

## **Mathematics: Applications & Interpretation SL & HL**

1 Page Formula Sheet – First Examinations 2021 – Updated Version 1.1

Prior Learning SI	. & HL
Area: Parallelogram	A=bh , $b=$ base, $h=$ height
Area: Triangle	$A=\frac{1}{2}(bh)$ , $b$ = base, $h$ = height
Area: Trapezoid	$A=rac{1}{2}(a+b)h$ , $a,b$ = parallel sides, $h$ = height
Area: Circle	$A=\pi r^2$ , $r$ = radius
Circumference: Circle	$C=2\pi r$ , $r$ = radius
Volume: Cuboid	V = lwh , $ l$ = length, $w$ = width, $h$ = height
Volume: Cylinder	$V=\pi r^2 h$ , $r$ = radius, $h$ = height
Volume: Prism	$V=Ah$ , $\it A={ m cross-section}$ area, $\it h={ m height}$
Area: Cylinder curve	$A=2\pi rh$ , $r$ = radius, $h$ = height
Distance between two points $(x_1, y_1)$ , $(x_2, y_2)$	$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$
Coordinates of midpoint	$\left(\frac{x_1+x_2}{2}, \frac{y_1+y_2}{2}\right)$ , for endpoints $(x_1, y_1), (x_2, y_2)$
Prior Learning HL	only
Solutions of a quadratic equation in the form $ax^2 + bx + c = 0$	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} , a \neq 0$

Topic 1: Number	and algebra - SL & HL
The nth term of an arithmetic sequence	$u_n = u_1 + (n-1)d$
Sum of <i>n</i> terms of an arithmetic sequence	$s_n = \frac{n}{2}(2u_1 + (n-1)d) = \frac{n}{2}(u_1 + u_n)$
The nth term of a geometric sequence	$u_n = u_1 r^{n-1}$
Sum of <i>n</i> terms of a finite geometric seq.	$s_n = \frac{u_1(r^n - 1)}{r - 1} = \frac{u_1(1 - r^n)}{1 - r}, r \neq 1$
Compound interest	$FV = PV \times \left(1 + \frac{r}{100k}\right)^{kn}$ $FV \text{ is future value, } PV \text{ is present value, } n \text{ is the number of years, } k \text{ is the number of compounding periods per year, } r\%  is the number of one of the period of the peri$
Exponents & logarithms	$a^x = b \iff x = \log_a b$ , $a, b > 0, a \neq 1$
Percentage error	$arepsilon = \left  rac{v_A - v_E}{v_E}  ight   imes 100\%$ $v_A$ = approximate value, $v_E$ = exact value

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Topic 1: Number a	nd algebra - HL only
Laws of logarithms for $a, x, y > 0$	$\log_{\alpha} xy = \log_{\alpha} x + \log_{\alpha} y$ $\log_{\alpha} \frac{x}{y} = \log_{\alpha} x - \log_{\alpha} y$ $\log_{\alpha} x^{m} = m \log_{\alpha} x$
The sum of an infinite geometric sequence	$s_{\infty} = \frac{u_1}{1-r}$ , $ r  < 1$
Complex numbers	z = a + bi
Discriminant	$\Delta = b^2 - 4ac$
Modulus-argument (polar) & Exponential (Euler) form	$z = r(\cos\theta + i\sin\theta) = re^{i\theta} = r\operatorname{cis}\theta$
Determinant of a 2×2 matrix	$A = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \Rightarrow \det A =  A  = ad - bc$
Inverse of a 2×2 matrix	$A = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \Rightarrow A^{-1} = \frac{1}{\det A} \begin{pmatrix} d & -b \\ -c & a \end{pmatrix}$
Power formula for a matrix	${\it M}^n = {\it P} {\it D}^n {\it P}^{-1}$ , where ${\it P}$ is the matrix of eigenvectors and ${\it D}$ is the diagonal matrix of eigenvalues

Topic 2: Function	ns – SL & HL
Equations of a straight line	y = mx + c; $ax + by + d = 0$ ; $y - y_1 = m(x - x_1)$
Gradient formula	$m = \frac{y_2 - y_1}{x_2 - x_1}$
Axis of symmetry of a quadratic function	$f(x) = ax^2 + bx + c \Rightarrow x = -\frac{b}{2a}$
Topic 2: Functions – HL only	
Logistic function	$f(x) = \frac{L}{1 + Ce^{-kx}} , L, k, C > 0$

