

Grade B checklist

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

Pure mathematics

- ☐ **Prove an expression is always positive** Complete the square to get $(x - a)^2 + k$ with $k > 0$, then use $(x - a)^2 \geq 0$. (Proof by deduction, exhaustion and counter-example)

- ☐ **Prove simple number results by contradiction** e.g. to prove 'if n^2 is odd then n is odd', assume n is even and show n^2 is even. (Proof by contradiction)

- ☐ **Solve equations using a common base** e.g. $8^x = 4^{x+1}$ gives $2^{3x} = 2^{2x+2}$, so $x = 2$. (Laws of indices)

- ☐ **Solve equations with fractional or negative powers** e.g. $x^{-\frac{3}{2}} = \frac{1}{8}$ gives $x^{\frac{3}{2}} = 8$, so $x = 8^{\frac{2}{3}} = 4$. (Laws of indices)

- ☐ **Rationalise denominators using the conjugate** For $a + \sqrt{b}$, multiply top and bottom by $a - \sqrt{b}$; the denominator becomes $a^2 - b$. (Surds)

- ☐ **Find the range of k for given roots** Form an inequality in k from the discriminant and solve it, often as a quadratic inequality. (Quadratics and the discriminant)

- ☐ **Solve a quadratic in a function of x** Put $u = x^2$, $u = \sqrt{x}$ or $u = 2^x$, solve for u , then find x . (Quadratics and the discriminant)

- ☐ **Use the discriminant to decide if graphs meet** Substitute the line into the curve, form a quadratic and test the sign of $b^2 - 4ac$. (Simultaneous equations)

- ☐ **Solve inequalities using graphs** $f(x) > g(x)$ where the graph of f is above the graph of g ; find the intersections first. (Inequalities)

- ☐ **Use factors of the form $ax - b$** ($ax - b$) is a factor of $f(x)$ if and only if $f\left(\frac{b}{a}\right) = 0$. (Polynomials, algebraic division and the factor theorem)

- ☐ **Solve modulus equations and inequalities** Solve both $ax + b = g(x)$ and $-(ax + b) = g(x)$, then check each answer with a sketch. (Curve sketching and the modulus function)

- ☐ **State the domain and range of an inverse** The domain of f^{-1} is the range of f ; the range of f^{-1} is the domain of f . (Composite and inverse functions)

- ☐ **Solve equations involving composite functions** Form $fg(x)$ algebraically, set it equal to the value and solve. (Composite and inverse functions)

- ☐ **Sketch $|f(x)|$ and $f(|x|)$ from $y = f(x)$** $|f(x)|$ reflects parts below the x -axis upwards; $f(|x|)$ reflects the $x \geq 0$ part in the y -axis. (Transformations of graphs)

- ☐ **Handle a repeated linear factor** For $(x - b)^2$ you need both $\frac{B}{x-b}$ and $\frac{C}{(x-b)^2}$. (Partial fractions)

- ☐ **Compare coefficients to find a constant** Equate the coefficients of x^2 (or the constants) when substitution does not give every constant. (Partial fractions)

- ☐ **Find a maximum using completed square form** Write the model as $a - b(t - c)^2$ to read off the maximum a when $t = c$. (Modelling with functions)

