

Markscheme

May 2026

**Mathematics:
applications and interpretation**

Higher level

Paper 3

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Instructions to Examiners

Abbreviations

- M** Marks awarded for attempting to use a correct **Method**.
- A** Marks awarded for an **Answer** or for **Accuracy**; often dependent on preceding **M** marks.
- R** Marks awarded for clear **Reasoning**.
- AG** Answer given in the question and so no marks are awarded.
- FT** Follow through. The practice of awarding marks, despite student errors in previous parts, for their correct methods/answers using incorrect results.

Using the markscheme

1 General

Award marks using the annotations as noted in the markscheme *eg M1, A2*.

2 Method and Answer/Accuracy marks

- Do **not** automatically award full marks for a correct answer; all working **must** be checked, and marks awarded according to the markscheme.
- It is generally not possible to award **M0** followed by **A1**, as **A** mark(s) depend on the preceding **M** mark(s), if any.
- Where **M** and **A** marks are noted on the same line, *e.g. M1A1*, this usually means **M1** for an **attempt** to use an appropriate method (*e.g.* substitution into a formula) and **A1** for using the **correct** values.
- Where there are two or more **A** marks on the same line, they may be awarded independently; so if the first value is incorrect, but the next two are correct, award **A0A1A1**.
- Where the markscheme specifies **A3**, **M2** *etc.*, do **not** split the marks, unless there is a note.
- The response to a “show that” question does not need to restate the **AG** line, unless a **Note** makes this explicit in the markscheme.
- Once a correct answer to a question or part question is seen, ignore further working even if this working is incorrect and/or suggests a misunderstanding of the question. This will encourage a uniform approach to marking, with less examiner discretion. Although some students may be advantaged for that specific question item, it is likely that these students will lose marks elsewhere too.
- An exception to the previous rule is when an incorrect answer from further working is used **in a subsequent part**. For example, when a correct exact value is followed by an incorrect decimal approximation in the first part and this approximation is then used in the second part. In this situation, award **FT** marks as appropriate but do not award the final **A1** in the first part.

Examples:

	Correct answer seen	Further working seen	Any FT issues?	Action
1.	$8\sqrt{2}$	5.65685... (incorrect decimal value)	No. Last part in question.	Award A1 for the final mark (condone the incorrect further working)
2.	$\frac{35}{72}$	0.468111... (incorrect decimal value)	Yes. Value is used in subsequent parts.	Award A0 for the final mark (and full FT is available in subsequent parts)

3 Implied marks

Implied marks appear in **brackets e.g. (M1)**, and can only be awarded if **correct** work is seen or implied by subsequent working/answer.

4 Follow through marks (only applied after an error is made)

Follow through (**FT**) marks are awarded where an incorrect answer from one **part** of a question is used correctly in **subsequent** part(s) (e.g. incorrect value from part (a) used in part (d) or incorrect value from part (c)(i) used in part (c)(ii)). Usually, to award **FT** marks, **there must be working present** and not just a final answer based on an incorrect answer to a previous part. However, if all the marks awarded in a subsequent part are for the answer or are implied, then **FT** marks should be awarded for *their* correct answer, even when working is not present.

For example: following an incorrect answer to part (a) that is used in subsequent parts, where the markscheme for the subsequent part is **(M1)A1**, it is possible to award full marks for *their* correct answer, **without working being seen**. For longer questions where all but the answer marks are implied this rule applies but may be overwritten by a **Note** in the Markscheme.

- Within a question part, once an **error** is made, no further **A** marks can be awarded for work which uses the error, but **M** marks may be awarded if appropriate.
- If the question becomes much simpler because of an error then use discretion to award fewer **FT** marks, by reflecting on what each mark is for and how that maps to the simplified version.
- If the error leads to an inappropriate value (e.g. probability greater than 1, $\sin \theta = 1.5$, non-integer value where integer required), do not award the mark(s) for the final answer(s).
- The markscheme may use the word “their” in a description, to indicate that students may be using an incorrect value.
- If the student’s answer to the initial question clearly contradicts information given in the question, it is not appropriate to award any **FT** marks in the subsequent parts. This includes when students fail to complete a “show that” question correctly, and then in subsequent parts use their incorrect answer rather than the given value.
- Exceptions to these **FT** rules will be explicitly noted on the markscheme.
- If a student makes an error in one part but gets the correct answer(s) to subsequent part(s), award marks as appropriate, unless the command term was “Hence”.

