



Singapore Examinations and Assessment Board



**Cambridge Assessment  
International Education**

**Singapore–Cambridge General Certificate of Education  
Ordinary Level (2023)**

# **Mathematics (Syllabus 4052)**

**(To be implemented from year of examination in 2023)**

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## INTRODUCTION

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The syllabus is intended to provide students with fundamental mathematical knowledge and skills. The content is organised into three strands, namely, *Number and Algebra*, *Geometry and Measurement*, and *Statistics and Probability*. Besides conceptual understanding and skill proficiency explicated in the content strands, important mathematical processes such as reasoning, communication and application (including the use of models) are also emphasised and assessed.

## AIMS

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The O-Level Mathematics syllabus aims to enable all students to:

- acquire mathematical concepts and skills for continuous learning in mathematics and to support learning in other subjects
- develop thinking, reasoning, communication, application and metacognitive skills through a mathematical approach to problem-solving
- connect ideas within mathematics and between mathematics and other subjects through applications of mathematics
- build confidence and foster interest in mathematics.

## ASSESSMENT OBJECTIVES

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The assessment will test candidates' abilities to:

### AO1 Use and apply standard techniques

- recall and use facts, terminology and notation
- read and use information directly from tables, graphs, diagrams and texts
- carry out routine mathematical procedures

### AO2 Solve problems in a variety of contexts

- interpret information to identify the relevant mathematics concept, rule or formula to use
- translate information from one form to another
- make and use connections across topics/subtopics
- formulate problems into mathematical terms
- analyse and select relevant information and apply appropriate mathematical techniques to solve problems
- interpret results in the context of a given problem

### AO3 Reason and communicate mathematically

- justify mathematical statements
- provide explanation in the context of a given problem
- write mathematical arguments

Approximate weightings for the assessment objectives are as follows:

AO1	45%
AO2	40%
AO3	15%

## SCHEME OF ASSESSMENT

Paper	Duration	Description	Marks	Weighting
Paper 1	2 hours 15 minutes	There will be about 26 short answer questions. Candidates are required to answer <b>all</b> questions.	90	50%
Paper 2	2 hours 15 minutes	There will be 9 to 10 questions of varying marks and lengths. The last question in this paper will focus specifically on applying mathematics to a real-world scenario. Candidates are required to answer <b>all</b> questions.	90	50%

### NOTES

- Omission of essential working will result in loss of marks.
- Relevant mathematical formulae will be provided for candidates.
- Candidates should also have geometrical instruments with them for both papers.
- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place in the case of angles in degrees, unless a different level of accuracy is specified in the question. In questions which explicitly require an answer to be shown to be correct to a specific accuracy, the answer must be first shown to a higher degree of accuracy.
- SI units will be used in questions involving mass and measures.  
Both the 12-hour and 24-hour clock may be used for quoting times of the day. In the 24-hour clock, for example, 3.15 a.m. will be denoted by 03 15; 3.15 p.m. by 15 15.
- Candidates are expected to be familiar with the solidus notation for the expression of compound units, e.g. 5 cm/s for 5 centimetres per second, 13.6 g/cm<sup>3</sup> for 13.6 grams per cubic centimetre.
- Unless the question requires the answer in terms of  $\pi$ , the calculator value for  $\pi$  or  $\pi = 3.142$  should be used.
- Spaces will be provided in each question paper for working and answers.

## PROBLEMS IN REAL-WORLD CONTEXTS

Notwithstanding the presentation of the topics in 3 separate strands in the syllabus document, it is envisaged that some examination questions (including the extended problem involving real-world contexts at the end of Paper 2) may integrate ideas from more than one topic.

Problems in real-world contexts may be based on contexts:

- In everyday life (including travel/excursion plans, transport schedules, sports and games, recipes, floor plans, navigation etc.)
- Involving personal and household finance (including simple and compound interest, taxation, instalments, utilities bills, money exchange, etc.)

