GCE

Mathematics B MEI

H640/03: Pure Mathematics and Comprehension

A Level

Mark Scheme for June 2025

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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MARKING INSTRUCTIONS

PREPARATION FOR MARKING
RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Online Training: OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are available in RM Assessor

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **required number** of standardisation responses.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the RM Assessor messaging system.

5. **Crossed-Out Responses**
   Where a candidate has crossed out a response and provided a clear alternative then the crossed-out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed-out response where legible.

Rubric Error Responses – Optional Questions
Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM Assessor, which will select the highest mark from those awarded. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

Multiple-Choice Question Responses
When a multiple-choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses
When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only one mark per response)
Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

Short Answer Questions (requiring a more developed response, worth two or more marks)
If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space).

Longer Answer Questions (requiring a developed response)
Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there, then add the annotation 'SEEN' to confirm that the work has been seen and mark any responses using the annotations in section 11.

7. There is a NR (**No Response**) option. Award NR (No Response):

   - if there is nothing written at all in the answer space
   - OR if there is a comment which does not in any way relate to the question (e.g., 'can't do', 'don't know')
   - OR if there is a mark (e.g., a dash, a question mark) which is not an attempt at the question.

   Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).

8. The RM Assessor **comments box** is used by your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response: Not applicable in F501
    To determine the level – start at the highest level and work down until you reach the level that matches the answer
    To determine the mark within the level, consider the following

Descriptor	Award mark
On the borderline of this level and the one below	At bottom of level
Just enough achievement on balance for this level	Above bottom and either below middle or at middle of level (depending on number of marks available)
Meets the criteria but with some slight inconsistency	Above middle and either below top of level or at middle of level (depending on number of marks available)
Consistently meets the criteria for this level	At top of level

11. **Annotations**

Annotation	Meaning
✓and ✗	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0, M1	Method mark awarded 0, 1
A0, A1	Accuracy mark awarded 0, 1
B0, B1	Independent mark awarded 0, 1
SC	Special case
^	Omission sign
MR	Misread
BP	Blank Page
Seen	
Highlighting	

Other abbreviations in mark scheme	Meaning
dep*	Mark dependent on a previous mark, indicated by *. The * may be omitted if only one previous M mark
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working
AG	Answer given
awrt	Anything which rounds to
BC	By Calculator
DR	This question included the instruction: In this question you must show detailed reasoning.

Subject Specific Marking Instructions

a. Annotations must be used during your marking. For a response awarded zero (or full) marks a single appropriate annotation (cross, tick, M0 or ^) is sufficient, but not required.

For responses that are not awarded either 0 or full marks, you must make it clear how you have arrived at the mark you have awarded and all responses must have enough annotation for a reviewer to decide if the mark awarded is correct without having to mark it independently.

It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

Award NR (No Response)
- if there is nothing written at all in the answer space and no attempt elsewhere in the script
- OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
- OR if there is a mark (e.g. a dash, a question mark, a picture) which isn't an attempt at the question.

Note: Award 0 marks only for an attempt that earns no credit (including copying out the question).

If a candidate uses the answer space for one question to answer another, for example using the space for 8(b) to answer 8(a), then give benefit of doubt unless it is ambiguous for which part it is intended.

b. An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct solutions leading to correct answers are awarded full marks but work must not always be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly. Correct but unfamiliar or unexpected methods are often signalled by a correct result following an apparently incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.

If you are in any doubt whatsoever you should contact your Team Leader.

c. The following types of marks are available.

M

A suitable method has been selected and applied in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using

some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, e.g. by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.
A method mark may usually be implied by a correct answer unless the question includes the DR statement, the command words “Determine” or “Show that”, or some other indication that the method must be given explicitly.

A
Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

B
Mark for a correct result or statement independent of Method marks.

Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

d. When a part of a question has two or more ‘method’ steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation ‘dep*’ is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.

e. The abbreviation FT implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only – differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, what is acceptable will be detailed in the mark scheme. If this is not the case, please escalate the question to your Team Leader who will decide on a course of action with the Principal Examiner.

Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be ‘follow through’. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

f. Unless units are specifically requested, there is no penalty for wrong or missing units as long as the answer is numerically correct and expressed either in SI or in the units of the question. (e.g. lengths will be assumed to be in metres unless in a particular question all the lengths are in km, when this would be assumed to be the unspecified unit.)
We are usually quite flexible about the accuracy to which the final answer is expressed; over-specification is usually only penalised where the scheme explicitly says so.
- When a value is given in the paper only accept an answer correct to at least as many significant figures as the given value.
- When a value is not given in the paper accept any answer that agrees with the correct value to 2 s.f. unless a different level of accuracy has been asked for in the question, or the mark scheme specifies an acceptable range.
  NB for Specification A the rubric specifies 3 s.f. as standard, so this statement reads “3 s.f”.

