions rather than as decimals
    - brackets
- substitute numerical values into formulae and expressions, including scientific formulae
- understand and use the concepts and vocabulary of expressions, equations, formulae, identities inequalities, terms and factors
- simplify and manipulate algebraic expressions (including those involving surds and algebraic fractions) by:
    - collecting like terms
    - multiplying a single term over a bracket
    - taking out common factors
    - expanding products of two or more binomials
- understand and use standard mathematical formulae; rearrange formulae to change the subject
- work with coordinates in all four quadrants
- solve linear equations in one unknown algebraically (including those with the unknown on both sides of the equation); find approximate solutions using a graph
- translate simple situations or procedures into algebraic expressions or formulae

Ratio, proportion and rates of change

- change freely between related standard units (e.g. time, length, area, volume/capacity, mass) and compound units (e.g. speed, rates of pay, prices, density, pressure) in numerical and algebraic contexts
- use scale factors, scale diagrams and maps
- express one quantity as a fraction of another, where the fraction is less than 1 or greater than 1
- use ratio notation, including reduction to simplest form
- divide a given quantity into two parts in a given part:part or part:whole ratio; express the division of a quantity into two parts as a ratio; apply ratio to real contexts and problems (such as those involving conversion, comparison, scaling, mixing, concentrations)
- express a multiplicative relationship between two quantities as a ratio or a fraction
- understand and use proportion as equality of ratios
- relate ratios to fractions and to linear functions
- define percentage as 'number of parts per hundred'; interpret percentages and percentage changes as a fraction or a decimal, and interpret these multiplicatively; express one quantity as a percentage of another; compare two quantities using percentages; work with percentages greater than 100%; solve problems involving percentage change, including percentage increase/decrease and original value problems, and simple interest including in financial mathematics
- solve problems involving direct and inverse proportion, including graphical and algebraic representations
- use compound units such as speed, rates of pay, unit pricing, density and pressure
- compare lengths, areas and volumes using ratio notation; make links to similarity (including trigonometric ratios) and scale factors
- understand that X is inversely proportional to Y is equivalent to X is proportional to $\frac{1}{Y}$; construct and interpret equations that describe direct and inverse proportion

Geometry and measures

- use conventional terms and notations: points, lines, vertices, edges, planes, parallel lines, perpendicular lines, right angles, polygons, regular polygons and polygons with reflection and/or rotation symmetries; use the standard conventions for labelling and referring to the sides and angles of triangles; draw diagrams from written description
- apply the properties of angles at a point, angles at a point on a straight line, vertically opposite angles; understand and use alternate and corresponding angles on parallel lines; derive and use the

sum of angles in a triangle (e.g. to deduce and use the angle sum in any polygon, and to derive properties of regular polygons)
- apply angle facts and properties of quadrilaterals to conjecture and derive results about angles and sides, including Pythagoras' Theorem and the fact that the base angles of an isosceles triangle are equal, and use known results to obtain simple proofs
- use standard units of measure and related concepts (length, area, volume/capacity, mass, time, money, etc.)
- know and apply formulae to calculate: area of triangles, parallelograms, trapezia; volume of cuboids and other right prisms (including cylinders)
- know the formulae: circumference of a circle = 2πr = πd, area of a circle = πr 2 ; calculate: perimeters of 2D shapes, including circles; areas of circles and composite shapes; surface area and volume of spheres, pyramids, cones and composite solids
- know the formulae for: Pythagoras' theorem, $a^2 + b^2 = c^2$, and the trigonometric ratios, sinθ = $\frac{opposite}{hypotenuse}$, cosθ = $\frac{adjacent}{hypotenuse}$and tanθ = $\frac{opposite}{adjacent}$; apply them to find angles and lengths in right-angled triangles and, where possible, general triangles in two and three dimensional figures

USE OF TECHNOLOGY

In this course students will be expected to work with both word processing and spreadsheet software, as well as using a graphical calculator. Appropriate calculators should include the following features:

- the ability to calculate with 2D and 3D vectors
- the ability to perform matrix operations, including finding inverse matrices
- the ability to evaluate definite integrals
- the ability to draw graphs defined in the form $y = f(x)$

In addition, the course will involve working with websites and applications which visually render mathematical objects (such as vectors) to understand graphical elements of mathematics. As examples, these could include Desmos and GeoGebra.

***SUBJECT CONTENT**
The content below will be covered in all the assessment components of the course.[3]

Module	Content
1. Reporting & Mechanics	• Know fundamental and derived SI units • Convert between different units of quantities. • State values in scientific notation and use suitable numeral prefixes • State units in the accepted SI format • State final answer to correct number of significant figures • Know and identify random and systematic error • Distinguish between precision and accuracy • Understand how to record and propagate uncertainties as absolute, relative, fractional and percentage errors • Know the difference between percentage error and percentage discrepancy • Recognize uncertainties as error bars in graphs • Determine the uncertainties in the gradient and intercepts of a straight-line graph. • Understand how to process data to linearise graphs • Identify and draw free-body diagrams representing the forces acting on an object. • Calculate the weight of a body • Determine the resultant force in moving and equilibrium situations • State Newton's 1st law with example • State Newton's 2nd law and solve problems • Explain Newton's 3rd law and solve problems • Fluid resistance and terminal velocity
2. Energy & Power	• Explain what is meant by work. • Solve problems involving the work done by a force. • Outline what is meant by kinetic energy. • Outline what is meant by change in gravitational potential energy. • State the principle of conservation of energy. • Understand how to carry out an investigation to show the conservation of energy from GPE to KE. • Define power, including units • Define and apply the concept of efficiency. Solve problems including momentum, work, energy and power
3. Waves	• Be able to describe the wave form using the terms displacement, amplitude, frequency • Understand that progressive waves are a means to transfer energy from one place to another. • Describe (with examples) transverse (light) and of longitudinal (sound) waves.

[3] Details of Units 6-10 are taken from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/517726/gce-subject-level-conditions-and-requirements-for-mathematics.pdf and https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/515123/gce-subject-level-conditions-and-requirements-for-further-mathematics.pdf