These problems may also require:

- Interpreting and analysing data from tables and graphs, including distance-time and speed-time graphs;
- Interpreting the solution in the context of the problem.

## USE OF CALCULATORS

An approved calculator may be used in **both** Paper 1 and Paper 2.

## SUBJECT CONTENT

No.	Topic/Sub-topics	Content
<b>NUMBER AND ALGEBRA</b>		
<b>N1</b>	<b>Numbers and their operations</b>	<ul style="list-style-type: none"> <li>primes and prime factorisation</li> <li>finding highest common factor (HCF) and lowest common multiple (LCM), squares, cubes, square roots and cube roots by prime factorisation</li> <li>negative numbers, integers, rational numbers, real numbers, and their four operations</li> <li>calculations with calculator</li> <li>representation and ordering of numbers on the number line</li> <li>use of the symbols <math>&lt;</math>, <math>&gt;</math>, <math>\leq</math>, <math>\geq</math></li> <li>approximation and estimation (including rounding off numbers to a required number of decimal places or significant figures and estimating the results of computation)</li> <li>use of standard form <math>A \times 10^n</math>, where <math>n</math> is an integer, and <math>1 \leq A &lt; 10</math></li> <li>positive, negative, zero and fractional indices</li> <li>laws of indices</li> </ul>
<b>N2</b>	<b>Ratio and proportion</b>	<ul style="list-style-type: none"> <li>ratios involving rational numbers</li> <li>writing a ratio in its simplest form</li> <li>map scales (distance and area)</li> <li>direct and inverse proportion</li> </ul>
<b>N3</b>	<b>Percentage</b>	<ul style="list-style-type: none"> <li>expressing one quantity as a percentage of another</li> <li>comparing two quantities by percentage</li> <li>percentages greater than 100%</li> <li>increasing/decreasing a quantity by a given percentage</li> <li>reverse percentages</li> </ul>
<b>N4</b>	<b>Rate and speed</b>	<ul style="list-style-type: none"> <li>average rate and average speed</li> <li>conversion of units (e.g. km/h to m/s)</li> </ul>

No.	Topic/Sub-topics	Content
N5	<b>Algebraic expressions and formulae</b>	<ul style="list-style-type: none"> <li>• using letters to represent numbers</li> <li>• interpreting notations: <ul style="list-style-type: none"> <li>– <math>ab</math> as <math>a \times b</math></li> <li>– <math>\frac{a}{b}</math> as <math>a \div b</math> or <math>a \times \frac{1}{b}</math></li> <li>– <math>a^2</math> as <math>a \times a</math>, <math>a^3</math> as <math>a \times a \times a</math>, <math>a^2b</math> as <math>a \times a \times b</math>, ...</li> <li>– <math>3y</math> as <math>y + y + y</math> or <math>3 \times y</math></li> <li>– <math>3(x + y)</math> as <math>3 \times (x + y)</math></li> <li>– <math>\frac{3+y}{5}</math> as <math>(3 + y) \div 5</math> or <math>\frac{1}{5} \times (3 + y)</math></li> </ul> </li> <li>• evaluation of algebraic expressions and formulae</li> <li>• translation of simple real-world situations into algebraic expressions</li> <li>• recognising and representing patterns/relationships by finding an algebraic expression for the <math>n</math>th term</li> <li>• addition and subtraction of linear expressions</li> <li>• simplification of linear expressions such as: <ul style="list-style-type: none"> <li><math>-2(3x - 5) + 4x</math></li> <li><math>\frac{2x}{3} - \frac{3(x-5)}{2}</math></li> </ul> </li> <li>• use brackets and extract common factors</li> <li>• factorisation of linear expressions of the form <math>ax + bx + kay + kby</math></li> <li>• expansion of the product of algebraic expressions</li> <li>• changing the subject of a formula</li> <li>• finding the value of an unknown quantity in a given formula</li> <li>• use of: <ul style="list-style-type: none"> <li>– <math>(a + b)^2 = a^2 + 2ab + b^2</math></li> <li>– <math>(a - b)^2 = a^2 - 2ab + b^2</math></li> <li>– <math>a^2 - b^2 = (a + b)(a - b)</math></li> </ul> </li> <li>• factorisation of quadratic expressions <math>ax^2 + bx + c</math></li> <li>• multiplication and division of simple algebraic fractions such as: <ul style="list-style-type: none"> <li><math>\left(\frac{3a}{4b^2}\right)\left(\frac{5ab}{3}\right)</math></li> <li><math>\frac{3a}{4} \div \frac{9a^2}{10}</math></li> </ul> </li> <li>• addition and subtraction of algebraic fractions with linear or quadratic denominator such as: <ul style="list-style-type: none"> <li><math>\frac{1}{x-2} + \frac{2}{x-3}</math></li> <li><math>\frac{1}{x^2-9} + \frac{2}{x-3}</math></li> <li><math>\frac{1}{x-3} + \frac{2}{(x-3)^2}</math></li> </ul> </li> </ul>

