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|  | **GCSE: Edexcel specification p.1-8** | Personal | Pedagogy (teaching) |  |
|  | **Number: *Structure and calculation*** | RP | AP | GP | RT | AT | GT | Notes |
|  | 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 (i.e. if there are m ways of doing one task and for each of these, there are n ways of doing another task, then the total number of ways the two tasks can be done is m × n ways) |  |  |  |  |  |  |  |
|  | 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 |  |  |  |  |  |  |  |
|  | calculate with roots, and with integer and fractional indices |  |  |  |  |  |  |  |
|  | calculate exactly with fractions, surds and multiples of π; simplify surd expressions involving squares (e.g. √12 = √(4 × 3) = √4 × √3 = 2√3) and rationalise denominators |  |  |  |  |  |  |  |
|  | calculate with and interpret standard form A × 10*n*, where 1 ≤ A < 10 and *n* is an integer |  |  |  |  |  |  |  |
|  | **Number: *Fractions, decimals and percentages*** | RP | AP | GP | RT | AT | GT | Notes |
|  | work interchangeably with terminating decimals and their correspondingfractions (such as 3.5 and or 0.375 or ); change recurring decimals into their corresponding fractions and vice versa |  |  |  |  |  |  |  |
|  | identify and work with fractions in ratio problems |  |  |  |  |  |  |  |
|  | interpret fractions and percentages as operators |  |  |  |  |  |  |  |
|  | **Number: *Measures and accuracy***  | RP | AP | GP | RT | AT | GT | Notes |
|  | 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 |  |  |  |  |  |  |  |
|  | apply and interpret limits of accuracy, including upper and lower bounds |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  | **Algebra: *Notation, vocabulary and manipulation*** | RP | AP | GP | RT | AT | GT | Notes |
|  | use and interpret algebraic manipulation, including:coefficients written as fractions rather than as decimalsbrackets |  |  |  |  |  |  |  |
|  | 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 termsmultiplying a single term over a brackettaking out common factorsexpanding products of two or more binomialsfactorising quadratic expressions of the form including the difference of two squares; factorising quadratic expressions of the form simplifying expressions involving sums, products and powers, including the laws of indices |  |  |  |  |  |  |  |
|  | understand and use standard mathematical formulae; rearrange formulae tochange the subject |  |  |  |  |  |  |  |
|  | know the difference between an equation and an identity; arguemathematically to show algebraic expressions are equivalent, and usealgebra to support and construct arguments and proofs |  |  |  |  |  |  |  |
|  | where appropriate, interpret simple expressions as functions with inputsand outputs; interpret the reverse process as the ‘inverse function’;interpret the succession of two functions as a ‘composite function’(the use of formal function notation is expected) |  |  |  |  |  |  |  |
|  | **Algebra: *Graphs*** | RP | AP | GP | RT | AT | GT | Notes |
|  | work with coordinates in all four quadrants |  |  |  |  |  |  |  |
|  | plot graphs of equations that correspond to straight-line graphs in the coordinate plane; use the form to identify parallel and perpendicular lines; find the equation of the line through two given points or through one point with a given gradient |  |  |  |  |  |  |  |
|  | identify and interpret gradients and intercepts of linear functions graphically and algebraically |  |  |  |  |  |  |  |
|  | identify and interpret roots, intercepts, turning points of quadratic functions graphically; deduce roots algebraically and turning points by completing the square |  |  |  |  |  |  |  |
|  | recognise, sketch and interpret graphs of linear functions, quadratic functions, simple cubic functions, the reciprocal function exponential functions for positive values of , and the trigonometric functions (with arguments in degrees) for angles of any size |  |  |  |  |  |  |  |
|  | sketch translations and reflections of a given function |  |  |  |  |  |  |  |
|  | plot and interpret graphs (including reciprocal graphs and exponential graphs) and graphs of non-standard functions in real contexts to find approximate solutions to problems such as simple kinematic problems involving distance, speed and acceleration |  |  |  |  |  |  |  |
|  | calculate or estimate gradients of graphs and areas under graphs (including quadratic and other non-linear graphs), and interpret results in cases such as distance-time graphs, velocity-time graphs and graphs in financial contexts (this does not include calculus) |  |  |  |  |  |  |  |
