Cambridge IGCSE · Additional Mathematics 0606

Additional Mathematics 0606 formulas and definitions

All 155 formulas, facts and definitions to learn, by syllabus topic. Formulas the exam gives you are left out.

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1 Functions

$fg(x) = f(g(x))$: do g first; $f^2(x) = f(f(x))$

gf exists only if the range of f lies inside the domain of g

Domain of $gf \subseteq$ domain of f; range of $gf \subseteq$ range of g

f^{-1} exists only if f is one-one

Domain of f^{-1} = range of f; range of f^{-1} = domain of f

$ff^{-1}(x) = f^{-1}f(x) = x$

The graph of $y = f^{-1}(x)$ is the reflection of $y = f(x)$ in $y = x$

Self-inverse: $ff(x) = x$, i.e. $f^{-1} = f$

$|a| = a$ if $a \geqslant 0$ and $|a| = -a$ if $a < 0$

$y = e^x$ and $y = \ln x$ are inverses: $e^{\ln x} = x$ for $x > 0$, $\ln(e^x) = x$

$e^x > 0$ for all x; $\ln(ax + b)$ needs $ax + b > 0$

$a(x - p)^2 + q$ has vertex (p, q)

2 Quadratic functions

$x^2 + bx + c = \left(x + \frac{b}{2}\right)^2 - \frac{b^2}{4} + c$

$a(x + p)^2 + q$ has vertex $(-p, q)$: a minimum if $a > 0$, a maximum if $a < 0$

Vertex at $x = -\dfrac{b}{2a}$, from $\dfrac{dy}{dx} = 2ax + b = 0$

Range for all real x: $f(x) \geqslant q$ if $a > 0$; $f(x) \leqslant q$ if $a < 0$

$b^2 - 4ac > 0$: two distinct real roots; $= 0$: equal roots; < 0: no real roots; $\geqslant 0$: real roots

Line and curve: substitute, then discriminant > 0 meets twice, $= 0$ tangent, < 0 does not meet

$ax^2 + bx + c > 0$ for all x exactly when $a > 0$ and $b^2 - 4ac < 0$

$(x-\alpha)(x-\beta)<0 \iff \alpha<x<\beta; (x-\alpha)(x-\beta)>0 \iff x<\alpha$ or $x>\beta$ (for $\alpha<\beta$)

3 Factors of polynomials

$p(x) = (\text{divisor}) \times q(x) + r$

Remainder theorem: dividing $p(x)$ by $x-a$ leaves $p(a)$; by $ax-b$ leaves $p\left(\frac{b}{a}\right)$; by x leaves $p(0)$

Factor theorem: $x-a$ is a factor $\iff p(a)=0$; $ax-b$ is a factor $\iff p\left(\frac{b}{a}\right)=0$

An integer root of a cubic with integer coefficients divides the constant term

Roots α, β, γ and leading coefficient k: $p(x) = k(x-\alpha)(x-\beta)(x-\gamma)$

Quadratic factor with $b^2-4ac<0$: the cubic equation has only one real root; $=0$: a repeated root

$\frac{d}{dx}(x^n) = nx^{n-1}$, so $p'(0)$ is the coefficient of x

4 Equations, inequalities and graphs

$|X| = c\ (c \geqslant 0) \iff X = c$ or $X = -c$

$|X| = |Y| \iff X = \pm Y \iff X^2 = Y^2$

$|X| < c \iff -c < X < c$

$|X| > c \iff X < -c$ or $X > c$

$|X| \leqslant |Y| \iff X^2 \leqslant Y^2$ (both sides $\geqslant 0$)

$y = |f(x)|$: reflect the parts of $y = f(x)$ below the x-axis in the x-axis

$y = |ax+b|$: V shape, vertex $\left(-\frac{b}{a}, 0\right)$, y-intercept $|b|$

Cubic $k(x-p)(x-q)(x-r)$: roots p, q, r; y-intercept $-kpqr$; $k>0$ starts low and ends high, $k<0$ the other way

$a^{2x} = (a^x)^2,\ a^{x+n} = a^n \cdot a^x,\ e^{-x} = \frac{1}{e^x},\ x = (\sqrt{x})^2$

5 Simultaneous equations

After substituting a line into a quadratic curve: $b^2-4ac>0$ two points, $=0$ touches (one point), <0 no points

Mid-point of (x_1, y_1) and (x_2, y_2): $\left(\frac{x_1+x_2}{2}, \frac{y_1+y_2}{2}\right)$