No.	Topic/Sub-topics	Content
N6	Functions and graphs	<ul style="list-style-type: none"> <li>• Cartesian coordinates in two dimensions</li> <li>• graph of a set of ordered pairs as a representation of a relationship between two variables</li> <li>• linear functions (<math>y = ax + b</math>) and quadratic functions (<math>y = ax^2 + bx + c</math>)</li> <li>• graphs of linear functions</li> <li>• the gradient of a linear graph as the ratio of the vertical change to the horizontal change (positive and negative gradients)</li> <li>• graphs of quadratic functions and their properties: <ul style="list-style-type: none"> <li>– positive or negative coefficient of <math>x^2</math></li> <li>– maximum and minimum points</li> <li>– symmetry</li> </ul> </li> <li>• sketching the graphs of quadratic functions given in the form: <ul style="list-style-type: none"> <li>– <math>y = (x - p)^2 + q</math></li> <li>– <math>y = -(x - p)^2 + q</math></li> <li>– <math>y = (x - a)(x - b)</math></li> <li>– <math>y = -(x - a)(x - b)</math></li> </ul> </li> <li>• graphs of power functions of the form <math>y = ax^n</math>, where <math>n = -2, -1, 0, 1, 2, 3</math>, and simple sums of not more than three of these</li> <li>• graphs of exponential functions <math>y = ka^x</math>, where <math>a</math> is a positive integer</li> <li>• estimation of the gradient of a curve by drawing a tangent</li> </ul>
N7	Equations and inequalities	<ul style="list-style-type: none"> <li>• solving linear equations in one variable</li> <li>• solving simple fractional equations that can be reduced to linear equations such as: <math display="block">\frac{x}{3} + \frac{x-2}{4} = 3</math> <math display="block">\frac{3}{x-2} = 6</math> </li> <li>• solving simultaneous linear equations in two variables by <ul style="list-style-type: none"> <li>– substitution and elimination methods</li> <li>– graphical method</li> </ul> </li> <li>• solving quadratic equations in one unknown by <ul style="list-style-type: none"> <li>– factorisation</li> <li>– use of formula</li> <li>– completing the square for <math>y = x^2 + px + q</math></li> <li>– graphical method</li> </ul> </li> <li>• solving fractional equations that can be reduced to quadratic equations such as: <math display="block">\frac{6}{x+4} = x+3</math> <math display="block">\frac{1}{x-2} + \frac{2}{x-3} = 5</math> </li> <li>• formulating equations to solve problems</li> <li>• solving linear inequalities in one variable, and representing the solution on the number line</li> </ul>

