Paper 1 and Paper 2: Pure Mathematics

To support the co-teaching of this qualification with the AS Mathematics qualification, common content has been highlighted in bold.

Topics	What students need to learn:		
	Content		Guidance
1 **Proof**	1.1	**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:**	**Examples of proofs:**
		Proof by deduction	**Proof by deduction** **e.g. using completion of the square, prove that $n^2 - 6n + 10$ is positive for all values of n or, for example, differentiation from first principles for small positive integer powers of x** or proving results for arithmetic and geometric series. **This is the most commonly used method of proof throughout this specification**
		Proof by exhaustion	**Proof by exhaustion** **Given that p is a prime number such that $3 < p < 25$, prove by exhaustion, that $(p - 1)(p + 1)$ is a multiple of 12.**
		Disproof by counter example	**Disproof by counter example** **e.g. show that the statement "$n^2 - n + 1$ is a prime number for all values of n" is untrue**
		Proof by contradiction (including proof of the irrationality of $\sqrt{2}$ and the infinity of primes, and application to unfamiliar proofs).	

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2 **Algebra and functions**	2.1	**Understand and use the laws of indices for all rational exponents.**	$a^m \times a^n = a^{m+n}$, $a^m \div a^n = a^{m-n}$, $(a^m)^n = a^{mn}$ **The equivalence of $a^{\frac{m}{n}}$ and $\sqrt[n]{a^m}$ should be known.**
	2.2	**Use and manipulate surds, including rationalising the denominator.**	**Students should be able to simplify algebraic surds using the results** $\left(\sqrt{x}\right)^2 = x$, $\sqrt{xy} = \sqrt{x}\sqrt{y}$ **and** $\left(\sqrt{x}+\sqrt{y}\right)\left(\sqrt{x}-\sqrt{y}\right) = x - y$
	2.3	**Work with quadratic functions and their graphs.**	**The notation $\mathrm{f}(x)$ may be used**
		The discriminant of a quadratic function, including the conditions for real and repeated roots.	**Need to know and to use** $b^2 - 4ac > 0$, $b^2 - 4ac = 0$ **and** $b^2 - 4ac < 0$
		Completing the square.	$ax^2 + bx + c = a\left(x + \frac{b}{2a}\right)^2 + \left(c - \frac{b^2}{4a}\right)$
		Solution of quadratic equations	**Solution of quadratic equations by factorisation, use of the formula, use of a calculator or completing the square.**
		including solving quadratic equations in a function of the unknown.	**These functions could include powers of x, trigonometric functions of x, exponential and logarithmic functions of x.**
	2.4	**Solve simultaneous equations in two variables by elimination and by substitution, including one linear and one quadratic equation.**	**This may involve powers of 2 in one unknown or in both unknowns,** **e.g. solve** $y = 2x + 3$, $y = x^2 - 4x + 8$ **or** $2x - 3y = 6$, $x^2 - y^2 + 3x = 50$

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2 **Algebra and functions** *continued*	2.5	**Solve linear and quadratic inequalities in a single variable and interpret such inequalities graphically,**	**e.g. solving** $ax + b > cx + d$, $px^2 + qx + r \geq 0$, $px^2 + qx + r < ax + b$ **and interpreting the third inequality as the range of x for which the curve $y = px^2 + qx + r$ is below the line with equation $y = ax + b$**
		including inequalities with brackets and fractions.	**These would be reducible to linear or quadratic inequalities** **e.g. $\frac{a}{x} < b$ becomes $ax < bx^2$**
		Express solutions through correct use of 'and' and 'or', or through set notation.	**So, e.g. $x < a$ or $x > b$ is equivalent to $\{ x : x < a \} \cup \{ x : x > b \}$ and $\{ x : c < x \} \cap \{ x : x < d \}$ is equivalent to $x > c$ and $x < d$**
		Represent linear and quadratic inequalities such as $y > x + 1$ and $y > ax^2 + bx + c$ graphically.	**Shading and use of dotted and solid line convention is required.**
	2.6	**Manipulate polynomials algebraically, including expanding brackets and collecting like terms, factorisation and simple algebraic division; use of the factor theorem.**	**Only division by $(ax + b)$ or $(ax - b)$ will be required.** **Students should know that if $f(x) = 0$ when $x = \frac{b}{a}$, then $(ax - b)$ is a factor of $f(x)$.** **Students may be required to factorise cubic expressions such as $x^3 + 3x^2 - 4$ and $6x^3 + 11x^2 - x - 6$.**
		Simplify rational expressions, including by factorising and cancelling, and algebraic division (by linear expressions only).	Denominators of rational expressions will be linear or quadratic, e.g. $\frac{1}{ax+b}$, $\frac{ax+b}{px^2+qx+r}$, $\frac{x^3+a^3}{x^2-a^2}$

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2 **Algebra and functions** *continued*	2.7	**Understand and use graphs of functions; sketch curves defined by simple equations including polynomials**	**Graph to include simple cubic and quartic functions,** **e.g. sketch the graph with equation $y = x^2(2x - 1)^2$**
		The modulus of a linear function.	Students should be able to sketch the graph of $y = \lvert ax + b \rvert$ They should be able to use their graph. For example, sketch the graph with equation $y = \lvert 2x - 1 \rvert$ and use the graph to solve the equation $\lvert 2x - 1 \rvert = x$ or the inequality $\lvert 2x - 1 \rvert > x$
		$y = \frac{a}{x}$ **and** $y = \frac{a}{x^2}$ **(including their vertical and horizontal asymptotes)**	**The asymptotes will be parallel to the axes e.g. the asymptotes of the curve with equation** $y = \frac{2}{x+a} + b$ **are the lines with equations** $y = b$ **and** $x = -a$
		Interpret algebraic solution of equations graphically; use intersection points of graphs to solve equations.	
		Understand and use proportional relationships and their graphs.	**Express relationship between two variables using proportion "∝" symbol or using equation involving constant** **e.g. the circumference of a semicircle is directly proportional to its diameter so** $C \propto d$ **or** $C = kd$ **and the graph of** C **against** d **is a straight line through the origin with gradient** k**.**

Topics	What students need to learn:		
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2 **Algebra and functions** *continued*	2.8	Understand and use composite functions; inverse functions and their graphs.	The concept of a function as a one-one or many-one mapping from $\mathbb{R}$ (or a subset of $\mathbb{R}$) to $\mathbb{R}$. The notation $f : x \mapsto$ and $f(x)$ will be used. Domain and range of functions. Students should know that fg will mean 'do g first, then f' and that if f^{-1} exists, then $f^{-1}f(x) = ff^{-1}(x) = x$ They should also know that the graph of $y = f^{-1}(x)$ is the image of the graph of $y = f(x)$ after reflection in the line $y = x$
	2.9	**Understand the effect of simple transformations on the graph of $y = f(x)$, including sketching associated graphs:** $y = af(x)$, $y = f(x) + a$, $y = f(x + a)$, $y = f(ax)$ and combinations of these transformations	Students should be able to find the graphs of $y = \lvert f(x) \rvert$ and $y = \lvert f(-x) \rvert$, given the graph of $y = f(x)$. Students should be able to apply a combination of these transformations to any of the functions in the A Level specification (quadratics, cubics, quartics, reciprocal, $\frac{a}{x^2}$, $\lvert x \rvert$, $\sin x$, $\cos x$, $\tan x$, e^x and a^x) and sketch the resulting graph. Given the graph of $y = f(x)$, students should be able to sketch the graph of, e.g. $y = 2f(3x)$, or $y = f(-x) + 1$, and should be able to sketch (for example) $y = 3 + \sin 2x$, $y = -\cos\left(x + \frac{\pi}{4}\right)$
	2.10	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).	Partial fractions to include denominators such as $(ax + b)(cx + d)(ex + f)$ and $(ax + b)(cx + d)^2$. Applications to integration, differentiation and series expansions.

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2 **Algebra and functions** *continued*	2.11	Use of functions in modelling, including consideration of limitations and refinements of the models.	For example, use of trigonometric functions for modelling tides, hours of sunlight, etc. Use of exponential functions for growth and decay (see Paper 1, Section 6.7). Use of reciprocal function for inverse proportion (e.g. pressure and volume).
3 **Coordinate geometry in the (x,y) plane**	3.1	**Understand and use the equation of a straight line, including the forms $y - y_1 = m(x - x_1)$ and $ax + by + c = 0$;** **Gradient conditions for two straight lines to be parallel or perpendicular.** **Be able to use straight line models in a variety of contexts.**	**To include the equation of a line through two given points, and the equation of a line parallel (or perpendicular) to a given line through a given point.** **$m' = m$ for parallel lines and $m' = -\frac{1}{m}$ for perpendicular lines** **For example, the line for converting degrees Celsius to degrees Fahrenheit, distance against time for constant speed, etc.**
	3.2	**Understand and use the coordinate geometry of the circle including using the equation of a circle in the form $(x - a)^2 + (y - b)^2 = r^2$** **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.**	**Students should be able to find the radius and the coordinates of the centre of the circle given the equation of the circle, and vice versa.** **Students should also be familiar with the equation $x^2 + y^2 + 2fx + 2gy + c = 0$** **Students should be able to find the equation of a circumcircle of a triangle with given vertices using these properties.** **Students should be able to find the equation of a tangent at a specified point, using the perpendicular property of tangent and radius.**