Length: $\sqrt{(x_2-x_1)^2+(y_2-y_1)^2}$

Gradient: $m = \frac{y_2-y_1}{x_2-x_1}$; perpendicular gradient $-\frac{1}{m}$

Line through (x_1, y_1) with gradient m: $y-y_1 = m(x-x_1)$

$\ln A + \ln B = \ln AB, \ln A - \ln B = \ln \frac{A}{B}, k \ln A = \ln A^k$ (any base)

$\log_a A = k \iff A = a^k; \log_{a^2} A = \frac{1}{2} \log_a A$

$a^m \times a^n = a^{m+n}, a^m \div a^n = a^{m-n}, (a^m)^n = a^{mn}$

Rationalise: $\frac{k}{a + \sqrt{b}} = \frac{k(a - \sqrt{b})}{a^2 - b}$

6 Logarithmic and exponential functions

$\log_a b = c \iff a^c = b$, with $a > 0, a \neq 1, b > 0$

$\log_a 1 = 0,\ \log_a a = 1,\ \log_a a^k = k,\ a^{\log_a x} = x$

$\lg x = \log_{10} x,\ \ln x = \log_e x;\ e^{\ln x} = x,\ \ln e^x = x$

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

$\log_a \frac{x}{y} = \log_a x - \log_a y$

$\log_a x^k = k \log_a x$

$\log_a b = \frac{\log_c b}{\log_c a}$

$\log_b a = \frac{1}{\log_a b},\ \log_{a^n} x = \frac{1}{n} \log_a x$

$a^x = b \Rightarrow x = \frac{\lg b}{\lg a} = \frac{\ln b}{\ln a}$

$y = ke^{nx} + a$: asymptote $y = a$, y-intercept $k + a$

$y = k \ln(ax + b)$: asymptote $x = -\frac{b}{a}$, x-intercept where $ax + b = 1$

$e^x > 0$ for every x; $\ln x$ needs $x > 0$

7 Straight-line graphs

Gradient $m = \frac{y_2 - y_1}{x_2 - x_1}$

$y = mx + c; y - y_1 = m(x - x_1); ax + by + c = 0$ has gradient $-\frac{a}{b}$

Parallel: $m_1 = m_2$

Perpendicular: $m_1 m_2 = -1$, so $m_2 = -\frac{1}{m_1}$

Midpoint $\left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$

Length $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$

Triangle area $\frac{1}{2} |(x_1 y_2 + x_2 y_3 + x_3 y_1) - (y_1 x_2 + y_2 x_3 + y_3 x_1)|$, or $\frac{1}{2} \times \text{base} \times \text{height}$

$y = Ax^n \iff \ln y = n \ln x + \ln A$

$y = Ab^x \iff \ln y = x \ln b + \ln A$; $y = Ae^{kx} \iff \ln y = kx + \ln A$

Straight-line form $Y = mX + c$: $m = \dfrac{Y_2 - Y_1}{X_2 - X_1}$, c = value of Y when $X = 0$

8 Coordinate geometry of the circle

$x^2 + y^2 + 2gx + 2fy + c = 0$ has centre $(-g, -f)$ and radius $\sqrt{g^2 + f^2 - c}$

Distance between two points: $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$

Midpoint: $\left(\dfrac{x_1 + x_2}{2}, \dfrac{y_1 + y_2}{2}\right)$ (centre = midpoint of a diameter)

Tangent at a point is perpendicular to the radius: $m_{\text{tangent}} = -\dfrac{1}{m_{\text{radius}}}$

Line meets circle: substitute, then $b^2 - 4ac > 0$ chord, $= 0$ tangent, < 0 no intersection

Perpendicular bisector of a chord passes through the centre

Angle in a semicircle is 90°

Two circles: compare the distance between centres with $r_1 + r_2$ and $|r_1 - r_2|$

9 Circular measure

π radians $= 180^\circ$; degrees $\to$ radians $\times \frac{\pi}{180}$, radians $\to$ degrees $\times \frac{180}{\pi}$

Arc length $s = r\theta$ (θ in radians)

Sector area $A = \frac{1}{2}r^2\theta$ (θ in radians)

Perimeter of a sector $= 2r + r\theta$

Major sector angle $= 2\pi - \theta$

Segment area $= \frac{1}{2}r^2(\theta - \sin\theta)$

Chord length $= 2r \sin\frac{\theta}{2}$

Circle: circumference $2\pi r$, area πr^2

A tangent is perpendicular to the radius at the point of contact

10 Trigonometry

$\sec A = \dfrac{1}{\cos A}$, $\operatorname{cosec} A = \dfrac{1}{\sin A}$, $\cot A = \dfrac{1}{\tan A}$