5 Mis-read

If a student incorrectly copies values or information from the question, this is a mis-read (**MR**). A student should be penalized only once for a particular misread. Use the **MR** stamp to indicate that this has been a misread and do not award the first mark, even if this is an **M** mark, but award all others as appropriate.

- If the question becomes much simpler because of the **MR**, then use discretion to award fewer marks.
- If the **MR** leads to an inappropriate value (e.g. probability greater than 1, $\sin \theta = 1.5$, non-integer value where integer required), do not award the mark(s) for the final answer(s).
- Miscopying of students' own work does **not** constitute a misread, it is an error.
- If a student uses a correct answer, to a "show that" question, to a higher degree of accuracy than given in the question, this is NOT a misread and full marks may be scored in the subsequent part.
- **MR** can only be applied when work is seen. For calculator questions with no working and incorrect answers, examiners should **not** infer that values were read incorrectly.

6 Alternative methods

Students will sometimes use methods other than those in the markscheme. Unless the question specifies a method, other correct methods should be marked in line with the markscheme. If the command term is 'Hence' and not 'Hence or otherwise' then alternative methods are not permitted unless covered by a note in the mark scheme.

- Alternative methods for complete questions are indicated by **METHOD 1**, **METHOD 2**, etc.
- Alternative solutions for parts of questions are indicated by **EITHER . . . OR**.

7 Alternative forms

Unless the question specifies otherwise, **accept** equivalent forms.

- As this is an international examination, accept all alternative forms of **notation** for example 1.9 and 1,9 or 1000 and 1,000 and 1.000.
- Do not accept final answers written using calculator notation. However, **M** marks and intermediate **A** marks can be scored, when presented using calculator notation, provided the evidence clearly reflects the demand of the mark.
- In the markscheme, equivalent **numerical** and **algebraic** forms will generally be written in brackets immediately following the answer.
- In the markscheme, some **equivalent** answers will generally appear in brackets. Not all equivalent notations/answers/methods will be presented in the markscheme and examiners are asked to apply appropriate discretion to judge if the student work is equivalent.

8 Format and accuracy of answers

If the level of accuracy is specified in the question, a mark will be linked to giving the answer to the required accuracy. If the level of accuracy is not stated in the question, the general rule applies to final answers: *unless otherwise stated in the question all numerical answers must be given exactly or correct to three significant figures*.

Where values are used in subsequent parts, the markscheme will generally use the exact value, however students may also use the correct answer to 3 sf in subsequent parts. The markscheme will often explicitly include the subsequent values that come “*from the use of 3 sf values*”.

Simplification of final answers: Students are advised to give final answers using good mathematical form. In general, for an **A** mark to be awarded, arithmetic should be completed, and

any values that lead to integers should be simplified; for example, $\sqrt{\frac{25}{4}}$ should be written as $\frac{5}{2}$.

An exception to this is simplifying fractions, where lowest form is not required (although the numerator and the denominator must be integers); for example, $\frac{10}{4}$ may be left in this form or

written as $\frac{5}{2}$. However, $\frac{10}{5}$ should be written as 2, as it simplifies to an integer.

Algebraic expressions should be simplified by completing any operations such as addition and multiplication, e.g. $4e^{2x} \times e^{3x}$ should be simplified to $4e^{5x}$, and $4e^{2x} \times e^{3x} - e^{4x} \times e^x$ should be simplified to $3e^{5x}$. Unless specified in the question, expressions do not need to be factorized, nor do factorized expressions need to be expanded, so $x(x+1)$ and x^2+x are both acceptable.

Please note: intermediate **A** marks do NOT need to be simplified.

9 Calculators

A GDC is required for this paper, but if you see work that suggests a student has used any calculator not approved for IB DP examinations (eg CAS enabled devices), please follow the procedures for malpractice.

10 Presentation of student work

Crossed out work: If a student has drawn a line through work on their examination script, or in some other way crossed out their work, do not award any marks for that work unless an explicit note from the student indicates that they would like the work to be marked.

More than one solution: Where a student offers two or more different answers to the same question, an examiner should only mark the first response unless the student indicates otherwise. If the layout of the responses makes it difficult to judge, examiners should apply appropriate discretion to judge which is “first”.