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3 **Coordinate geometry in the (x, y) plane** *continued*	3.3	Understand and use the parametric equations of curves and conversion between Cartesian and parametric forms.	For example: $x = 3\cos t,\ y = 3\sin t$ describes a circle centre O radius 3 $x = 2 + 5\cos t,\ y = -4 + 5\sin t$ describes a circle centre $(2, -4)$ with radius 5 $x = 5t,\ y = \frac{5}{t}$ describes the curve $xy = 25$ (or $y = \frac{25}{x}$) $x = 5t, y = 3t^2$ describes the quadratic curve $25y = 3x^2$ and other familiar curves covered in the specification. Students should pay particular attention to the domain of the parameter t, as a specific section of a curve may be described.
	3.4	Use parametric equations in modelling in a variety of contexts.	A shape may be modelled using parametric equations or students may be asked to find parametric equations for a motion. For example, an object moves with constant velocity from $(1, 8)$ at $t = 0$ to $(6, 20)$ at $t = 5$. This may also be tested in Paper 3, section 7 (kinematics).
4 **Sequences and series**	4.1	**Understand and use the binomial expansion of $(a + bx)^n$ for positive integer n; the notations $n!$ and ^nC_r link to binomial probabilities.** Extend to any rational n, including its use for approximation; be aware that the expansion is valid for $\left\|\frac{bx}{a}\right\| < 1$ (proof not required)	**Use of Pascal's triangle.** **Relation between binomial coefficients.** **Also be aware of alternative notations such as $\binom{n}{r}$ and ^nC_r** **Considered further in Paper 3 Section 4.1.** May be used with the expansion of rational functions by decomposition into partial fractions May be asked to comment on the range of validity.

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4 **Sequences and series** *continued*	4.2	Work with sequences including those given by a formula for the nth term and those generated by a simple relation of the form $x_{n+1} = \mathrm{f}(x_n)$; increasing sequences; decreasing sequences; periodic sequences.	For example $u_n = \frac{1}{3n+1}$ describes a decreasing sequence as $u_{n+1} < u_n$ for all integer n $u_n = 2^n$ is an increasing sequence as $u_{n+1} > u_n$ for all integer n $u_{n+1} = \frac{1}{u_n}$ for $n > 1$ and $u_1 = 3$ describes a periodic sequence of order 2
	4.3	Understand and use sigma notation for sums of series.	Knowledge that $\sum_1^n 1 = n$ is expected
	4.4	Understand and work with arithmetic sequences and series, including the formulae for nth term and the sum to n terms	The proof of the sum formula for an arithmetic sequence should be known including the formula for the sum of the first n natural numbers.
	4.5	Understand and work with geometric sequences and series, including the formulae for the nth term and the sum of a finite geometric series; the sum to infinity of a convergent geometric series, including the use of $\|r\| < 1$; modulus notation	The proof of the sum formula should be known. Given the sum of a series students should be able to use logs to find the value of n. The sum to infinity may be expressed as S_∞
	4.6	Use sequences and series in modelling.	Examples could include amounts paid into saving schemes, increasing by the same amount (arithmetic) or by the same percentage (geometric) or could include other series defined by a formula or a relation.

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5 **Trigonometry**	5.1	**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 $\frac{1}{2}ab\sin C$** Work with radian measure, including use for arc length and area of sector.	**Use of x and y coordinates of points on the unit circle to give cosine and sine respectively,** **including the ambiguous case of the sine rule.** Use of the formulae $s = r\theta$ and $A = \frac{1}{2}r^2\theta$ for arc lengths and areas of sectors of a circle.
	5.2	Understand and use the standard small angle approximations of sine, cosine and tangent $\sin\theta \approx \theta$, $\cos\theta \approx 1 - \frac{\theta^2}{2}$, $\tan\theta \approx \theta$ Where θ is in radians.	Students should be able to approximate, e.g. $\frac{\cos 3x - 1}{x\sin 4x}$ when x is small, to $-\frac{9}{8}$
	5.3	**Understand and use the sine, cosine and tangent functions; their graphs, symmetries and periodicity.** Know and use exact values of sin and cos for $0, \frac{\pi}{6}, \frac{\pi}{4}, \frac{\pi}{3}, \frac{\pi}{2}, \pi$ and multiples thereof, and exact values of tan for $0, \frac{\pi}{6}, \frac{\pi}{4}, \frac{\pi}{3}, \pi$ and multiples thereof.	**Knowledge of graphs of curves with equations such as $y = \sin x$, $y = \cos(x + 30°)$, $y = \tan 2x$ is expected.**
	5.4	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.	Angles measured in both degrees and radians.

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5 **Trigonometry** *continued*	5.5	**Understand and use** $\tan\theta = \frac{\sin\theta}{\cos\theta}$ **Understand and use** $\sin^2\theta + \cos^2\theta = 1$ $\sec^2\theta = 1 + \tan^2\theta$ and $\text{cosec}^2\theta = 1 + \cot^2\theta$	**These identities may be used to solve trigonometric equations** and angles may be in degrees or radians. **They may also be used to prove further identities.**
	5.6	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 $a\cos\theta + b\sin\theta$ in the equivalent forms of $r\cos(\theta \pm \alpha)$ or $r\sin(\theta \pm \alpha)$	To include application to half angles. Knowledge of the $\tan\left(\frac{1}{2}\theta\right)$ formulae will *not* be required. Students should be able to solve equations such as $a\cos\theta + b\sin\theta = c$ in a given interval.
	5.7	**Solve simple trigonometric equations in a given interval, including quadratic equations in sin, cos and tan and equations involving multiples of the unknown angle.**	**Students should be able to solve equations such as** $\mathbf{\sin(x + 70°) = 0.5 \text{ for } 0 < x < 360°}$, $\mathbf{3 + 5\cos 2x = 1 \text{ for } -180° < x < 180°}$ $\mathbf{6\cos^2 x + \sin x - 5 = 0, 0 \leqslant x < 360°}$ These may be in degrees or radians and this will be specified in the question.
	5.8	Construct proofs involving trigonometric functions and identities.	Students need to prove identities such as $\cos x \cos 2x + \sin x \sin 2x \equiv \cos x$.
	5.9	Use trigonometric functions to solve problems in context, including problems involving vectors, kinematics and forces.	Problems could involve (for example) wave motion, the height of a point on a vertical circular wheel, or the hours of sunlight throughout the year. Angles may be measured in degrees or in radians.

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6 **Exponentials and logarithms**	6.1	**Know and use the function a^x and its graph, where a is positive.** **Know and use the function e^x and its graph.**	**Understand the difference in shape between $a < 1$ and $a > 1$** To include the graph of $y = e^{ax+b} + c$
	6.2	**Know that the gradient of e^{kx} is equal to ke^{kx} and hence understand why the exponential model is suitable in many applications.**	**Realise that when the rate of change is proportional to the y value, an exponential model should be used.**
	6.3	**Know and use the definition of $\log_a x$ as the inverse of a^x, where a is positive and $x \geqslant 0$.** **Know and use the function $\ln x$ and its graph.** **Know and use $\ln x$ as the inverse function of e^x**	$a \neq 1$ **Solution of equations of the form $e^{ax+b} = p$ and $\ln(ax + b) = q$ is expected.**
	6.4	**Understand and use the laws of logarithms:** $\log_a x + \log_a y = \log_a (xy)$ $\log_a x - \log_a y = \log_a \left(\frac{x}{y}\right)$ $k \log_a x = \log_a x^k$ **(including, for example, $k = -1$ and $k = -\frac{1}{2}$)**	**Includes $\log_a a = 1$**
	6.5	**Solve equations of the form $a^x = b$**	**Students may use the change of base formula. Questions may be of the form, e.g. $2^{3x-1} = 3$**
	6.6	**Use logarithmic graphs to estimate parameters in relationships of the form** $y = ax^n$ **and** $y = kb^x$**, given data for x and y**	**Plot $\log y$ against $\log x$ and obtain a straight line where the intercept is $\log a$ and the gradient is n** **Plot $\log y$ against x and obtain a straight line where the intercept is $\log k$ and the gradient is $\log b$**

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6 **Exponentials and logarithms** *continued*	6.7	**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.**	**Students may be asked to find the constants used in a model.** **They need to be familiar with terms such as initial, meaning when $t = 0$.** **They may need to explore the behaviour for large values of t or to consider whether the range of values predicted is appropriate.** **Consideration of an improved model may be required.**
7 **Differentiation**	7.1	**Understand and use the derivative of $\mathrm{f}(x)$ as the gradient of the tangent to the graph of $y = \mathrm{f}(x)$ at a general point (x, y); the gradient of the tangent as a limit; interpretation as a rate of change**	**Know that $\frac{\mathrm{d}y}{\mathrm{d}x}$ is the rate of change of y with respect to x.** **The notation $\mathrm{f}'(x)$ may be used for the first derivative and $\mathrm{f}''(x)$ may be used for the second derivative.**
		sketching the gradient function for a given curve	**Given for example the graph of $y = \mathrm{f}(x)$, sketch the graph of $y = \mathrm{f}'(x)$ using given axes and scale. This could relate speed and acceleration for example.**
		second derivatives	
		differentiation from first principles for small positive integer powers of x and for $\sin x$ and $\cos x$	**For example, students should be able to use, for $n = 2$ and $n = 3$, the gradient expression** $\lim_{h \to 0}\left(\frac{(x+h)^n - x^n}{h}\right)$ **Students may use δx or h**