$\tan A = \dfrac{\sin A}{\cos A}$, $\cot A = \dfrac{\cos A}{\sin A}$

Exact values of $\sin$, $\cos$, $\tan$ at $0, 30^\circ, 45^\circ, 60^\circ, 90^\circ$ (table above)

Signs by quadrant: CAST

Second solutions: $\sin$: $180^\circ - \alpha$ $(\pi - \alpha)$; $\cos$: $360^\circ - \alpha$ $(2\pi - \alpha)$; $\tan$: $\alpha + 180^\circ$ $(\alpha + \pi)$

$y = a\sin bx + c$ or $a\cos bx + c$: amplitude a, period $\dfrac{360^\circ}{b} = \dfrac{2\pi}{b}$, maximum $c + a$, minimum $c - a$

$y = a\tan bx + c$: period $\dfrac{180^\circ}{b} = \dfrac{\pi}{b}$; asymptotes where $bx = \pm 90^\circ, \pm 270^\circ, \ldots$

π radians $= 180^\circ$

11 Permutations and combinations

$n! = n(n-1)(n-2)\cdots 2 \times 1$, and $0! = 1$

$n! = n \times (n-1)!$

${}^nP_r = \dfrac{n!}{(n-r)!} = n(n-1)\cdots(n-r+1)$

${}^nP_r = r! \times {}^nC_r$

${}^nC_r = {}^nC_{n-r}$

n different items in a row: $n!$ ways

"And then": multiply; separate cases ("or"): add

Wanted $=$ total $-$ unwanted

k items together: treat them as one unit, then multiply by $k!$

12 Series

$\binom{n}{1} = n$, $\binom{n}{2} = \dfrac{n(n-1)}{2}$, $\binom{n}{3} = \dfrac{n(n-1)(n-2)}{6}$

$d = u_2 - u_1$; $r = \dfrac{u_2}{u_1}$

Three terms x, y, z in a row: AP if $2y = x + z$; GP if $y^2 = xz$

$u_n = S_n - S_{n-1}$

A sum to infinity exists only when $-1 < r < 1$

13 Vectors in two dimensions

$\begin{pmatrix} x \\ y \end{pmatrix} = x\mathbf{i} + y\mathbf{j}$; magnitude $\sqrt{x^2 + y^2}$

$\overrightarrow{AB} = \mathbf{b} - \mathbf{a}$; distance $AB = |\mathbf{b} - \mathbf{a}|$

Unit vector along $\mathbf{a}$: $\dfrac{\mathbf{a}}{|\mathbf{a}|}$; vector of length L along $\mathbf{a}$: $\dfrac{L}{|\mathbf{a}|}\mathbf{a}$

Parallel: $\mathbf{p} = k\mathbf{q}$ ($k > 0$ same direction, $k < 0$ opposite)

Like vectors: if $\lambda\mathbf{a} + \mu\mathbf{b} = \lambda'\mathbf{a} + \mu'\mathbf{b}$ ($\mathbf{a}$, $\mathbf{b}$ not parallel) then $\lambda = \lambda'$, $\mu = \mu'$

$AP : PB = m : n \Rightarrow \overrightarrow{OP} = \mathbf{a} + \dfrac{m}{m+n}(\mathbf{b} - \mathbf{a}) = \dfrac{n\mathbf{a} + m\mathbf{b}}{m+n}$; midpoint $\frac{1}{2}(\mathbf{a} + \mathbf{b})$

Collinear: $\overrightarrow{AC} = k\overrightarrow{AB}$ with the point A in common

Position at time t: $\mathbf{r} = \mathbf{r}_0 + t\mathbf{v}$; speed $= |\mathbf{v}|$

Speed v on bearing θ: $v\sin\theta\,\mathbf{i} + v\cos\theta\,\mathbf{j}$; at angle α to the x-axis: $v\cos\alpha\,\mathbf{i} + v\sin\alpha\,\mathbf{j}$

14 Calculus

14.1–14.4 Differentiation

$\dfrac{d}{dx}(x^n) = nx^{n-1}$, for any rational n

$\dfrac{d}{dx}(\sin x) = \cos x$, $\dfrac{d}{dx}(\cos x) = -\sin x$, $\dfrac{d}{dx}(\tan x) = \sec^2 x$ (x in radians)

$\dfrac{d}{dx}(e^x) = e^x$, $\dfrac{d}{dx}(\ln x) = \dfrac{1}{x}$

Constant multiples and sums: $\dfrac{d}{dx}\big(kf(x) + g(x)\big) = kf'(x) + g'(x)$; a constant gives 0