|  | recognise and use the equation of a circle with centre at the origin; find the equation of a tangent to a circle at a given point |  |  |  |  |  |  |  |
|  | Algebra: Solving equations and inequalities |  |  |  |  |  |  |  |
|  | solve linear equations in one unknown algebraically (including those with the unknown on both sides of the equation); find approximate solutions using a graph |  |  |  |  |  |  |  |
|  | solve quadratic equations (including those that require rearrangement) algebraically by factorising, by completing the square and by using the quadratic formula; find approximate solutions using a graph  |  |  |  |  |  |  |  |
|  | solve two simultaneous equations in two variables (linear/linear or linear/quadratic) algebraically; find approximate solutions using a graph |  |  |  |  |  |  |  |
|  | find approximate solutions to equations numerically using iteration |  |  |  |  |  |  |  |
|  | translate simple situations or procedures into algebraic expressions or formulae; derive an equation (or two simultaneous equations), solve the equation(s) and interpret the solution |  |  |  |  |  |  |  |
|  | solve linear inequalities in one or two variable(s), and quadratic inequalities in one variable; represent the solution set on a number line,using set notation and on a graph |  |  |  |  |  |  |  |
|  | **Algebra: *Sequences*** | RP | AP | GP | RT | AT | GT | Notes |
|  | generate terms of a sequence from either a term-to-term or a position-to-term rule |  |  |  |  |  |  |  |
|  | recognise and use sequences of triangular, square and cube numbers, simple arithmetic progressions, Fibonacci type sequences, quadratic sequences, and simple geometric progressions where is an integer, and is a rational number > 0 or a surd) and other sequences |  |  |  |  |  |  |  |
|  | deduce expressions to calculate the nth term of linear and quadratic sequences |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  | **Ratio, proportion and rates of change** | RP | AP | GP | RT | AT | GT | Notes |
|  | 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 includingin 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 s equivalent to ; construct and interpret equations that describe direct and inverse proportion |  |  |  |  |  |  |  |
|  | interpret the gradient of a straight line graph as a rate of change; recognise and interpret graphs that illustrate direct and inverse proportion |  |  |  |  |  |  |  |
|  | interpret the gradient at a point on a curve as the instantaneous rate of change; apply the concepts of average and instantaneous rate of change (gradients of chords and tangents) in numerical, algebraic and graphical contexts (this does not include calculus) |  |  |  |  |  |  |  |
|  | set up, solve and interpret the answers in growth and decay problems, including compound interest and work with general iterative processes |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  | **Geometry and measures: *Properties and constructions*** | RP | AP | GP | RT | AT | GT | Notes |
|  | 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 |  |  |  |  |  |  |  |
|  | use the standard ruler and compass constructions (perpendicular bisector of a line segment, constructing a perpendicular to a given line from/at a given point, bisecting a given angle); use these to construct given figures and solve loci problems; know that the perpendicular distance from a point to a line is the shortest distance to the line |  |  |  |  |  |  |  |
|  | 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) |  |  |  |  |  |  |  |
|  | derive and apply the properties and definitions of: special types of quadrilaterals, including square, rectangle, parallelogram, trapezium, kite and rhombus; and triangles and other plane figures using appropriate language |  |  |  |  |  |  |  |
|  | use the basic congruence criteria for triangles (SSS, SAS, ASA, RHS) |  |  |  |  |  |  |  |
|  | apply angle facts, triangle congruence, similarity 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 |  |  |  |  |  |  |  |
|  | identify, describe and construct congruent and similar shapes, including on coordinate axes, by considering rotation, reflection, translation and enlargement (including fractional and negative scale factors) |  |  |  |  |  |  |  |
|  | describe the changes and invariance achieved by combinations of rotations, reflections and translations  |  |  |  |  |  |  |  |
|  | identify and apply circle definitions and properties, including: centre, radius, chord, diameter, circumference, tangent, arc, sector and segment |  |  |  |  |  |  |  |