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7 **Differentiation** *continued*	7.1 *cont.*	**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.	**Use the condition $f''(x) > 0$ implies a minimum and $f''(x) < 0$ implies a maximum for points where $f'(x) = 0$** Know that at an inflection point $f''(x)$ changes sign. Consider cases where $f''(x) = 0$ and $f'(x) = 0$ where the point may be a minimum, a maximum or a point of inflection (e.g. $y = x^n$, $n > 2$)
	7.2	**Differentiate x^n, for rational values of n, and related constant multiples, sums and differences.** Differentiate e^{kx} and a^{kx}, $\sin kx$, $\cos kx$, $\tan kx$ and related sums, differences and constant multiples. Understand and use the derivative of $\ln x$	**For example, the ability to differentiate expressions such as $(2x + 5)(x - 1)$ and $\frac{x^2 + 3x - 5}{4x^{\frac{1}{2}}}$, $x > 0$, is expected.** Knowledge and use of the result $\frac{d}{dx}(a^{kx}) = ka^{kx} \ln a$ is expected.
	7.3	**Apply differentiation to find gradients, tangents and normals** **maxima and minima and stationary points.** points of inflection **Identify where functions are increasing or decreasing.**	**Use of differentiation to find equations of tangents and normals at specific points on a curve.** **To include applications to curve sketching. Maxima and minima problems may be set in the context of a practical problem.** **To include applications to curve sketching.**

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7 **Differentiation** *continued*	7.4	Differentiate using the product rule, the quotient rule and the chain rule, including problems involving connected rates of change and inverse functions.	Differentiation of $\operatorname{cosec} x$, $\cot x$ and $\sec x$. Differentiation of functions of the form $x = \sin y$, $x = 3\tan 2y$ and the use of $\frac{\mathrm{d}y}{\mathrm{d}x} = \frac{1}{\left(\frac{\mathrm{d}x}{\mathrm{d}y}\right)}$ Use of connected rates of change in models, e.g. $\frac{\mathrm{d}V}{\mathrm{d}t} = \frac{\mathrm{d}V}{\mathrm{d}r} \times \frac{\mathrm{d}r}{\mathrm{d}t}$ Skill will be expected in the differentiation of functions generated from standard forms using products, quotients and composition, such as $2x^4 \sin x$, $\frac{e^{3x}}{x}$, $\cos^2 x$ and $\tan^2 2x$.
	7.5	Differentiate simple functions and relations defined implicitly or parametrically, for first derivative only.	The finding of equations of tangents and normals to curves given parametrically or implicitly is required.
	7.6	Construct simple differential equations in pure mathematics and in context, (contexts may include kinematics, population growth and modelling the relationship between price and demand).	Set up a differential equation using given information. For example: In a simple model, the rate of decrease of the radius of the mint is inversely proportional to the square of the radius.
8 **Integration**	8.1	**Know and use the Fundamental Theorem of Calculus**	**Integration as the reverse process of differentiation. Students should know that for indefinite integrals a constant of integration is required.**
	8.2	**Integrate x^n (excluding $n = -1$) and related sums, differences and constant multiples.** Integrate e^{kx}, $\frac{1}{x}$, $\sin kx$, $\cos kx$ and related sums, differences and constant multiples.	**For example, the ability to integrate expressions such as $\frac{1}{2}x^2 - 3x^{-\frac{1}{2}}$ and $\frac{(x+2)^2}{x^{\frac{1}{2}}}$ is expected.** **Given $f'(x)$ and a point on the curve, students should be able to find an equation of the curve in the form $y = f(x)$.** To include integration of standard functions such as $\sin 3x$, $\sec^2 2x$, $\tan x$, e^{5x}, $\frac{1}{2x}$. Students are expected to be able to use trigonometric identities to integrate, for example, $\sin^2 x$, $\tan^2 x$, $\cos^2 3x$.

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8 **Integration** *continued*	8.3	**Evaluate definite integrals; use a definite integral to find the area under a curve** and the area between two curves	**Students will be expected to be able to evaluate the area of a region bounded by a curve and given straight lines,** or between two curves. This includes curves defined parametrically. **For example, find the finite area bounded by the curve $y = 6x - x^2$ and the line $y = 2x$** Or find the finite area bounded by the curve $y = x^2 - 5x + 6$ and the curve $y = 4 - x^2$.
	8.4	Understand and use integration as the limit of a sum.	Recognise $\int_a^b \mathrm{f}(x)\,\mathrm{d}x = \lim_{\delta x \to 0} \sum_{x=a}^{b} \mathrm{f}(x)\,\delta x$
	8.5	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.)	Students should recognise integrals of the form $\int \frac{\mathrm{f}'(x)}{\mathrm{f}(x)}\,\mathrm{d}x = \ln \mathrm{f}(x) + c$. The integral $\int \ln x \,\mathrm{d}x$ is required
	8.6	Integrate using partial fractions that are linear in the denominator.	Integration of rational expressions such as those arising from partial fractions, e.g. $\frac{2}{3x+5}$ Note that the integration of other rational expressions, such as $\frac{x}{x^2+5}$ and $\frac{2}{(2x-1)^4}$ is also required (see previous paragraph).

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8 **Integration** *continued*	8.7	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.)	Students may be asked to sketch members of the family of solution curves.
	8.8	Interpret the solution of a differential equation in the context of solving a problem, including identifying limitations of the solution; includes links to kinematics.	The validity of the solution for large values should be considered.
9 **Numerical methods**	9.1	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. Understand how change of sign methods can fail.	Students should know that sign change is appropriate for continuous functions in a small interval. When the interval is too large sign may not change as there may be an even number of roots. If the function is not continuous, sign may change but there may be an asymptote (not a root).
	9.2	Solve equations approximately using simple iterative methods; be able to draw associated cobweb and staircase diagrams.	Understand that many mathematical problems cannot be solved analytically, but numerical methods permit solution to a required level of accuracy. Use an iteration of the form $x_{n+1} = f(x_n)$ to find a root of the equation $x = f(x)$ and show understanding of the convergence in geometrical terms by drawing cobweb and staircase diagrams.
	9.3	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.	For the Newton-Raphson method, students should understand its working in geometrical terms, so that they understand its failure near to points where the gradient is small.

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9 **Numerical methods** *continued*	9.4	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.	For example, evaluate $\int_0^1 \sqrt{(2x+1)}\ \mathrm{d}x$ using the values of $\sqrt{(2x+1)}$ at $x = 0$, 0.25, 0.5, 0.75 and 1 and use a sketch on a given graph to determine whether the trapezium rule gives an over-estimate or an under-estimate.
	9.5	Use numerical methods to solve problems in context.	Iterations may be suggested for the solution of equations not soluble by analytic means.
10 **Vectors**	10.1	**Use vectors in two dimensions** and in three dimensions	**Students should be familiar with column vectors and with the use of i and j unit vectors in two dimensions** and $\mathbf{i}$, $\mathbf{j}$ and $\mathbf{k}$ unit vectors in three dimensions.
	10.2	**Calculate the magnitude and direction of a vector and convert between component form and magnitude/direction form.**	**Students should be able to find a unit vector in the direction of $\mathbf{a}$, and be familiar with the notation $\lvert\mathbf{a}\rvert$.**
	10.3	**Add vectors diagrammatically and perform the algebraic operations of vector addition and multiplication by scalars, and understand their geometrical interpretations.**	**The triangle and parallelogram laws of addition.** **Parallel vectors.**
	10.4	**Understand and use position vectors; calculate the distance between two points represented by position vectors.**	$\overrightarrow{OB} - \overrightarrow{OA} = \overrightarrow{AB} = \mathbf{b} - \mathbf{a}$ **The distance d between two points (x_1, y_1) and (x_2, y_2) is given by $d^2 = (x_1 - x_2)^2 + (y_1 - y_2)^2$** In three dimensions, the distance d between two points (x_1, y_1, z_1) and (x_2, y_2, z_2) is given by $d^2 = (x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2$

Topics	What students need to learn:		
	Content		Guidance
10 **Vectors** *continued*	10.5	**Use vectors to solve problems in pure mathematics and in context (including forces).**	**For example, finding position vector of the fourth corner of a shape (e.g. parallelogram) $ABCD$ with three given position vectors for the corners A, B and C.** **Contexts such as velocity, displacement, kinematics and forces will be covered in Paper 3, Sections 6.1, 7.3 and 8.1 – 8.4**

Assessment information

- First assessment: May/June 2018.
- The assessments are 2 hours each.
- The assessments are out of 100 marks.
- Students must answer all questions.
- Calculators can be used in the assessments.
- The booklet *Mathematical Formulae and Statistical Tables* will be provided for use in the assessments.

Synoptic assessment

Synoptic assessment requires students to work across different parts of a qualification and to show their accumulated knowledge and understanding of a topic or subject area.

Synoptic assessment enables students to show their ability to combine their skills, knowledge and understanding with breadth and depth of the subject.

These papers assess synopticity.

Sample assessment materials

A sample paper and mark scheme for these papers can be found in the *Pearson Edexcel Level 3 Advanced GCE in Mathematics Sample Assessment Materials (SAMs)* document.