Follow through should be used so that only one mark in any question is lost for each distinct accuracy error.
Candidates using a value of 9.80, 9.81 or 10 for g should usually be penalised for any final accuracy marks which do not agree to the value found with 9.8 which is given in the rubric.

g. Rules for replaced work and multiple attempts:
- If one attempt is clearly indicated as the one to mark, or only one is left uncrossed out, then mark that attempt and ignore the others.
- If more than one attempt is left not crossed out, then mark the last attempt unless it only repeats part of the first attempt or is substantially less complete.
- if a candidate crosses out all of their attempts, the assessor should attempt to mark the crossed out answer(s) as above and award marks appropriately.

h. For a genuine misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate’s data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some units. This is achieved by withholding one A or B mark in the question. Marks designated as cao may be awarded as long as there are no other errors.
If a candidate corrects the misread in a later part, do not continue to follow through. Note that a miscopy of the candidate’s own working is not a misread but an accuracy error.

i. If a calculator is used, some answers may be obtained with little or no working visible. Allow full marks for correct answers, provided that there is nothing in the wording of the question specifying that analytical methods are required such as the bold “In this question you must show detailed reasoning”, or the command words “Show” or “Determine”. Where an answer is wrong but there is some evidence of method, allow appropriate method marks. Wrong answers with no supporting method score zero. If in doubt, consult your Team Leader.

j. If in any case the scheme operates with considerable unfairness consult your Team Leader.

Question			Answer	Marks	AO	Guidance
1	(a)		$(1+\frac{1}{2}(3x)+\cdots$	M1	1.1	• Use of binomial expansion as far as $1+\frac{1}{2}(3x)$ • soi by correct answer, nfww
			$\ldots\ldots\ldots\ldots\ldots+\frac{\frac{1}{2}\left(\frac{1}{2}-1\right)}{2!}(3x)^2)$ oe	M1	1.1	• Full expansion up to quadratic term. • Condone e.g. $3x^2$ but not x^2 • soi by correct answer
			$1+\frac{3x}{2}-\frac{9x^2}{8}$ oe	A1	1.1	• Allow exact decimals: $1+1.5x-1.125x^2$ • Ignore cubic and higher order terms. • Mark final answer isw writing terms as a list after correct answer seen, but **A0** if correct answer spoilt by further manipulation
				[3]		
1	(b)		Valid for $\lvert x\rvert<\frac{1}{3}$	B1	1.1	• OR $-\frac{1}{3}<x<\frac{1}{3}$ OR $x<\frac{1}{3}\cap x>-\frac{1}{3}$ • Condone $\lvert x\rvert\le\frac{1}{3}$ or $-\frac{1}{3}\le x\le\frac{1}{3}$ (as $n>0$) • Must be x not e.g. $3x$ • Mark final answer
				[1]		

Question			Answer	Marks	AO	Guidance
2			$(\mathrm{gf}(x) =)\frac{3}{x} - 1$ oe	B1	1.1	• OR $\frac{3-x}{x}$ • **B1 BOD** for $3/x - 1$ but **B0** if ambiguous e.g. $3 - x/x$ • Mark answers in answer space provided first. If this is blank then mark answer written elsewhere in space.
			Domain $\{x: x \in \mathbb{R}, x \neq 0\}$	B1 [2]	1.1	• Or other forms for the domain e.g. $x \in \mathbb{R}, x \neq 0$ • Condone missing brackets • Need not use set notation but **must** have **both** $x \in \mathbb{R}$ **and** $x \neq 0$

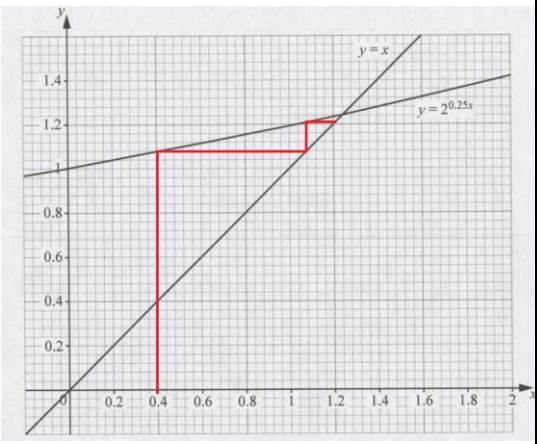
	Question		Answer	Marks	AO	Guidance
3	(a)		Straight line drawn	B1 [1]	1.1	• Line through (3, 0) and (0, 6), mark intent • Condone good freehand line • Condone line stopping at axes • Ignore additional lines, perhaps as part of solution to (b) or (c), as long as it is not several attempts at (a)