No.	Topic/Sub-topics	Content																								
N8	Set language and notation	<ul style="list-style-type: none"> <li>use of set language and the following notation:               <table style="margin-left: 20px; border: none;"> <tr> <td>Union of <math>A</math> and <math>B</math></td> <td><math>A \cup B</math></td> </tr> <tr> <td>Intersection of <math>A</math> and <math>B</math></td> <td><math>A \cap B</math></td> </tr> <tr> <td>Number of elements in set <math>A</math></td> <td><math>n(A)</math></td> </tr> <tr> <td>'... is an element of ...'</td> <td><math>\in</math></td> </tr> <tr> <td>'... is not an element of ...'</td> <td><math>\notin</math></td> </tr> <tr> <td>Complement of set <math>A</math></td> <td><math>A'</math></td> </tr> <tr> <td>The empty set</td> <td><math>\emptyset</math></td> </tr> <tr> <td>Universal set</td> <td><math>\mathcal{U}</math></td> </tr> <tr> <td><math>A</math> is a subset of <math>B</math></td> <td><math>A \subseteq B</math></td> </tr> <tr> <td><math>A</math> is not a subset of <math>B</math></td> <td><math>A \not\subseteq B</math></td> </tr> <tr> <td><math>A</math> is a (proper) subset of <math>B</math></td> <td><math>A \subset B</math></td> </tr> <tr> <td><math>A</math> is not a (proper) subset of <math>B</math></td> <td><math>A \not\subset B</math></td> </tr> </table> </li> <li>union and intersection of two sets</li> <li>Venn diagrams</li> </ul>	Union of $A$ and $B$	$A \cup B$	Intersection of $A$ and $B$	$A \cap B$	Number of elements in set $A$	$n(A)$	'... is an element of ...'	$\in$	'... is not an element of ...'	$\notin$	Complement of set $A$	$A'$	The empty set	$\emptyset$	Universal set	$\mathcal{U}$	$A$ is a subset of $B$	$A \subseteq B$	$A$ is not a subset of $B$	$A \not\subseteq B$	$A$ is a (proper) subset of $B$	$A \subset B$	$A$ is not a (proper) subset of $B$	$A \not\subset B$
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N9	Matrices	<ul style="list-style-type: none"> <li>display of information in the form of a matrix of any order</li> <li>interpreting the data in a given matrix</li> <li>product of a scalar quantity and a matrix</li> <li>problems involving the calculation of the sum and product (where appropriate) of two matrices</li> </ul>																								
<b>GEOMETRY AND MEASUREMENT</b>																										
G1	Angles, triangles and polygons	<ul style="list-style-type: none"> <li>right, acute, obtuse and reflex angles</li> <li>vertically opposite angles, angles on a straight line and angles at a point</li> <li>angles formed by two parallel lines and a transversal: corresponding angles, alternate angles, interior angles</li> <li>properties of triangles, special quadrilaterals and regular polygons (pentagon, hexagon, octagon and decagon), including symmetry properties</li> <li>classifying special quadrilaterals on the basis of their properties</li> <li>angle sum of interior and exterior angles of any convex polygon</li> <li>construction of simple geometrical figures from given data using compasses, ruler, set squares and protractors, where appropriate</li> </ul>																								