Topic 3: Geometr	y and trigonometry – SL & HL
Distance between 2 points $(x_1, y_1, z_1)$ , $(x_2, y_2, z_2)$	$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}$
Coordinates of midpoint of a line with endpoints $(x_1, y_1, z_1)$ , $(x_2, y_2, z_2)$	$\left(\frac{x_1+x_2}{2}, \frac{y_1+y_2}{2}, \frac{z_1+z_2}{2}\right)$
Volume: Right-pyramid	$V = \frac{1}{3}Ah$ , $A$ = base area, $h$ = height
Volume: Right cone	$V=rac{1}{3}\pi r^2 h$ , $r$ = radius, $h$ = height
Area: Cone curve	$A=\pi r l$ , $r$ = radius, $l$ = slant height
Volume: Sphere	$V=rac{4}{3}\pi r^3$ , $r$ = radius
Surface area: Sphere	$A=4\pi r^2$ , $r$ = radius
Sine rule	$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$
Cosine rule	$c^2 = a^2 + b^2 - 2ab\cos C$ $\cos C = \frac{a^2 + b^2 - c^2}{2ab}$
Area: Triangle	$A = \frac{1}{2}ab\sin C$
Length of an arc	$l = \frac{\theta}{360} \times 2\pi r$ $\theta = \text{angle in degrees}, r = \text{radius}$
Area of a sector	$A = \frac{\theta}{360} \times \pi r^2$ $\theta = \text{angle in degrees}, r = \text{radius}$
Topic 3: Geometry	and trigonometry – HL only
Length of an arc	$l=r\theta$ $r=$ radius, $\theta=$ angle in radians

	$l = r\theta$
Length of an arc	$r = radius$ , $\theta = angle in radians$
Area of a sector	$A = \frac{1}{2}r^2\theta$ $r = \text{radius}, \ \theta = \text{angle in radians}$
Identities	$\cos^2 \theta + \sin^2 \theta = 1$ $\tan \theta = \frac{\sin \theta}{\cos \theta}$
Transformation matrices	$  \begin{pmatrix} \cos 2\theta & \sin 2\theta \\ \sin 2\theta & -\cos 2\theta \end{pmatrix} $ · reflection in the line $y = (\tan \theta)x$ $  \begin{pmatrix} k & 0 \\ 0 & 1 \end{pmatrix} $ · horizontal stretch by scale factor of $k$ $  \begin{pmatrix} 1 & 0 \\ 0 & k \end{pmatrix} $ · vertical stretch with scale factor of $k$ $  \begin{pmatrix} k & 0 \\ 0 & k \end{pmatrix} $ , centre $(0,0)$ · enlargement with scale factor of $k$ $  \begin{pmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{pmatrix} $ , anticlockwise rotation of angle $\theta$ about the origin $(\theta > 0)$ $  \begin{pmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{pmatrix}$ , clockwise rotation of angle $\theta$ about the origin $(\theta > 0)$
Magnitude of a vector	$ v  = \sqrt{v_1^2 + v_2^2 + v_3^2}$
Vector equ. of a line	$r = a + \lambda b$
Parametric form of the equation of a line	$x = x_0 + \lambda l$ , $y = y_0 + \lambda m$ , $z = z_0 + \lambda n$
Scalar product	$\begin{split} \pmb{v}\cdot \pmb{w} &= v_1w_1 + v_2w_2 + v_3w_3\\ \pmb{v}\cdot \pmb{w} &=  \pmb{v}  \pmb{w} \cos\theta\\ \text{where }\theta\text{ is the angle between } \pmb{v}\text{ and }\pmb{w} \end{split}$

 $\cos \theta = \frac{v_1 w_1 + v_2 w_2 + v_3 w_3}{v_1 + v_2 w_2 + v_3 w_3}$ 

 $\mathbf{v} \times \mathbf{w} = \begin{pmatrix} v_2 w_3 - v_3 w_2 \\ v_3 w_1 - v_1 w_3 \\ v_1 w_2 - v_2 w_1 \end{pmatrix}$ 

