

Grade E checklist

88 skills. Tick each one when you can do it. For grade E you need the skills for the grades below it too.

Pure mathematics

- ☐ **Disprove a statement with a counter-example** Find one value that makes the statement false, show the working and say that it disproves the statement. (Proof by deduction, exhaustion and counter-example)

- ☐ **Use the multiplication, division and power laws** $a^m \times a^n = a^{m+n}$, $a^m \div a^n = a^{m-n}$ and $(a^m)^n = a^{mn}$. (Laws of indices)

- ☐ **Evaluate zero and negative powers** $a^0 = 1$ and $a^{-n} = \frac{1}{a^n}$, e.g. $2^{-3} = \frac{1}{8}$. (Laws of indices)

- ☐ **Simplify a surd using a square factor** $\sqrt{72} = \sqrt{36}\sqrt{2} = 6\sqrt{2}$. (Surds)

- ☐ **Add and subtract like surds** $\sqrt{50} + \sqrt{8} = 5\sqrt{2} + 2\sqrt{2} = 7\sqrt{2}$. (Surds)

- ☐ **Solve a quadratic by factorising or formula** Factorise when you can; otherwise use $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$. (Quadratics and the discriminant)

- ☐ **Solve linear simultaneous equations by elimination** Make the coefficients of one unknown match, then add or subtract the equations. (Simultaneous equations)

- ☐ **Solve a linear inequality** Solve it like an equation, but reverse the sign if you multiply or divide by a negative number. (Inequalities)

- ☐ **Expand brackets and collect like terms** Multiply every term in one bracket by every term in the other, e.g. $(x + 2)(x^2 - 3x + 1) = x^3 - x^2 - 5x + 2$. (Polynomials, algebraic division and the factor theorem)

- ☐ **Sketch a cubic from its factorised form** Mark the roots and the y -intercept; a positive x^3 coefficient goes from bottom left to top right. (Curve sketching and the modulus function)

- ☐ **Evaluate a composite function at a number** $fg(3)$ means find $g(3)$ first, then put the answer into f . (Composite and inverse functions)

- ☐ **Translate a graph vertically and horizontally** $f(x) + a$ moves the graph up by a ; $f(x + a)$ moves it left by a . (Transformations of graphs)

- ☐ **Use a model to make a prediction** Substitute into the formula and give the answer in context, with units. (Modelling with functions)

- ☐ **Find the gradient between two points** $m = \frac{y_2 - y_1}{x_2 - x_1}$: the change in y divided by the change in x . (Straight lines)

- ☐ **Find a line from a point and gradient** Use $y - y_1 = m(x - x_1)$, then rearrange if a particular form is asked for. (Straight lines)

- ☐ **State the centre and radius from the equation** $(x - a)^2 + (y - b)^2 = r^2$ has centre (a, b) and radius r . (Circles)

- ☐ **Find a point from a parameter value** Substitute the value of t into both x and y . (Parametric equations)

- ☐ **Expand $(a + b)^n$ for positive integer n** Use Pascal's triangle or nC_r to write down all $n + 1$ terms, e.g. $(1 + 2x)^4 = 1 + 8x + 24x^2 + 32x^3 + 16x^4$. (Binomial expansion)