Question			Answer	Marks	AO	• Guidance
3	(b)		A is $(3, 0)$ and B is $(0, 6)$	B1	1.1	• Coordinates soi by correct midpoint • Condone labels A and B reversed or omitted • Condone missing brackets for coordinates throughout if intent is clear
			Midpoint is $\left(\frac{3}{2}, 3\right)$	M1	1.1	• Correct midpoint or correct method to find the midpoint. e.g. $\left(\frac{3+0}{2}, \frac{0+6}{2}\right)$ • Allow embedded in the equation for perp. bisector
			Gradient of AB is -2	M1	1.1	• Correct gradient or correct method to find gradient e.g. $y = -2x + c$ or $\frac{6-0}{0-3}$ or $\frac{6-3}{0-1.5}$ or $\frac{0-3}{3-1.5}$ oe • FT *their* midpoint if used • Implied by correct gradient of perpendicular bisector
			Gradient of perpendicular bisector is $\frac{1}{2}$	M1	1.1	• FT $\frac{-1}{\textit{their}\text{ gradient}}$ • May be seen embedded in the equation.
			Equation $(y - 3) = \frac{1}{2}\left(x - \frac{3}{2}\right)$	M1	1.1	• Using *their* midpoint and *their* gradient of perpendicular bisector • Allow $y = \frac{1}{2}x + c$ **<u>and</u>** $3 = \frac{1}{2} \times \frac{3}{2} + c$ oe
			$y = \frac{1}{2}x + \frac{9}{4}$	A1	1.1	• OR $2x - 4y = -9$ • Allow any correct equivalent simplified form e.g. $4y = 2x + 9$ or $y - \frac{1}{2}x = \frac{9}{4}$ or $\frac{1}{2}x - y + \frac{9}{4} = 0$ or any multiple of these. • Allow decimals e.g. $y = 0.5x + 2.25$ • isw after correct equation seen
				[6]		

Question			Answer	Marks	AO	Guidance
3	(c)		$(AB^2 = a^2 + a^2 =)3^2 + 6^2$ Or $(AC^2 =)1.5^2 + 3^2$ where C is the midpoint of the square $a^2 + a^2 = 45$	B1 M1	3.1a 1.1	• Use of Pythagoras which will help to calculate side e.g. AC^2, BC^2, AB^2 or AC, BC, AB soi • FT *their* midpoint from (a) if used • Further working may not be seen as likely to be done by calculator
			Alternative method 1 for M1 $a^2 = 2AC^2 = 2(1.5^2 + 3^2)$	M1		• Using $AC = \sqrt{1.5^2 + 3^2}$ where C is the midpoint of the square
			Alternative method 2 for M1 $a = \sqrt{3^2 + 6^2} \times \cos 45°$ oe	M1		• Use of trigonometry to find *a*
			Alternative method 3 for M1 $a = \frac{\sqrt{1.5^2+3^2}}{\cos 45°}$ oe	M1		• Use of trigonometry to find *a* • Using $AC = \sqrt{1.5^2 + 3^2}$ where C is the midpoint of the square
			Alternative method 4 for M1 $(x - 1.5)^2 + (0.5x - 0.75)^2 = 1.5^2 + 3^2$ $4x^2 - 12x - 27 = 0$	M1		• Use of *their* AC and *their* equation of perpendicular bisector to form a quadratic equation to give the *x*-coordinates of the other two vertices of the square
			$\frac{3}{2}\sqrt{10}$ oe	A1	1.1	• Accept any exact correct answer e.g. $\frac{3\sqrt{10}}{2}, \frac{3}{4}\sqrt{40}, 1.5\sqrt{10}$
			Alternative method using vectors $(\overrightarrow{CB} =) \begin{pmatrix}-1.5\\3\end{pmatrix}$ so $(\overrightarrow{CD} =) \begin{pmatrix}3\\1.5\end{pmatrix}$ where D is another vertex of the square. D is $(4.5, 4.5)$ so $a^2 = (4.5^2 + 1.5^2)$ $\frac{3}{2}\sqrt{10}$ oe	B1 M1 A1	 1.1	• FT *their* midpoint from (a) • Vector from C to B or A or vice versa **and** rotating to get vector to one of the other two vertices • Or $(-1.5, 1.5)$ • Accept any exact correct answer e.g. $\frac{3\sqrt{10}}{2}, \frac{3}{4}\sqrt{40}, 1.5\sqrt{10}$
				[3]		