|  | apply and prove the standard circle theorems concerning angles, radii, tangents and chords, and use them to prove related results |  |  |  |  |  |  |  |
|  | solve geometrical problems on coordinate axes |  |  |  |  |  |  |  |
|  | identify properties of the faces, surfaces, edges and vertices of: cubes, cuboids, prisms, cylinders, pyramids, cones and spheres |  |  |  |  |  |  |  |
|  | construct and interpret plans and elevations of 3D shapes |  |  |  |  |  |  |  |
|  | **Geometry and measures: *Mensuration and calculation*** | RP | AP | GP | RT | AT | GT | Notes |
|  | use standard units of measure and related concepts (length, area, volume/capacity, mass, time, money, etc.) |  |  |  |  |  |  |  |
|  | measure line segments and angles in geometric figures, including interpreting maps and scale drawings and use of bearings  |  |  |  |  |  |  |  |
|  | 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 , area of a ; calculate: perimeters of 2D shapes, including circles; areas of circles and composite shapes; surface area and volume of spheres, pyramids, cones and composite solids |  |  |  |  |  |  |  |
|  | calculate arc lengths, angles and areas of sectors of circles |  |  |  |  |  |  |  |
|  | apply the concepts of congruence and similarity, including the relationships between lengths, areas and volumes in similar figures |  |  |  |  |  |  |  |
|  | know the formulae for: Pythagoras’ theorem, and the trigonometric ratios, ; apply them to find angles and lengths in right-angled triangles and, where possible, general triangles in two and three dimensional figures |  |  |  |  |  |  |  |
|  | know the exact values of know the exact value of  |  |  |  |  |  |  |  |
|  | know and apply the sine rule , cosine rule , to find unknown lengths and angles |  |  |  |  |  |  |  |
|  | know and apply to calculate the area, sides or angles of any triangle |  |  |  |  |  |  |  |
|  | **Geometry and measures: *Vectors***  | RP | AP | GP | RT | AT | GT | Notes |
|  | describe translations as 2D vectors |  |  |  |  |  |  |  |
|  | apply addition and subtraction of vectors, multiplication of vectors by a scalar, and diagrammatic and column representations of vectors; use vectors to construct geometric arguments and proofs |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  | **Probability** | RP | AP | GP | RT | AT | GT | Notes |
|  | record, describe and analyse the frequency of outcomes of probability experiments using tables and frequency trees |  |  |  |  |  |  |  |
|  | apply ideas of randomness, fairness and equally likely events to calculate expected outcomes of multiple future experiments |  |  |  |  |  |  |  |
|  | relate relative expected frequencies to theoretical probability, using appropriate language and the 0-1 probability scale |  |  |  |  |  |  |  |
|  | apply the property that the probabilities of an exhaustive set of outcomes sum to one; apply the property that the probabilities of an exhaustive set of mutually exclusive events sum to one |  |  |  |  |  |  |  |
|  | understand that empirical unbiased samples tend towards theoretical probability distributions, with increasing sample size |  |  |  |  |  |  |  |
|  | enumerate sets and combinations of sets systematically, using tables, grids, Venn diagrams and tree diagrams |  |  |  |  |  |  |  |
|  | enumerate sets and combinations of sets systematically, using tables, grids, Venn diagrams and tree diagrams |  |  |  |  |  |  |  |
|  | construct theoretical possibility spaces for single and combined experiments with equally likely outcomes and use these to calculate theoretical probabilities |  |  |  |  |  |  |  |
|  | calculate the probability of independent and dependent combined events, including using tree diagrams and other representations, and know the underlying assumptions |  |  |  |  |  |  |  |
|  | calculate and interpret conditional probabilities through representation using expected frequencies with two-way tables, tree diagrams and Venn diagrams |  |  |  |  |  |  |  |
|  |   |  |  |  |  |  |  |  |
|  | **Statistics** | RP | AP | GP | RT | AT | GT | Notes |
|  | infer properties of populations or distributions from a sample, while knowing the limitations of sampling |  |  |  |  |  |  |  |
|  | interpret and construct tables, charts and diagrams, including frequency tables, bar charts, pie charts and pictograms for categorical data, vertical line charts for ungrouped discrete numerical data, tables and line graphs for time series data and know their appropriate use |  |  |  |  |  |  |  |
|  | construct and interpret diagrams for grouped discrete data and continuous data, i.e. histograms with equal and unequal class intervals and cumulative frequency graphs, and know their appropriate use |  |  |  |  |  |  |  |
