

Grade D checklist

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

Pure mathematics

- ☐ **Write general even, odd and consecutive integers** Use $2n$, $2n + 1$, and n , $n + 1$, where n is an integer, so the argument covers every case. (Proof by deduction, exhaustion and counter-example)

- ☐ **Evaluate fractional powers without a calculator** $a^{\frac{m}{n}} = (\sqrt[n]{a})^m$, e.g. $27^{\frac{2}{3}} = 3^2 = 9$. (Laws of indices)

- ☐ **Expand brackets containing surds** $(3 + \sqrt{5})(2 - \sqrt{5}) = 6 - 3\sqrt{5} + 2\sqrt{5} - 5 = 1 - \sqrt{5}$. (Surds)

- ☐ **Complete the square** $x^2 + 6x + 2 = (x + 3)^2 - 7$; when $a \neq 1$, take a out of the x terms first. (Quadratics and the discriminant)

- ☐ **Sketch a quadratic with intercepts and vertex** Show the shape, the y -intercept, any roots and the turning point from the completed square. (Quadratics and the discriminant)

- ☐ **Find constants from two conditions** Substitute two given points into a formula to get two linear equations, then solve them. (Simultaneous equations)

- ☐ **Solve one linear and one quadratic equation** Rearrange the linear equation for x or y and substitute into the quadratic. (Simultaneous equations)

- ☐ **Solve a quadratic inequality using a sketch** Find the critical values, sketch the parabola and choose the part above or below the x -axis. (Inequalities)

- ☐ **Show a factor using the factor theorem** Show $f(a) = 0$ and conclude that $(x - a)$ is a factor of $f(x)$. (Polynomials, algebraic division and the factor theorem)

- ☐ **Show repeated roots correctly on a sketch** A squared factor such as $(x - 2)^2$ means the curve touches the x -axis at $x = 2$ without crossing. (Curve sketching and the modulus function)

- ☐ **Sketch reciprocal graphs and their asymptotes** $y = \frac{a}{x}$ and $y = \frac{a}{x^2}$ both have asymptotes $x = 0$ and $y = 0$. (Curve sketching and the modulus function)

- ☐ **Use proportional relationships and their graphs** $y \propto x^n$ means $y = kx^n$; find k from one pair of values. (Curve sketching and the modulus function)

- ☐ **Find a composite function algebraically** Replace x in f with the whole expression for $g(x)$: $fg(x) = f(g(x))$. (Composite and inverse functions)

- ☐ **Find the inverse of a function** Write $y = f(x)$, rearrange to make x the subject, then write the result in terms of x . (Composite and inverse functions)

- ☐ **Stretch a graph parallel to either axis** $af(x)$: stretch parallel to the y -axis, scale factor a ; $f(ax)$: parallel to the x -axis, scale factor $\frac{1}{a}$. (Transformations of graphs)

- ☐ **Reflect a graph in either axis** $-f(x)$ reflects the graph in the x -axis; $f(-x)$ reflects it in the y -axis. (Transformations of graphs)

- ☐ **Split a fraction with two linear factors** $\frac{px+q}{(x-a)(x-b)} \equiv \frac{A}{x-a} + \frac{B}{x-b}$. (Partial fractions)