	• Describe and use appropriately: crest, trough, compression and rarefaction. • Be able to describe the wave form using the terms displacement, amplitude, frequency, period, wavelength, wave speed and intensity. • Draw and understand displacement–time graphs and displacement–position graphs. • Understand that all electromagnetic (EM) waves travel at the same speed in a vacuum. • Describe the reflection and transmission of waves at a boundary between two media. • State and apply Snell's law • Explain and discuss qualitatively the diffraction of waves at apertures and obstacles. • Be able to describe the wave form using the terms angular frequency, period and phase difference. • Define angular frequency $\omega = 2\pi/T$ or $\omega = 2\pi f$ • Define simple harmonic motion (SHM) and state the defining equation as $a = -\omega^2 x$ • Solve problems using the defining equation for SHM. • Apply the equations $v = v_0 cos\omega t$, $v = v_0 \sin\omega t$, $x = x_0 cos\omega t$ and $x = x_0 \sin\omega t$ as solutions to the defining equation for SHM. – REQUIRED PRACTICAL • Solve problems, both graphically and by calculation, for acceleration, velocity and displacement during SHM. • Describe the interchange between kinetic energy and potential energy during SHM. • Solve problems graphically involving energy changes during SHM. • Describe and solve problems of standing (stationary) waves. • Explain how one-dimensional standing waves are formed. • Discuss the modes of vibration of strings and air in open and in closed pipes. • Know how to find higher frequencies • Compare and contrast both stationary and travelling waves.
4. Electric circuits	• Investigating combinations of resistors in parallel and series circuits • Analyse $\frac{V}{I}$ graphs • Be able to solve problems using the equations: $R = \rho\frac{l}{A}, P = VI = I^2R = \frac{V^2}{R}$ • Investigating combinations of resistors in parallel and series circuits • State characteristics of ideal and not ideal ammeters and voltmeters. • Be able to design an experiment affecting one or more factors that affect resistance in a wire - REQUIRED PRACTICAL • Definition of emf and PD and the difference between them • Source of emf and terminal PD.; 'lost volts' • Be able to design an experiment that can determine internal resistance of a source. • Be able to use the terms emf, internal resistance and other electrical quantities and apply them correctly.
5. Physics for Engineering	• Understand and use moments in simple static contexts • Young's modulus • REQUIRED PRACTICAL – Young's modulus • Hooke's Law • Applications (bridges, see-saws, etc.) • Material resistance • Metal properties

6. Further Trigonometry	• Understand and use the standard small angle approximations of sine, cosine and tangent functions $sin\theta \approx \theta$, $\cos\theta \approx 1 - \frac{\theta^2}{2}$ and $tan\theta \approx \theta$. • Understand and use the definitions of secant, cosecant and cotangent and of arcsin, arccos and arctan; their relationships to sine, cosine and tangent; understanding of their graphs; their ranges and domains • Understand and use $sec^2\theta = 1 + tan^2\theta$ and $cosec^2\theta = 1 + cot^2\theta$. • Understand and use double angle formulae; use of formulae for $\sin(A \pm B)$, $\cos(A \pm B)$ and $\tan(A \pm B)$; understand geometrical proofs of these formulae. • Understand and use expressions for $acos\theta + bsin\theta$ in the equivalent forms of $Rcos(\theta \pm \alpha)$ and $Rsin(\theta \pm \alpha)$.
7. Further Calculus	• Differentiate $\sin kx$, $\cos kx$, $\tan kx$ and related sums, differences and constant multiples. • Understand and use the derivative of $\ln x$. • Differentiate simple functions and relations defined implicitly, for first derivative only. • Construct simple differential equations in pure mathematics and in context, (contexts may include kinematics, population growth and modelling the relationship between price and demand). • Integrate e^{kx}, $\frac{1}{x}$, $\sin kx$, $\cos kx$, and related sums, differences and constant multiples. • Evaluate the analytical solution of simple first order differential equations with separable variables, including finding particular solutions. (Separation of variables may require factorisation involving a common factor) • Interpret the solution of a differential equation in the context of solving a problem, including identifying limitations of the solution; includes links to kinematics.
8. Complex Numbers	• Solve any quadratic equation with real coefficients; solve cubic or quartic equations with real coefficients (given sufficient information to deduce at least one root for cubics or at least one complex root or quadratic factor for quartics) • Add, subtract, multiply and divide complex numbers in the form $x + iy$ with x and y real; understand and use the terms 'real part' and 'imaginary part' • Understand and use the complex conjugate; know that non-real roots of polynomial equations with real coefficients occur in conjugate pairs • Use and interpret Argand diagrams
9. Vectors	• Use vectors in two dimensions and in three dimensions • Calculate the magnitude and direction of a vector and convert between component form and magnitude/direction form • Add vectors diagrammatically and perform the algebraic operations of vector addition and multiplication by scalars, and understand their geometrical interpretations • Understand and use position vectors; calculate the distance between two points represented by position vectors • Use vectors to solve problems in pure mathematics and in context, including forces and kinematics • Understand and use the vector and Cartesian forms of an equation of a straight line in 3D • Understand and use the vector and Cartesian forms of the equation of a plane

	• Calculate the scalar product and use it to express the equation of a plane, and to calculate the angle between two lines, the angle between two planes and the angle between a line and a plane • Check whether vectors are perpendicular by using the scalar product • Find the intersection of a line and a plane • Calculate the perpendicular distance between two lines, from a point to a line and from a point to a plane • Calculate the cross product and use it to find a perpendicular vector in 3D.
10. Matrix Algebra	• Add, subtract and multiply conformable matrices; multiply a matrix by a scalar • Understand and use zero and identity matrices • Use matrices to represent linear transformations in 2-D; successive transformations; single transformations in 3-D (3-D transformations confined to reflection in one of x = 0, y = 0, z = 0 or rotation about one of the coordinate axes) (knowledge of 3-D vectors is assumed) • Find invariant points and lines for a linear transformation • Calculate determinants of 2 x 2 and 3 x 3 matrices and interpret as scale factors, including the effect on orientation • Understand and use singular and non-singular matrices, properties of inverse matrices • Calculate and use the inverse of non-singular 2 x 2 matrices] and 3 x 3 matrices. • Solve three linear simultaneous equations in three variables by use of the inverse matrix • Interpret geometrically the solution and failure of solution of three simultaneous linear equations
11. Numerical Methods	• Locate roots of $f(x) = 0$ by considering changes of sign of $f(x)$ in an interval of x on which $f(x)$ is sufficiently well-behaved. Understand how change of sign methods can fail. • Solve equations approximately using simple iterative methods • Solve equations using the Newton-Raphson method and other recurrence relations of the form $x_{n+1} = g(x_n)$. Understand how such methods can fail. • Understand and use numerical integration of functions, including the use of the trapezium rule and estimating the approximate area under a curve and limits that it must lie between. • Use numerical methods to solve problems in context

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*ASSESSMENT OVERVIEW

Assessment Objectives

Assessment objectives (AOs) are designed for Level 3 Mathematics. CATS UFP places a strong emphasis on the use of maths in an international context when compared to other Level 3 qualifications

	Objective	Weighting
AO1	**Demonstrate knowledge and understanding of mathematical and scientific ideas, processes, techniques and procedures** • **Mathematical/scientific evidences and concepts** • **Mathematical/scientific methods and systems** • **Mathematical/scientific terminology**	16% - 22%

	• **Logical presentation of mathematical/scientific information**	
AO2	**Apply knowledge and understanding and use:** • **Mathematical/scientific evidences and concepts** • **Mathematical/scientific methods and systems** • **Mathematical/scientific terminology to transfer information efficiently** • **Suitable logical steps are evident to present mathematical/scientific information**	40% - 46%
AO3	**Analyse, interpret and evaluate scientific information, ideas and evidence, including in relation to issues, to:** • **aim, research questions and predictions** • **Mathematical/scientific methods and systems** • **Mathematical/scientific explanations of concepts, projects and investigations**	26% - 32%
AO4	**Demonstrate the appropriate research, experimental skills, and personal skills necessary to carry out insightful and ethical investigations and presentations:** • **develop and apply 21st century communication skills** • **become critically aware, as global citizen, of the ethical implications of using science and technology** • **carry out practicals in groups effectively**	10%

