



HKDSE Mathematics

Compulsory Part

Hoksi Education

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Preface

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As the cost of new books in Hong Kong continues to rise, buying textbooks and reference books has placed a growing burden on many students and their families. Hoksi Education Limited therefore created this project to provide high-quality reference books that are free, open, and accessible to all.

This book is one of the project’s first publications. It covers the **Compulsory Part** of the Hong Kong Diploma of Secondary Education (HKDSE) Mathematics curriculum and is written and published as an open-source textbook. Through open collaboration, we hope to keep improving its content and build a lasting collection of learning resources that genuinely serves Hong Kong students.

Contributing

We welcome contributions from students, teachers, parents, and other readers. Whether you spot an error, can clarify an explanation, want to add an example or exercise, or have another suggestion, your contribution can make this book more accurate and useful.

- **No programming experience required:** You do not need to install any tools. Use “Report an issue” in the website sidebar or [open a GitHub issue](#). Include the language, chapter or page, the problem you found, and your suggested change. For mathematical or factual errors, please include your working or a source.
- **If you are familiar with Git or programming:** Use “Edit this page” in the website sidebar, or fork the [GitHub repository](#), edit the relevant `.qmd` source file, and submit a Pull Request describing your changes.

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PDF Downloads

Complete textbook

- Download the complete *HKDSE Mathematics Compulsory Part* PDF

Individual chapters

- Quadratic Equations in One Unknown
- Functions and Graphs
- Coordinate Geometry
- Statistics

1 Quadratic Equations in One Unknown

1.1 The discriminant

A quadratic equation in one unknown has the form

$$ax^2 + bx + c = 0, \quad a \neq 0, \quad (1.1)$$

where a , b and c are real. The quantity

$$\Delta = b^2 - 4ac$$

is called the **discriminant** of Equation 1.1, and it determines the nature of the roots.

Table 1.1: Nature of the roots of a quadratic equation

Discriminant	Nature of roots
$\Delta > 0$	Two distinct real roots
$\Delta = 0$	One double (repeated) real root
$\Delta < 0$	No real roots (two complex roots)

i Key result

The roots of Equation 1.1 are

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}.$$

1.2 Worked example

Example 1.1 (Finding a range of values of k). The equation $x^2 + kx + (k + 3) = 0$ has two distinct real roots. Find the range of values of k .

Solution. Here $a = 1$, $b = k$ and $c = k + 3$, so

$$\Delta = k^2 - 4(1)(k + 3) = k^2 - 4k - 12 = (k - 6)(k + 2).$$

Two distinct real roots means $\Delta > 0$, so $(k - 6)(k + 2) > 0$. The product is positive when both factors are positive or both are negative, giving

$$k < -2 \quad \text{or} \quad k > 6.$$

1.3 Relations between roots and coefficients

If α and β are the roots of Equation 1.1, then

$$\alpha + \beta = -\frac{b}{a}, \quad \alpha\beta = \frac{c}{a}.$$

These identities let you answer questions about the roots without ever solving the equation.

Example 1.2 (Using the sum and product of roots). If α and β are the roots of $2x^2 - 5x + 1 = 0$, find $\alpha^2 + \beta^2$.

Solution. We have $\alpha + \beta = \frac{5}{2}$ and $\alpha\beta = \frac{1}{2}$. Then

$$\alpha^2 + \beta^2 = (\alpha + \beta)^2 - 2\alpha\beta = \left(\frac{5}{2}\right)^2 - 2\left(\frac{1}{2}\right) = \frac{25}{4} - 1 = \frac{21}{4}.$$

1.4 Exercises

1. Solve $3x^2 - 7x + 2 = 0$ by factorisation.
2. The equation $x^2 - 2mx + (m + 6) = 0$ has a double root. Find all possible values of m .
3. If α and β are the roots of $x^2 + 4x - 9 = 0$, find $\frac{1}{\alpha} + \frac{1}{\beta}$.
4. Form a quadratic equation whose roots are $3 + \sqrt{2}$ and $3 - \sqrt{2}$.