|  | interpret, analyse and compare the distributions of data sets from univariate empirical distributions through:● appropriate graphical representation involving discrete, continuous and grouped data, including box plots ● appropriate measures of central tendency (median, mean, mode and modal class) and spread (range, including consideration of outliers, quartiles and inter-quartile range) |  |  |  |  |  |  |  |
|  | apply statistics to describe a population |  |  |  |  |  |  |  |
|  | use and interpret scatter graphs of bivariate data; recognise correlation and know that it does not indicate causation; draw estimated lines of best fit; make predictions; interpolate and extrapolate apparent trends while knowing the dangers of so doing |  |  |  |  |  |  |  |
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|  | **A-level: AQA specification p.9-18**  | Personal | Pedagogy (teaching) |  |
|  |  | RP | AP | GP | RT | AT | GT | Notes |
| **A** | **Overarching themes**  | ‘ticking off’ the overarching themes is difficult; instead you can note when you have engaged with these concepts |
| **A1** | **Mathematical argument, language and proof** |
|  | Construct and present mathematical arguments through appropriate use of diagrams; sketching graphs; logical deduction; precise statements involving correct use of symbols and connecting language, including: constant, coefficient, expression, equation, function, identity, index, term, variable. |  |  |  |  |  |  |  |
|  | Understand and use mathematical language and syntax as set out in the content |  |  |  |  |  |  |  |
|  | Understand and use mathematical language and syntax as set out in the content |  |  |  |  |  |  |  |
|  | Understand and use the definition of a function; domain and range of functions |  |  |  |  |  |  |  |
|  | Comprehend and critique mathematical arguments, proofs and justifications of methods and formulae, including those relating to applications of mathematics |  |  |  |  |  |  |  |
| **A2** | **Mathematical problem solving** |  |  |
|  | Recognise the underlying mathematical structure in a situation and simplify and abstract appropriately to enable problems to be solved |  |  |  |  |  |  |  |
|  | Construct extended arguments to solve problems presented in an unstructured form, including problems in context. |  |  |  |  |  |  |  |
|  | Interpret and communicate solutions in the context of the original problem. |  |  |  |  |  |  |  |
|  | Understand that many mathematical problems cannot be solved analytically, but numerical methods permit solution to a required level of accuracy |  |  |  |  |  |  |  |
|  | Evaluate, including by making reasoned estimates, the accuracy or limitations of solutions, including those obtained using numerical methods |  |  |  |  |  |  |  |
|  | Understand the concept of a mathematical problem solving cycle, including specifying the problem, collecting information, processing and representing information and interpreting results, which may identify the need to repeat the cycle. |  |  |  |  |  |  |  |
|  | Understand, interpret and extract information from diagrams and construct mathematical diagrams to solve problems, including in mechanics |  |  |  |  |  |  |  |
| **A3** | **Mathematical modelling** |  |  |
|  | Translate a situation in context into a mathematical model, making simplifying assumptions |  |  |  |  |  |  |  |
|  | Use a mathematical model with suitable inputs to engage with and explore situations (for a given model or a model constructed or selected by the student) |  |  |  |  |  |  |  |
|  | Interpret the outputs of a mathematical model in the context of the original situation (for a given model or a model constructed or selected by the student). |  |  |  |  |  |  |  |
|  | Understand that a mathematical model can be refined by considering its outputs and simplifying assumptions; evaluate whether the model is appropriate |  |  |  |  |  |  |  |
|  | Understand and use modelling assumptions. |  |  |  |  |  |  |  |
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| **B** | **Topics**  |  |  |  |  |  |  |  |
| **B1** | **Proof** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and use the structure of mathematical proof, proceeding from given assumptions through a series of logical steps to a conclusion; use methods of proof, including proof by deduction, proof by exhaustion. |  |  |  |  |  |  |  |
|  | Disproof by counter example. |  |  |  |  |  |  |  |
|  | Proof by contradiction (including proof of the irrationality of √2 and the infinity of primes, and application to unfamiliar proofs). |  |  |  |  |  |  |  |
