A Level Math Revision
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FORMULA POSTER

A Level Mathematics (UK)

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alevelmathrevision.com
alevel-frontend/formula-sheet-uk
Interactive version

E A O = printed in that board's formulae booklet (Edexcel 9MA0 · AQA 7357 · OCR A H240). E A O grey = not printed: learn it for that board.

Algebra & functions

E A O **Quadratic formula:** $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$ → Solving quadratics that do not factorise; "for what k" root questions

E A O **Discriminant b^2-4ac: >0 two real roots, $=0$ one repeated root, <0 no real roots** → Decide how many real roots a quadratic has

E A O **Completing the square:** $ax^2+bx+c = a\left(x+\frac{b}{2a}\right)^2 + c - \frac{b^2}{4a}$ → Completed-square form: solve equations; find the turning point

E A O **Indices:** $a^m a^n = a^{m+n}$, $(a^m)^n = a^{mn}$, $a^{-n} = \frac{1}{a^n}$, $a^{\frac{m}{n}} = \sqrt[n]{a^m}$ → Negative and fractional indices; rewrite terms as ax^n

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E A O **Surds:** $\sqrt{ab} = \sqrt{a}\sqrt{b}$, $\frac{1}{\sqrt{a}+\sqrt{b}} = \frac{\sqrt{a}-\sqrt{b}}{a-b}$ → Simplify surds; rationalise denominators with the conjugate

E A O **Factor theorem:** $f(a)=0 \iff (x-a)$ **is a factor** → Test whether $(x-a)$ is a factor; fully factorise cubics

E A O **Partial fractions:** $\frac{px+q}{(x-a)(x-b)} = \frac{A}{x-a} + \frac{B}{x-b}$, $\frac{\dots}{(x-a)^2(x-b)} = \frac{A}{x-a} + \frac{B}{(x-a)^2} + \frac{C}{x-b}$ → Proper fractions with distinct or repeated linear factors

E A O **Modulus; composite; inverse:** $|x|<a \iff -a<x<a$; $fg(x)=f(g(x))$; $ff^{-1}(x)=x$ → Composite and inverse functions with their domains and ranges

Watch for: Write the domain of f^{-1} every time; for $fg(x)$, apply g first

E A O **Transformations: $f(x)+a$ up a; $f(x+a)$ left a; $af(x)$ vertical $\times a$; $f(ax)$ horizontal $\times\frac{1}{a}$** → Combine transformations, tracking key points

Watch for: Inside the bracket: horizontal and "opposite"

Watch for Write the domain of f^{-1} every time (it is the range of f)

Calculator solve equations: keystrokes at alevelmathrevision.com/alevel-frontend/calculator-skills

Sequences & series

E A O **Arithmetic nth term:** $u_n = a+(n-1)d$ → Finding a term, or setting up equations from two terms

E A O **Arithmetic series:** $S_n = \frac{1}{2}n(a+l) = \frac{1}{2}n[2a+(n-1)d]$

E A O **Geometric nth term:** $u_n = ar^{n-1}$ → Finding a term, or setting up equations from two terms

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E A O **Geometric series:** $S_n = \frac{a(1-r^n)}{1-r}$, $S_\infty = \frac{a}{1-r}$ $(|r|<1)$

E A O **Binomial, $n \in \mathbb{N}$:** $(a+b)^n = a^n + \binom{n}{1}a^{n-1}b + \binom{n}{2}a^{n-2}b^2 + \dots + b^n$

E A O **Binomial coefficient:** $\binom{n}{r} = {}^nC_r = \frac{n!}{r!(n-r)!}$

E A O **Binomial, $|x|<1$, $n \in \mathbb{Q}$:** $(1+x)^n = 1+nx+\frac{n(n-1)}{1\times2}x^2+\dots$

E A O $(a+bx)^n = a^n(1+\frac{b}{a}x)^n$, **valid for $|x| < \left|\frac{a}{b}\right|$** → Take out a factor first to get the form $(1+bx)^n$

Watch for: Write $a^n(1+\frac{bx}{a})^n$: raise the factor to the power

E A O **Sigma; recurrence:** $\sum_{r=1}^{n} r = \frac{1}{2}n(n+1)$; $u_{n+1} = f(u_n)$ → Sigma notation; sequences from recurrence relations