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Assessment Objective weightings per course element

	MCQs	Examinations	Poster	Controlled Assessment	Practically confident	Overall
Course weighting	**10%**	**50%**	**20%**	**20%**	**0% (Requirement to pass)**	**100%**
AO1 weighting	**35-45%**	**20-30%**	**0%**	**10%**	**n/a**	**16%-22%**
AO2 weighting	**35-45%**	**45-55%**	**0%**	**70%**	**n/a**	**40%-46%**
AO3 weighting	**15-25%**	**20-30%**	**50%**	**20%**	**n/a**	**26%-32%**

AO4 weighting	**0%**	**0%**	**50%**	**0%**	**100%**	**10%**

Assessment structure

Engineering UFP involves different methods of assessment: a multiple-choice paper, a poster project, a controlled assessment and two examination papers. The multiple-choice questions give students the opportunity to test their knowledge on the first four modules of the course in a short-answer format. The controlled assessment gives students the opportunity to analyse a construction project from both a mechanical and financial viewpoint. For the poster project, students pick an appropriate topic from a tranche of Engineering (in the form of a specific question) that relates a topic from the science being studied to a cross curricular issue. The examination papers cover the latter modules of the course content in a traditional exam format.

Assessment Components:

MCQs:

25 marks

40 minutes

10% of the qualification

Examined Content:

- Reporting & Mechanics
- Energy & Power
- Waves
- Electric Circuits
- Physics for Engineering

Assessment overview:

- Students will be given 25 MCQs on these topics.
- Students must answer all questions.
- Calculators may be used in this assessment.

Examination:

90 marks

50% of the qualification

2 hours

Examined Content:

- Further trigonometry
- Further calculus
- Complex Numbers
- Vectors
- Matrix Algebra
- Numerical Methods

Assessment overview

- Paper 1 and Paper 2 may contain questions on any topics from the Pure Mathematics content.
- Students must answer all questions.
- Calculators may be used in this assessment.

Poster:

36 marks

20% of the qualification

Examined content: Independent work

Assessment overview

- Students pick an appropriate subject (in the form of a specific question) that relates to an area of Engineering in which they are interested.
- A short-written article of why the topic was chosen by the student and why it is important to others.
- A written report of 1500 words that allows you to discuss research in more detail (not including references).
- An abstract (a summary of the key points of your research) of 250 words.
- Production of a digital A1 sized poster using the information from your essay and including appropriate referencing of sources and an abstract that summarises your research.
- Your written reflections regarding - on your production of the poster; the sources used and the extending the ideas of your research.

Controlled Assessment:
20 marks
20% of the qualification
2 hours

Examined content:

- Reporting & Mechanics
- Energy & Power
- Physics for Engineering

Assessment overview:

- 20 mark paper covering science and logistics of a construction project. Assessment will focus on mathematical and scientific justification for a Engineering model, plus a criticism of these solutions from a modelling assumption and long-term financial viewpoint.

Practically confident:
0 marks
A requirement to complete the qualification

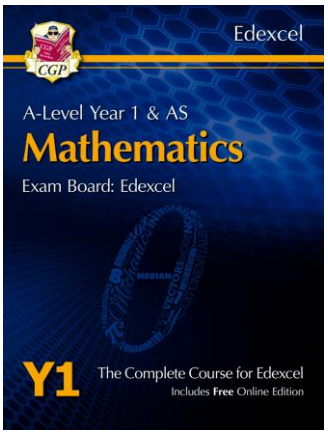
Examined content:

- Waves
- Physics for Engineers
- Electric Circuits

Assessment overview:

- Students will be required to successfully complete at least three practical experiments in pairs or small groups.

Suggested Reading:



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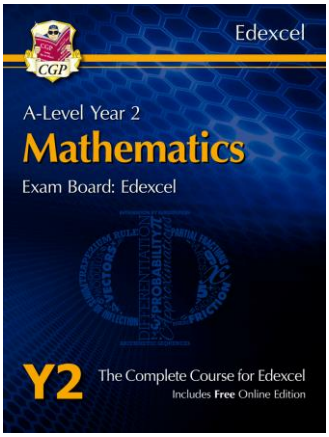

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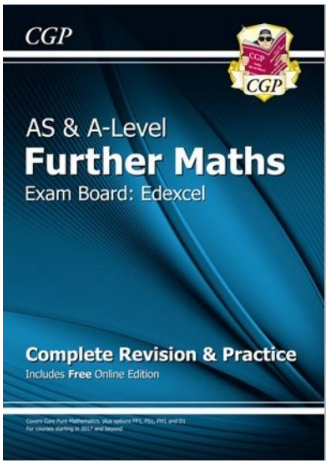

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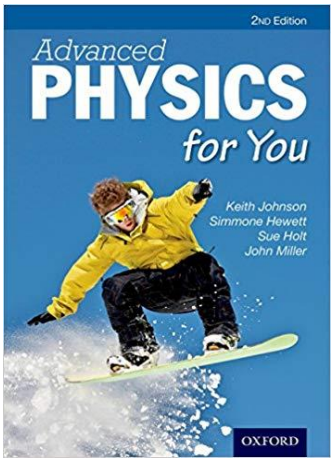

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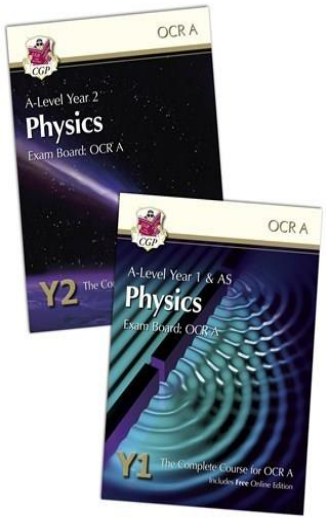

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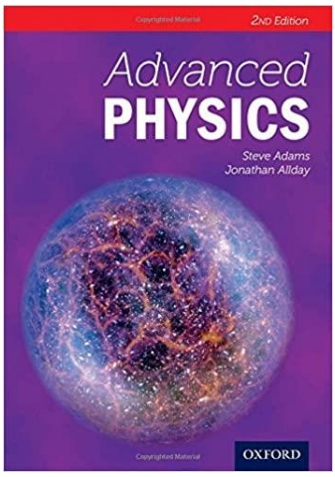

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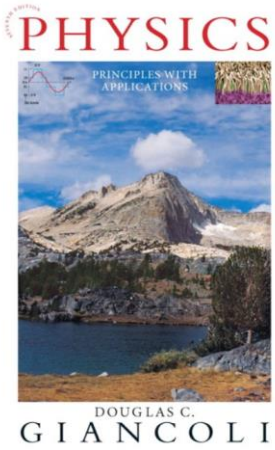

Advanced Physics (Advanced Sciences)
ISBN: 978 1 29205 712 5

Teaching Plan:

Topic	No. of hours	Assessment Element
• Reporting and Mechanics	15	
• Energy and Power	10	
• Waves	20	
• Electric Circuits	15	
• Physics for Engineering	20	
• Further Trigonometry	15	
• Further Calculus	15	
• Complex numbers	5	
• Vectors	10	
• Matrices	10	
• Numerical Methods	5	
Total	140	

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APPENDIX A. POSTER DETAILS

Individual and unique posters linking the science with another curriculum aspect. The poster is worth 20% of the whole course.