 $|\mathbf{v} \times \mathbf{w}| = |\mathbf{v}||\mathbf{w}|\sin\theta$ 

|v||w|

where heta is the angle between  $extbf{ extit{v}}$  and  $extbf{ extit{w}}$ 

 $A = |\boldsymbol{v} \times \boldsymbol{w}|$  , where  $\boldsymbol{v}$  and  $\boldsymbol{w}$  form two

adjacent sides of a parallelogram

	Topic 4. Statistic.	and probability - 3
2	Interquartile range	$IQR = Q_3 - Q_1$
	Mean, $\overline{x}$ , of a set of data	$ar{x} = rac{\sum_{i=1}^k f_i x_i}{n}$ , where $n$
	Probability of an event A	n(A)
	Complementary events	P(A) + P(A') = 1
	Combined events	$P(A \cup B) = P(A) + P(B)$
	Mutually exclusive event	$P(A \cup B) = P(A) + P(B)$
	Conditional probability	$P(A B) = \frac{P(A \cap B)}{P(B)}$
	Independent events	$P(A \cap B) = P(A)P(B)$
	Expected value of a discrete random variable X	$E(X) = \sum x P(X = x)$
	Binomial distribution	$X \sim B(n, p)$
	Mean ; Variance	E(X) = np ; $Var(X) = n$
	Topic 4: Statistics a	and probability – HL on
	Linear transformation of single random variable	a $E(aX + b) = aE(X) + b$ $Var(aX + b) = a^{2}Var(X)$
	Linear combinations of $n$ independent random variables, $X_1, X_2, \dots X_n$	$E(a_1X_1 \pm a_2X_2 \pm \dots \pm a_nX_n$
	Unbiased estimate of population variance	$s_{n-1}^2 = \frac{n}{n-1} s_n^2  \text{Samp}$
	Poisson distribution	$X \sim Po(m)$
	Mean ; Variance	E(X) = m; $Var(X) = n$
	Transition matrices	$oldsymbol{T}^n oldsymbol{s}_0 = oldsymbol{s}_n$ , where $oldsymbol{s}_0$ is the
	<b>Topic 5: Calculus</b>	- SL & HL
	Derivative of $x^n$	$f(x) = x^n \ \Rightarrow \ f'(x) = nx^n$
	Integral of $x^n$	$f(x) = x^n \implies f'(x) = nx^n$ $\int x^n dx = \frac{x^{n+1}}{n+1} + C, n \neq -1$
	Area enclosed by a curve and the <i>x</i> -axis	$A = \int_{a}^{b} y  dx  , \qquad \text{where } f(x)$
	The trapezoidal rule where $h = \frac{b-a}{n}$	$\int_{a}^{b} y  dx \approx \frac{1}{2} h((y_0 + y_n) + 2(y_1 + y_2 +$
	Topic 5: Calculus –	
	Derivative of sin x	$f(x) = \sin x \implies f'(x) = c$
	Derivative of cos x	$f(x) = \cos x \implies f'(x) = -\frac{1}{2}$
	Derivative of tan x	$f(x) = \tan x \implies f'(x) = \frac{1}{6}$
	Derivative of $e^x$	$f(x) = e^x \implies f'(x) = e^x$
n	Derivative of ln x	$f(x) = \ln x \implies f'(x) = \frac{1}{x}$
	Chain rule	$y = g(u)$ , $u = f(x) \Rightarrow \frac{dy}{dx}$
	Product rule	$y = uv \implies \frac{dy}{dx} = u \frac{dv}{dx} + v$
	Quotient rule	$y = \frac{u}{v} \implies \frac{dy}{dx} = \frac{v \frac{du}{dx} - u}{v^2}$
		$\int \frac{1}{x} dx = \ln x  + C$
ı		$\int \sin x  dx = -\cos x + C$
	Standard integrals	$\int \cos x  dx = \sin x + C$
		$\int \frac{1}{\cos^2 x} dx = \tan x + C$ $\int e^x dx = e^x + C$
	Area enclosed by a	$\int e^{-} dx = e^{-} + c$