Calculator find sums of sequences: keystrokes at alevelmathrevision.com/alevel-frontend/calculator-skills

Coordinate geometry

E A O **Line; gradient:** $y-y_1 = m(x-x_1)$, $m = \frac{y_2-y_1}{x_2-x_1}$ → Equation of a line from a gradient and a point, or two points

E A O **Perpendicular gradients: $m_1m_2=-1$** → Equations of parallel and perpendicular lines

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E A O **Midpoint; distance:** $\left(\frac{x_1+x_2}{2}, \frac{y_1+y_2}{2}\right)$, $\sqrt{(x_2-x_1)^2+(y_2-y_1)^2}$ → Distance between two points; midpoint and perpendicular bisector

E A O **Circle, centre (a,b), radius r:** $(x-a)^2+(y-b)^2=r^2$ → Complete the square to find the centre and radius

E A O **Circles: tangent $\perp$ radius; angle in a semicircle is 90°; perpendicular from centre bisects a chord** → Tangent equations; the circumcircle of a triangle

E A O **Parametric → Cartesian: eliminate t, e.g. with $\sin^2 t+\cos^2 t=1$** → Convert parametric equations to Cartesian form

E A O **Sphere; cone (curved surface, slant l):** $A=4\pi r^2$; $A=\pi rl$

Calculator find intersections and max/min: keystrokes at alevelmathrevision.com/alevel-frontend/calculator-skills

Trigonometry

E A O **Sine rule; cosine rule:** $\frac{a}{\sin A} = \frac{b}{\sin B}$, $a^2 = b^2+c^2-2bc\cos A$ → A side and its opposite angle (sine); two sides and the angle between (cosine)

E A O **Area; arc; sector (radians):** $\frac{1}{2}ab\sin C$; $s=r\theta$; $A=\frac{1}{2}r^2\theta$ → Arc lengths, sector areas and segments in radians

E A O **Identities:** $\tan\theta = \frac{\sin\theta}{\cos\theta}$, $\sin^2\theta+\cos^2\theta=1$ → Simplify expressions and prove simple identities

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E A O **Reciprocal:** $\sec^2\theta = 1+\tan^2\theta$, $\operatorname{cosec}^2\theta = 1+\cot^2\theta$ → Equations mixing $\tan^2$ and sec, or $\cot^2$ and cosec

E A O **Double angle:** $\sin 2A = 2\sin A\cos A$, $\cos 2A = \cos^2 A - \sin^2 A = 2\cos^2 A - 1 = 1 - 2\sin^2 A$ → Equations with $2x$ and x together, and integrating $\sin^2 x$

E A O **Double angle (tan):** $\tan 2A = \frac{2\tan A}{1-\tan^2 A}$ → Simplify expressions with $\tan 2A$

E A O **Compound sin:** $\sin(A\pm B) = \sin A\cos B \pm \cos A\sin B$

E A O **Compound cos:** $\cos(A\pm B) = \cos A\cos B \mp \sin A\sin B$

E A O **Compound tan:** $\tan(A\pm B) = \frac{\tan A\pm\tan B}{1\mp\tan A\tan B}$

E A O **Harmonic form, $R>0$:** $a\sin\theta+b\cos\theta = R\sin(\theta+\alpha)$, $R=\sqrt{a^2+b^2}$, $\tan\alpha=\frac{b}{a}$ → Maximum and minimum values; solving $a\sin\theta+b\cos\theta=c$

Watch for: Expand, match coefficients, then divide for $\tan\alpha$

E A O **Small angles (radians):** $\sin\theta\approx\theta$, $\cos\theta\approx1-\frac{\theta^2}{2}$, $\tan\theta\approx\theta$

E A O **Exact values:** $\sin 30° = \frac{1}{2}$, $\sin 45° = \frac{\sqrt{2}}{2}$, $\sin 60° = \frac{\sqrt{3}}{2}$, $\tan 30° = \frac{1}{\sqrt{3}}$, $\tan 60° = \sqrt{3}$ → sin, cos and tan of angles in all four quadrants