- ☐ **Criticise the limitations of a model** Give a reason in context, e.g. it predicts negative values or unlimited growth, or relies on extrapolation. (Modelling with functions)
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- ☐ **Find the perpendicular bisector of a segment** Use the midpoint of the segment and the negative reciprocal of its gradient. (Straight lines)
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- ☐ **Use chord and semicircle properties** The perpendicular bisector of a chord passes through the centre; an angle in a semicircle is 90° . (Circles)
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- ☐ **Find where a line meets a circle** Substitute the line into the circle's equation and solve the resulting quadratic. (Circles)
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- ☐ **State the domain and range of the curve** Use the range of the parameter: $x = 2 \cos t$ gives $-2 \leq x \leq 2$. (Parametric equations)
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- ☐ **Sketch a curve given parametrically** Recognise the Cartesian form (e.g. a circle) or plot points, and draw only the part given by the parameter. (Parametric equations)
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- ☐ **Find greatest heights and distances** Find the vertex of $y(t)$ by completing the square or by symmetry, then find the position. (Parametric equations in modelling)
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- ☐ **Convert a model to a Cartesian path** Eliminate t to get y in terms of x , with a domain that matches the context. (Parametric equations in modelling)
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- ☐ **Expand $(a + bx)^n$ and state its validity** Take out a^n to get $a^n(1 + \frac{b}{a}x)^n$, expand, and give the valid range $|x| < |\frac{a}{b}|$. (Binomial expansion)
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- ☐ **Describe a sequence as increasing, decreasing or periodic** Use the definitions: $u_{n+1} > u_n$ for all n , $u_{n+1} < u_n$ for all n , or terms repeating in a cycle. (Sequences and recurrence relations)
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- ☐ **Evaluate a geometric series in sigma notation** A rule such as 3×2^n gives a geometric series: find the first term by substituting, then use S_n or S_∞ . (Sigma notation)
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- ☐ **Find the number of terms from a sum** Solve the quadratic in n from S_n , then choose the correct positive integer. (Arithmetic sequences and series)
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- ☐ **Find and use the sum to infinity** Check that $|r| < 1$, then use $S_\infty = \frac{a}{1-r}$. (Geometric sequences and series)
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- ☐ **Find when a model reaches a target** Form an equation or inequality in n and solve it with a quadratic or with logarithms. (Modelling with sequences and series)
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- ☐ **Find the area of a segment** Segment = sector – triangle = $\frac{1}{2}r^2(\theta - \sin \theta)$. (Sine and cosine rules, radians, arcs and sectors)
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- ☐ **Approximate an expression for small θ** Replace each trig function with its approximation and simplify to an expression in θ . (Small angle approximations)
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- ☐ **Replace θ by a multiple such as 3θ** $\sin 3\theta \approx 3\theta$ and $\cos 3\theta \approx 1 - \frac{(3\theta)^2}{2} = 1 - \frac{9\theta^2}{2}$. (Small angle approximations)
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- ☐ **Estimate a value and its percentage error** Substitute a small angle into the approximation and compare with the calculator value in radian mode. (Small angle approximations)
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- ☐ **Find maximum, minimum and period after transformations** For $y = a \sin(bx + c) + d$ with $b > 0$: maximum $d + |a|$, minimum $d - |a|$, period $\frac{360^\circ}{b}$. (Graphs of sin, cos and tan)
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- ☐ **Sketch the graphs of sec, cosec and cot** The asymptotes are where the function you take the reciprocal of is zero; where cos or sin is 1 or -1, so is its reciprocal. (sec, cosec, cot and inverse trig functions)
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- ☐ **State domains and ranges of inverse functions** arcsin: domain $[-1, 1]$, range $[-\frac{\pi}{2}, \frac{\pi}{2}]$; arccos: domain $[-1, 1]$, range $[0, \pi]$; arctan: domain all real numbers, range $(-\frac{\pi}{2}, \frac{\pi}{2})$. (sec, cosec, cot and inverse trig functions)
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- ☐ **Solve equations in sec, cosec and cot** Turn them into cos, sin or tan, e.g. $\sec 2x = -2$ becomes $\cos 2x = -\frac{1}{2}$. (sec, cosec, cot and inverse trig functions)
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- ☐ **Derive the sec and cosec identities** Divide $\sin^2 \theta + \cos^2 \theta = 1$ by $\cos^2 \theta$, or by $\sin^2 \theta$. (Pythagorean identities)
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- ☐ **Solve quadratic equations using an identity** Replace $\cos^2 x$ by $1 - \sin^2 x$ (or similar) to get a quadratic in one function. (Pythagorean identities)
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- ☐ **Use given ratios to find compound values** e.g. given tan A and sin B, find $\cos(A + B)$ or $\sin 2A$ exactly, taking care with signs. (Compound and double angles; $R \cos(\theta \pm \alpha)$)
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- ☐ **Write $a \cos \theta + b \sin \theta$ in R form** Expand $R \cos(\theta - \alpha)$ and compare coefficients: $R = \sqrt{a^2 + b^2}$ and $\tan \alpha = \frac{b}{a}$. (Compound and double angles; $R \cos(\theta \pm \alpha)$)