Paper 3: Statistics and Mechanics

All the Pure Mathematics content is assumed knowledge for Paper 3 and may be tested in parts of questions.

To support the co-teaching of this qualification with the AS Mathematics qualification, common content has been highlighted in bold.

Topics	What students need to learn:		
	Content		Guidance
1 **Statistical sampling**	1.1	**Understand and use the terms 'population' and 'sample'.** **Use samples to make informal inferences about the population.**	**Students will be expected to comment on the advantages and disadvantages associated with a census and a sample.**
		Understand and use sampling techniques, including simple random sampling and opportunity sampling.	**Students will be expected to be familiar with: simple random sampling, stratified sampling, systematic sampling, quota sampling and opportunity (or convenience) 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.	
2 **Data presentation and interpretation**	2.1	**Interpret diagrams for single-variable data, including understanding that area in a histogram represents frequency.** **Connect to probability distributions.**	**Students should be familiar with histograms, frequency polygons, box and whisker plots (including outliers) and cumulative frequency diagrams.**

Topics	What students need to learn:		
	Content		Guidance
2 **Data presentation and interpretation** *continued*	2.2	**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).**	**Students should be familiar with the terms explanatory (independent) and response (dependent) variables.** **Use of interpolation and the dangers of extrapolation. Variables other than x and y may be used.** Use to make predictions within the range of values of the explanatory variable. Change of variable may be required, e.g. using knowledge of logarithms to reduce a relationship of the form $y = ax^n$ or $y = kb^x$ into linear form to estimate a and n or k and b.
		Understand informal interpretation of correlation. **Understand that correlation does not imply causation.**	**Use of terms such as positive, negative, zero, strong and weak are expected.**
	2.3	**Interpret measures of central tendency and variation, extending to standard deviation.**	**Data may be discrete, continuous, grouped or ungrouped. Understanding and use of coding.** **Measures of central tendency: mean, median, mode.** **Measures of variation: variance, standard deviation, range and interpercentile ranges.** **Use of linear interpolation to calculate percentiles from grouped data is expected.**
		Be able to calculate standard deviation, including from summary statistics.	**Students should be able to use the statistic x** $S_{xx} = \sum(x-\bar{x})^2 = \sum x^2 - \frac{(\sum x)^2}{n}$ **Use of standard deviation = $\sqrt{\frac{S_{xx}}{n}}$ (or equivalent) is expected but the use of $S = \sqrt{\frac{S_{xx}}{n-1}}$ (as used on spreadsheets) will be accepted.**

Topics	What students need to learn:		
	Content		**Guidance**
2 **Data presentation and interpretation** *continued*	2.4	**Recognise and interpret possible outliers in data sets and statistical diagrams.**	**Any rule needed to identify outliers will be specified in the question.** **For example, use of $Q_1 - 1.5 \times \text{IQR}$ and $Q_3 + 1.5 \times \text{IQR}$ or mean $\pm 3 \times$ standard deviation.**
		Select or critique data presentation techniques in the context of a statistical problem.	**Students will be expected to draw simple inferences and give interpretations to measures of central tendency and variation.** Significance tests, other than those mentioned in Section 5, will not be expected.
		Be able to clean data, including dealing with missing data, errors and outliers.	**For example, students may be asked to identify possible outliers on a box plot or scatter diagram.**
3 **Probability**	3.1	**Understand and use mutually exclusive and independent events when calculating probabilities.**	**Venn diagrams or tree diagrams may be used.** Set notation to describe events may be used. Use of $\text{P}(B\|A) = \text{P}(B)$, $\text{P}(A\|B) = \text{P}(A)$, $\text{P}(A \cap B) = \text{P}(A)\,\text{P}(B)$ in connection with independent events.
		Link to discrete and continuous distributions.	**No formal knowledge of probability density functions is required but students should understand that area under the curve represents probability in the case of a continuous distribution.**
	3.2	Understand and use conditional probability, including the use of tree diagrams, Venn diagrams, two-way tables. Understand and use the conditional probability formula $\text{P}(A\|B) = \frac{\text{P}(A \cap B)}{\text{P}(B)}$	Understanding and use of $\text{P}(A') = 1 - \text{P}(A)$, $\text{P}(A \cup B) = \text{P}(A) + \text{P}(B) - \text{P}(A \cap B)$, $\text{P}(A \cap B) = \text{P}(A)\,\text{P}(B\|A)$.

Topics	What students need to learn:		
	Content		Guidance
3 **Probability** *continued*	3.3	Modelling with probability, including critiquing assumptions made and the likely effect of more realistic assumptions.	For example, questioning the assumption that a die or coin is fair.
4 **Statistical distributions**	4.1	**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.**	**Students will be expected to use distributions to model a real-world situation and to comment critically on the appropriateness.** **Students should know and be able to identify the discrete uniform distribution.** **The notation $X \sim \mathrm{B}(n, p)$ may be used.** **Use of a calculator to find individual or cumulative binomial probabilities.**
	4.2	Understand and use the Normal distribution as a model; find probabilities using the Normal distribution	The notation $X \sim \mathrm{N}(\mu, \sigma^2)$ may be used. Knowledge of the shape and the symmetry of the distribution is required. Knowledge of the probability density function is not required. Derivation of the mean, variance and cumulative distribution function is not required. Questions may involve the solution of simultaneous equations. Students will be expected to use their calculator to find probabilities connected with the normal distribution.
		Link to histograms, mean, standard deviation, points of inflection	Students should know that the points of inflection on the normal curve are at $x = \mu \pm \sigma$. The derivation of this result is not expected.
		and the binomial distribution.	Students should know that when n is large and p is close to 0.5 the distribution $\mathrm{B}(n, p)$ can be approximated by $\mathrm{N}(np, np[1 - p])$ The application of a continuity correction is expected.

Topics	What students need to learn:		
	Content		Guidance
4 **Statistical distributions** *continued*	4.3	Select an appropriate probability distribution for a context, with appropriate reasoning, including recognising when the binomial or Normal model may not be appropriate.	Students should know under what conditions a binomial distribution or a Normal distribution might be a suitable model.
5 **Statistical hypothesis testing**	5.1	**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, *p*-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).	**An informal appreciation that the expected value of a binomial distribution is given by np may be required for a 2-tail test.** Students should know that the product moment correlation coefficient r satisfies $\lvert r \rvert \leq 1$ and that a value of $r = \pm 1$ means the data points all lie on a straight line. Students will be expected to calculate a value of r using their calculator but use of the formula is not required. Hypotheses should be stated in terms of ρ with a null hypothesis of $\rho = 0$ where ρ represents the population correlation coefficient. Tables of critical values or a *p*-value will be given.

Topics	What students need to learn:		
	Content		Guidance
5 **Statistical hypothesis testing** *continued*	5.2	**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**	**Hypotheses should be expressed in terms of the population parameter *p***
		appreciate that the significance level is the probability of incorrectly rejecting the null hypothesis.	**A formal understanding of Type I errors is not expected.**
	5.3	Conduct a statistical hypothesis test for the mean of a Normal distribution with known, given or assumed variance and interpret the results in context.	Students should know that: If $X \sim \mathrm{N}(\mu, \sigma^2)$ then $\overline{X} \sim \mathrm{N}\left(\mu, \frac{\sigma^2}{n}\right)$ and that a test for μ can be carried out using: $\frac{\overline{X} - \mu}{\sigma / \sqrt{n}} \sim \mathrm{N}(0, 1^2)$. No proofs required. Hypotheses should be stated in terms of the population mean μ. Knowledge of the Central Limit Theorem or other large sample approximations is not required.
6 **Quantities and units in mechanics**	6.1	**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**.**	**Students may be required to convert one unit into another e.g. km h^{-1} into m s^{-1}**

Topics	What students need to learn:		
	Content		Guidance
7 **Kinematics**	7.1	**Understand and use the language of kinematics: position; displacement; distance travelled; velocity; speed; acceleration.**	**Students should know that distance and speed must be positive.**
	7.2	**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.**	**Graphical solutions to problems may be required.**
	7.3	**Understand, use and derive the formulae for constant acceleration for motion in a straight line.** Extend to 2 dimensions using vectors.	**Derivation may use knowledge of sections 7.2 and/or 7.4** Understand and use *suvat* formulae for constant acceleration in 2-D, e.g. $\mathbf{v} = \mathbf{u} + \mathbf{a}t$, $\mathbf{r} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$ with vectors given in $\mathbf{i} - \mathbf{j}$ or column vector form. Use vectors to solve problems.
	7.4	**Use calculus in kinematics for motion in a straight line:** $v = \frac{\mathrm{d}r}{\mathrm{d}t}$, $a = \frac{\mathrm{d}v}{\mathrm{d}t} = \frac{\mathrm{d}^2 r}{\mathrm{d}t^2}$ $r = \int v \; \mathrm{d}t$, $v = \int a \; \mathrm{d}t$ Extend to 2 dimensions using vectors.	**The level of calculus required will be consistent with that in Sections 7 and 8 in the Pure Mathematics content.** Differentiation and integration of a vector with respect to time. e.g. Given $\mathbf{r} = t^2\mathbf{i} + t^{\frac{3}{2}}\mathbf{j}$, find $\dot{\mathbf{r}}$ and $\ddot{\mathbf{r}}$ at a given time.
	7.5	Model motion under gravity in a vertical plane using vectors; projectiles.	Derivation of formulae for time of flight, range and greatest height and the derivation of the equation of the path of a projectile may be required.