- ☐ **Find constants in a model from data** Substitute given pairs of values to form equations and solve for the unknown constants. (Modelling with functions)
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- ☐ **Give a line's equation with integer coefficients** Clear any fractions and collect all the terms on one side, with a , b and c integers. (Straight lines)
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- ☐ **Use the parallel and perpendicular gradient rules** Parallel lines have equal gradients; perpendicular gradients multiply to give -1 . (Straight lines)
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- ☐ **Write the equation from centre and radius** Substitute into $(x - a)^2 + (y - b)^2 = r^2$; find r with the distance formula if needed. (Circles)
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- ☐ **Convert to Cartesian form by substitution** Rearrange one equation for t and substitute: $x = t + 1$, $y = t^2$ gives $y = (x - 1)^2$. (Parametric equations)
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- ☐ **Find positions at given times** Substitute the value of t into both equations and give the answers in context with units. (Parametric equations in modelling)
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- ☐ **Find a given term or coefficient** The term in x^r in $(a + bx)^n$ is $\binom{n}{r}a^{n-r}(bx)^r$, so you can find it without writing out the whole expansion. (Binomial expansion)
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- ☐ **Generate terms from a recurrence relation** Use a rule such as $u_{n+1} = 2u_n - 3$ with the first term to find $u_2, u_3, \dots$ in turn. (Sequences and recurrence relations)
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- ☐ **Count the terms and evaluate short sums** From $r = a$ to $r = b$ there are $b - a + 1$ terms; for a few terms, just add them. (Sigma notation)
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- ☐ **Find the sum of an arithmetic series** Use $S_n = \frac{n}{2}[2a + (n - 1)d]$ or $S_n = \frac{n}{2}(a + l)$. (Arithmetic sequences and series)
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- ☐ **Find the sum of a finite geometric series** Use $S_n = \frac{a(1-r^n)}{1-r}$ with the correct values of a , r and n . (Geometric sequences and series)
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- ☐ **Find a value in a given year** Use the n th term, taking care over what $n = 1$ represents in the context. (Modelling with sequences and series)
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- ☐ **Find the area of a triangle** Use $\frac{1}{2}ab \sin C$, where C is the angle between the sides a and b . (Sine and cosine rules, radians, arcs and sectors)
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- ☐ **Find arc length and sector area** Use $s = r\theta$ and $A = \frac{1}{2}r^2\theta$, with θ in radians. (Sine and cosine rules, radians, arcs and sectors)
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- ☐ **State the period of each graph** $\sin$ and $\cos$ repeat every 360° (2π); $\tan$ repeats every 180° (π). (Graphs of $\sin$, $\cos$ and $\tan$)
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- ☐ **Use $\tan \theta = \frac{\sin \theta}{\cos \theta}$ to simplify** e.g. $\sin \theta = 2 \cos \theta$ becomes $\tan \theta = 2$. (Pythagorean identities)
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- ☐ **Use $\tan x = \frac{\sin x}{\cos x}$ to solve equations** Turn $3 \sin x = 2 \cos x$ into $\tan x = \frac{2}{3}$ and solve. (Solving trigonometric equations)
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- ☐ **Find the magnitude and direction of a vector** Use $\sqrt{a^2 + b^2}$ and $\tan \theta = \frac{b}{a}$, with a sketch to get the direction right. (Trigonometry in context)
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- ☐ **Sketch $y = a^x$ for $0 < a < 1$** A decreasing curve through $(0, 1)$; it is the reflection of $y = \left(\frac{1}{a}\right)^x$ in the y -axis. (Exponential functions and graphs)
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- ☐ **Differentiate e^{kx} and Ae^{kx}** Multiply by k : the derivative of $5e^{-2x}$ is $-10e^{-2x}$. (The function e^x and its gradient)
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- ☐ **Use ln and e as inverse functions** $\ln(e^x) = x$ for all x , and $e^{\ln x} = x$ for $x > 0$. (Logarithms)
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- ☐ **Use the power law, including negative powers** $3 \log_a x = \log_a x^3$, $-\log_a x = \log_a \frac{1}{x}$ and $-\frac{1}{2} \log_a x = \log_a \frac{1}{\sqrt{x}}$. (Laws of logarithms)
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- ☐ **Solve $e^{kx} = b$ using ln** E.g. $e^{0.4x} = 9$ gives $x = \frac{\ln 9}{0.4} = 5.49$ (3 s.f.). (Solving exponential equations)
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- ☐ **Take logs of $y = ax^n$** $\log y = n \log x + \log a$: a straight line when $\log y$ is plotted against $\log x$. (Using log graphs to estimate parameters)
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- ☐ **Take logs of $y = kb^x$** $\log y = x \log b + \log k$: a straight line when $\log y$ is plotted against x . (Using log graphs to estimate parameters)
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- ☐ **Use a model to predict a value** Substitute the given time into the model and include units. (Exponential growth and decay models)
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- ☐ **Find a second derivative** Differentiate $\frac{dy}{dx}$ again to get $\frac{d^2y}{dx^2}$, the rate of change of the gradient. (First principles, second derivatives and concavity)
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- ☐ **Differentiate roots and reciprocals of x** Rewrite as powers first: $\sqrt{x} = x^{\frac{1}{2}}$, $\frac{5}{x^2} = 5x^{-2}$. (Differentiating standard functions)
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- ☐ **Find the equation of a tangent** Use $y - y_1 = m(x - x_1)$ with $m = f'(x_1)$. (Tangents, normals and stationary points)
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- ☐ **Find the equation of a normal** The normal is perpendicular to the tangent, so its gradient is $-\frac{1}{m}$. (Tangents, normals and stationary points)
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- ☐ **Use the chain rule on powers of functions** E.g. $\frac{d}{dx}(3x - 1)^5 = 15(3x - 1)^4$. (Product, quotient and chain rules)
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- ☐ **Find a curve through a given point** Integrate the gradient function, then substitute the coordinates of the point to find c . (The fundamental theorem of calculus)
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- ☐ **Integrate exponentials and $1/x$** $\int e^{kx} dx = \frac{1}{k}e^{kx} + c$ and $\int \frac{1}{x} dx = \ln|x| + c$. (Integrating standard functions)
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- ☐ **Find the area under a curve** For a curve above the x -axis, the area between the curve, the axis and the lines $x = a$ and $x = b$ is $\int_a^b y dx$. (Definite integrals and areas under curves)
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- ☐ **Find where two graphs intersect** Set the two equations equal and solve to get the limits of the region. (Areas between curves and parametric areas)
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- ☐ **Rearrange an equation into $f(x) = 0$** To find where $e^x = 4 - x$, use $f(x) = e^x + x - 4$. (Locating roots by change of sign)
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- ☐ **Rearrange $f(x) = 0$ into $x = g(x)$** Use algebra to isolate an x on one side, e.g. $x^3 - 4x - 2 = 0 \Rightarrow x = \sqrt[3]{4 + \frac{2}{x}}$. (Iteration and staircase/cobweb diagrams)
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- ☐ **Differentiate $f(x)$ accurately** A correct $f'(x)$ is the first mark; use the chain, product or quotient rule where needed. (The Newton–Raphson method)
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- ☐ **Apply the trapezium rule formula** $\frac{1}{2}h[(y_0 + y_n) + 2(y_1 + \dots + y_{n-1})]$ with the values from the table. (Numerical integration: the trapezium rule)
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- ☐ **Form an equation from a context** Turn a condition such as 'the concentration falls to 2 mg per litre' into an equation $f(t) = 0$. (Numerical methods in context)