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- ☐ **Solve quadratic equations in sin, cos or tan** Factorise, solve each factor, and reject any impossible value. (Solving trigonometric equations)
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- ☐ **Prove identities involving sec, cosec and cot** Write everything in terms of sin and cos, then simplify. (Proving trigonometric identities)
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- ☐ **Use double angle formulae in proofs** Replace $\sin 2\theta$ and $\cos 2\theta$ with expressions in θ , choosing the form of $\cos 2\theta$ that simplifies best. (Proving trigonometric identities)
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- ☐ **Interpret the parameters of a trig model** In $y = a + b \sin(ct)$ with $b > 0$, a is the mean level, b is the amplitude and $\frac{360^\circ}{c}$ is the period. (Trigonometry in context)
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- ☐ **Sketch transformed exponential graphs** For $y = Ae^{kx} + c$, show the y-intercept $(0, A + c)$ and the asymptote $y = c$. (Exponential functions and graphs)
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- ☐ **Find exact axis intercepts using logarithms** Set $y = 0$ and solve with ln, e.g. $4 - e^{2x} = 0$ gives $x = \frac{1}{2} \ln 4 = \ln 2$. (Exponential functions and graphs)
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- ☐ **Find where the gradient has a given value** Solve an equation such as $6e^{2x} - 5 = 7$ using ln. (The function e^x and its gradient)
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- ☐ **Sketch transformed log graphs** E.g. $y = \ln(x + 3)$ has asymptote $x = -3$ and meets the axes at $(-2, 0)$ and $(0, \ln 3)$. (Logarithms)
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- ☐ **Solve equations involving logarithms** Combine into one log, then change to index form, e.g. $\log_2 x(x - 2) = 3 \Rightarrow x(x - 2) = 8$. (Laws of logarithms)
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- ☐ **Solve equations with different bases** E.g. $2^{x+3} = 5^x$: take logs, expand, collect the x terms and factorise. (Solving exponential equations)
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- ☐ **Find a and n from a line** The gradient is n ; the intercept c is $\log a$, so $a = 10^c$ (or $a = e^c$ if the axes use ln). (Using log graphs to estimate parameters)
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- ☐ **Find k and b from a line** The intercept c is $\log k$ and the gradient m is $\log b$, so $k = 10^c$ and $b = 10^m$. (Using log graphs to estimate parameters)
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- ☐ **Find the constants from given data** Use the starting value for A , then a second value to find k using $\ln$.
(Exponential growth and decay models)
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- ☐ **Differentiate x^2 or x^3 from first principles** Expand $f(x+h)$, simplify $\frac{f(x+h)-f(x)}{h}$, then let $h \rightarrow 0$. (First principles, second derivatives and concavity)
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- ☐ **Find where a curve is convex or concave** Convex where $f''(x) \geq 0$; concave where $f''(x) \leq 0$. (First principles, second derivatives and concavity)
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- ☐ **Differentiate a^{kx} and $\tan kx$** $\frac{d}{dx}(a^{kx}) = ka^{kx} \ln a$ and $\frac{d}{dx}(\tan kx) = k \sec^2 kx$. (Differentiating standard functions)
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- ☐ **Find where a function is increasing or decreasing** Solve $f'(x) \geq 0$ (increasing) or $f'(x) \leq 0$ (decreasing). (Tangents, normals and stationary points)
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- ☐ **Use the quotient rule** $\frac{d}{dx}\left(\frac{u}{v}\right) = \frac{v \frac{du}{dx} - u \frac{dv}{dx}}{v^2}$ (given in the formula booklet). (Product, quotient and chain rules)
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- ☐ **Use $\frac{dy}{dx} = 1 \div \frac{dx}{dy}$** When x is given in terms of y , differentiate with respect to y and take the reciprocal. (Product, quotient and chain rules)
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- ☐ **Find an unknown rate at an instant** Differentiate the formula first, then substitute the value at that instant. (Connected rates of change)
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- ☐ **Differentiate products such as xy implicitly** Use the product rule: $\frac{d}{dx}(xy) = x \frac{dy}{dx} + y$. (Implicit and parametric differentiation)
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- ☐ **Find tangents and normals to parametric curves** Find the value of t , the point (x, y) and the gradient, then use $y - y_1 = m(x - x_1)$. (Implicit and parametric differentiation)
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- ☐ **Find the constant of proportionality** Substitute a known rate and value at the same moment, e.g. $-5 = -k\sqrt{400}$ gives $k = 0.25$. (Constructing differential equations)
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- ☐ **Integrate twice from a second derivative** Each integration brings a new constant, so you need two conditions, such as a point on the curve and a stationary point. (The fundamental theorem of calculus)
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- ☐ **Reverse standard derivatives such as $\tan kx$** Because $\frac{d}{dx}(\tan kx) = k \sec^2 kx$, $\int \sec^2 kx \, dx = \frac{1}{k} \tan kx + c$. (Integrating standard functions)
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- ☐ **Deal with regions below the x-axis** The integral is negative there, so split the integral at each root and add the sizes of the separate answers. (Definite integrals and areas under curves)