Topics	What students need to learn:		
	Content		Guidance
8 **Forces and Newton's laws**	8.1	**Understand the concept of a force; understand and use Newton's first law.**	**Normal reaction, tension, thrust or compression, resistance.**
	8.2	**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 2-D vectors);** extend to situations where forces need to be resolved (restricted to 2 dimensions).	**Problems will involve motion in a straight line with constant acceleration in scalar form, where the forces act either parallel or perpendicular to the motion.** **Problems may involve motion in a straight line with constant acceleration in vector form, where the forces are given in $\mathbf{i} - \mathbf{j}$ form or as column vectors.** Extend to problems where forces need to be resolved, e.g. a particle moving on an inclined plane.
	8.3	**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.)**	**The default value of g will be $9.8\ \text{m s}^{-2}$ but some questions may specify another value, e.g. $g = 10\ \text{m s}^{-2}$**

Topics	What students need to learn:		
	Content		Guidance
8 **Forces and Newton's laws** *continued*	8.4	**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 2-D vectors); application to problems involving smooth pulleys and connected particles;** resolving forces in 2 dimensions; equilibrium of a particle under coplanar forces.	**Connected particle problems could include problems with particles in contact e.g. lift problems.** Problems may be set where forces need to be resolved, e.g. at least one of the particles is moving on an inclined plane.
	8.5	Understand and use addition of forces; resultant forces; dynamics for motion in a plane.	Students may be required to resolve a vector into two components or use a vector diagram, e.g. problems involving two or more forces, given in magnitude-direction form.
	8.6	Understand and use the $\mathrm{F} \leq \mu R$ model for friction; coefficient of friction; motion of a body on a rough surface; limiting friction and statics.	An understanding of $\mathrm{F} = \mu R$ when a particle is moving. An understanding of $\mathrm{F} \leq \mu R$ in a situation of equilibrium.
9 **Moments**	9.1	Understand and use moments in simple static contexts.	Equilibrium of rigid bodies. Problems involving parallel and non-parallel coplanar forces, e.g. ladder problems.

Assessment information

- First assessment: May/June 2018.
- The assessment is 2 hours.
- The assessment is out of 100 marks.
- Students must answer all questions.
- Calculators can be used in the assessment.
- The booklet '*Mathematical Formulae and Statistical Tables*' will be provided for use in the assessment.

Synoptic assessment

Synoptic assessment requires students to work across different parts of a qualification and to show their accumulated knowledge and understanding of a topic or subject area.

Synoptic assessment enables students to show their ability to combine their skills, knowledge and understanding with breadth and depth of the subject.

This paper assesses synopticity.

Sample assessment materials

A sample paper and mark scheme for this paper can be found in the *Pearson Edexcel Level 3 Advanced GCE in Mathematics Sample Assessment Materials (SAMs)* document.

Assessment Objectives

Students must:		% in GCE A Level
AO1	**Use and apply standard techniques** Students should be able to: • select and correctly carry out routine procedures; and • accurately recall facts, terminology and definitions	48–52
AO2	**Reason, interpret and communicate mathematically** Students should be able to: • construct rigorous mathematical arguments (including proofs) • make deductions and inferences • assess the validity of mathematical arguments • explain their reasoning; and • use mathematical language and notation correctly. *Where questions/tasks targeting this Assessment Objective will also credit candidates for the ability to 'use and apply standard techniques' (AO1) and/or to 'solve problems within mathematics and in other contexts' (AO3) an appropriate proportion of the marks for the question/task must be attributed to the corresponding Assessment Objective(s).*	23–27
AO3	**Solve problems within mathematics and in other contexts** Students should be able to: • translate problems in mathematical and non-mathematical contexts into mathematical processes • interpret solutions to problems in their original context, and, where appropriate, evaluate their accuracy and limitations • translate situations in context into mathematical models • use mathematical models; and • evaluate the outcomes of modelling in context, recognise the limitations of models and, where appropriate, explain how to refine them. *Where questions/tasks targeting this Assessment Objective will also credit candidates for the ability to 'use and apply standard techniques' (AO1) and/or to 'reason, interpret and communicate mathematically' (AO2) an appropriate proportion of the marks for the question/task must be attributed to the corresponding Assessment Objective(s).*	23–27
	Total	**100%**

Further guidance on the interpretation of these assessment objectives is given in *Appendix 4*.

Breakdown of Assessment Objectives

Paper	Assessment Objectives			Total for all Assessment Objectives
	AO1 %	AO2 %	AO3 %	
Paper 1: Pure Mathematics 1	16.00–17.33	8.66–10	6.33–7.67	33.33%
Paper 2: Pure Mathematics 2	16.00–17.33	8.66–10	6.33–7.67	33.33%
Paper 3: Statistics and Mechanics	16.00–17.33	5.66–7.00	10.33–11.67	33.33%
Total for GCE A Level	**48-52**	**23-27**	**23-27**	**100%**

NB: Totals have been rounded either up or down.

3 Administration and general information

Entries

Details of how to enter students for the examinations for this qualification can be found in our *UK Information Manual*. A copy is made available to all examinations officers and is available on our website: qualifications.pearson.com

Discount code and performance tables

Centres should be aware that students who enter for more than one GCE qualification with the same discount code will have only one of the grades they achieve counted for the purpose of the school and college performance tables. This will be the grade for the larger qualification (i.e. the A Level grade rather than the AS grade). If the qualifications are the same size, then the better grade will be counted (please see *Appendix 8*: *Codes*).

Students should be advised that if they take two GCE qualifications with the same discount code, colleges, universities and employers which they wish to progress to are likely to take the view that this achievement is equivalent to only one GCE. The same view may be taken if students take two GCE qualifications that have different discount codes but have significant overlap of content. Students or their advisers who have any doubts about their subject combinations should check with the institution they wish to progress to before embarking on their programmes.

Access arrangements, reasonable adjustments, special consideration and malpractice

Equality and fairness are central to our work. Our equality policy requires all students to have equal opportunity to access our qualifications and assessments, and our qualifications to be awarded in a way that is fair to every student.

We are committed to making sure that:

- students with a protected characteristic (as defined by the Equality Act 2010) are not, when they are undertaking one of our qualifications, disadvantaged in comparison to students who do not share that characteristic
- all students achieve the recognition they deserve for undertaking a qualification and that this achievement can be compared fairly to the achievement of their peers.

Language of assessment

Assessment of this qualification will be available in English. All student work must be in English.

Access arrangements

Access arrangements are agreed before an assessment. They allow students with special educational needs, disabilities or temporary injuries to:

- access the assessment
- show what they know and can do without changing the demands of the assessment.

The intention behind an access arrangement is to meet the particular needs of an individual student with a disability, without affecting the integrity of the assessment. Access arrangements are the principal way in which awarding bodies comply with the duty under the Equality Act 2010 to make 'reasonable adjustments'.

Access arrangements should always be processed at the start of the course. Students will then know what is available and have the access arrangement(s) in place for assessment.

Reasonable adjustments

The Equality Act 2010 requires an awarding organisation to make reasonable adjustments where a person with a disability would be at a substantial disadvantage in undertaking an assessment. The awarding organisation is required to take reasonable steps to overcome that disadvantage.

A reasonable adjustment for a particular person may be unique to that individual and therefore might not be in the list of available access arrangements.

Whether an adjustment will be considered reasonable will depend on a number of factors, including:

- the needs of the student with the disability
- the effectiveness of the adjustment
- the cost of the adjustment; and
- the likely impact of the adjustment on the student with the disability and other students.

An adjustment will not be approved if it involves unreasonable costs to the awarding organisation, or affects timeframes or the security or integrity of the assessment. This is because the adjustment is not 'reasonable'.

Special consideration

Special consideration is a post-examination adjustment to a student's mark or grade to reflect temporary injury, illness or other indisposition at the time of the examination/ assessment, which has had, or is reasonably likely to have had, a material effect on a candidate's ability to take an assessment or demonstrate their level of attainment in an assessment.

Further information

Please see our website for further information about how to apply for access arrangements and special consideration.

For further information about access arrangements, reasonable adjustments and special consideration, please refer to the JCQ website: www.jcq.org.uk.

Malpractice

Candidate malpractice

Candidate malpractice refers to any act by a candidate that compromises or seeks to compromise the process of assessment or which undermines the integrity of the qualifications or the validity of results/certificates.

Candidate malpractice in examinations **must** be reported to Pearson using a *JCQ Form M1* (available at www.jcq.org.uk/exams-office/malpractice). The form should be emailed to candidatemalpractice@pearson.com. Please provide as much information and supporting documentation as possible. Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report malpractice constitutes staff or centre malpractice.

Staff/centre malpractice

Staff and centre malpractice includes both deliberate malpractice and maladministration of our qualifications. As with candidate malpractice, staff and centre malpractice is any act that compromises or seeks to compromise the process of assessment or which undermines the integrity of the qualifications or the validity of results/certificates.

All cases of suspected staff malpractice and maladministration **must** be reported immediately, before any investigation is undertaken by the centre, to Pearson on a *JCQ Form M2(a)* (available at www.jcq.org.uk/exams-office/malpractice). The form, supporting documentation and as much information as possible should be emailed to pqsmalpractice@pearson.com. Note that the final decision regarding appropriate sanctions lies with Pearson.