Answers

1. $x = \frac{1}{3}$ or $x = 2$.
2. $m = -2$ or $m = 3$.
3. $\frac{4}{9}$.
4. $x^2 - 6x + 7 = 0$.

2 Functions and Graphs

2.1 Function notation

A **function** f assigns to each input x in its domain exactly one output $f(x)$. The set of all outputs is the **range**.

Example 2.1 (Evaluating a function). Let $f(x) = 2x^2 - 3x + 1$. Find $f(-2)$ and $f(a + 1)$.

Solution.

$$f(-2) = 2(-2)^2 - 3(-2) + 1 = 8 + 6 + 1 = 15,$$

$$f(a + 1) = 2(a + 1)^2 - 3(a + 1) + 1 = 2a^2 + a.$$

2.2 The graph of a quadratic function

The graph of $y = ax^2 + bx + c$ is a parabola. Completing the square gives the **vertex form**

$$y = a \left(x + \frac{b}{2a} \right)^2 + \frac{4ac - b^2}{4a},$$

so the vertex is at $x = -\frac{b}{2a}$ and the axis of symmetry is the vertical line through it.

- If $a > 0$ the parabola opens upwards and the vertex is a **minimum**.
- If $a < 0$ the parabola opens downwards and the vertex is a **maximum**.

Exam technique

Optimisation questions in the Compulsory Part almost always reduce to finding the vertex of a parabola. Complete the square rather than guessing.

Example 2.2 (Maximising an area). A rectangular pen is built against a straight wall using 40 m of fencing on the remaining three sides. Find the largest possible area.

Solution. Let the two sides perpendicular to the wall have length x m. Then the side parallel to the wall is $40 - 2x$ m, and the area is

$$A(x) = x(40 - 2x) = -2x^2 + 40x = -2(x - 10)^2 + 200.$$

Since the coefficient of x^2 is negative, A is greatest when $x = 10$, giving a maximum area of 200 m^2 .

2.3 Transformations of graphs

Starting from $y = f(x)$:

Table 2.1: Common graph transformations

Transformation	New equation	Effect
Translate up by k	$y = f(x) + k$	Shift k units in $+y$
Translate right h	$y = f(x - h)$	Shift h units in $+x$
Reflect in x -axis	$y = -f(x)$	Flip vertically
Reflect in y -axis	$y = f(-x)$	Flip horizontally
Vertical stretch	$y = kf(x)$	Scale y -values by k

2.4 Exercises

1. Let $f(x) = x^2 - 6x + 5$. Write $f(x)$ in vertex form and state the coordinates of the vertex.
2. The graph of $y = f(x)$ is translated 3 units to the left and 2 units down. Write the equation of the new graph in terms of f .
3. Find the maximum value of $-3x^2 + 12x - 7$.

Answers

1. $f(x) = (x - 3)^2 - 4$; vertex $(3, -4)$.
2. $y = f(x + 3) - 2$.
3. 5, attained at $x = 2$.

3 Coordinate Geometry

3.1 Distance, midpoint and slope

For points $A(x_1, y_1)$ and $B(x_2, y_2)$:

$$AB = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}, \quad M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right),$$

$$m_{AB} = \frac{y_2 - y_1}{x_2 - x_1} \quad (x_1 \neq x_2).$$

Two non-vertical lines are parallel when $m_1 = m_2$, and perpendicular when $m_1 m_2 = -1$.

3.2 Equations of straight lines

Table 3.1: Equations of a straight line

Form	Equation	Use when you know
Slope–intercept	$y = mx + c$	Slope and y -intercept
Point–slope	$y - y_1 = m(x - x_1)$	A point and the slope
General	$Ax + By + C = 0$	Any line, including vertical

Example 3.1 (Perpendicular bisector). Find the equation of the perpendicular bisector of the segment joining $A(1, 2)$ and $B(5, -6)$.