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| **B2** | **Algebra and functions** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and use the laws of indices for all rational exponents |  |  |  |  |  |  |  |
|  | Use and manipulate surds, including rationalising the denominator |  |  |  |  |  |  |  |
|  | Work with quadratic functions and their graphs; the discriminant of a quadraticfunction, including the conditions for real and repeated roots; completing thesquare; solution of quadratic equations including solving quadratic equations in afunction of the unknown |  |  |  |  |  |  |  |
|  | Solve simultaneous equations in two variables by elimination and by substitution, including one linear and one quadratic equation. |  |  |  |  |  |  |  |
|  | Solve linear and quadratic inequalities in a single variable and interpret such inequalities graphically, including inequalities with brackets and fractions Express solutions through correct use of ‘and’ and ‘or’, or through set notation.Represent linear and quadratic inequalities such as graphically. |  |  |  |  |  |  |  |
|  | Manipulate polynomials algebraically, including expanding brackets and collecting like terms, factorisation and simple algebraic division; use of the factor theorem.Simplify rational expressions including by factorising and cancelling, and algebraic division (by linear expressions only). |  |  |  |  |  |  |  |
|  | Understand and use graphs of functions; sketch curves defined by simple equations including polynomials, the modulus of a linear function, (including their vertical and horizontal asymptotes); interpret algebraic solution of equations graphically; use intersection points of graphs to solve equations.Understand and use proportional relationships and their graphs. |  |  |  |  |  |  |  |
|  | Understand and use composite functions; inverse functions and their graphs. |  |  |  |  |  |  |  |
|  | Understand the effect of simple transformations on the graph of y = f x including sketching associated graphs: , and combinations of these transformations. |  |  |  |  |  |  |  |
|  | Decompose rational functions into partial fractions (denominators not more complicated than squared linear terms and with no more than 3 terms, numerators constant or linear). |  |  |  |  |  |  |  |
|  | Use of functions in modelling, including consideration of limitations and refinements of the models. |  |  |  |  |  |  |  |
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| **B3** | **Coordinate geometry in the (x,y) plane** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and use the equation of a straight line, including the forms: ; gradient conditions for two straight lines to be parallel or perpendicularBe able to use straight line models in a variety of contexts. |  |  |  |  |  |  |  |
|  | Understand and use the coordinate geometry of the circle including using the equation of a circle in the form ; completing the square to find the centre and radius of a circle; use of the following properties:• the angle in a semicircle is a right angle• the perpendicular from the centre to a chord bisects the chord• the radius of a circle at a given point on its circumference is perpendicular to the tangent to the circle at that point. |  |  |  |  |  |  |  |
|  | Understand and use the parametric equations of curves and conversion betweenCartesian and parametric forms. |  |  |  |  |  |  |  |
|  | Use parametric equations in modelling in a variety of contexts |  |  |  |  |  |  |  |
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| **B4** | **Sequences and series** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and use the binomial expansion of for positive integer; the notations and; link to binomial probabilities.Extend to any rational n, including its use for approximation; be aware that the expansion is valid for (proof not required). |  |  |  |  |  |  |  |
|  | Work with sequences including those given by a formula for the nth term and those generated by a simple relation of the form; increasing sequences; decreasing sequences; periodic sequences. |  |  |  |  |  |  |  |
|  | Understand and use sigma notation for sums of series. |  |  |  |  |  |  |  |
|  | Understand and work with arithmetic sequences and series, including the formulae for nth term and the sum to terms. |  |  |  |  |  |  |  |
|  | Understand and work with geometric sequences and series including the formulae for the th term and the sum of a finite geometric series; the sum to infinity of a convergent geometric series, including the use of ; modulus notation |  |  |  |  |  |  |  |
|  | Use sequences and series in modelling. |  |  |  |  |  |  |  |