Failure to report malpractice itself constitutes malpractice.

More detailed guidance on malpractice can be found in the latest version of the document *General and Vocational Qualifications Suspected Malpractice in Examinations and Assessments Policies and Procedures,* available at www.jcq.org.uk/exams-office/malpractice.

Awarding and reporting

This qualification will be graded, awarded and certificated to comply with the requirements of Ofqual's General Conditions of Recognition.

This A Level qualification will be graded and certificated on a six-grade scale from A* to E using the total combined marks (out of 300) for the three compulsory papers. Individual papers are not graded.

Students whose level of achievement is below the minimum judged by Pearson to be of sufficient standard to be recorded on a certificate will receive an unclassified U result.

The first certification opportunity for this qualification will be 2018.

Student recruitment and progression

Pearson follows the JCQ policy concerning recruitment to our qualifications in that:

- they must be available to anyone who is capable of reaching the required standard
- they must be free from barriers that restrict access and progression
- equal opportunities exist for all students.

Prior learning and other requirements

There are no prior learning or other requirements for this qualification.

Students who would benefit most from studying this qualification are likely to have a Level 2 qualification such as a GCSE in Mathematics.

Progression

Students can progress from this qualification to:

- a range of different, relevant academics or vocational higher education qualifications
- employment in a relevant sector
- further training.

Appendices

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Appendix 1: Formulae

Formulae that students are expected to know for A Level Mathematics are given below and will not appear in the booklet *Mathematical Formulae and Statistical Tables*, which will be provided for use with the paper.

Pure Mathematics

Quadratic Equations

$ax^2 + bx + c = 0$ has roots $\dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Laws of Indices

$a^x a^y \equiv a^{x+y}$

$a^x \div a^y \equiv a^{x-y}$

$(a^x)^y \equiv a^{xy}$

Laws of Logarithms

$x = a^n \Leftrightarrow n = \log_a x$ for $a > 0$ and $x > 0$

$\log_a x + \log_a y \equiv \log_a (xy)$

$\log_a x - \log_a y \equiv \log_a \left(\dfrac{x}{y}\right)$

$k \log_a x \equiv \log_a \left(x^k\right)$

Coordinate Geometry

A straight line graph, gradient m passing through (x_1, y_1) has equation $y - y_1 = m(x - x_1)$

Straight lines with gradients m_1 and m_2 are perpendicular when $m_1 m_2 = -1$

Sequences

General term of an arithmetic progression:

$u_n = a + (n-1)d$

General term of a geometric progression:

$u_n = ar^{n-1}$

Trigonometry

In the triangle ABC

Sine rule: $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$

Cosine rule: $a^2 = b^2 + c^2 - 2bc\cos A$

Area $= \frac{1}{2}ab\sin C$

$\cos^2 A + \sin^2 A \equiv 1$

$\sec^2 A \equiv 1 + \tan^2 A$

$\text{cosec}^2 A \equiv 1 + \cot^2 A$

$\sin 2A \equiv 2\sin A\cos A$

$\cos 2A \equiv \cos^2 A - \sin^2 A$

$\tan 2A \equiv \frac{2\tan A}{1-\tan^2 A}$

Mensuration

Circumference and area of circle, radius r and diameter d:

$C = 2\pi r = \pi d \qquad A = \pi r^2$

Pythagoras' theorem:

In any right-angled triangle where a, b and c are the lengths of the sides and c is the hypotenuse, $c^2 = a^2 + b^2$

Area of a trapezium = $\frac{1}{2}(a+b)h$, where a and b are the lengths of the parallel sides and h is their perpendicular separation.

Volume of a prism = area of cross section × length

For a circle of radius r, where an angle at the centre of θ radians subtends an arc of length s and encloses an associated sector of area A:

$s = r\theta \qquad A = \frac{1}{2}r^2\theta$

Calculus and Differential Equations

Differentiation

Function	Derivative
x^n	nx^{n-1}
$\sin kx$	$k\cos kx$
$\cos kx$	$-k\sin kx$
e^{kx}	ke^{kx}
$\ln x$	$\frac{1}{x}$
$f(x)+g(x)$	$f'(x)+g'(x)$
$f(x)g(x)$	$f'(x)g(x)+f(x)g'(x)$
$f(g(x))$	$f'(g(x))g'(x)$

Integration

Function	Integral
x^n	$\frac{1}{n+1}x^{n+1}+c,\ n\neq -1$
$\cos kx$	$\frac{1}{k}\sin kx+c$
$\sin kx$	$-\frac{1}{k}\cos kx+c$
e^{kx}	$\frac{1}{k}e^{kx}+c$
$\frac{1}{x}$	$\ln\lvert x\rvert+c,\ x\neq 0$
$f'(x)+g'(x)$	$f(x)+g(x)+c$
$f'(g(x))g'(x)$	$f(g(x))+c$

Area under a curve $=\int_a^b y\ dx\ (y\geqslant 0)$

Vectors

$$|x\mathbf{i} + y\mathbf{j} + z\mathbf{k}| = \sqrt{(x^2 + y^2 + z^2)}$$

Statistics

The mean of a set of data: $\bar{x} = \dfrac{\sum x}{n} = \dfrac{\sum fx}{\sum f}$

The standard Normal variable: $Z = \dfrac{X - \mu}{\sigma}$ where $X \sim \mathrm{N}(\mu, \sigma^2)$

Mechanics

Forces and Equilibrium

Weight = mass × g

Friction: $F \leqslant \mu R$

Newton's second law in the form: $F = ma$

Kinematics

For motion in a straight line with variable acceleration:

$$v = \frac{\mathrm{d}r}{\mathrm{d}t} \qquad a = \frac{\mathrm{d}v}{\mathrm{d}t} = \frac{\mathrm{d}^2 r}{\mathrm{d}t^2}$$

$$r = \int v \,\mathrm{d}t \qquad v = \int a \,\mathrm{d}t$$

Appendix 2: Notation

The tables below set out the notation that must be used in A Level Mathematics examinations. Students will be expected to understand this notation without need for further explanation.

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	$\{x_1, x_2, \ldots\}$	the set with elements $x_1, x_2, \ldots$
1.6	$\{x : \ldots\}$	the set of all x such that $\ldots$
1.7	$\mathrm{n}(A)$	the number of elements in set A
1.8	$\varnothing$	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, $\{1, 2, 3, \ldots\}$
1.12	$\mathbb{Z}$	the set of integers, $\{0, \pm 1, \pm 2, \pm 3, \ldots\}$
1.13	$\mathbb{Z}^+$	the set of positive integers, $\{1, 2, 3, \ldots\}$
1.14	$\mathbb{Z}_0^+$	the set of non-negative integers, $\{0, 1, 2, 3, \ldots\}$
1.15	$\mathbb{R}$	the set of real numbers
1.16	$\mathbb{Q}$	the set of rational numbers, $\left\{\frac{p}{q} : p \in \mathbb{Z}, q \in \mathbb{Z}^+\right\}$
1.17	$\cup$	union
1.18	$\cap$	intersection
1.19	(x, y)	the ordered pair x, y
1.20	$[a, b]$	the closed interval $\{x \in \mathbb{R} : a \le x \le b\}$
1.21	$[a, b)$	the interval $\{x \in \mathbb{R} : a \le x < b\}$
1.22	$(a, b]$	the interval $\{\{x \in \mathbb{R} : a < x \le b\}$
1.23	(a, b)	the open interval $\{x \in \mathbb{R} : a < x < b\}$

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	$\leqslant, \leq$	is less than or equal to, is not greater than
2.11	$>$	is greater than
2.12	$\geqslant, \geq$	is greater than or equal to, is not less than
2.13	$p \Rightarrow q$	p implies q (if p then q)
2.14	$p \Leftarrow q$	p is implied by q (if q then p)
2.15	$p \Leftrightarrow q$	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	$a \times b,\ ab,\ a \cdot b$	a multiplied by b
3.4	$a \div b,\ \frac{a}{b}$	a divided by b
3.5	$\sum_{i=1}^{n} a_i$	$a_1 + a_2 + \ldots + a_n$
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	$\lvert a \rvert$	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	$\binom{n}{r},\ {}^{n}C_r,\ {}_{n}C_r$	the binomial coefficient $\frac{n!}{r!(n-r)!}$ for $n, r \in \mathbb{Z}_0^+, r \leqslant n$ or $\frac{n(n-1)\ldots(n-r+1)}{r!}$ for $n \in \mathbb{Q}, r \in \mathbb{Z}_0^+$

4	Functions	
4.1	$\mathrm{f}(x)$	the value of the function f at x
4.2	$\mathrm{f} : x \mapsto y$	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 $\mathrm{gf}(x) = \mathrm{g}(\mathrm{f}(x))$
4.5	$\lim_{x \to a} \mathrm{f}(x)$	the limit of $\mathrm{f}(x)$ as x tends to a
4.6	$\Delta x,\ \delta x$	an increment of x
4.7	$\frac{\mathrm{d}y}{\mathrm{d}x}$	the derivative of y with respect to x
4.8	$\frac{\mathrm{d}^n y}{\mathrm{d}x^n}$	the nth derivative of y with respect to x
4.9	$\mathrm{f}'(x),\ \mathrm{f}''(x),\ \ldots,\ \mathrm{f}^{(n)}(x)$	the first, second, ..., n^{th} derivatives of $\mathrm{f}(x)$ with respect to x