No.	Topic/Sub-topics	Content
G2	<b>Congruence and similarity</b>	<ul style="list-style-type: none"> <li>• congruent figures and similar figures</li> <li>• properties of similar triangles and polygons: <ul style="list-style-type: none"> <li>– corresponding angles are equal</li> <li>– corresponding sides are proportional</li> </ul> </li> <li>• enlargement and reduction of a plane figure</li> <li>• scale drawings</li> <li>• properties and construction of perpendicular bisectors of line segments and angle bisectors</li> <li>• determining whether two triangles are <ul style="list-style-type: none"> <li>– congruent</li> <li>– similar</li> </ul> </li> <li>• ratio of areas of similar plane figures</li> <li>• ratio of volumes of similar solids</li> <li>• solving simple problems involving similarity and congruence</li> </ul>
G3	<b>Properties of circles</b>	<ul style="list-style-type: none"> <li>• symmetry properties of circles: <ul style="list-style-type: none"> <li>– equal chords are equidistant from the centre</li> <li>– the perpendicular bisector of a chord passes through the centre</li> <li>– tangents from an external point are equal in length</li> <li>– the line joining an external point to the centre of the circle bisects the angle between the tangents</li> </ul> </li> <li>• angle properties of circles: <ul style="list-style-type: none"> <li>– angle in a semicircle is a right angle</li> <li>– angle between tangent and radius of a circle is a right angle</li> <li>– angle at the centre is twice the angle at the circumference</li> <li>– angles in the same segment are equal</li> <li>– angles in opposite segments are supplementary</li> </ul> </li> </ul>
G4	<b>Pythagoras' theorem and trigonometry</b>	<ul style="list-style-type: none"> <li>• use of Pythagoras' theorem</li> <li>• determining whether a triangle is right-angled given the lengths of three sides</li> <li>• use of trigonometric ratios (sine, cosine and tangent) of acute angles to calculate unknown sides and angles in right-angled triangles</li> <li>• extending sine and cosine to obtuse angles</li> <li>• use of the formula <math>\frac{1}{2} ab \sin C</math> for the area of a triangle</li> <li>• use of sine rule and cosine rule for any triangle</li> <li>• problems in two and three dimensions including those involving angles of elevation and depression and bearings</li> </ul>

No.	Topic/Sub-topics	Content
<b>G5</b>	<b>Mensuration</b>	<ul style="list-style-type: none"> <li>• area of parallelogram and trapezium</li> <li>• problems involving perimeter and area of composite plane figures</li> <li>• volume and surface area of cube, cuboid, prism, cylinder, pyramid, cone and sphere</li> <li>• conversion between <math>\text{cm}^2</math> and <math>\text{m}^2</math>, and between <math>\text{cm}^3</math> and <math>\text{m}^3</math></li> <li>• problems involving volume and surface area of composite solids</li> <li>• arc length, sector area and area of a segment of a circle</li> <li>• use of radian measure of angle (including conversion between radians and degrees)</li> </ul>
<b>G6</b>	<b>Coordinate geometry</b>	<ul style="list-style-type: none"> <li>• finding the gradient of a straight line given the coordinates of two points on it</li> <li>• finding the length of a line segment given the coordinates of its end points</li> <li>• interpreting and finding the equation of a straight line graph in the form <math>y = mx + c</math></li> <li>• geometric problems involving the use of coordinates</li> </ul>
<b>G7</b>	<b>Vectors in two dimensions</b>	<ul style="list-style-type: none"> <li>• use of notations: <math>\begin{pmatrix} x \\ y \end{pmatrix}</math>, <math>\overline{AB}</math>, <math>\mathbf{a}</math>, <math> \overline{AB} </math> and <math> \mathbf{a} </math></li> <li>• representing a vector as a directed line segment</li> <li>• translation by a vector</li> <li>• position vectors</li> <li>• magnitude of a vector <math>\begin{pmatrix} x \\ y \end{pmatrix}</math> as <math>\sqrt{x^2 + y^2}</math></li> <li>• use of sum and difference of two vectors to express given vectors in terms of two coplanar vectors</li> <li>• multiplication of a vector by a scalar</li> <li>• geometric problems involving the use of vectors</li> </ul>