Solution. The midpoint is $M = (3, -2)$ and

$$m_{AB} = \frac{-6 - 2}{5 - 1} = -2,$$

so the perpendicular bisector has slope $\frac{1}{2}$. Using point–slope form,

$$y + 2 = \frac{1}{2}(x - 3) \quad \Rightarrow \quad x - 2y - 7 = 0.$$

3.3 Circles

The circle with centre (a, b) and radius r has equation

$$(x - a)^2 + (y - b)^2 = r^2, \quad (3.1)$$

which expands to the general form

$$x^2 + y^2 + Dx + Ey + F = 0, \quad (3.2)$$

with centre $(-\frac{D}{2}, -\frac{E}{2})$ and radius $\sqrt{\frac{D^2+E^2}{4} - F}$.

Watch out

Equation 3.2 only represents a real circle when $\frac{D^2+E^2}{4} - F > 0$. If the expression is zero the equation describes a single point; if it is negative there are no real points at all.

3.4 Exercises

1. Find the distance between $(-3, 4)$ and $(2, -8)$.
2. Find the centre and radius of $x^2 + y^2 - 6x + 8y - 11 = 0$.
3. The line $2x - 3y + 6 = 0$ passes through $P(a, 4)$. Find a .

Answers

1. 13.
2. Centre $(3, -4)$, radius 6.
3. $a = 3$.

4 Statistics

4.1 Measures of central tendency

For a data set $x_1, x_2, \dots, x_n$ the **mean** is

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i.$$

The **median** is the middle value once the data are ordered, and the **mode** is the most frequently occurring value.

Which measure to use

The mean uses every value but is dragged towards outliers. The median is resistant to outliers, which is why income and house-price data are usually reported as medians.

4.2 Measures of dispersion

The **standard deviation** of a population is

$$\sigma = \sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2}.$$

The **interquartile range** is $\text{IQR} = Q_3 - Q_1$. A value is commonly treated as an outlier if it lies below $Q_1 - 1.5 \text{ IQR}$ or above $Q_3 + 1.5 \text{ IQR}$.

Example 4.1 (Effect of a linear transformation). A data set has mean 50 and standard deviation 8. Each value is multiplied by 3 and then decreased by 10. Find the new mean and standard deviation.

Solution. If $y = 3x - 10$ then

$$\bar{y} = 3\bar{x} - 10 = 3(50) - 10 = 140,$$

$$\sigma_y = |3| \sigma_x = 3(8) = 24.$$

Adding a constant shifts the data but does not spread it out, so it leaves the standard deviation unchanged.

4.3 Standard scores

The **standard score** of a value x is

$$z = \frac{x - \bar{x}}{\sigma},$$

measuring how many standard deviations x lies from the mean. Standard scores allow results from different tests to be compared directly.

4.4 Exercises

1. Find the mean and median of 4, 7, 7, 9, 13, 20.
2. A student scores 72 on a test with mean 60 and standard deviation 8. Find the standard score.
3. Every value in a data set is increased by 5. State the effect on the mean, the median and the standard deviation.

Answers

1. Mean 10, median 8.
2. $z = 1.5$.
3. Mean and median both increase by 5; the standard deviation is unchanged.

References

Formula Sheet

Algebra

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}, \quad \alpha + \beta = -\frac{b}{a}, \quad \alpha\beta = \frac{c}{a}$$

$$a^m a^n = a^{m+n}, \quad \log_a(xy) = \log_a x + \log_a y, \quad \log_a x = \frac{\log_b x}{\log_b a}$$

Coordinate geometry

$$AB = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}, \quad m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$(x - a)^2 + (y - b)^2 = r^2$$

Mensuration

$$V_{\text{cone}} = \frac{1}{3}\pi r^2 h, \quad V_{\text{sphere}} = \frac{4}{3}\pi r^3, \quad A_{\text{sphere}} = 4\pi r^2$$

Trigonometry

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}, \quad c^2 = a^2 + b^2 - 2ab \cos C$$

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

Statistics

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i, \quad \sigma = \sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2}, \quad z = \frac{x - \bar{x}}{\sigma}$$

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