- ☐ **Use 3D coordinates and axes** The point $(2, -1, 4)$ has position vector $2\mathbf{i} - \mathbf{j} + 4\mathbf{k}$ relative to the origin. (Vectors in 2D and 3D)

- ☐ **Find the magnitude of a 3D vector** $|x\mathbf{i} + y\mathbf{j} + z\mathbf{k}| = \sqrt{x^2 + y^2 + z^2}$. (Magnitude and direction)

- ☐ **Express a route in terms of given vectors** For example $\overrightarrow{AB} = \overrightarrow{AO} + \overrightarrow{OB} = -\mathbf{a} + \mathbf{b}$. (Vector arithmetic and geometry)

- ☐ **Find the vector between two points** $\overrightarrow{AB} = \mathbf{b} - \mathbf{a}$: subtract the start from the end. (Position vectors and distances)

- ☐ **Find a resultant force** Add the force vectors: $\mathbf{R} = \mathbf{F}_1 + \mathbf{F}_2 + \dots$. (Vector problems)

Statistics

- ☐ **Describe systematic, quota and opportunity sampling** Say how each method is carried out and whether it needs a sampling frame. (Sampling methods and the large data set)

- ☐ **Estimate quartiles from a cumulative frequency graph** Read across from $\frac{n}{4}$, $\frac{n}{2}$ and $\frac{3n}{4}$ on the cumulative frequency axis. (Histograms, box plots and cumulative frequency)

- ☐ **Draw a histogram with unequal class widths** Plot frequency density on the vertical axis, with the bars touching at the class boundaries. (Histograms, box plots and cumulative frequency)

- ☐ **Interpret the gradient of a regression line** Say how much the response variable changes, with units, for each increase of 1 in the explanatory variable. (Correlation and regression)

- ☐ **Estimate the mean from grouped data** Use the class midpoints: $\bar{x} \approx \frac{\Sigma fx}{\Sigma f}$. (Measures of location and spread)