1. (a) (i) two sample (Student) t -test. **A1**

(ii) **EITHER**
the quiz scores are normally distributed **R1**

OR
the populations (can be considered to) have equal variances **R1**

(iii) $H_0 : \mu_A = \mu_B$ **A1**

$H_1 : \mu_A > \mu_B$. **A1**

Note: Accept an equivalent statement in words, must include “population mean” / “mean for all students at school A/B”. Do not award **A1A1** for an imprecise “the means are equal”. Award **A0A1** for: $H_0 : \bar{x}_A = \bar{x}_B$ and $H_1 : \bar{x}_A > \bar{x}_B$, and hence for equivalent statements in words (e.g. the means are equal). Accept use of μ_1 and μ_2 for μ_A and μ_B respectively.

(iv) recognizing/attempting to find s_{n-1} **(M1)**

$p = 0.0336$ (0.0335611...) **A2**

(v) (the test is significant) $p < 0.05$, **R1**
(there is sufficient evidence to reject the null hypothesis)

there is sufficient evidence that the students in school A scored better than the students in school B **A1**

[9 marks]

(b) an appropriate reason within the given context **R1**
e.g.

- the investigation looked only at two schools
- there may be other reasons why the students in school A scored better, e.g. can depend on the teacher or other circumstances

Note: Do not accept answers like “difference in sample size (from school A and school B)”. Do not accept imprecise and generic answers like “not enough data”, unless it is tied back to a specific part of the context, as this is too vague.

[1 mark]

- (c) attempt to use mid-interval values (any two of 10, 27, 42, 57, 72 and 90 seen) (M1)
52.3 A2

Note: Award at most **M1A1A0** for 52.8 as a result of use of mid-interval values of 10.5, 27.5 etc.
Award **M1A1A0** for a correct use of mean formula, seen, leading to an incorrect answer
Using mean formula correctly with one incorrect mid-interval value earns **M1A1A0**.

[3 marks]

- (d) (i) first two rows A1
expected value (of “Unrestricted use” with “marks 19 or less”) is equal to 3.83
(3.825)
therefore combine the first two rows, as this is less than 5 R1

Note: Do not award **A1R0**.
Award **A0R1** for general “first two rows because expected values are less than 5”.

- (ii) H_0 : achievement is independent of use of mobile phones
 H_1 : achievement is not independent of use of mobile phones A1

Note: Award **A1** for both hypotheses correct. Accept “not associated” in place of independent.
Do not accept “correlated” or “related”. Accept “dependent” in place of “not independent”
for the alternative hypothesis.

$p = 0.0999$ (0.0998633...) A2

Note: If first two rows are not joined, $p = 0.201374...$ Award **A0**.

$p > 0.05$ therefore not enough evidence to support Ling’s belief A1

Note: The **A1** for hypotheses and **A2** for p -value can be awarded independently.
The conclusion must refer to Ling’s belief for the **A1** to be awarded.
The comparison to 0.05 must be seen for the final **A1** to be awarded.

[6 marks]

- (e) 0.05 A1
[1 mark]

- (f) (i) $\frac{15.3^2}{60}$ **OR** $\frac{15.3}{\sqrt{60}}$ **OR** 1.97522... seen (this may be seen in part (ii)) **(A1)**
 recognizing use of (inverse) normal distribution to find the critical region or the critical value **(M1)**
 $\bar{X} > 68.0489...$ or $\bar{X} = 68.0489...$ **A1**

Note: Use of the confidence interval function or two-tailed test on the GDC will lead to $\bar{X} < 60.9238...$ or $\bar{X} > 68.6713...$.
 Award at most **(A1)(M1)A0** for this answer or $\bar{X} > 68.6713$.