E A O **Inverse trig ranges:** $\arcsin \in [-\frac{\pi}{2}, \frac{\pi}{2}]$, $\arccos \in [0,\pi]$, $\arctan \in (-\frac{\pi}{2}, \frac{\pi}{2})$ → arcsin, arccos and arctan with restricted domains and ranges

E A O **Radians: π rad $= 180°$** → Convert between degrees and radians

Watch for Check the angle mode before every trig calculation

Calculator solve equations: keystrokes at alevelmathrevision.com/alevel-frontend/calculator-skills

Exponentials & logarithms

E A O **Definition:** $a^x = b \iff x = \log_a b$ → Convert between forms such as $2^5=32$ and $\log_2 32 = 5$

E A O **Laws:** $\log_a xy = \log_a x + \log_a y$, $\log_a \frac{x}{y} = \log_a x - \log_a y$, $\log_a x^k = k\log_a x$ → Solving log equations and linearising data

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Watch for: Take the same log of both sides; one law per line

E A O **Change of base:** $\log_a x = \frac{\log_b x}{\log_b a}$

E A O **Exponential form:** $a^x = e^{x\ln a}$

E A O **Inverses:** $e^{\ln x} = x$, $\ln e^x = x$ → Natural logarithms to solve equations involving e^x

E A O **Linearising:** $y = ax^n \Rightarrow \log y = \log a + n\log x$; $y = kb^x \Rightarrow \log y = \log k + x\log b$ → Change exponential relationships into linear form

Watch for Take the same log of both sides, one law per line

Calculator do regression: keystrokes at alevelmathrevision.com/alevel-frontend/calculator-skills

Statistics & probability

E A O **Mean:** $\bar{x} = \frac{\sum x}{n} = \frac{\sum fx}{\sum f}$ → Mean of raw and grouped data

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E A O **Standard deviation:** $\sigma = \sqrt{\frac{S_{xx}}{n}} = \sqrt{\frac{\sum x^2}{n} - \bar{x}^2}$

E A O **Outliers (common rule):** $< Q_1 - 1.5(Q_3-Q_1)$ or $> Q_3 + 1.5(Q_3-Q_1)$ → Identify outliers; draw box plots

E A O **Coding $y = \frac{x-a}{b}$:** $\bar{x} = a + b\bar{y}$, $\sigma_x = |b|\sigma_y$ → Getting back to the original data from coded summaries

E A O **Union:** $P(A\cup B) = P(A)+P(B)-P(A\cap B)$

E A O **Intersection:** $P(A\cap B) = P(A)\times P(B\mid A)$

E A O **Conditional:** $P(A\mid B) = \frac{P(A\cap B)}{P(B)}$

E A O **Independent:** $P(A\cap B) = P(A)P(B)$, $P(A\mid B) = P(A)$

E A O **Binomial $X\sim B(n,p)$:** $P(X=x) = \binom{n}{x}p^x(1-p)^{n-x}$

E A O **Binomial mean, variance:** $E(X)=np$, $\operatorname{Var}(X)=np(1-p)$

E A O **Standard normal:** $Z = \frac{X-\mu}{\sigma} \sim N(0,1)$ → Using the normal tables, and finding an unknown mean or standard deviation

Watch for: Sketch, shade and write the probability before invNorm

E A O **Normal: points of inflection at $\mu\pm\sigma$; about 68%, 95%, 99.7% within 1, 2, 3 s.d.** → Shape and properties of the normal distribution

E A O **Normal approx. to $B(n,p)$ (n large, p near ½):** $N(np,\ np(1-p))$ → Approximate $B(n,p)$ when n is large and p near 0.5

E A O **Use a continuity correction, e.g. $P(X\le4) \approx P(Y<4.5)$** → Approximating a binomial with a normal

Watch for: Only use a continuity correction for a discrete distribution

E A O **Sample mean:** $\bar{X} \sim N\left(\mu, \frac{\sigma^2}{n}\right)$, $Z = \frac{\bar{X}-\mu}{\sigma/\sqrt{n}}$

E A O **Tests: reject H_0 if p-value $<\alpha$; two-tailed: $\alpha/2$ each tail; PMCC test H_0: $\rho=0$** → Binomial tests; halve the significance level for each tail