- ☐ **Find terms from an nth term formula** Substitute $n = 1, 2, 3, \dots$ into a formula such as $u_n = 3n^2 - 1$.
(Sequences and recurrence relations)
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- ☐ **Write out the terms of a sigma sum** Substitute each value of r from the bottom limit to the top limit, e.g. $\sum_{r=1}^4 r^2 = 1 + 4 + 9 + 16$. (Sigma notation)
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- ☐ **Find the nth term of an arithmetic sequence** Use $u_n = a + (n - 1)d$, e.g. the 20th term of 7, 11, 15, ... is $7 + 19 \times 4 = 83$. (Arithmetic sequences and series)
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- ☐ **Find the nth term of a geometric sequence** Use $u_n = ar^{n-1}$, e.g. the 6th term of 3, 6, 12, ... is $3 \times 2^5 = 96$. (Geometric sequences and series)
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- ☐ **Choose an arithmetic or geometric model** A fixed amount added each time is arithmetic; a fixed percentage change each time is geometric. (Modelling with sequences and series)
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- ☐ **Use the sine and cosine rules** Choose the rule from what you know: a side and its opposite angle means the sine rule; two sides and the included angle, or three sides, means the cosine rule. (Sine and cosine rules, radians, arcs and sectors)
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- ☐ **Convert between degrees and radians** Use π radians = 180° , e.g. $60^\circ = \frac{\pi}{3}$ and $\frac{3\pi}{4} = 135^\circ$. (Sine and cosine rules, radians, arcs and sectors)
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- ☐ **Sketch the sin, cos and tan graphs** Mark the key points: where they cross the axes, the maximum and minimum values, and the asymptotes of tan. (Graphs of sin, cos and tan)
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- ☐ **Solve $\sin x = k$ in a given interval** Find the calculator value, then use symmetry (or CAST) to find every other solution in the interval. (Solving trigonometric equations)
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- ☐ **Resolve a vector into components** A force F at angle θ to the horizontal has components $F \cos \theta$ (horizontal) and $F \sin \theta$ (vertical). (Trigonometry in context)
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- ☐ **Sketch $y = a^x$ for $a > 1$** An increasing curve through $(0, 1)$ that gets closer and closer to the x-axis as $x \rightarrow -\infty$ but never touches it. (Exponential functions and graphs)
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- ☐ **State the gradient function of e^x** If $y = e^x$ then $\frac{dy}{dx} = e^x$: the gradient at every point equals the y-coordinate. (The function e^x and its gradient)
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- ☐ **Convert between index form and log form** $\log_a b = c$ means exactly the same as $a^c = b$. (Logarithms)
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- ☐ **Evaluate simple logarithms without a calculator** For example $\log_2 32 = 5$, $\log_5 1 = 0$ and $\log_9 3 = \frac{1}{2}$. (Logarithms)
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- ☐ **Use the addition and subtraction laws** $\log_a x + \log_a y = \log_a xy$ and $\log_a x - \log_a y = \log_a \frac{x}{y}$. (Laws of logarithms)
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- ☐ **Solve $a^x = b$ by taking logarithms** $x \log a = \log b$, so $x = \frac{\log b}{\log a}$; e.g. $5^x = 40$ gives $x = 2.29$ (3 s.f.). (Solving exponential equations)
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- ☐ **Find the initial value of a model** Put $t = 0$: $Ae^0 = A$, so A is the starting amount. (Exponential growth and decay models)
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- ☐ **Interpret a derivative as gradient and rate** $f'(x)$ is the gradient of the tangent at $(x, f(x))$ and the rate of change of y with respect to x . (First principles, second derivatives and concavity)
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- ☐ **Differentiate polynomials term by term** $\frac{d}{dx}(x^n) = nx^{n-1}$; a constant differentiates to 0. (Differentiating standard functions)
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- ☐ **Find the gradient at a point** Differentiate, then substitute the x-coordinate into $\frac{dy}{dx}$. (Tangents, normals and stationary points)
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- ☐ **Integrate as the reverse of differentiation** If $\frac{dy}{dx} = 6x^2$ then $y = 2x^3 + c$, because differentiating $2x^3 + c$ gives back $6x^2$. (The fundamental theorem of calculus)
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- ☐ **Add a constant to every indefinite integral** The derivative of any constant is zero, so an indefinite integral is only known up to $+c$. (The fundamental theorem of calculus)
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- ☐ **Integrate powers of x, including fractional powers** Rewrite roots and fractions as powers first, e.g. $\frac{2}{\sqrt{x}} = 2x^{-\frac{1}{2}}$, which integrates to $4x^{\frac{1}{2}} + c$. (Integrating standard functions)
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- ☐ **Evaluate a definite integral of a polynomial** Integrate, substitute the upper limit, then subtract the value at the lower limit. (Definite integrals and areas under curves)
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- ☐ **Show a root lies in an interval** Work out $f(a)$ and $f(b)$, show they have opposite signs, and conclude using continuity. (Locating roots by change of sign)
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- ☐ **Calculate iterates from a formula** Substitute x_0 to get x_1 , then x_1 to get x_2 , and so on, using the ANS key. (Iteration and staircase/cobweb diagrams)
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- ☐ **Complete a table of values** Substitute each x into the function (radians for trigonometric functions) and round as instructed. (Numerical integration: the trapezium rule)
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- ☐ **Write vectors in i, j, k and column form** $3\mathbf{i} - 2\mathbf{j} + 5\mathbf{k} = \begin{pmatrix} 3 \\ -2 \\ 5 \end{pmatrix}$. (Vectors in 2D and 3D)
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- ☐ **Add, subtract and scale vectors** Work component by component, e.g. $2(\mathbf{i} - 3\mathbf{j}) + (4\mathbf{i} + \mathbf{j}) = 6\mathbf{i} - 5\mathbf{j}$. (Vectors in 2D and 3D)
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- ☐ **Find the magnitude of a 2D vector** $|3\mathbf{i} - 4\mathbf{j}| = \sqrt{3^2 + (-4)^2} = 5$. (Magnitude and direction)
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- ☐ **Add vectors using the triangle law** $\overrightarrow{AB} + \overrightarrow{BC} = \overrightarrow{AC}$: follow the route from start to finish. (Vector arithmetic and geometry)
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- ☐ **Write the position vector of a point** The point $(3, -1, 2)$ has position vector $3\mathbf{i} - \mathbf{j} + 2\mathbf{k}$. (Position vectors and distances)
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Statistics