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

7	Vectors	
7.1	**a**, $\underline{a}$, $\underset{\sim}{a}$	the vector **a**, $\underline{a}$, $\underset{\sim}{a}$; these alternatives apply throughout section 9
7.2	$\overrightarrow{AB}$	the vector represented in magnitude and direction by the directed line segment **AB**
7.3	$\hat{\mathbf{a}}$	a unit vector in the direction of **a**
7.4	**i, j, k**	unit vectors in the directions of the cartesian coordinate axes
7.5	$\lvert \mathbf{a} \rvert$, a	the magnitude of **a**
7.6	$\lvert \overrightarrow{AB} \rvert$, AB	the magnitude of $\overrightarrow{AB}$

7	Vectors	
7.7	$\begin{pmatrix} a \\ b \end{pmatrix}$, $a\mathbf{i}+b\mathbf{j}$	column vector and corresponding unit vector notation
7.8	$\mathbf{r}$	position vector
7.9	$\mathbf{s}$	displacement vector
7.10	$\mathbf{v}$	velocity vector
7.11	$\mathbf{a}$	acceleration vector

8	Probability and Statistics	
8.1	A, B, C, etc.	events
8.2	$\mathrm{A} \cup \mathrm{B}$	union of the events A and B
8.3	$\mathrm{A} \cap \mathrm{B}$	intersection of the events A and B
8.4	$\mathrm{P}(A)$	probability of the event A
8.5	A'	complement of the event A
8.6	$\mathrm{P}(A \mid B)$	probability of the event A conditional on the event B
8.7	X, Y, R, etc.	random variables
8.8	x, y, r, etc.	values of the random variables X, Y, R etc.
8.9	$x_1, x_2, \ldots$	observations
8.10	$f_1, f_2, \ldots$	frequencies with which the observations $x_1, x_2, \ldots$ occur
8.11	$\mathrm{p}(x)$, $\mathrm{P}(X = x)$	probability function of the discrete random variable X
8.12	$p_1, p_2, \ldots$	probabilities of the values $x_1, x_2, \ldots$ of the discrete random variable X
8.13	$\mathrm{E}(X)$	expectation of the random variable X
8.14	$\mathrm{Var}(X)$	variance of the random variable X
8.15	$\sim$	has the distribution
8.16	$\mathrm{B}(n, p)$	binomial distribution with parameters n and p, where n is the number of trials and p is the probability of success in a trial
8.17	q	$q = 1 - p$ for binomial distribution
8.18	$\mathrm{N}(\mu, \sigma^2)$	Normal distribution with mean μ and variance σ^2

8	Probability and Statistics	
8.19	$Z \sim \mathrm{N}(0,1)$	standard Normal distribution
8.20	ϕ	probability density function of the standardised Normal variable with distribution $\mathrm{N}(0,\ 1)$
8.21	Φ	corresponding cumulative distribution function
8.22	μ	population mean
8.23	σ^2	population variance
8.24	σ	population standard deviation
8.25	$\overline{x}$	sample mean
8.26	s^2	sample variance
8.27	s	sample standard deviation
8.28	H_0	Null hypothesis
8.29	H_1	Alternative hypothesis
8.30	r	product moment correlation coefficient for a sample
8.31	ρ	product moment correlation coefficient for a population

9	Mechanics	
9.1	kg	kilograms
9.2	m	metres
9.3	km	kilometres
9.4	m/s, $\mathrm{m\,s}^{-1}$	metres per second (velocity)
9.5	$\mathrm{m/s}^2$, $\mathrm{m\,s}^{-2}$	metres per second per second (acceleration)
9.6	F	Force or resultant force
9.7	N	Newton
9.8	N m	Newton metre (moment of a force)
9.9	t	time
9.10	s	displacement
9.11	u	initial velocity
9.12	v	velocity or final velocity
9.13	a	acceleration
9.14	g	acceleration due to gravity
9.15	μ	coefficient of friction

Appendix 3: Use of calculators

Students may use a calculator in all A Level Mathematics examinations. Students are responsible for making sure that their calculators meet the guidelines set out in this appendix.

The use of technology permeates the study of A Level Mathematics. Calculators used **must** include the following features:

- an iterative function
- the ability to compute summary statistics and access probabilities from standard statistical distributions.

In addition, students **must** be told these regulations before sitting an examination:

<table>
<tr>
<td>Calculators must be:
• of a size suitable for use on the desk
• either battery- or solar powered
• free of lids, cases and covers that have printed instructions or formulas.</td>
<td rowspan="2">Calculators must not:
• be designed or adapted to offer any of these facilities
o language translators
o symbolic algebra manipulation
o symbolic differentiation or integration
o communication with other machines or the internet
• be borrowed from another student during an examination for any reason*
• have retrievable information stored in them – this includes
o databanks
o dictionaries
o mathematical formulas
o text.</td>
</tr>
<tr>
<td>The student is responsible for the following:
• the calculator's power supply
• the calculator's working condition
• clearing anything stored in the calculator.</td>
</tr>
</table>

Advice: *an invigilator may give a student a replacement calculator.

Appendix 4: Assessment Objectives

The following tables outline in detail the strands and elements of each Assessment Objective for A Level Mathematics, as provided by Ofqual in the document *GCE Subject Level Guidance for Mathematics.*

- A 'strand' is a discrete bullet point that is formally part of an assessment objective
- An 'element' is an ability that the assessment objective does not formally separate, but that could be discretely targeted or credited.

AO1: Use and apply standard techniques. **Learners should be able to:** ▪ **select and correctly carry out routine procedures** ▪ **accurately recall facts, terminology and definitions**	***50% (A Level)*** ***60% (AS)***
Strands	**Elements**
1. select and correctly carry out routine procedures	1a – select routine procedures
	1b – correctly carry out routine procedures
2. accurately recall facts, terminology and definitions	This strand is a single element

AO2: Reason, interpret and communicate mathematically **Learners should be able to:** ▪ **construct rigorous mathematical arguments (including proofs)** ▪ **make deductions and inferences** ▪ **assess the validity of mathematical arguments** ▪ **explain their reasoning** ▪ **use mathematical language and notation correctly**	***25% (A Level)*** ***20% (AS)***
Strands	**Elements**
1. construct rigorous mathematical arguments (including proofs)	This strand is a single element
2. make deductions and inferences	2a – make deductions
1.	2b – make inferences
3. assess the validity of mathematical arguments	This strand is a single element
4. explain their reasoning	This strand is a single element
5. use mathematical language and notation correctly	This strand is a single element

AO3: Solve problems within mathematics and in other contexts **Learners should be able to:** ▪ **translate problems in mathematical and non-mathematical contexts into mathematical processes** ▪ **interpret solutions to problems in their original context, and, where appropriate, evaluate their accuracy and limitations** ▪ **translate situations in context into mathematical models** ▪ **use mathematical models** ▪ **evaluate the outcomes of modelling in context, recognise the limitations of models and, where appropriate, explain how to refine them**	***25% (A Level)*** ***20% (AS)***
Strands	**Elements**
1. translate problems in mathematical and non-mathematical contexts into mathematical processes	1a – translate problems in mathematical contexts into mathematical processes
1.	1b – translate problems in non-mathematical contexts into mathematical processes
2. interpret solutions to problems in their original context, and, where appropriate evaluate their accuracy and limitations	2a – interpret solutions to problems in their original context
1.	2b – where appropriate, evaluation the accuracy and limitations of solutions to problems
3. translate situations in context into mathematical models	This strand is a single element
4. use mathematical models	This strand is a single element
5. evaluate the outcomes of modelling in context, recognise the limitations of models and, where appropriate, explain how to refine them	5a – evaluate the outcomes of modelling in context
	5b – recognise the limitations of models
	5c – where appropriate, explain how to refine models

Assessment Objectives coverage

There will be full coverage of all elements of the Assessment Objectives, with the exception of AO3.2b and AO3.5c, in each set of A Level Mathematics assessments offered by Pearson. Elements AO3.2b and AO3.5c will be covered in each route through the qualification within three years.

Appendix 5: The context for the development of this qualification

All our qualifications are designed to meet our World Class Qualification Principles[1] and our ambition to put the student at the heart of everything we do.

We have developed and designed this qualification by:

- reviewing other curricula and qualifications to ensure that it is comparable with those taken in high-performing jurisdictions overseas
- consulting with key stakeholders on content and assessment, including learned bodies, subject associations, higher-education academics, teachers and employers to ensure this qualification is suitable for a UK context
- reviewing the legacy qualification and building on its positive attributes.

This qualification has also been developed to meet criteria stipulated by Ofqual in their documents *GCE Qualification Level Conditions and Requirements* and *GCE Subject Level Conditions and Requirements for Mathematics*, published in April 2016.

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[1] Pearson's World Class Qualification Principles ensure that our qualifications are:

- **demanding**, through internationally benchmarked standards, encouraging deep learning and measuring higher-order skills
- **rigorous**, through setting and maintaining standards over time, developing reliable and valid assessment tasks and processes, and generating confidence in end users of the knowledge, skills and competencies of certified students
- **inclusive**, through conceptualising learning as continuous, recognising that students develop at different rates and have different learning needs, and focusing on progression
- **empowering**, through promoting the development of transferable skills, see *Appendix 6.*

From Pearson's Expert Panel for World Class Qualifications

May 2014

"The reform of the qualifications system in England is a profoundly important change to the education system. Teachers need to know that the new qualifications will assist them in helping their learners make progress in their lives.