Watch for Translate the words into an inequality first

Calculator do binomial and Poisson; do a normal distribution; find mean, SD and quartiles; find r and Spearman's rank: keystrokes at alevelmathrevision.com/alevel-frontend/calculator-skills

Differentiation

E A O **First principles:** $f'(x) = \lim_{h\to0}\frac{f(x+h)-f(x)}{h}$

E A O **Standard:** $(x^n)' = nx^{n-1}$, $(e^{kx})' = ke^{kx}$, $(\ln x)' = \frac{1}{x}$, $(\sin kx)' = k\cos kx$, $(\cos kx)' = -k\sin kx$ → Every calculus question with exponentials, logs or trig

E A O **Exponential base a:** $(a^{kx})' = ka^{kx}\ln a$ → Differentiate a^x

E A O **Trig:** $(\tan kx)' = k\sec^2 kx$,

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$(\sec kx)' = k\sec kx\tan kx$, $(\cot kx)' = -k\operatorname{cosec}^2 kx$, $(\operatorname{cosec} kx)' = -k\operatorname{cosec} kx\cot kx$

E A O **Product; chain:** $(uv)' = uv'+vu'$, $\frac{dy}{dx} = \frac{dy}{du}\cdot\frac{du}{dx}$ → Differentiating products and functions of functions

E A O **Quotient:** $\frac{d}{dx}\left(\frac{f}{g}\right) = \frac{f'g-fg'}{g^2}$

E A O **Inverse; parametric:** $\frac{dy}{dx} = \frac{1}{dx/dy}$; $\frac{dy}{dx} = \frac{dy/dt}{dx/dt}$ → $\frac{dy}{dx}$ for curves given parametrically

E A O **Implicit:** $\frac{d}{dx}f(y) = f'(y)\frac{dy}{dx}$, $\frac{d}{dx}(xy) = x\frac{dy}{dx}+y$ → Gradients of curves you cannot write as $y=\dots$

E A O **Stationary: $f'=0$; max if $f''<0$, min if $f''>0$. Convex $f''>0$, concave $f''<0$; inflection: f'' changes sign** → Classify stationary points; concave or convex; inflection

Watch for: $f''=0$ is not enough: test the sign either side

E A O **Tangent; normal:** $y-y_1 = f'(x_1)(x-x_1)$; $m_n = -\frac{1}{f'(x_1)}$ → Equations of the tangent and the normal at a point

Watch for After $f''(x)=0$, test the sign of f'' either side

Calculator find derivatives and integrals; find intersections and max/min: keystrokes at alevelmathrevision.com/alevel-frontend/calculator-skills

Mechanics

E A O **Constant acceleration:** $v=u+at$, $s=ut+\frac{1}{2}at^2$, $s=vt-\frac{1}{2}at^2$, $s=\frac{1}{2}(u+v)t$, $v^2=u^2+2as$

E A O **… in vectors:** $\mathbf{v}=\mathbf{u}+\mathbf{at}$, $\mathbf{r}=\mathbf{ut}+\frac{1}{2}\mathbf{at}^2$ → Constant acceleration formulae in vector form

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E A O **Variable acceleration: $v=\frac{dr}{dt}$, $a=\frac{dv}{dt}=\frac{d^2r}{dt^2}$, $r=\int v\,dt$, $v=\int a\,dt$** → Motion when the acceleration is not constant (suvat does not apply)

Watch for: If a depends on t, use calculus, not suvat

E A O **Forces: $F=ma$, $W=mg$, $F\le\mu R$ (limiting: $F=\mu R$)** → Every dynamics question

Watch for: After using $g=9.8$, give 2 or 3 s.f. with units

E A O **Moments: moment $=F\times d_\perp$; equilibrium: $\sum F=0$, $\sum M=0$** → Rods on supports, ladders and tipping questions

Watch for: Label every force; measure distances from the chosen point

E A O **Projectiles (speed U, angle α):** $x=Ut\cos\alpha$, $y=Ut\sin\alpha-\frac{1}{2}gt^2$ → Time of flight, range and greatest height

E A O **Slope at θ: weight component $mg\sin\theta$ down the slope; $R=mg\cos\theta$ if nothing else acts perpendicular to it** → Resolve forces parallel and perpendicular to an inclined plane