(ii) $P\left(\bar{X} < 68.0489... \mid \bar{X} \sim N\left(68.3, \frac{15.3^2}{60}\right)\right)$
 $= 0.449$ (0.449430...) **A1**

[4 marks]

- (g) (i) increasing the significance level **A1**
 (ii) this will increase the probability of a Type I error **R1**

[2 marks]

Total [26 marks]

2. (a) (i) $(x + yi) \times i$
 $= xi - y \quad (= -y + xi)$ A1

(ii) 90° OR $\frac{\pi}{2}$ rad anticlockwise (rotation) A1
 about the origin A1

[3 marks]

(b) translation by $\begin{pmatrix} a \\ b \end{pmatrix}$ OR translation a units to the right and b units up A1
[1 mark]

(c) multiplication by k OR $(f(z) =) kz$ A1

Note: Award **A0** for an answer of $\begin{pmatrix} k & 0 \\ 0 & k \end{pmatrix}$ or $\begin{pmatrix} k & 0 \\ 0 & k \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$ without a result.

[1 mark]

(d) (i) $(g^{-1}(z) =) z - 2 - i$ A1

(ii) attempt to find f (their(d)(i)) M1
 $h(z) = g(f(z - 2 - i))$
 $= g(2i(z - 2 - i))$
 $= g(2iz + 2 - 4i)$ A1
 $= 2iz + 2 - 4i + 2 + i$
 $= 2iz + 4 - 3i$ AG

[3 marks]

(e) (i) substituting one of the given complex numbers into h and attempt to simplify M1
 $A' = (2, -1), B' = (2, 1), C' = (-2, 1)$ A1A1

Note: Award **A1A0** if only one or two are correct, **A1A1** if all three correct.

(ii) rotation 90° anticlockwise (or equivalent) A1
 and enlargement by scale factor 2 A1
 (both) with centre in $B(2, 1)$ A1

Note: Transformations can be given in any order. Award **A1A0A0** if an accurate sketch of their points from (e)(i) is shown but no correct rotation or enlargement is identified.

[6 marks]

(f) $R_\theta(z, t) = z \times (\cos \theta t^\circ + i \sin \theta t^\circ)$ A1
[1 mark]

(g) recognizing that the image of a point (x, y) will be $\begin{pmatrix} x \\ y \end{pmatrix} + vt$ e.g. $\begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} 2 \\ -1 \end{pmatrix} t$

$$T(z, t) = z + vt \quad \text{e.g. } T(z, t) = z + \begin{pmatrix} 2 \\ -1 \end{pmatrix} t$$

$$T(z, t) = z + vt \quad \text{e.g. } T(z, t) = z + \begin{pmatrix} 2 \\ -1 \end{pmatrix} t \quad (M1)$$

$$T(z, t) = z + (2 - i)t \quad A1$$

[2 marks]

(h) (i) substitute $k = 3$ into expression for E (seen anywhere) (M1)
 $(r =) 3$ A1

(ii) $(r =) 5$ A1

[3 marks]

Note: The first implied (M1) can be awarded for either correct final radius e.g. it is possible to award (M1)A0A1.

(i) **EITHER**
 considering how the multiplying factor changes (e.g. repeating for further values of t for E_3 etc.) (M1)
 recognizing multiplying factor increases by $k - 1$ per second A1

OR
 after t seconds the size will be p times the original size, where $p = (1 + (k - 1)t)$ M1
 as $\frac{dp}{dt} = k - 1$, the object will increase or decrease at a constant rate A1

[2 marks]

(j) attempt to find value of k e.g. solving $1 + (k - 1)5 = 0$ **OR** -0.2 seen anywhere **(M1)**

attempt to find the velocity **OR** $5 + 3i$ or $\begin{pmatrix} 5 \\ 3 \end{pmatrix}$ seen anywhere **(M1)**

multiplying by $1 - 0.2t$ **OR** adding $(5 + 3i)t$ **A1**

multiplying by $\cos 360t^\circ + i \sin 360t^\circ$ **A1**

$A(z, t) = (1 - 0.2t)(\cos 360t^\circ + i \sin 360t^\circ)z + (5 + 3i)t$ **A1**

Note: Award first **(M1)** for $\frac{5}{3}$ or 0.6 seen for attempt to find shrinking rate.

[5 marks]

(k) attempt to find an expression for t in terms of n e.g. $t = \frac{n}{60}$ or $t = 60n$ **M1**

$B_n(z) = A\left(z, \frac{n}{60}\right) \quad \left(= \left(1 - \frac{1}{300}n\right)(\cos 6n^\circ + i \sin 6n^\circ)z + \left(\frac{1}{12} + \frac{1}{20}i\right)n \right)$ **A1**

[2marks]

Total [29 marks]