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| **B5** | **Trigonometry** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and use the definitions of sine, cosine and tangent for all arguments; the sine and cosine rules; the area of a triangle in the form  |  |  |  |  |  |  |  |
|  | Work with radian measure, including use for arc length and area of sector. |  |  |  |  |  |  |  |
|  | understand and use the standard small angle approximations of sine, cosine and tangentwhere is in radians. |  |  |  |  |  |  |  |
|  | Understand and use the sine, cosine and tangent functions; their graphs, symmetries and periodicity. |  |  |  |  |  |  |  |
|  | Know and use exact values of sin and cos for and multiples thereof, and exact values of tan for and multiples thereof. |  |  |  |  |  |  |  |
|  | 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  |  |  |  |  |  |  |  |
|  | Understand and use  |  |  |  |  |  |  |  |
|  | Understand and use double angle formulae; use of formulae for  ; understand geometrical proofs of these formulae. |  |  |  |  |  |  |  |
|  | Understand and use expressions for a cos θ + b sin θ in the equivalent forms of |  |  |  |  |  |  |  |
|  | Solve simple trigonometric equations in a given interval, including quadratic equations in sin, cos and tan and equations involving multiples of the unknown angle. |  |  |  |  |  |  |  |
|  | Construct proofs involving trigonometric functions and identities |  |  |  |  |  |  |  |
|  | Use trigonometric functions to solve problems in context, including problems involving vectors, kinematics and forces. |  |  |  |  |  |  |  |
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| **B6** | **Exponentials and logarithms** | RP | AP | GP | RT | AT | GT |  |
|  | Know and use the function and its graph, where is positive. |  |  |  |  |  |  |  |
|  | Know and use the function and its graph.  |  |  |  |  |  |  |  |
|  | Know that the gradient of is equal to and hence understand why the exponential model is suitable in many applications. |  |  |  |  |  |  |  |
|  | Know and use the definition of as the inverse of , where a is positive and Know and use the function and its graphKnow and use as the inverse function of  |  |  |  |  |  |  |  |
|  | Understand and use the laws of logarithms:(including, for example, ). |  |  |  |  |  |  |  |
|  | Solve equations of the form  |  |  |  |  |  |  |  |
|  | Use logarithmic graphs to estimate parameters in relationships of the form and , given data for  |  |  |  |  |  |  |  |
|  | Understand and use exponential growth and decay; use in modelling (examples may include the use of e in continuous compound interest, radioactive decay, drug concentration decay, exponential growth as a model for population growth); consideration of limitations and refinements of exponential models. |  |  |  |  |  |  |  |
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| **B7** | **Differentiation** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and use the derivative of as the gradient of the tangent to the graph of at a general point ; the gradient of the tangent as a limit; interpretation as a rate of change; sketching the gradient function for a given curve; second derivatives; differentiation from first principles for small positive integer powers of and for  |  |  |  |  |  |  |  |
|  | Understand and use the second derivative as the rate of change of gradient; connection to convex and concave sections of curves and points of inflection. |  |  |  |  |  |  |  |
|  | Differentiate , for rational values of , and related constant multiples, sumsand differences |  |  |  |  |  |  |  |
|  | Differentiate and related sums, differences and constant multiples  |  |  |  |  |  |  |  |
|  | Understand and use the derivative of  |  |  |  |  |  |  |  |
|  | Apply differentiation to find gradients, tangents and normals, maxima and minima and stationary points, points of inflection.Identify where functions are increasing or decreasing |  |  |  |  |  |  |  |
|  | Differentiate using the product rule, the quotient rule and the chain rule, including problems involving connected rates of change and inverse functions. |  |  |  |  |  |  |  |
|  | Differentiate simple functions and relations defined implicitly or parametrically, 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). |  |  |  |  |  |  |  |
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| **B8** | **Integration** | RP | AP | GP | RT | AT | GT |  |
|  | Know and use the Fundamental Theorem of Calculus. |  |  |  |  |  |  |  |
|  | Integrate (excluding = -1), and related sums, differences and constant multiples |  |  |  |  |  |  |  |
|  | Integrate and related sums, differences and constant multiples |  |  |  |  |  |  |  |