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- ☐ **Find the area between two curves** Integrate the difference of the two functions between the intersection points. (Areas between curves and parametric areas)
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- ☐ **Handle regions bounded by tangents or normals** Find the line's equation and where it meets the axis, then add or subtract areas. (Areas between curves and parametric areas)
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- ☐ **Evaluate the limit by integrating** Integrate and substitute the limits to give an exact value. (Integration as the limit of a sum)
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- ☐ **Use a given substitution to integrate** Replace every x and dx so that the integral is entirely in u , then integrate. (Integration by substitution)
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- ☐ **Change the limits for a definite integral** Convert each x -limit to a u -limit so that you never need to go back to x . (Integration by substitution)
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- ☐ **Integrate products involving $\ln x$** Let $u = \ln x$; for $\int \ln x \, dx$, write it as $\int 1 \times \ln x \, dx$. (Integration by parts)
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- ☐ **Evaluate definite integrals by parts exactly** Apply the limits to both uv and the remaining integral.
(Integration by parts)
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- ☐ **Integrate a repeated-factor term** $\int \frac{B}{(ax+b)^2} dx = -\frac{B}{a(ax+b)} + c$: a power, not a logarithm. (Integration using partial fractions)
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- ☐ **Combine logarithms into an exact answer** Use the laws of logarithms to write the answer in the form the question asks for. (Integration using partial fractions)
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- ☐ **Find a particular solution from a condition** Substitute the given values of x and y to find the constant.
(Separable differential equations)
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- ☐ **Rearrange a logarithmic solution into $y = \dots$** From $\ln |y| = f(x) + c$, write $y = Ae^{f(x)}$, where A is a constant. (Separable differential equations)
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- ☐ **Find a time or value from a solution** Substitute into the solution and rearrange, using logs to solve for t .
(Differential equations in context: interpreting solutions)
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- ☐ **Interpret terms and constants in context** Say what each term represents, with units, e.g. a constant inflow rate or a rate proportional to the amount present. (Differential equations in context: interpreting solutions)
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- ☐ **Explain how a sign change can mislead** A vertical asymptote (a break in the graph) can give a sign change with no root. (Locating roots by change of sign)
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- ☐ **Explain how roots can be missed** With no sign change there may still be two roots, or a root where the curve just touches the axis. (Locating roots by change of sign)
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- ☐ **Explain convergence or divergence from iterates** Say whether the values approach a limit, and whether it is the root you want. (Iteration and staircase/cobweb diagrams)
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- ☐ **Iterate to the accuracy required** Repeat using ANS until the values agree to the accuracy asked. (The Newton–Raphson method)
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- ☐ **Explain the method using tangents** x_{n+1} is where the tangent to the curve at $x = x_n$ crosses the x -axis. (The Newton–Raphson method)
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- ☐ **State over- or underestimate with a reason** Convex curve (bending upwards): overestimate. Concave curve (bending downwards): underestimate. (Numerical integration: the trapezium rule)
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- ☐ **Explain how to improve the estimate** Use more strips (a smaller h), so the trapezia fit the curve more closely. (Numerical integration: the trapezium rule)
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- ☐ **Interpret numerical answers in context** Give units and convert where sensible, e.g. 7.154 hours is about 7 hours 9 minutes. (Numerical methods in context)
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- ☐ **Describe edges and diagonals of cuboids** Write edges and diagonals of a cuboid in terms of $\mathbf{i}$, $\mathbf{j}$ and $\mathbf{k}$ from the coordinates of its vertices. (Vectors in 2D and 3D)
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- ☐ **Find the direction of a 2D vector** Use $\tan$ with a sketch to find the angle with the positive x -axis in the correct quadrant. (Magnitude and direction)
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- ☐ **Prove that three points are collinear** Show that two of the vectors joining them are parallel and share a point. (Vector arithmetic and geometry)
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- ☐ **Find a missing vertex of a parallelogram** Use equal opposite sides: in $ABCD$, $\overrightarrow{AD} = \overrightarrow{BC}$, so $\mathbf{d} = \mathbf{a} + \mathbf{c} - \mathbf{b}$. (Position vectors and distances)
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- ☐ **Find speed and direction from velocity** Speed is $|\mathbf{v}|$; the direction is an angle or bearing found with trigonometry. (Vector problems)