For these assessment elements of the course, marks for each element of the marking criteria will be awarded on a points system. Each "Seen Expansively" will be worth three points, each "seen clearly" will be worth two points, each "Seen, but vaguely" will be worth one point, and each "Not Seen" is not worthy of credit.

	Points awarded				
Marking Statement	Not Seen	Seen, but vaguely	Seen clearly	Seen expansively	Comment as to why points were awarded
	0	1	2	3	•

The coursework is separated into the following marking criteria that are marked individually:

Criteria	Total Available Marks	Weighting of poster (%)	Requirements of work provided by student	Marking Responsibility
Engage	**4**	**11**	• A written report sent in word processed document, titled "Engage".	Centres
Report	**12**	**33**	• A written 1500-word report sent in word processed document (references not included in word count), titled "Report".	Centres
Reference	**4**	**11**	• A written 1500-word report sent in word processed document (references not included in word count), titled "Report"	Centres
Abstract	**4**	**11**	• A written 250-word report sent in word processed document, titled "Abstract"	Centres
Produce	**8**	**22**	• Aa visually appealing A1 poster including all or most of the elements from the "Report & Reference" and "Abstract".	Centres
Reflect	**4**	**11**	• A written 250-word report sent in word processed document, titled "Reflect"	Centres
Totals	**36**	**100**	n/a	

Engage Marking Criteria Form for Teachers (can be shared with students)

The extent to which the student engages with topic exploration and personalisation.

Curiosity is recognized through explaining personal interests and showing evidence of curiosity or initiative.

An explanation of why the topic was chosen and how it is relevant to the science studied should be included.

Engage Marking Criteria					
	Points awarded				
Marking Statement	Not Seen	Seen, but vaguely	Seen clearly	Seen expansively	Comment as to why points were awarded
Student created question without excessive guidance from teacher.					•
Question is specific & obviously cross curricular.					•
Explanation of why question is relevant to student.					•
Explanation of why question is important to others as well as student.					•

Relevant Level and marked awarded based on above completed form:

Mark to Award	Criteria
4	• 11-12 points awarded
3	• 8-10 points awarded
2	• 5-7 points awarded
1	• 3-4 points awarded
0	• 2 or fewer points scored on the table above,

Report Criteria Form for Teachers (can be shared with students)

The extent to which the student informs us of the relationship to answer the question asked.

Report Marking Criteria					
	Points awarded				
Marking Statement	Not Seen	Seen, but vaguely	Seen clearly	Seen expansively	Comment as to why points were awarded
Evidence Seen that is specific to question.					•
Evidence shows at least 2 quantifiable relationship.					•
Evidence includes relevant data in the form of tables and graphs.					•

Relevant Level and marked awarded based on above completed form:

Mark to Award	Criteria
12	• 9 points awarded **& Below 1,500 Words.**
11	• 9 points awarded **& Above 1,500 Words.**
10	• 8 points awarded **& Below 1,500 Words.**
9	• 8 points awarded **& Above 1,500 Words.**
8	• At least 6 points awarded **& Below 1,500 Words.**
7	• At least 6 points awarded **& Above 1,500 Words.**
6	• At least 4 points awarded **& Below 1,500 Words.**
5	• At least 4 points awarded **& Above 1,500 Words.**
4	• At least 2 points awarded **& Below 1,500 Words.**
3	• At least 2 points awarded **& Above 1,500 Words.**
2	• 1 point awarded **& Below 1,500 Words.**

1	• 1 point awarded **& Above 1,500 Words.**
0	• None of the other levels are applicable.

Reference Marking Criteria Form for Teachers (can be shared with students)

The extent to which the student displays the choice of sources used.

Referencing should be completed in the Harvard style.

*N.B. While Wikipedia is a useful website for gathering preliminary information, it should not be used as a reference and would not count as "appropriate".

Reference Marking Criteria					
	Points awarded				
Marking Statement	Not Seen	Seen, but vaguely	Seen clearly	Seen expansively	Comment as to why points were awarded
There are at least 4 appropriate references					•
Include both online and offline (or journal) references					•
Has appropriate "in body" Referencing					•
Has appropriate bibliography in alphabetical order					•

Relevant Level and marked awarded based on above completed form:

Mark to Award	Criteria
4	• 11-12 points awarded
3	• 8-10 points awarded
2	• 5-7 points awarded
1	• 3-4 points awarded
0	• 2 or fewer points scored on the table above,

Abstract Marking Criteria Form for Teachers (can be shared with students)

The extent to which the student summarises the main finding of the research succinctly.

Abstract Marking Criteria					
	Points awarded				
Marking Statement	Not Seen	Seen, but vaguely	Seen clearly	Seen expansively	Comment as to why points were awarded
Abstract summarises main findings from the research.					•

Relevant Level and marked awarded based on above completed form:

Mark to Award	Criteria
4	• 11-12 points awarded
3	• 8-10 points awarded
2	• 5-7 points awarded
1	• 3-4 points awarded
0	• 2 or fewer points scored on the table above,

Produce Marking Criteria Form for Teachers (can be shared with students)

The way the student produces a digital A1 sized poster including the elements of the Report, References and Abstract.

Produce Marking Criteria					
	Points awarded				
Marking Statement	Not Seen	Seen, but vaguely	Seen clearly	Seen expansively	Comment as to why points were awarded
Poster includes sections from the report, references* and abstract.					•
The formatting of text and headings is sensible.					•
The layout of the poster is sensible and logical.					•
There are appropriately titled sections.					•
Spelling, Punctuation and appropriate terminology is used.					•

Relevant Level and marked awarded based on above completed form:

Mark to Award	Criteria
8	• 14-15 points awarded
7	• 12-13 points awarded
6	• 10-11 points awarded
5	• 9-10 points awarded
4	• 7-8 points awarded
3	• 5-6 points awarded
2	• 3-4 points awarded
1	• 1-2 points awarded

0	• None of the other levels are applicable.

*Four references should be seen on the poster

Reflect Marking Criteria Form for Teachers (can be shared with students)

The extent to which the student reflects on their poster and their research. This should be written by the student after the hand in of the poster.

Reflect Marking Criteria					
	Points awarded				
Marking Statement	Not Seen	Seen, but vaguely	Seen clearly	Seen expansively	Comment as to why points were awarded
Strengths and limitations regarding their poster creation / design are mentioned.					•
Strengths and limitations regarding their sources are mentioned.					•
Improvements are suggested for both the poster creation / design and sources					•

Relevant Level and marked awarded based on above completed form:

Mark to Award	Criteria
4	• 8-9 points awarded
3	• 6-7 points awarded
2	• 4-5 points awarded
1	• 2-3 points awarded
0	• None of the other levels are applicable.