No.	Topic/Sub-topics	Content
<b>STATISTICS AND PROBABILITY</b>		
<b>S1</b>	<b>Data handling and analysis</b>	<ul style="list-style-type: none"> <li>• simple concepts in collecting, classifying and tabulating data</li> <li>• analysis and interpretation of: <ul style="list-style-type: none"> <li>– tables</li> <li>– bar graphs</li> <li>– pictograms</li> <li>– line graphs</li> <li>– pie charts</li> <li>– dot diagrams</li> <li>– histograms with equal class intervals</li> <li>– stem-and-leaf diagrams</li> <li>– cumulative frequency diagrams</li> <li>– box-and-whisker plots</li> </ul> </li> <li>• purposes and uses, advantages and disadvantages of the different forms of statistical representations</li> <li>• drawing simple inference from statistical diagrams</li> <li>• explaining why a given statistical diagram leads to misinterpretation of data</li> <li>• mean, mode and median as measures of central tendency for a set of data</li> <li>• purposes and use of mean, mode and median</li> <li>• calculation of the mean for grouped data</li> <li>• quartiles and percentiles</li> <li>• range, interquartile range and standard deviation as measures of spread for a set of data</li> <li>• calculation of the standard deviation for a set of data (grouped and ungrouped)</li> <li>• using the mean and standard deviation to compare two sets of data</li> </ul>
<b>S2</b>	<b>Probability</b>	<ul style="list-style-type: none"> <li>• probability as a measure of chance</li> <li>• probability of single events (including listing all the possible outcomes in a simple chance situation to calculate the probability)</li> <li>• probability of simple combined events (including using possibility diagrams and tree diagrams, where appropriate)</li> <li>• addition and multiplication of probabilities (mutually exclusive events and independent events)</li> </ul>

## MATHEMATICAL FORMULAE

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### *Compound interest*

$$\text{Total amount} = P \left( 1 + \frac{r}{100} \right)^n$$

### *Mensuration*

$$\text{Curved surface area of a cone} = \pi r l$$

$$\text{Surface area of a sphere} = 4\pi r^2$$

$$\text{Volume of a cone} = \frac{1}{3} \pi r^2 h$$

$$\text{Volume of a sphere} = \frac{4}{3} \pi r^3$$

$$\text{Area of triangle } ABC = \frac{1}{2} ab \sin C$$

$$\text{Arc length} = r\theta, \text{ where } \theta \text{ is in radians}$$

$$\text{Sector area} = \frac{1}{2} r^2 \theta, \text{ where } \theta \text{ is in radians}$$

### *Trigonometry*

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$a^2 = b^2 + c^2 - 2bc \cos A$$

### *Statistics*

$$\text{Mean} = \frac{\sum fx}{\sum f}$$

$$\text{Standard deviation} = \sqrt{\frac{\sum fx^2}{\sum f} - \left( \frac{\sum fx}{\sum f} \right)^2}$$

## MATHEMATICAL NOTATION

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The list which follows summarises the notation used in Cambridge's Mathematics examinations. Although primarily directed towards A-Level, the list also applies, where relevant, to examinations at all other levels.

### 1. Set Notation

$\in$	is an element of
$\notin$	is not an element of
$\{x_1, x_2, \dots\}$	the set with elements $x_1, x_2, \dots$
$\{x: \dots\}$	the set of all $x$ such that
$n(A)$	the number of elements in set $A$
$\emptyset$	the empty set
$\mathcal{U}$	universal set
$A'$	the complement of the set $A$
$\mathbb{Z}$	the set of integers, $\{0, \pm 1, \pm 2, \pm 3, \dots\}$
$\mathbb{Z}^+$	the set of positive integers, $\{1, 2, 3, \dots\}$
$\mathbb{Q}$	the set of rational numbers
$\mathbb{Q}^+$	the set of positive rational numbers, $\{x \in \mathbb{Q}: x > 0\}$
$\mathbb{Q}_0^+$	the set of positive rational numbers and zero, $\{x \in \mathbb{Q}: x \geq 0\}$
$\mathbb{R}$	the set of real numbers
$\mathbb{R}^+$	the set of positive real numbers, $\{x \in \mathbb{R}: x > 0\}$
$\mathbb{R}_0^+$	the set of positive real numbers and zero, $\{x \in \mathbb{R}: x \geq 0\}$
$\mathbb{R}^n$	the real $n$ -tuples
$\mathbb{C}$	the set of complex numbers
$\subseteq$	is a subset of
$\subset$	is a proper subset of
$\not\subseteq$	is not a subset of
$\not\subset$	is not a proper subset of
$\cup$	union
$\cap$	intersection
$[a, b]$	the closed interval $\{x \in \mathbb{R}: a \leq x \leq b\}$
$[a, b)$	the interval $\{x \in \mathbb{R}: a \leq x < b\}$
$(a, b]$	the interval $\{x \in \mathbb{R}: a < x \leq b\}$
$(a, b)$	the open interval $\{x \in \mathbb{R}: a < x < b\}$