When these changes were first proposed we were approached by Pearson to join an 'Expert Panel' that would advise them on the development of the new qualifications.

We were chosen, either because of our expertise in the UK education system, or because of our experience in reforming qualifications in other systems around the world as diverse as Singapore, Hong Kong, Australia and a number of countries across Europe.

We have guided Pearson through what we judge to be a rigorous qualification development process that has included:

- extensive international comparability of subject content against the highest-performing jurisdictions in the world
- benchmarking assessments against UK and overseas providers to ensure that they are at the right level of demand
- establishing External Subject Advisory Groups, drawing on independent subject-specific expertise to challenge and validate our qualifications
- subjecting the final qualifications to scrutiny against the DfE content and Ofqual accreditation criteria in advance of submission.

Importantly, we have worked to ensure that the content and learning is future oriented. The design has been guided by what is called an 'Efficacy Framework', meaning learner outcomes have been at the heart of this development throughout.

We understand that ultimately it is excellent teaching that is the key factor to a learner's success in education. As a result of our work as a panel we are confident that we have supported the development of qualifications that are outstanding for their coherence, thoroughness and attention to detail and can be regarded as representing world-class best practice."

Sir Michael Barber (Chair)

Chief Education Advisor, Pearson plc

Professor Lee Sing Kong

Director, National Institute of Education, Singapore

Bahram Bekhradnia

President, Higher Education Policy Institute

Professor Jonathan Osborne

Stanford University

Dame Sally Coates

Principal, Burlington Danes Academy

Professor Dr Ursula Renold

Federal Institute of Technology, Switzerland

Professor Robin Coningham

Pro-Vice Chancellor, University of Durham

Professor Bob Schwartz

Harvard Graduate School of Education

Dr Peter Hill

Former Chief Executive ACARA

All titles correct as at May 2014

Appendix 6: Transferable skills

The need for transferable skills

In recent years, higher education institutions and employers have consistently flagged the need for students to develop a range of transferable skills to enable them to respond with confidence to the demands of undergraduate study and the world of work.

The Organisation for Economic Co-operation and Development (OECD) defines skills, or competencies, as 'the bundle of knowledge, attributes and capacities that can be learned and that enable individuals to successfully and consistently perform an activity or task and can be built upon and extended through learning.' [1]

To support the design of our qualifications, the Pearson Research Team selected and evaluated seven global 21st-century skills frameworks. Following on from this process, we identified the National Research Council's (NRC) framework as the most evidence-based and robust skills framework. We adapted the framework slightly to include the Program for International Student Assessment (PISA) ICT Literacy and Collaborative Problem Solving (CPS) Skills.

The adapted National Research Council's framework of skills involves: [2]

Cognitive skills

- **Non-routine problem solving** – expert thinking, metacognition, creativity.
- **Systems thinking** – decision making and reasoning.
- **Critical thinking** – definitions of critical thinking are broad and usually involve general cognitive skills such as analysing, synthesising and reasoning skills.
- **ICT literacy** – access, manage, integrate, evaluate, construct and communicate. [3]

Interpersonal skills

- **Communication** – active listening, oral communication, written communication, assertive communication and non-verbal communication.
- **Relationship-building skills** – teamwork, trust, intercultural sensitivity, service orientation, self-presentation, social influence, conflict resolution and negotiation.
- **Collaborative problem solving** – establishing and maintaining shared understanding, taking appropriate action, establishing and maintaining team organisation.

Intrapersonal skills

- **Adaptability** – ability and willingness to cope with the uncertain, handling work stress, adapting to different personalities, communication styles and cultures, and physical adaptability to various indoor and outdoor work environments.
- **Self-management and self-development** – ability to work remotely in virtual teams, work autonomously, be self-motivating and self-monitoring, willing and able to acquire new information and skills related to work.

Transferable skills enable young people to face the demands of further and higher education, as well as the demands of the workplace, and are important in the teaching and learning of this qualification. We will provide teaching and learning materials, developed with stakeholders, to support our qualifications.

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[1] OECD – *Better Skills, Better Jobs, Better Lives* (OECD Publishing, 2012)

[2] Koenig J A, National Research Council – *Assessing 21st Century Skills: Summary of a Workshop* (National Academies Press, 2011)

[3] PISA – *The PISA Framework for Assessment of ICT Literacy* (2011)

Appendix 7: Level 3 Extended Project qualification

What is the Extended Project?

The Extended Project is a standalone qualification that can be taken alongside GCEs. It supports the development of independent learning skills and helps to prepare students for their next step – whether that be higher education or employment. The qualification:

- is recognised by higher education for the skills it develops
- is worth half of an Advanced GCE qualification at grades A*–E
- carries UCAS points for university entry.

The Extended Project encourages students to develop skills in the following areas: research, critical thinking, extended writing and project management. Students identify and agree a topic area of their choice for in-depth study (which may or may not be related to a GCE subject they are already studying), guided by their teacher.

Students can choose from one of four approaches to produce:

- a dissertation (for example an investigation based on predominately secondary research)
- an investigation/field study (for example a practical experiment)
- a performance (for example in music, drama or sport)
- an artefact (for example creating a sculpture in response to a client brief or solving an engineering problem).

The qualification is coursework based and students are assessed on the skills of managing, planning and evaluating their project. Students will research their topic, develop skills to review and evaluate the information, and then present the final outcome of their project.

The Extended Project has 120 guided learning hours (GLH) consisting of a 40-GLH taught element that includes teaching the technical skills (for example research skills) and an 80-GLH guided element that includes mentoring students through the project work. The qualification is 100% internally assessed and externally moderated.

How to link the Extended Project with mathematics

The Extended Project creates the opportunity to develop transferable skills for progression to higher education and to the workplace, through the exploration of either an area of personal interest or a topic of interest from within the mathematics qualification content.

Through the Extended Project, students can develop skills that support their study of mathematics, including:

- conducting, organising and using research
- independent reading in the subject area
- planning, project management and time management
- defining a hypothesis to be tested in investigations or developing a design brief
- collecting, handling and interpreting data and evidence
- evaluating arguments and processes, including arguments in favour of alternative interpretations of data and evaluation of experimental methodology
- critical thinking.

In the context of the Extended Project, critical thinking refers to the ability to identify and develop arguments for a point of view or hypothesis, and to consider and respond to alternative arguments.

Types of Extended Project related to mathematics

Students may produce a dissertation on any topic that can be researched and argued. In mathematics this might involve working on a substantial statistical project or a project that requires the use of mathematical modelling.

Projects can give students the opportunity to develop mathematical skills that cannot be adequately assessed in examination questions.

- ***Statistics*** – students can have the opportunity to plan a statistical enquiry project, use different methods of sampling and data collection, use statistical software packages to process and investigate large quantities of data and review results to decide if more data is needed.
- ***Mathematical modelling*** – students can have the opportunity to choose modelling assumptions, compare with experimental data to assess the appropriateness of their assumptions and refine their modelling assumptions until they get the required accuracy of results.

Using the Extended Project to support breadth and depth

In the Extended Project, students are assessed on the quality of the work they produce and the skills they develop and demonstrate through completing this work. Students should demonstrate that they have extended themselves in some significant way beyond what they have been studying in mathematics. Students can demonstrate extension in one or more dimensions:

- ***deepening understanding*** – where a student explores a topic in greater depth than in the specification content. This could be an in-depth exploration of one of the topics in the specification
- ***broadening skills*** – where a student learns a new skill. This might involve learning the skills in statistics or mathematical modelling mentioned above or learning a new mathematical process and its practical uses
- ***widening perspectives*** – where the student's project spans different subjects. Projects in a variety of subjects need to be supported by data and statistical analysis. Students studying mathematics with design and technology can carry out design projects involving the need to model a situation mathematically in planning their design.

A wide range of information to support the delivery and assessment of the Extended Project, including the specification, teacher guidance for all aspects, an editable scheme of work and exemplars for all four approaches, can be found on our website.

Appendix 8: Codes

Type of code	Use of code	Code
Discount codes	Every qualification eligible for performance tables is assigned a discount code indicating the subject area to which it belongs. Discount codes are published by the DfE.	Please see the GOV.UK website*
Regulated Qualifications Framework (RQF) codes	Each qualification title is allocated an Ofqual Regulated Qualifications Framework (RQF) code. The RQF code is known as a Qualification Number (QN). This is the code that features in the DfE Section 96 and on the LARA as being eligible for 16–18 and 19+ funding, and is to be used for all qualification funding purposes. The QN will appear on students' final certification documentation.	The QN for this qualification is: 603/1333/X
Subject codes	The subject code is used by centres to enter students for a qualification. Centres will need to use the entry codes only when claiming students' qualifications.	A Level – 9MA0
Paper codes	These codes are provided for reference purposes. Students do not need to be entered for individual papers.	Paper 1: 9MA0/01 Paper 2: 9MA0/02 Paper 3: 9MA0/03

*https://www.gov.uk/government/publications/key-stage-4-qualifications-discount-codes-and-point-scores

TM22/01/20 9781446957097_GCE2017_AL_MATHS_ISSUE 4.DOC.1-74/0

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