APPENDIX B. CONTROLLED ASSESSMENT DETAILS

Students will be expected to complete a 20 mark controlled assessment on Units 1, 2 & 5.

This assessment will take the format of analysing the construction project of a bridge. Students will be expected to analyse the model of a bridge, focussing on different supporting systems, properties of the materials used in the bridge's construction and the financial aspect of this construction project.

As well as using formulae in this assessment, students will need to understand Engineering principles and justify conclusions drawn from the values they calculate. Students will need to be familiar with modelling assumptions in Engineering and understand how these are being used in this simulation, including the limitations that these models bring.

See the sample assessment materials for more details

APPENDIX C: TEACHING GUIDANCE AND CONTENT DETAILS

1.1 Observing & Reporting in Physics		
Spec ID	**Assessment statement**	**Additional Guidance**
1.1.1	**Fundamental and derived SI units**	Students need to know the following fundamental units: Kilogram (kg), metre (m), second (s), ampere (A), mole and kelvin (K).
1.1.2*	**Convert between different units of quantities.**	
1.1.3	**State values in scientific notation and use suitable numeral prefixes.**	Use and know prefixes from peta to femto
1.1.4	**State units in the accepted SI format**	Students should use **m s^{-2}** not **m/s^2** and **m s^{-1}** not **m/s**.
1.1.5*	**State final answer to correct number of significant figures**	Students need to know the rules for calculations with significant digits and rounding
1.1.6	**Know and identify random and systematic error**	Include zero error and reaction time
1.1.7	**Distinguish between precision and accuracy**	Students should know how to reduce the effect of errors
1.1.8*	**Understand how to record and propagate uncertainties as absolute, relative, fractional and percentage errors**	Errors in final answer should not have more than 1 or at most two sf's
1.1.9*	**Know the difference between percentage error and percentage discrepancy**	% discrepancy = $\frac{accepted\ value - experimental\ value}{accepted\ value} x\ 100\%$
1.1.10*	**Recognize uncertainties as error bars in graphs**	Only the larger error of IV or DV need to be included
1.1.11*	**Determine the uncertainties in the gradient and intercepts of a straight-line graph.**	Know how to use maximum and minimum trendline to find the uncertainty in the gradient
1.1.12*	**Understand how to process data to linearize graphs**	Include hyperbola and parabola

1.2 Dynamics		
Spec ID	**Assessment statement**	**Additional Guidance**
1.2.1	**Identify and draw free-body diagrams representing the forces acting on an object.**	This includes labelling (with a name or symbol) and having vectors that a proportional to their magnitudes.
1.2.2*	**Calculate the weight of a body**	$W = mg$
1.2.3*	**Determine the resultant force in moving and equilibrium situations**	
1.2.4	**State Newton's 1st law with example**	Students should explain the meaning of inertia
1.2.5*	**State Newton's 2nd law and solve problems**	$F = ma \; and \; F = \frac{\Delta p}{\Delta t}$
1.2.6*	**Explain Newton's 3rd law and solve problems**	Students should understand the requirements for forces to be a 3rd law pair $F_{AB} = -F_{BA}$
1.2.7	**Fluid resistance and terminal velocity**	Qualitatively describe the effects of fluid resistance on falling objects including reaching terminal velocity

2.1 Work		
Spec ID	**Assessment statement**	**Additional Guidance**
2.1.1	**Explain what is meant by work**	Using the equations: W = Fs & $W = \Delta E$
2.1.2*	**Solve problems involving the work done by a force.**	Problems include $W = Fs\ cos\theta$
2.1.3	**Outline what is meant by kinetic energy.**	$KE = \frac{1}{2}mv^2$
2.1.4*	**Outline what is meant by change in gravitational potential energy.**	GPE = mgΔh
2.1.5	**State the principle of conservation of energy.**	Students need to know the transfer of energy between KE and GPE $KE = GPE$ $W = \Delta E$
2.1.6	**Understand how to design and carry out an investigation to show the conservation of energy from GPE to KE.**	
2.1.7	**Define power, including units**	$P = \frac{E}{\Delta t}$
2.1.8	**Define and apply the concept of efficiency.**	Efficiency in terms of work, energy and power. Students need to know what wasted energy means and which forms it can take $eff = \frac{useful\ work/energy/power}{total\ work/energy/power} x100\%$
2.1.9*	**Solve problems including momentum, work, energy and power**	

3.1 Traveling Waves		
Spec ID	**Assessment statement**	**Additional Guidance**
3.1.1	**Be able to describe the wave form using the terms displacement, amplitude, frequency**	
3.1.2	**Understand that progressive waves are a means to transfer energy from one place to another.**	
3.1.3	**Describe (with examples) transverse (light) and of longitudinal (sound) waves.**	Understand the oscillation of particles and the direction of the energy transfer.
3.1.4	**Describe and use appropriately; crest, trough, compression and rarefaction.**	
3.1.5	**Be able to describe the wave form using the terms displacement, amplitude, frequency, period, wavelength, wave speed and intensity.**	Apply and use the wave equation $v = f\lambda$
3.1.6*	**Draw and understand displacement–time graphs and displacement–position graphs.**	For both transverse and longitudinal waves.
3.1.7	**Understand that all electromagnetic (EM) waves travel at the same speed in a vacuum.**	Explain the order of the EM spectrum in terms of increasing and decreasing wavelength and frequency and recall the orders visible light.
3.1.8	**Describe the reflection and transmission of waves at a boundary between two media.**	Know the law of reflection. This should include the sketching of incident, reflected and transmitted waves.

Spec ID	Assessment statement	Additional Guidance
3.1.9*	**State and apply Snell's law**	Students should be able to define refractive index in terms of the ratio of the speeds of the wave in the two media and in terms of the angles of incidence and refraction. $\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1}$
3.1.11	**Explain and discuss qualitatively the diffraction of waves at apertures and obstacles.**	The effect of wavelength compared to aperture or obstacle dimensions should be discussed.