## 2. Miscellaneous Symbols

=	is equal to
≠	is not equal to
≡	is identical to or is congruent to
≈	is approximately equal to
∝	is proportional to
<	is less than
≤; ≯	is less than or equal to; is not greater than
>	is greater than
≥; ≮	is greater than or equal to; is not less than
∞	infinity

## 3. Operations

$a + b$	$a$ plus $b$
$a - b$	$a$ minus $b$
$a \times b, ab, a.b$	$a$ multiplied by $b$
$a \div b, \frac{a}{b}, a/b$	$a$ divided by $b$
$a : b$	the ratio of $a$ to $b$
$\sum_{i=1}^n a_i$	$a_1 + a_2 + \dots + a_n$
$\sqrt{a}$	the positive square root of the real number $a$
$ a $	the modulus of the real number $a$
$n!$	$n$ factorial for $n \in \mathbb{Z}^+ \cup \{0\}$ , ( $0! = 1$ )
$\binom{n}{r}$	the binomial coefficient $\frac{n!}{r!(n-r)!}$ , for $n, r \in \mathbb{Z}^+ \cup \{0\}$ , $0 \leq r \leq n$ $\frac{n(n-1)\dots(n-r+1)}{r!}$ , for $n \in \mathbb{Q}$ , $r \in \mathbb{Z}^+ \cup \{0\}$

4. *Functions*

$f$	the function $f$
$f(x)$	the value of the function $f$ at $x$
$f: A \rightarrow B$	$f$ is a function under which each element of set $A$ has an image in set $B$
$f: x \mapsto y$	the function $f$ maps the element $x$ to the element $y$
$f^{-1}$	the inverse of the function $f$
$g \circ f, gf$	the composite function of $f$ and $g$ which is defined by $(g \circ f)(x)$ or $gf(x) = g(f(x))$
$\lim_{x \rightarrow a} f(x)$	the limit of $f(x)$ as $x$ tends to $a$
$\Delta x; \delta x$	an increment of $x$
$\frac{dy}{dx}$	the derivative of $y$ with respect to $x$
$\frac{d^n y}{dx^n}$	the $n$ th derivative of $y$ with respect to $x$
$f'(x), f''(x), \dots, f^{(n)}(x)$	the first, second, ... $n$ th derivatives of $f(x)$ with respect to $x$
$\int y dx$	indefinite integral of $y$ with respect to $x$
$\int_a^b y dx$	the definite integral of $y$ with respect to $x$ for values of $x$ between $a$ and $b$
$\dot{x}, \ddot{x}, \dots$	the first, second, ... derivatives of $x$ with respect to time

5. *Exponential and Logarithmic Functions*

$e$	base of natural logarithms
$e^x, \exp x$	exponential function of $x$
$\log_a x$	logarithm to the base $a$ of $x$
$\ln x$	natural logarithm of $x$
$\lg x$	logarithm of $x$ to base 10

6. *Circular Functions and Relations*

$\sin, \cos, \tan,$ $\operatorname{cosec}, \sec, \cot$	} the circular functions
$\sin^{-1}, \cos^{-1}, \tan^{-1}$ $\operatorname{cosec}^{-1}, \sec^{-1}, \cot^{-1}$	} the inverse circular functions