Volume of revolution

Distance; Displacement

travelled from  $t_1$  to  $t_2$ 

Euler's method

Euler's method for

coupled systems

Exact solution for

differential equations

coupled linear

about x or y-axes

Mutually exclusive events	$P(A \cup B) = P(A) + P(B)$
Conditional probability	$P(A B) = \frac{P(A \cap B)}{P(B)}$
Independent events	$P(A \cap B) = P(A)P(B)$
Expected value of a discrete random variable X	$E(X) = \sum x P(X = x)$
Binomial distribution	$X \sim B(n, p)$
Mean ; Variance	E(X) = np; $Var(X) = np(1-p)$
Topic 4: Statistics ar	nd probability – HL only
Linear transformation of a single random variable	$E(aX + b) = aE(X) + b$ $Var(aX + b) = a^{2}Var(X)$
	$E(a_1X_1 \pm a_2X_2 \pm \dots \pm a_nX_n) =$
Linear combinations of $n$	$a_1 E(X_1) \pm a_2 E(X_2) \pm \dots \pm a_n E(X_n)$
independent random	$Var(a_1X_1 \pm a_2X_2 \pm \pm a_nX_n) =$
variables, $X_1, X_2, \dots, X_n$	$a_1^2 \text{Var}(X_1) + a_2^2 \text{Var}(X_2) + \dots + a_n^2 \text{Var}(X_n)$
Unbiased estimate of	
population variance	$s_{n-1}^2 = \frac{n}{n-1} s_n^2$ Sample statistics
Poisson distribution	$X \sim Po(m)$
Mean ; Variance	E(X) = m; $Var(X) = m$
Transition matrices	$oldsymbol{T}^n oldsymbol{s}_0 = oldsymbol{s}_n$ , where $oldsymbol{s}_0$ is the initial state
Topic 5: Calculus	· SL & HL
Derivative of $x^n$	$f(x) = x^n \implies f'(x) = nx^{n-1}$
Integral of $x^n$	$\int x^n dx = \frac{x^{n+1}}{n+1} + C, n \neq -1$
Area enclosed by a	
curve and the x-axis	$A = \int_{a}^{b} y  dx ,  \text{where } f(x) > 0$
The trapezoidal rule	$\int_a^b y  dx \approx$
The trapezoidal rule where $h = \frac{b-a}{n}$	• 4
where $h = \frac{b-a}{n}$	$\frac{1}{2}h((y_0+y_n)+2(y_1+y_2+\ldots+y_{n-1}))$
where $h = \frac{b-a}{n}$ Topic 5: Calculus – H	$\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1}))$ HL only
where $h = \frac{b-a}{n}$ Topic 5: Calculus – Horivative of $\sin x$	$\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1}))$ HL only $f(x) = \sin x \implies f'(x) = \cos x$
where $h = \frac{b-a}{n}$ Topic 5: Calculus – For Derivative of $\sin x$ Derivative of $\cos x$	$\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1}))$ <b>!L only</b> $f(x) = \sin x \implies f'(x) = \cos x$ $f(x) = \cos x \implies f'(x) = -\sin x$
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where $h = \frac{b-a}{n}$ Topic 5: Calculus — Properties of $\sin x$ Derivative of $\cos x$ Derivative of $\tan x$ Derivative of $e^x$	$\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1}))$ <b>!L only</b> $f(x) = \sin x \implies f'(x) = \cos x$ $f(x) = \cos x \implies f'(x) = -\sin x$ $f(x) = \tan x \implies f'(x) = \frac{1}{\cos^2 x}$ $f(x) = e^x \implies f'(x) = e^x$ $f(x) = \ln x \implies f'(x) = \frac{1}{x}$ $y = g(u), u = f(x) \implies \frac{dy}{dx} = \frac{dy}{du} \times \frac{du}{dx}$
where $h = \frac{b-a}{n}$ Topic 5: Calculus – I  Derivative of $\sin x$ Derivative of $\cos x$ Derivative of $\tan x$ Derivative of $e^x$ Derivative of $\ln x$	$\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1}))$ <b>IL only</b> $f(x) = \sin x \implies f'(x) = \cos x$ $f(x) = \cos x \implies f'(x) = -\sin x$ $f(x) = \tan x \implies f'(x) = \frac{1}{\cos^2 x}$ $f(x) = e^x \implies f'(x) = e^x$ $f(x) = \ln x \implies f'(x) = \frac{1}{x}$ $y = g(u), u = f(x) \implies \frac{dy}{dx} = \frac{dy}{du} \times \frac{du}{dx}$ $y = uv \implies \frac{dy}{dx} = u\frac{dv}{dx} + v\frac{du}{dx}$
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where $h = \frac{b-a}{n}$ Topic 5: Calculus — Perivative of $\sin x$ Derivative of $\cos x$ Derivative of $\tan x$ Derivative of $e^x$ Derivative of $\ln x$ Chain rule  Product rule	$\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1}))$ <b>!L only</b> $f(x) = \sin x \implies f'(x) = \cos x$ $f(x) = \cos x \implies f'(x) = -\sin x$ $f(x) = \tan x \implies f'(x) = \frac{1}{\cos^2 x}$ $f(x) = e^x \implies f'(x) = e^x$ $f(x) = \ln x \implies f'(x) = \frac{1}{x}$ $y = g(u), u = f(x) \implies \frac{dy}{dx} = \frac{dy}{du} \times \frac{du}{dx}$ $y = uv \implies \frac{dy}{dx} = u\frac{dv}{dx} + v\frac{du}{dx}$ $y = \frac{u}{v} \implies \frac{dy}{dx} = \frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$
where $h = \frac{b-a}{n}$ Topic 5: Calculus — Perivative of $\sin x$ Derivative of $\cos x$ Derivative of $\tan x$ Derivative of $e^x$ Derivative of $\ln x$ Chain rule  Product rule	$\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1}))$ $\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1}))$ $\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1}))$ $\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1}))$ $\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1}))$ $\frac{1}{2}cos^2x$ $f(x) = tan x \Rightarrow f'(x) = \frac{1}{cos^2x}$ $f(x) = tan x \Rightarrow f'(x) = \frac{1}{x}$ $y = g(u), u = f(x) \Rightarrow \frac{dy}{dx} = \frac{dy}{dx} \Rightarrow \frac{du}{dx} \Rightarrow \frac{du}{dx}$ $y = uv \Rightarrow \frac{dy}{dx} = u \frac{dv}{dx} + v \frac{du}{dx}$ $y = \frac{u}{v} \Rightarrow \frac{dy}{dx} = \frac{v \frac{du}{dx} - u \frac{dv}{dx}}{v^2}$ $\int \frac{1}{x} dx = \ln x  + C$
where $h = \frac{b-a}{n}$ Topic 5: Calculus — Perivative of $\sin x$ Derivative of $\cos x$ Derivative of $\tan x$ Derivative of $e^x$ Derivative of $\ln x$ Chain rule  Product rule  Quotient rule	$\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1}))$ $\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_1 + y_2 + \dots + y_{n-1}))$ $\frac{1}{2}h((y_0 + y_n) + 2(y_1 + y_1 +$
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 $V = \int_{a}^{b} \pi y^2 dx \text{ or } V = \int_{a}^{b} \pi x^2 dy$ 