3.2 Simple Harmonic Motion (SHM)

Spec ID	Assessment statement	Additional Guidance
3.2.1	**Be able to describe the wave form using the terms angular frequency, period and phase difference.**	$T = \frac{1}{f}$
3.2.2	**Define angular frequency** $\omega = \frac{2\pi}{T}$ **or ω = 2πf**	
3.2.3	**Define simple harmonic motion (SHM)** **and state the defining equation as** $a = -\omega^2 x$	Students should understand the meaning of the negative sign in the equation and recall the connection between ω and T.
3.2.4*	**Solve problems using the defining equation for SHM. – REQUIRED PRACTICAL**	
3.2.5*	**Apply the equations** $v = v_0 cos\omega t, v = v_0 \sin\omega t,\ x = x_0 \cos\omega t\ and\ x = x_0 \sin\omega t$ **as solutions to the defining equation for SHM**	
3.2.6*	**Solve problems, both graphically and by calculation, for acceleration, velocity and displacement during SHM.**	
3.2.8	**Describe the interchange between kinetic energy and potential energy during SHM.**	

3.2.9*	**Solve problems graphically involving energy changes during SHM.**	Energy calculations are not required

3.4 Stationary waves		
Spec ID	**Assessment statement**	**Additional Guidance**
3.4.1	**Describe and solve problems of standing (stationary) waves.**	The character of these waves in terms of energy transfer, amplitude and phase should be considered.
3.4.2	**Explain how one-dimensional standing waves are formed.**	Using the terms nodes and antinodes.
3.4.3	**Discuss the modes of vibration of strings and air in open and in closed pipes.**	The lowest-frequency mode is known either as the fundamental or as the first harmonic. The term overtone will not be used.
3.4.4*	**Know how to find higher frequencies**	$f_1 = nf_0$
3.4.5	**Compare and contrast both stationary and travelling waves.**	

3.6 Electric Circuits		
Spec ID	**Assessment statement**	**Additional Guidance**
3.6.1*	**Drawing and interpreting circuit diagrams**	Know basic circuit symbols
3.6.2	**Analyse $\frac{V}{I}$ graphs**	Using Ohm's law $R = \frac{V}{I}$ Know $\frac{V}{I}$ diagrams for ohmic and non –ohmic conductors such as filament lamp and diode only and identify their differences.
3.6.3*	**Be able to solve problems using the equations:** $R = \rho\frac{l}{A}, P = VI = I^2R = \frac{V^2}{R}$	Students need to know Kirchhoff's 1st and 2nd law. Application of the laws will be restricted to circuits with a maximum number of two source-carrying loops. The terms potential difference, current, charge, Kirchhoff's circuit laws, power, resistance and resistivity should be applied and utilised correctly.
3.6.4*	**Investigating combinations of resistors in parallel and series circuits**	Students need to find equivalent resistance for both $R_{equ} = R_1 + R_2 + \cdots, \frac{1}{R_{eqv}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$
3.6.5	**State characteristics of ideal and not ideal ammeters and voltmeters.**	Understand that non-ideal voltmeters are characterised by constant but finite resistance. Understand that non-ideal ammeters are characterised by constant but non-zero resistance.
3.6.6	**REQUIRED PRACTICAL** **Be able to design an experiment affecting one or more factors that affect resistance in a wire.**	This should be in the context of a wire and how it can be applied to other contexts.
3.6.7	**Definition of emf and PD and the difference between them**	

3.6.8*	**Source of emf and terminal PD.; 'lost volts'**	Use and derivation of equation $\varepsilon = I(R + r)$
3.6.9	**Be able to design an experiment that can determine internal resistance of a source.**	Know that in a $\frac{V}{I}$ diagram the y-intercept is the emf of the cell and the gradient represents the magnitude of the internal resistance r.
3.6.10	**Be able to use the terms emf, internal resistance and other electrical quantities and apply them correctly.**	

5 Physics for Engineering		
Spec ID	**Assessment statement**	**Additional Guidance**
5.1	**Understand and use moments in simple static contexts**	Know that a moment is force multiplied by distance, including when the force is acting at an angle. Know how to take moments about a point on a 2D object.
5.2	**Hooke's law**	To know that load applied to a material (not only springs), will result in either elastic deformation or inelastic deformation, if in the latter case the elasticity limit of the material was reached. **To apply**: F = kx, where k is defined as the force constant (in Nm^{-1}) and x = extension (in metres). To be able to recognise and interpret Force against Extension graphs for different materials, including springs, metal wires, polythene and rubber bands. **Practical opportunity**: investigating the force constant k for springs connected in series and/or parallel.

5.3	**Young's Modulus**	To **define** Young's Modulus E as the mechanical property of a material that measures its tensile stiffness. **Apply** the **formulae**: E = Tensile stress/Tensile strain Tensile stress = Force/Cross-sectional area To know that *Tensile stress* is measured in Pascals (Pa). Tensile strain = extension/total length To know that *Tensile stress* has no units. Know that the unit of E is Pa (Pascals), just like for pressure. **Practical opportunity**: investigating the Young's Modulus in a long, stretched, metallic wire. Extension: To connect the idea of Young's Modulus and Force constant, deducing the fomula
5.4	**Applications (bridges, see-saws, etc.)**	One of these applications will be the focus of the **Controlled Assessment**. For **example**, the students could be given two data sets about two materials used to build a certain structure (like a bridge etc.) and to compare and decide what is the best solution from an engineering point of view (based on theoretical and practical calculations and demonstrations) and, also, to

		establish which solution is the most cost effective. Other topics included: weight of an object, moment of the force, equilibrium of moments, Newton's first Law, density and pressure, material resistance and properties of metals.
5.5	**Material resistance**	To know how to evaluate the elasticity or brittleness of a material, by using the Tensile stress against Tensile strain graph.
5.6	**Metal properties**	To compare quantitively and qualitatively the force constant and Young's Modulus for different metals. To connect the concepts of mass, density and volume, using: density = mass/volume. To be able to identify the most common properties of metals: atomic structure, thermal conduction, electrical conduction and the reactivity in the contact with oxygen or water (oxidation).

6. Further Trigonometry[4]		
Spec ID	**Assessment statement**	**Additional Guidance**
6.1	**Understand and use the standard small angle approximations of sine, cosine and tangent, where θ is in radians**	Understand & use the formulae: $sin\theta \approx \theta$ $cos\theta \approx 1 - \frac{\theta^2}{2}$ $tan\theta \approx \theta$
6.2	**Understand and use the definitions of secant, cosecant and cotangent and of arcsin, arccos and arctan; their relationships to sine, cosine and tangent; understanding of their graphs; their ranges and domains**	Domain and range are covered in the UFP Maths spec. and should be known for all these functions
6.3	**[Understand and use $1 + tan^2x \equiv sec^2x$ and $1 + cot^2x \equiv cosec^2x$**	
6.4	**Understand and use double angle formulae; use of formulae for $sin(A \pm B)$, $cos(A \pm B)$ and $tan(A \pm B)$.**	
6.5	**Understand and use expressions for $acos\theta + bsin\vartheta$ in the equivalent forms of $Rcos(\theta \pm \alpha)$ or $Rsin(\theta \pm \alpha)$.**	Questions on this in context should be covered.