|  | Evaluate definite integrals; use a definite integral to find the area under a curve and the area between two curves |  |  |  |  |  |  |  |
|  | Understand and use integration as the limit of a sum. |  |  |  |  |  |  |  |
|  | Carry out simple cases of integration by substitution and integration by parts; understand these methods as the inverse processes of the chain and product rules respectively(Integration by substitution includes finding a suitable substitution and is limited to cases where one substitution will lead to a function which can be integrated; integration by parts includes more than one application of the method but excludes reduction formulae). |  |  |  |  |  |  |  |
|  | Integrate using partial fractions that are linear in the denominator |  |  |  |  |  |  |  |
|  | 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 |  |  |  |  |  |  |  |
|  |
| **B9** | **Numerical methods** | RP | AP | GP | RT | AT | GT |  |
|  | Locate roots of by considering changes of sign of in an interval of on which is sufficiently well-behaved.Understand how change of sign methods can fail. |  |  |  |  |  |  |  |
|  | Solve equations approximately using simple iterative methods; be able to draw associated cobweb and staircase diagrams.Solve equations using the Newton-Raphson method and other recurrence relations of the form 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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| **B10** | **Vectors** | RP | AP | GP | RT | AT | GT |  |
|  | 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. |  |  |  |  |  |  |  |
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| **S1** | **Statistical sampling** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and use the terms ‘population’ and ‘sample’. |  |  |  |  |  |  |  |
|  | Use samples to make informal inferences about the population. |  |  |  |  |  |  |  |
|  | Understand and use sampling techniques, including simple random sampling and opportunity sampling |  |  |  |  |  |  |  |
|  | Select or critique sampling techniques in the context of solving a statistical problem, including understanding that different samples can lead to different conclusions about the population. |  |  |  |  |  |  |  |
| **S2** | **Data presentation and interpretation** | RP | AP | GP | RT | AT | GT |  |
|  | Interpret diagrams for single-variable data, including understanding that area in a histogram represents frequency.Connect to probability distributions |  |  |  |  |  |  |  |
|  | Interpret scatter diagrams and regression lines for bivariate data, including recognition of scatter diagrams which include distinct sections of the population (calculations involving regression lines are excluded).Understand informal interpretation of correlation.Understand that correlation does not imply causation. |  |  |  |  |  |  |  |
|  | Interpret measures of central tendency and variation, extending to standard deviation.Be able to calculate standard deviation, including from summary statistics |  |  |  |  |  |  |  |
|  | Recognise and interpret possible outliers in data sets and statistical diagrams.Select or critique data presentation techniques in the context of a statistical problem.Be able to clean data, including dealing with missing data, errors and outliers |  |  |  |  |  |  |  |
| **S3** | **Probability** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and use mutually exclusive and independent events when calculating probabilities.Link to discrete and continuous distributions. |  |  |  |  |  |  |  |
|  | Understand and use conditional probability, including the use of tree diagrams, Venn diagrams, two-way tables.Understand and use the conditional probability formula. |  |  |  |  |  |  |  |
|  | Modelling with probability, including critiquing assumptions made and the likely effect of more realistic assumptions |  |  |  |  |  |  |  |

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| **S4** | **Statistical distributions** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and use simple, discrete probability distributions (calculation of mean and variance of discrete random variables is excluded), including the binomial distribution, as a model; calculate probabilities using the binomial distribution |  |  |  |  |  |  |  |
|  | Understand and use the Normal distribution as a model; find probabilities using the Normal distribution.Link to histograms, mean, standard deviation, points of inflection and the binomial distribution. |  |  |  |  |  |  |  |
|  | Select an appropriate probability distribution for a context, with appropriate reasoning, including recognising when the binomial or Normal model may not be appropriate |  |  |  |  |  |  |  |