- ☐ **Define population, sample, census and sampling frame** A census measures every member of the population; a sample is a selection, chosen from a sampling frame (a list of the sampling units). (Sampling methods and the large data set)
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- ☐ **Describe how to take a simple random sample** Number every item in the sampling frame, then use random numbers to choose the required number of different items. (Sampling methods and the large data set)
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- ☐ **Calculate frequency densities for a histogram** Frequency density = frequency $\div$ class width, using the class boundaries. (Histograms, box plots and cumulative frequency)
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- ☐ **Read the median and quartiles from a box plot** The box shows Q_1 , the median and Q_3 ; the whiskers show the extent of the data and crosses show outliers. (Histograms, box plots and cumulative frequency)
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- ☐ **Describe the correlation shown in a scatter diagram** State positive, negative or no correlation, and whether it is strong or weak. (Correlation and regression)
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- ☐ **Identify the explanatory and response variables** The explanatory (independent) variable is set or controlled, or affects the other; the response (dependent) variable responds to it. (Correlation and regression)
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- ☐ **Find the mean, median and mode of data** Mean = $\frac{\sum x}{n}$; the median is the middle value of the ordered data; the mode is the most common value. (Measures of location and spread)
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- ☐ **Find quartiles and the interquartile range** Use the rule for positions in an ordered list, then $IQR = Q_3 - Q_1$. (Measures of location and spread)
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- ☐ **State what an outlier is** An outlier is a value that is very different from (much larger or smaller than) the rest of the data. (Outliers and cleaning data)
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- ☐ **Use set notation for events** Read and write $A \cap B$ (A and B), $A \cup B$ (A or B or both) and A' (not A). (Mutually exclusive and independent events; Venn and tree diagrams)
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- ☐ **Complete and use a Venn diagram** Fill it in from the intersection outwards, using probabilities or frequencies, and read off probabilities. (Mutually exclusive and independent events; Venn and tree diagrams)
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- ☐ **Find conditional probabilities from a two-way table** Divide by the total of the row or column that you are given. (Conditional probability)
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- ☐ **Calculate expected frequencies from probabilities** Expected frequency = number of trials $\times$ probability. (Modelling with probability)
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- ☐ **Use the fact that probabilities sum to 1** Solve $\sum P(X = x) = 1$ to find an unknown such as k . (Discrete distributions, including the discrete uniform and the binomial)
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- ☐ **Recognise a discrete uniform distribution** Each of the n possible values has probability $\frac{1}{n}$, e.g. the score on a fair die. (Discrete distributions, including the discrete uniform and the binomial)
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- ☐ **Describe the shape and properties of the normal distribution** Bell-shaped and symmetrical about the mean μ , with mean = median = mode, and total area 1. (The normal distribution)
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- ☐ **Find normal probabilities using a calculator** Use normal CD with μ and σ (not σ^2). (The normal distribution)
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- ☐ **Recognise when a binomial model is suitable** The variable counts successes in a fixed number of independent trials with a constant probability of success. (The normal approximation to the binomial; choosing a distribution)
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- ☐ **Write null and alternative hypotheses** H_0 gives the parameter a single value; H_1 says it is greater, less or different. (The language of hypothesis testing)
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- ☐ **Decide whether a test is one- or two-tailed** 'Increased' or 'decreased' gives a one-tailed test; 'changed' or 'different' gives a two-tailed test. (The language of hypothesis testing)
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- ☐ **Write hypotheses for a binomial test** $H_0 : p = p_0$, with H_1 from the wording and p defined in context. (Binomial hypothesis tests)
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- ☐ **Write hypotheses for a correlation test** $H_0 : \rho = 0$ and $H_1 : \rho > 0, \rho < 0$ or $\rho \neq 0$, with ρ defined. (Tests for correlation and for the mean of a normal distribution)
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Mechanics