[4] Elements taken from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/517726/gce-subject-level-conditions-and-requirements-for-mathematics.pdf

7. Further Calculus[5]		
Spec ID	**Assessment statement**	**Additional Guidance**
7.1	**Differentiate $\tan kx$ and related sums, differences and constant multiples.**	Augments content in the UFP Maths spec.
7.2	**Differentiate simple functions and relations defined implicitly**	Includes first and second derivatives
7.3	**Understand and use the derivative of $\ln x$.**	Includes combination with chain, product and quotient rules from the UFP Maths spec.
7.4	**Construct simple differential equations in pure mathematics and in context, (contexts may include kinematics, population growth and modelling the relationship between price and demand).**	
7.5	**Integrate e^{kx}, $\frac{1}{x}$, $\sin kx$, $\cos kx$, and related sums, differences and constant multiples.**	Includes combination with integration by substitution and partial fractions from the UFP Maths spec.
7.6	**Evaluate the analytical solution of simple first order differential equations with separable variables, including finding particular solutions. (Separation of variables may require factorisation involving a common factor)**	
7.7	**Interpret the solution of a differential equation in the context of solving a problem, including identifying limitations of the solution.**	

[5] Elements taken from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/517726/gce-subject-level-conditions-and-requirements-for-mathematics.pdf

8. Complex Numbers[6]		
Spec ID	**Assessment statement**	**Additional Guidance**
8.1	**Solve any quadratic equation with real coefficients; solve cubic or quartic equations with real coefficients (given sufficient information to deduce at least one root for cubics or at least one complex root or quadratic factor for quartics)**	Define the fundamental theorem of algebra
8.2	**Add, subtract, multiply and divide complex numbers in the form $x + iy$ with x and y real; understand and use the terms 'real part' and 'imaginary part'**	
8.3	**Understand and use the complex conjugate; know that non-real roots of polynomial equations with real coefficients occur in conjugate pairs**	
8.4	**Use and interpret Argand diagrams**	Includes representations of complex numbers and their conjugates, as well as solutions of real-coefficient polynomials

[6] Elements taken from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/515123/gce-subject-level-conditions-and-requirements-for-further-mathematics.pdf

9.1 Vector Fundamentals[7]		
Spec ID	**Assessment statement**	**Additional Guidance**
9.1.1	Use vectors in two dimensions and in three dimensions	
9.1.2	Calculate the magnitude and direction of a vector and convert between component form and magnitude/direction form	
9.1.3	Add vectors diagrammatically and perform the algebraic operations of vector addition and multiplication by scalars, and understand their geometrical interpretations	
9.1.4	Understand and use position vectors; calculate the distance between two points represented by position vectors	
9.1.5	Use vectors to solve problems in pure mathematics and in context, including forces	

[7] Elements taken from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/517726/gce-subject-level-conditions-and-requirements-for-mathematics.pdf

9.2 Vector Algebra [8]		
Spec ID	**Assessment statement**	**Additional Guidance**
9.2.1	**Understand and use the vector form of an equation of a straight line in 3D**	Primarily calculator based work. Use of Geogebra encouraged
9.2.2	**Understand and use the vector form of the equation of a plane**	Primarily calculator based work. Use of Geogebra encouraged
9.2.3	**Calculate the scalar product and use it to express the equation of a plane, and to calculate the angle between two lines, the angle between two planes and the angle between a line and a plane**	Primarily calculator based work. Use of Geogebra encouraged
9.2.4	**Check whether vectors are perpendicular by using the scalar product**	Primarily calculator based work. Use of Geogebra encouraged
9.2.5	**Find the intersection of a line and a plane**	Primarily calculator based work. Use of Geogebra encouraged
9.2.6	**Calculate the perpendicular distance between two lines, from a point to a line and from a point to a plane**	Primarily calculator based work. Use of Geogebra encouraged
9.2.7	**Calculate the cross product and use it to find a perpendicular vector in 3D.**	Primarily calculator based work. Use of Geogebra encouraged

[8] Elements taken from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/515123/gce-subject-level-conditions-and-requirements-for-further-mathematics.pdf

10.1 Matrix Operations[9]		
Spec ID	**Assessment statement**	**Additional Guidance**
10.1.1	**Add, subtract and multiply conformable matrices; multiply a matrix by a scalar**	
10.1.2	**Understand and use zero and identity matrices**	
10.1.3	**Understand and use singular and non-singular matrices; properties of inverse matrices**	Inverse matrices expected for 2x2 and 3x3 matrices only
10.1.4	**Calculate determinants of 2 x 2 and 3 x 3 matrices and interpret as scale factors, including the effect on orientation**	

10.2. Linear Algebra		
Spec ID	**Assessment statement**	**Additional Guidance**
10.2.1	**Use matrices to represent linear transformations in 2-D; successive transformations; single transformations in 3-D (3-D transformations confined to reflection in one of x = 0, y = 0, z = 0 or rotation about one of the coordinate axes) (knowledge of 3-D vectors is assumed)**	Primarily calculator based work. Use of Geogebra encouraged
10.2.2	**Find invariant points and lines for a linear transformation**	
10.2.3	**Solve three linear simultaneous equations in three variables by use of the inverse matrix**	
10.2.4	**Interpret geometrically the solution and failure of solution of three simultaneous linear equations**	Primarily calculator based work. Use of Geogebra encouraged

11.1 Fixed-Point Iteration[10]

[9] Elements taken from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/515123/gce-subject-level-conditions-and-requirements-for-further-mathematics.pdf

[10] Elements taken from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/517726/gce-subject-level-conditions-and-requirements-for-mathematics.pdf

Spec ID	Assessment statement	Additional Guidance
11.1.1	Locate roots of f(x) = 0 by considering changes of sign of $f(x)$ in an interval of x on which $f(x)$ is sufficiently well-behaved	
11.1.2	Understand how change of sign methods can fail	
11.1.3	Solve equations approximately using simple iterative methods	
11.1.4	Understand how such methods can fail	
11.1.5	Use numerical methods to solve problems in context	

11.2 Newton-Raphson Method[11]

Spec ID	Assessment statement	Additional Guidance
11.2.1	Solve equations using the Newton-Raphson method and other recurrence relations of the form $x_{n+1} = g(x_n)$	
11.2.2	Understand how such methods can fail	
11.2.3	Use numerical methods to solve problems in context	

11.3 Trapezium Rule[12]

Spec ID	Assessment statement	Additional Guidance
11.3.1	Understand and use numerical integration of functions, including the use of the trapezium rule and estimating the approximate area under a curve and limits that it must lie between	Use in context is expected

[11] Elements taken from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/517726/gce-subject-level-conditions-and-requirements-for-mathematics.pdf

[12] Elements taken from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/517726/gce-subject-level-conditions-and-requirements-for-mathematics.pdf

11.3.2	**Use trapezium rule to solve problems in context**

Appendix D. Symbology[13]

1. Set Notation

1.1 $\in$	is an element of
1.2 $\notin$	is not an element of
1.3 $\subseteq$	is a subset of
1.4 $\subset$	is a proper subset of
1.5 $\{x_1,x_2,\ldots,x_k\}$	the set with elements $x_1,x_2,\ldots,x_k$
1.6 {x : …}	the set of all x such that …
1.7 n(A)	the number of elements in set A
1.8 $\emptyset$	the empty set
1.9 ε	the universal set
1.10 A′	the complement of the set A
1.11 $\mathbb{N}$	the set of natural numbers, {1, 2, 3, …}
1.12 $\mathbb{Z}$	the set of integers, {0, ±1, ±2, ±3, …}
1.13 $\mathbb{Z}^+$	the set of positive integers, {1, 2, 3, …}
1.14 $\mathbb{Z}_0^+$	the set of non-negative integers, {0, 1, 2, 3, …}
1.15 $\mathbb{R}$	the set of real numbers
1.16 $\mathbb{Q}$	the set of rational numbers, $\{\frac{p}{q} : p \in \mathbb{Z}, q \in \mathbb{Z}^+\}$
1.17 $\cup$	union
1.18 $\cap$	intersection
1.19 (x,y)	the ordered pair x , y
1.20 [a,b]	the closed interval $\{x \in \mathbb{R}: a\leq x\leq b\}$
1.21 [a,b)	the interval $\{x \in \mathbb{R}: a\leq x<b\}$
1.22 (a,b]	the interval $\{x \in \mathbb{R}: a<x\leq b\}$
1.23 (a,b)	the open interval $\{x \in \mathbb{R}: a<x<b\}$
1.24 $\mathbb{C}$	the set of complex numbers