- ☐ **Find outlier limits using quartiles and the IQR** Use the rule given, e.g. below $Q_1 - 1.5 \times \text{IQR}$ or above $Q_3 + 1.5 \times \text{IQR}$. (Outliers and cleaning data)

- ☐ **Use tree diagrams for successive events** Multiply along the branches and add the end results, including for selections without replacement. (Mutually exclusive and independent events; Venn and tree diagrams)

- ☐ **Use conditional probabilities on tree diagrams** The second-stage branches are conditional probabilities, e.g. $P(B | A)$. (Conditional probability)

- ☐ **State an assumption made by a model** E.g. the die is fair, outcomes are equally likely, or trials are independent, in context. (Modelling with probability)

- ☐ **Calculate a binomial probability for one value** Use $P(X = r) = \binom{n}{r} p^r (1 - p)^{n-r}$ or your calculator's binomial PD. (Discrete distributions, including the discrete uniform and the binomial)

- ☐ **Use the approximate 68%, 95% and 99.7% rules** About 68% (roughly two-thirds) of values lie within $\mu \pm \sigma$, 95% within $\mu \pm 2\sigma$ and almost all within $\mu \pm 3\sigma$. (The normal distribution)

- ☐ **State the conditions for the normal approximation** n is large and p is close to 0.5. (The normal approximation to the binomial; choosing a distribution)

- ☐ **Explain what the significance level means** It sets how unlikely a result must be to reject H_0 , and is the probability of rejecting H_0 when it is true. (The language of hypothesis testing)

- ☐ **Carry out a one-tailed test with a p-value** Find $P(X \geq x)$ or $P(X \leq x)$ under H_0 and compare it with the significance level. (Binomial hypothesis tests)

- ☐ **Compare r with a critical value** Read the table for n and the significance level, then decide whether r is beyond the critical value. (Tests for correlation and for the mean of a normal distribution)

Mechanics

- ☐ **Give the units of derived quantities** Velocity m s^{-1} , acceleration m s^{-2} , force and weight N ($1 \text{ N} = 1 \text{ kg m s}^{-2}$), moment N m. (SI units and modelling assumptions)

- ☐ **Use signs to show direction in one dimension** Choose a positive direction; a negative velocity means moving the opposite way at that speed. (Displacement, velocity and acceleration)

- ☐ **Find acceleration and distance from a velocity–time graph** The gradient gives the acceleration and the area under the graph gives the displacement. (Kinematics graphs)

- ☐ **Handle deceleration and direction with signs** Choose a positive direction; a deceleration has the opposite sign to the velocity. (Constant acceleration (suvat))

- ☐ **Differentiate displacement to find velocity and acceleration** $v = \frac{ds}{dt}$ and $a = \frac{dv}{dt}$. (Variable acceleration using calculus)

- ☐ **Resolve the initial velocity into components** The horizontal component is $U \cos \alpha$ and the vertical component is $U \sin \alpha$. (Projectiles)

- ☐ **Find the magnitude and direction of a force** Use Pythagoras for the magnitude and $\tan \theta$ for the angle with $\mathbf{i}$. (Forces, resultants and equilibrium of a particle)

- ☐ **Combine $F = ma$ with suvat** Find a from the forces and then use suvat, or find a from suvat and then find a force. (Newton's second law and vectors)

- ☐ **Find the greatest height and time of flight** At the top $v = 0$; when it lands the displacement is 0 or a known negative value. (Weight and motion under gravity)

- ☐ **Solve car and trailer problems** Use the whole system to find the acceleration, then one part to find the tension or thrust. (Newton's third law, connected particles and pulleys)

- ☐ **Resolve weight on an inclined plane** On a slope at angle θ : $mg \sin \theta$ down the slope and $mg \cos \theta$ into the slope. (Resolving forces and inclined planes)

- ☐ **Use $F = \mu R$ on rough level ground** Find R by resolving vertically; when the object slides, the friction is μR . (Friction)

- ☐ **Find the reactions on a beam on two supports** Take moments about one support, then resolve vertically for the other reaction. (Moments, beams and rods in equilibrium)

- ☐ **Take moments for forces on an inclined rod** For a rod at θ to the horizontal, a vertical force at distance d along it has moment arm $d \cos \theta$; a horizontal force has $d \sin \theta$. (Ladders, tilting and limiting equilibrium)

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