- ☐ **Prove the type of a quadrilateral** Compare the sides as vectors (parallel, equal) and as lengths. (Vector problems)

Statistics

- ☐ **Give advantages and disadvantages in context** Link each point to the situation, e.g. no list of shoppers exists, so a quota sample is practical. (Sampling methods and the large data set)

- ☐ **Find a histogram's scale from a known bar** When area is not equal to frequency, use one bar to find the frequency per unit of area. (Histograms, box plots and cumulative frequency)

- ☐ **Recognise distinct groups in a scatter diagram** Spot separate clusters (e.g. two species) and explain why one line or one r for all the points may mislead. (Correlation and regression)

- ☐ **Use coding to find mean and standard deviation** Reverse the coding for the mean; for the standard deviation only the scaling matters. (Measures of location and spread)

- ☐ **Choose a suitable diagram for the data** Match the diagram to the data and the purpose, e.g. box plots to compare distributions. (Outliers and cleaning data)

- ☐ **Decide whether an outlier should be removed** Remove it only if it is an error; keep a genuine extreme value. (Outliers and cleaning data)

- ☐ **Use mutually exclusive and independent conditions** Use $P(A \cap B) = 0$ or $P(A \cap B) = P(A)P(B)$ to find missing probabilities. (Mutually exclusive and independent events; Venn and tree diagrams)

- ☐ **Reverse a tree diagram** Find the probability of a first-stage event given a second-stage event: one path divided by the total of all paths ending in that event. (Conditional probability)

- ☐ **Criticise an assumption in context** Give a specific reason why an assumption may not hold in the situation described. (Modelling with probability)

- ☐ **Criticise a binomial model in context** Explain why independence or a constant probability may not hold. (Discrete distributions, including the discrete uniform and the binomial)

- ☐ **Find an unknown mean or standard deviation** Standardise: $\frac{x - \mu}{\sigma} = z$, with z from the inverse normal for $Z \sim N(0, 1)$. (The normal distribution)