## 7. Complex Numbers

$i$	the square root of $-1$
$z$	a complex number, $z = x + iy$ $= r(\cos \theta + i \sin \theta)$ , $r \in \mathbb{R}_0^+$ $= re^{i\theta}$ , $r \in \mathbb{R}_0^+$
$\operatorname{Re} z$	the real part of $z$ , $\operatorname{Re}(x + iy) = x$
$\operatorname{Im} z$	the imaginary part of $z$ , $\operatorname{Im}(x + iy) = y$
$ z $	the modulus of $z$ , $ x + iy  = \sqrt{x^2 + y^2}$ , $ r(\cos \theta + i \sin \theta)  = r$
$\arg z$	the argument of $z$ , $\arg(r(\cos \theta + i \sin \theta)) = \theta$ , $-\pi < \theta \leq \pi$
$z^*$	the complex conjugate of $z$ , $(x + iy)^* = x - iy$

## 8. Matrices

$\mathbf{M}$	a matrix $\mathbf{M}$
$\mathbf{M}^{-1}$	the inverse of the square matrix $\mathbf{M}$
$\mathbf{M}^T$	the transpose of the matrix $\mathbf{M}$
$\det \mathbf{M}$	the determinant of the square matrix $\mathbf{M}$

## 9. Vectors

$\mathbf{a}$	the vector $\mathbf{a}$
$\overline{AB}$	the vector represented in magnitude and direction by the directed line segment $AB$
$\hat{\mathbf{a}}$	a unit vector in the direction of the vector $\mathbf{a}$
$\mathbf{i}, \mathbf{j}, \mathbf{k}$	unit vectors in the directions of the Cartesian coordinate axes
$ \mathbf{a} $	the magnitude of $\mathbf{a}$
$ \overline{AB} $	the magnitude of $\overline{AB}$
$\mathbf{a} \cdot \mathbf{b}$	the scalar product of $\mathbf{a}$ and $\mathbf{b}$
$\mathbf{a} \times \mathbf{b}$	the vector product of $\mathbf{a}$ and $\mathbf{b}$



## 10. Probability and Statistics

$A, B, C, \text{ etc.}$	events
$A \cup B$	union of events $A$ and $B$
$A \cap B$	intersection of the events $A$ and $B$
$P(A)$	probability of the event $A$
$A'$	complement of the event $A$ , the event 'not $A$ '
$P(A   B)$	probability of the event $A$ given the event $B$
$X, Y, R, \text{ etc.}$	random variables
$x, y, r, \text{ etc.}$	value of the random variables $X, Y, R, \text{ etc.}$
$x_1, x_2, \dots$	observations
$f_1, f_2, \dots$	frequencies with which the observations, $x_1, x_2 \dots$ occur
$p(x)$	the value of the probability function $P(X = x)$ of the discrete random variable $X$
$p_1, p_2, \dots$	probabilities of the values $x_1, x_2, \dots$ of the discrete random variable $X$
$f(x), g(x) \dots$	the value of the probability density function of the continuous random variable $X$
$F(x), G(x) \dots$	the value of the (cumulative) distribution function $P(X \leq x)$ of the random variable $X$
$E(X)$	expectation of the random variable $X$
$E[g(X)]$	expectation of $g(X)$
$\text{Var}(X)$	variance of the random variable $X$
$B(n, p)$	binomial distribution, parameters $n$ and $p$
$\text{Po}(\mu)$	Poisson distribution, mean $\mu$
$N(\mu, \sigma^2)$	normal distribution, mean $\mu$ and variance $\sigma^2$
$\mu$	population mean
$\sigma^2$	population variance
$\sigma$	population standard deviation
$\bar{x}$	sample mean
$s^2$	unbiased estimate of population variance from a sample, $s^2 = \frac{1}{n-1} \sum (x - \bar{x})^2$
$\phi$	probability density function of the standardised normal variable with distribution $N(0, 1)$
$\Phi$	corresponding cumulative distribution function
$\rho$	linear product-moment correlation coefficient for a population
$r$	linear product-moment correlation coefficient for a sample