E A O **Speed = $|\mathbf{v}|$; velocity–time graph: gradient = acceleration, area = displacement** → Displacement–time and velocity–time graphs

Watch for Draw and label every force first

Calculator solve equations: keystrokes at alevelmathrevision.com/alevel-frontend/calculator-skills

Integration

E A O **Standard:** $\int x^n\,dx = \frac{x^{n+1}}{n+1}+c$, $\int\frac{1}{x}\,dx = \ln|x|+c$, $\int e^{kx}\,dx = \frac{1}{k}e^{kx}+c$ → Reversing the standard derivatives

E A O **Trig:**

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$\int\cos kx\,dx = \frac{1}{k}\sin kx+c$, $\int\sin kx\,dx = -\frac{1}{k}\cos kx+c$ → Reversing the standard derivatives

E A O **More trig:** $\int\sec^2 kx\,dx = \frac{1}{k}\tan kx+c$, $\int\tan kx\,dx = \frac{1}{k}\ln|\sec kx|+c$, $\int\cot kx\,dx = \frac{1}{k}\ln|\sin kx|+c$

E A O **Reverse chain:** $\int\frac{f'(x)}{f(x)}\,dx = \ln|f(x)|+c$, $\int f'(x)[f(x)]^n\,dx = \frac{[f(x)]^{n+1}}{n+1}+c$ → Any fraction whose top is (a multiple of) the derivative of the bottom

E A O **Linear inside:** $\int f(ax+b)\,dx = \frac{1}{a}F(ax+b)+c$ → Integrate e^{3x+1} or $\cos(2x-1)$ by reversing the chain rule

E A O **By parts:** $\int u\frac{dv}{dx}\,dx = uv - \int v\frac{du}{dx}\,dx$

E A O **Substitution: $u=g(x)$, replace dx by $\frac{du}{g'(x)}$, change the limits** → Choose a substitution; change the limits

E A O **Area:** $\int_a^b y\,dx$; **between curves** $\int_a^b(y_{top}-y_{bottom})\,dx$; **parametric** $\int y\frac{dx}{dt}\,dt$ → Areas under and between curves

E A O **Identities to integrate:** $\sin^2 x = \frac{1}{2}(1-\cos 2x)$, $\cos^2 x = \frac{1}{2}(1+\cos 2x)$ → Integrating $\sin^2$ and $\cos^2$

E A O **Separable DE:** $\frac{dy}{dx} = f(x)g(y) \Rightarrow \int\frac{dy}{g(y)} = \int f(x)\,dx$ → Separable differential equations: general and particular solutions

Watch for Choose u to get simpler when differentiated ($\ln x$ is the exception)

Calculator find derivatives and integrals: keystrokes at alevelmathrevision.com/alevel-frontend/calculator-skills

Numerical methods & vectors

E A O **Trapezium rule, $h=\frac{b-a}{n}$:** $\int_a^b y\,dx \approx \frac{1}{2}h\{(y_0+y_n)+2(y_1+\dots+y_{n-1})\}$

E A O **Newton–Raphson:** $x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$

E A O **Sign change: continuous f with $f(a)f(b)<0$ has a root in (a,b). Iteration $x_{n+1}=g(x_n)$: staircase/cobweb** → Locate a root by a change of sign

Watch for: Conclude: sign change and f continuous, so a root in the interval

E A O **Magnitude; unit vector:** $|x\mathbf{i}+y\mathbf{j}+z\mathbf{k}| = \sqrt{x^2+y^2+z^2}$, $\hat{\mathbf{a}} = \frac{\mathbf{a}}{|\mathbf{a}|}$ → Magnitudes, unit vectors and angles with the axes

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E A O $\overrightarrow{AB}$; **distance AB:** $\mathbf{b}-\mathbf{a}$; $|\mathbf{b}-\mathbf{a}| = \sqrt{\Delta x^2+\Delta y^2+\Delta z^2}$ → The vector between two points and the distance between them

Watch for Sign change and f continuous on the interval, so a root in it

Calculator make a table of values; do vectors: keystrokes at alevelmathrevision.com/alevel-frontend/calculator-skills

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