2. Miscellaneous Symbols

2.1 =	is equal to
2.2 $\neq$	is not equal to
2.3 $\equiv$	is identical to or is congruent to
2.4 $\approx$	is approximately equal to
2.5 ∞	infinity
2.6 $\propto$	is proportional to
2.7 $\therefore$	therefore
2.8 $\because$	because
2.9 <	is less than
2.10 $\leqslant$	is less than or equal to, is not greater than
2.11 >	is greater than
2.12 $\geqslant$	is greater than or equal to, is not less than
2.13 p $\Rightarrow$ q	p implies q (if p then q)

[13] Elements taken from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/517726/gce-subject-level-conditions-and-requirements-for-mathematics.pdf

2.14 p ⇐ q	p is implied by q (if q then p)
2.15 p ⇔ q	p implies and is implied by q (p is equivalent to q)
2.16 *a*	first term for an arithmetic or geometric sequence
2.17 *l*	last term for an arithmetic sequence
2.18 *d*	common difference for an arithmetic sequence
2.19 *r*	common ratio for a geometric sequence
2.20 S_{n}	sum to n terms of a sequence
2.21 S_{∞}	sum to infinity of a sequence

3. Operations

3.1 a + b	a plus b
3.2 a − b	a minus b
3.3 a × b, ab, a·b	a multiplied by b
3.4 a ÷ b, $\frac{a}{b}$	a divided by b
3.5 $\sum_{i=1}^{n} a_i$	$a_1 + a_2 + \cdots + a_n$
3.6 $\prod_{i=1}^{n} a_i$	$a_1 \times a_2 \times \ldots \times a_n$
3.7 $\sqrt{a}$	the non-negative square root of a
3.8 |a|	the modulus of a
3.9 n!	n factorial: $n! = n \times (n-1) \times \ldots \times 2 \times 1, n \in \mathbb{N}, 0! = 1$
3.10 $\binom{n}{r}$, ${}^{n}C_{r}$	the binomial coefficient $\frac{n!}{(n-r)!\,r!}$ For $n, r \in \mathbb{Z}_0^+$, r ⩽ n

4. Functions

4.1 $f(x)$	the value of the function f at x
4.2 $f: x \mapsto y$	the function f maps the element x to the element y
4.3 f^{-1}	the inverse function of the function f
4.4 gf	the composite function of f and g which is defined by gf(x) = g(f(x))
4.5 $\lim_{x \to a} f(x)$	the limit of f(x) as x tends to a
4.6 Δx, δx	an increment of x
4.7 $\frac{dy}{dx}$	the derivative of y with respect to x
4.8 $\frac{d^n y}{dx^n}$	the n th derivative of y with respect to x
4.9 $f'(x), f''(x), \ldots, f^{(n)}(x)$	the first, second, ..., n th derivatives of f $f(x)$ with respect to x
4.10 $\dot{x}, \ddot{x}, \ldots$	the first, second, ... derivatives of x with respect to t
4.11 $\int y \; dx$	the indefinite integral of y with respect to x
4.12 $\int_a^b y \; dx$	the definite integral of y with respect to x between the limits x = a and x = b

5. Exponential and Logarithmic Functions

5.1 e	base of natural logarithms
5.2 e^x, exp x	exponential function of x
5.3 $log_a x$	logarithm to the base a of x
5.4 $\ln x, log_e x$	natural logarithm of x

6 Trigonometric Functions

6.1 sin, cos, tan, cosec, sec, cot	the trigonometric functions

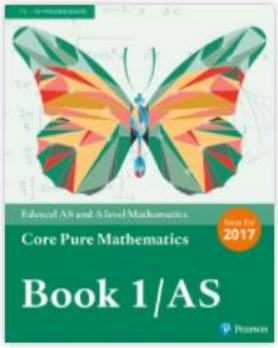
6.2 arcsin, arccos, arctan
$\sin^{-1}$, $\cos^{-1}$, $\tan^{-1}$ the inverse trigonometric functions
6.3 ° degrees
6.4 rad radians

7 Complex Numbers
7.1 i square root of −1
7.2 x + iy complex number with real part x and imaginary part y
7.3 z a complex number, z = x + iy
7.4 Re(z) the real part of z, Re(z) = x
7.5 Im(z) the imaginary part of z, Im(z) = y
7.6 |z| the modulus of z, $z = \sqrt{x + iy}$
7.7 z * the complex conjugate of z = x – iy

8 Matrices
8.1 **M** a matrix **M**
8.2 **0** zero matrix
8.3 **I** identity matrix
8.4 $\mathbf{M}^{-1}$ the inverse of the matrix **M**
8.5 $\mathbf{M}^{\mathbf{T}}$ the transpose of the matrix **M**
8.6 Δ, det **M** or $|\mathbf{M}|$ the determinant of the square matrix **M**

9 Vectors
9.1 **a**, a, a the vector **a**, a, a
9.2 $\overrightarrow{AB}$ the vector represented in magnitude and direction by the directed line segment AB
9.3 $\hat{\boldsymbol{a}}$ a unit vector in the direction of **a**
9.4 **i**, **j**, **k** unit vectors in the directions of the cartesian coordinate axes
9.5 |a| the magnitude of a
9.6 $|\overrightarrow{AB}$ the magnitude of $\overrightarrow{AB}$
9.7 $\binom{a}{b}$, a**i** + b**j** column vector and corresponding unit vector notation
9.8 **a**.**b**, **a**·**b** the scalar product of a and b
9.9 **a** x **b** the cross product of a and b
9.10 $\hat{\boldsymbol{n}}$ a normal unit vector

APPENDIX E. SUGGESTED EXTENSION READING



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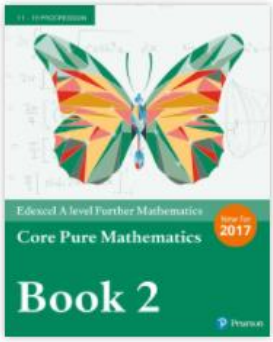

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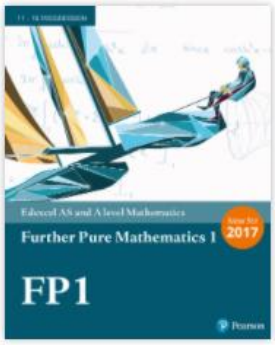

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