Chain rule: $\dfrac{dy}{dx} = \dfrac{dy}{du} \times \dfrac{du}{dx}$

$\dfrac{d}{dx}\,e^{f(x)} = f'(x)\,e^{f(x)}$, $\dfrac{d}{dx}\ln f(x) = \dfrac{f'(x)}{f(x)}$

$\dfrac{d}{dx}\sin(ax+b) = a\cos(ax+b)$, $\dfrac{d}{dx}\cos(ax+b) = -a\sin(ax+b)$, $\dfrac{d}{dx}\tan(ax+b) = a\sec^2(ax+b)$

Product rule: $\dfrac{d}{dx}(uv) = u\dfrac{dv}{dx} + v\dfrac{du}{dx}$

Quotient rule: $\dfrac{d}{dx}\left(\dfrac{u}{v}\right) = \dfrac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$

$\dfrac{d^2y}{dx^2} = \dfrac{d}{dx}\left(\dfrac{dy}{dx}\right)$

Small changes: $\delta y \approx \dfrac{dy}{dx}\,\delta x$; rates: $\dfrac{dy}{dt} = \dfrac{dy}{dx} \times \dfrac{dx}{dt}$

14.5–14.9 Applications of differentiation

Gradient of the curve at $x = a$: the value of $\frac{dy}{dx}$ at $x = a$

Tangent at (x_1, y_1) with gradient m: $y - y_1 = m(x - x_1)$

Normal gradient $= -\dfrac{1}{m}$ (perpendicular gradients multiply to -1)

Stationary point: $\dfrac{dy}{dx} = 0$

First derivative test: sign of $\frac{dy}{dx}$ goes $+, 0, -$ for a maximum and $-, 0, +$ for a minimum

Second derivative test: $\frac{d^2y}{dx^2} < 0$ maximum, $\frac{d^2y}{dx^2} > 0$ minimum

Small changes: $\delta y \approx \frac{dy}{dx} \times \delta x$, and $\delta x \approx \delta y \div \frac{dy}{dx}$

Connected rates: $\frac{dy}{dt} = \frac{dy}{dx} \times \frac{dx}{dt}$, and $\frac{dx}{dt} = \frac{dy}{dt} \div \frac{dy}{dx}$

Cylinder: $V = \pi r^2 h$, curved surface $2\pi rh$; circle: area πr^2, circumference $2\pi r$; sector: arc $r\theta$, area $\frac{1}{2}r^2\theta$

14.10–14.13 Integration

$\int x^n \, dx = \frac{x^{n+1}}{n+1} + c, n \neq -1$

$\int \frac{1}{x} \, dx = \ln x + c$

$\int (ax+b)^n \, dx = \frac{(ax+b)^{n+1}}{a(n+1)} + c, n \neq -1$

$\int \frac{1}{ax+b} \, dx = \frac{1}{a} \ln(ax+b) + c$

$\int e^{ax+b} \, dx = \frac{1}{a} e^{ax+b} + c$

$\int \sin(ax+b) \, dx = -\frac{1}{a} \cos(ax+b) + c$

$\int \cos(ax+b) \, dx = \frac{1}{a} \sin(ax+b) + c$

$\int \sec^2(ax+b) \, dx = \frac{1}{a} \tan(ax+b) + c$

$\int_a^b f(x) \, dx = F(b) - F(a)$, where $F'(x) = f(x)$

Area between graphs $= \int_a^b (\text{upper} - \text{lower}) \, dx$

Triangle $\frac{1}{2} \times \text{base} \times \text{height}$; trapezium $\frac{1}{2}(a+b)h$

14.14–14.15 Kinematics

$v = \frac{ds}{dt}, a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$

$v = \int a \, dt, s = \int v \, dt$, each with a constant found from given values

Displacement from t_1 to t_2: $\int_{t_1}^{t_2} v \, dt$ (signed area under the v–t graph)

Distance: split the interval at every time where $v = 0$ and add the sizes of the pieces

Speed $= |v|$

At rest: $v = 0$; greatest or least velocity: $a = 0$

Gradient of s–t = velocity; gradient of v–t = acceleration; area under a–t = change in velocity

Derivatives: $\frac{d}{dt}e^{kt} = ke^{kt}$, $\frac{d}{dt}\ln(at+b) = \frac{a}{at+b}$, $\frac{d}{dt}\sin kt = k\cos kt$, $\frac{d}{dt}\cos kt = -k\sin kt$

Integrals: $\int e^{kt}\,dt = \frac{1}{k}e^{kt}$, $\int \frac{1}{at+b}\,dt = \frac{1}{a}\ln(at+b)$, $\int \sin kt\,dt = -\frac{1}{k}\cos kt$, $\int \cos kt\,dt = \frac{1}{k}\sin kt$ (each $+c$)