| **S5** | **Statistical hypothesis testing** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and apply the language of statistical hypothesis testing, developed through a binomial model: null hypothesis, alternative hypothesis, significance level, test statistic, 1-tail test, 2-tail test, critical value, critical region, acceptance region, -value]; extend to correlation coefficients as measures of how close data points lie to a straight line and be able to interpret a given correlation coefficient using a given p-value or critical value (calculation of correlation coefficients is excluded). |  |  |  |  |  |  |  |
|  | Conduct a statistical hypothesis test for the proportion in the binomial distribution and interpret the results in context.Understand that a sample is being used to make an inference about the population and appreciate that the significance level is the probability of incorrectly rejecting the null hypothesis. |  |  |  |  |  |  |  |
|  | Conduct a statistical hypothesis test for the mean of a Normal distribution with known, given or assumed variance and interpret the results in context. |  |  |  |  |  |  |  |
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| **S6** | **Use of data in statistics** | RP | AP | GP | RT | AT | GT |  |
|  | become familiar with one or more specific large data set(s) in advance of the final assessment (these data must be real and sufficiently rich to enable the concepts and skills of data presentation and interpretation in the specification to be explored) |  |  |  |  |  |  |  |
|  | use technology such as spreadsheets or specialist statistical packages to explore the dataset(s) |  |  |  |  |  |  |  |
|  | interpret real data presented in summary or graphical form |  |  |  |  |  |  |  |
|  | use data to investigate questions arising in real contexts |  |  |  |  |  |  |  |
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| **M1** | **Quantities and units in mechanics** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and use fundamental quantities and units in the S.I. system: length, time, mass. Understand and use derived quantities and units: velocity, acceleration, force, weight, moment. |  |  |  |  |  |  |  |
| **M2** | **Kinematics** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and use the language of kinematics: position; displacement; distance travelled; velocity; speed; acceleration. |  |  |  |  |  |  |  |
|  | Understand, use and interpret graphs in kinematics for motion in a straight line: displacement against time and interpretation of gradient; velocity against time and interpretation of gradient and area under the graph |  |  |  |  |  |  |  |
|  | Understand, use and derive the formulae for constant acceleration for motion in a straight line; extend to 2 dimensions using vectors. |  |  |  |  |  |  |  |
|  | Use calculus in kinematics for motion in a straight line: ; extend to 2 dimensions using vectors. |  |  |  |  |  |  |  |
| **M3** | **Forces and Newton’s laws** | RP | AP | GP | RT | AT | GT |  |
|  | Understand the concept of a force; understand and use Newton’s first law. |  |  |  |  |  |  |  |
|  | Understand and use Newton’s second law for motion in a straight line (restricted to forces in two perpendicular directions or simple cases of forces given as 2D vectors); extend to situations where forces need to be resolved (restricted to 2 dimensions). |  |  |  |  |  |  |  |
|  | Understand and use weight and motion in a straight line under gravity; gravitational acceleration, g, and its value in S.I. units to varying degrees of accuracy. (The inverse square law for gravitation is not required and g may be assumed to be constant, but students should be aware that g is not a universal constant but depends on location). |  |  |  |  |  |  |  |
|  | Understand and use Newton’s third law; equilibrium of forces on a particle and motion in a straight line (restricted to forces in two perpendicular directions or simple cases of forces given as 2D vectors); application to problems involving smooth pulleys and connected particles; resolving forces in 2 dimensions; equilibrium of a particle under coplanar forces. |  |  |  |  |  |  |  |
|  | Understand and use addition of forces; resultant forces; dynamics for motion in a plane |  |  |  |  |  |  |  |
|  | Understand and use the model for friction; coefficient of friction; motion of a body on a rough surface; limiting friction and statics |  |  |  |  |  |  |  |
| **M4** | **Moments** | RP | AP | GP | RT | AT | GT |  |
|  | Understand and use moments in simple static contexts |  |  |  |  |  |  |  |