dist =  $\int_{t_1}^{t_2} |v(t)| dt$ ; disp =  $\int_{t_1}^{t_2} v(t) dt$ 

 $y_{n+1} = y_n + h \times f(x_n, y_n); \ x_{n+1} = x_n + h$ 

 $a = \frac{\mathrm{d}v}{\mathrm{d}t} = \frac{\mathrm{d}^2s}{\mathrm{d}t^2} = v\frac{\mathrm{d}v}{\mathrm{d}s}$ 

where h is a constant (step length)  $\overline{x_{n+1}} = x_n + h \times f_1(x_n, y_n, t_n)$ 

 $y_{n+1} = y_n + h \times f_2(x_n, y_n, t_n)$ 

where h is a constant (step length)

 $\boldsymbol{x} = A e^{\lambda_1 t} \boldsymbol{p}_1 + B e^{\lambda_2 t} \boldsymbol{p}_2$ 

 $t_{n+1} = t_n + h \\$ 

Topic 4: Statistics and probability - SL & HL  $IQR = Q_3 - Q_1$ 

 $ar{x} = rac{\sum_{i=1}^k f_i x_i}{n}$  , where  $n = \sum_{i=1}^k f_i$ 

 $P(A \cup B) = P(A) + P(B) - P(A \cap B)$ 

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Angle between two vectors

Vector product

Area of a

parallelogram

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