- ☐ **Approximate binomial probabilities using a normal distribution** Combine the parameters, the continuity correction and normal CD. (The normal approximation to the binomial; choosing a distribution)

- ☐ **Find the actual significance level of a test** Calculate the probability that the test statistic falls in the critical region when H_0 is true. (The language of hypothesis testing)

- ☐ **Find critical regions for a two-tailed test** Allow at most half the significance level in each tail. (Binomial hypothesis tests)

- ☐ **Find the actual significance level** Find the probability of the critical region under H_0 (adding both tails for a two-tailed test). (Binomial hypothesis tests)

- ☐ **Test a normal mean using a p-value** Find $P(\bar{X} \geq \bar{x})$ or $P(\bar{X} \leq \bar{x})$ under H_0 and compare it with the significance level. (Tests for correlation and for the mean of a normal distribution)

Mechanics

- ☐ **Explain how an assumption was used** Link the assumption to a step in your working, e.g. a smooth pulley means the tension is the same on both sides. (SI units and modelling assumptions)

- ☐ **Use $\mathbf{r} = \mathbf{r}_0 + \mathbf{v}t$ for constant velocity** Write the position vector at time t and use it to answer questions about where the object is. (Displacement, velocity and acceleration)

- ☐ **Compare two objects on one graph** Equal areas from the same start mean the objects are level; lines crossing only means equal velocities. (Kinematics graphs)

- ☐ **Derive the constant acceleration formulae** Use the gradient and area of a straight-line velocity–time graph, then eliminate variables. (Constant acceleration (suvat))

- ☐ **Interpret both roots of a quadratic in t** Two positive roots mean the object is at that displacement twice, for example on the way out and on the way back. (Constant acceleration (suvat))

- ☐ **Differentiate and integrate vectors in terms of t** Work on the $\mathbf{i}$ and $\mathbf{j}$ components separately; the constant of integration is a vector. (Variable acceleration using calculus)

- ☐ **Find the speed and direction at a given time** Combine the horizontal and vertical velocity components using Pythagoras and $\tan \theta$. (Projectiles)

- ☐ **Use the vector form of projectile motion** With $\mathbf{j}$ vertically up, $\mathbf{a} = -g\mathbf{j}$, so $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ and $\mathbf{r} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$. (Projectiles)

- ☐ **Resolve forces given by magnitude and direction** A force F at angle θ to a direction has components $F \cos \theta$ along it and $F \sin \theta$ perpendicular to it. (Forces, resultants and equilibrium of a particle)

- ☐ **Find an unknown force from vector motion** Find $\mathbf{a}$ from the motion, work out the resultant force $m\mathbf{a}$, then subtract the known forces. (Newton's second law and vectors)

- ☐ **Solve problems with two objects under gravity** Write both heights in terms of t , measured from the same point, and equate them. (Weight and motion under gravity)

- ☐ **Find the force exerted on a pulley** It is the resultant of the two tensions that act on the pulley. (Newton's third law, connected particles and pulleys)

- ☐ **Solve equilibrium on a slope with a horizontal force** Resolve the horizontal force and the weight parallel and perpendicular to the slope. (Resolving forces and inclined planes)

- ☐ **Solve rough inclined plane problems** Resolve perpendicular to the slope for R , then use $F = ma$ or equilibrium along the slope. (Friction)

- ☐ **Find the moment of a force at an angle** Use the perpendicular component $F \sin \theta$, or the perpendicular distance $d \sin \theta$. (Moments, beams and rods in equilibrium)

- ☐ **Draw the forces on a ladder correctly** Smooth wall: horizontal reaction only; rough ground: normal reaction up and friction towards the wall. (Ladders, tilting and limiting equilibrium)

- ☐ **Find μ for a ladder in limiting equilibrium** Resolve both ways, take moments about the foot, then use $F = \mu R$. (Ladders, tilting and limiting equilibrium)

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