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- ☐ **State the SI units of basic quantities** Length is measured in metres (m), mass in kilograms (kg) and time in seconds (s). (SI units and modelling assumptions)
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- ☐ **Convert units before substituting** Divide km h^{-1} by 3.6 to get m s^{-1} , divide grams by 1000 to get kilograms, and multiply minutes by 60 to get seconds. (SI units and modelling assumptions)
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- ☐ **Distinguish distance from displacement** Displacement is the vector from the start to the finish; distance is the total length of the path. (Displacement, velocity and acceleration)
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- ☐ **Find average speed and average velocity** Divide the total distance (for speed) or the total displacement (for velocity) by the total time. (Displacement, velocity and acceleration)
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- ☐ **Find velocity from a displacement–time graph** The gradient of a displacement–time graph is the velocity. (Kinematics graphs)
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- ☐ **Sketch a velocity–time graph from a description** Use straight lines for constant acceleration and label the key speeds and times. (Kinematics graphs)
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- ☐ **Choose and use the correct suvat formula** List s, u, v, a, t , then pick the formula that links the three you know with the one you want. (Constant acceleration (suvat))
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- ☐ **Draw a clear, labelled force diagram** Show the weight, normal reaction, tension or thrust, friction and any applied forces, each with an arrow. (Forces, resultants and equilibrium of a particle)
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- ☐ **Add forces given in vector form** Add the $\mathbf{i}$ components and the $\mathbf{j}$ components separately to get the resultant. (Forces, resultants and equilibrium of a particle)
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- ☐ **Apply $F = ma$ in a straight line** The resultant force in the direction of motion equals mass $\times$ acceleration. (Newton's second law and vectors)
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- ☐ **Calculate weight using $W = mg$** Mass in kg, $g = 9.8 \text{ m s}^{-2}$, weight in newtons. (Weight and motion under gravity)
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- ☐ **Use suvat for vertical motion under gravity** Take the acceleration as g downwards and choose up or down as positive. (Weight and motion under gravity)
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- ☐ **State Newton's third law** The forces between two bodies are equal in size, opposite in direction and act on different bodies. (Newton's third law, connected particles and pulleys)
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- ☐ **Resolve a force into two components** A force F at θ to a direction has components $F \cos \theta$ along it and $F \sin \theta$ perpendicular to it. (Resolving forces and inclined planes)
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- ☐ **Know the direction in which friction acts** Along the surface, opposing the motion, or the motion that would happen without friction. (Friction)
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- ☐ **Calculate the moment of a force** Moment = force $\times$ perpendicular distance from the point, stating clockwise or anticlockwise. (Moments, beams and rods in equilibrium)
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