Question			Answer	Marks	AO	Guidance
4			$6r^3 = \frac{2}{9}$	B1	3.1a	• Forming a correct equation • Or first 4 four terms seen $6, 2, \frac{2}{3}, \frac{2}{9}$ • soi by correct answer or correct value for r
			$r^3 = \frac{1}{27}$ so $r = \frac{1}{3}$	M1	1.1	• Attempt to solve *their* equation for 4th term of a geometric sequence including taking correct root for *their* equation • *Their* equation must be from an attempt to give 4th term of a geometric sequence e.g. $6r^4 = \frac{2}{9} \rightarrow r^4 = \frac{1}{27}$ so $r = \sqrt[4]{\frac{1}{27}} = 0.438[6 \ldots]$ • May be implied by correct answer • Ignore extra values of r for **M1**
			$(S_\infty =)$ 9	A1	1.1	• cao, nfww • Uses $\frac{a}{1-r}$ to find $S_\infty = \frac{6}{2/3}$, answer must be simplified. • **A0** if other values also found unless explicitly rejected
				[3]		

Question			Answer	Marks	AO	Guidance
5	(a)		**DR** $1^4 - 2^1 \quad (= -1 < 0)$ and $2^4 - 2^2 \quad (= 12 > 0)$	**M1**	**1.1**	**See appendix** • Allow $1^4 - 2^1$ or 1 – 2 **and** $2^4 - 2^2$ or 16 – 4 • Ignore '= 0' • Condone -1 and 12 only provided clearly linked to $x = 1$ and $x = 2$ e.g. as coordinates or in a table of values • Allow for using two values between 1 and 2 that are either side of 1.24 e.g. 1.2 and 1.3
			Values are -1 and 12 so there is a change of sign (and hence a root between 1 and 2)	**A1** **[2]**	**2.4**	• Correct values of function **<u>and</u>** comment on change of sign, allow e.g. $-1 < 0$ and $12 > 0$ • Condone no mention of function being sufficiently well-behaved (or continuous) • e.g. 1.2 and 1.3 leading to -0.22 and 0.39 (2 s.f. is sufficient)
5	(b)		$x^4 = 2^x$ $x = (2^x)^{\frac{1}{4}}$ $= 2^{0.25x}$	**B1** **[1]**	**2.1**	• AG • **Convincing** rearrangement to given result • Must show one step of working and no incorrect work seen • Must not work backwards • e.g. $4\log_2(x) - x = 0$ is **B0** as not convincingly from a correct process unless $4\log_2(x) = x$ is seen first
5	(c)		x_1 =1.07….	**M1**	**1.1**	• x_1 = awrt 1.07 (= 1.07177...). • soi by any of these values: 1.204…,1.232…,1.237…
			1.24	**A1** **[2]**	**2.2a**	• cao • Must have shown at least one iteration e.g. x_1 =1.07

Question			Answer	Marks	AO	Guidance
5	(d)			B1 B1 [2]	1.1 1.1	• Vertical line $x = 0.4$ drawn to meet the curve, could start line from $y = x$ • Correct completion of staircase diagram to head towards root with at least two vertical and two horizontal lines seen (lines need not extend beyond region between line and curve) • Condone good freehand lines, mark intent • **SC B1B0** for using a different starting value e.g. $x = 0$ with at least two vertical and two horizontal lines seen. Correct staircase diagram converging to root from *their* starting value.
5	(e)		$x^4 = 2^x$ $x = \log_2(x^4)$ $= 4\log_2 x$	B1 [1]	2.1	• AG • **Convincing** rearrangement to given result • Must show at least one step of working and no incorrect work seen • e.g. $\log_2(x^4) - \log_2(2^x) = 0$ is **B0** as not convincingly from a correct process unless $\log_2(x^4) = \log_2(2^x)$ is seen first • Must not work backwards
5	(f)		**DR** $x_1 = 0$ Not possible to find log of zero	M1 A1 [2]	1.1 2.4	• Or $4\log_2 1 = 0$ • Condone e.g. math error or x_2 is invalid or x_2 has no solution provided log 0 is mentioned

Question			Answer	Marks	AO	Guidance
6	(a)		Explanation, e.g. • The function is positive for all integers so there will be no change of sign • There are two roots between 2 and 3 but the student only checks integers	B1 [1]	2.4	**See appendix** • Or f(2) and f(3) both positive so no change of sign • Or there are two roots between 2 and 3 which will be missed • Must mention integers if they don't explicitly state 2 and 3 • ignore attempts to evaluate f(2) and f(3) • Must have **either** 'no sign change' **or** 'two roots'
	(b)		$\frac{dy}{dx} = 13 - \frac{34}{x} = 0$ $x = \frac{34}{13}$ or $2\frac{8}{13}$	M1 A1 [2]	1.1a 1.1	• Differentiation and setting equal to zero. • Constant must differentiate to zero; sign errors condoned. • Allow for $13 + \frac{k}{x} = 0$ where k is a non-zero constant • Condone poor/no notation • Exact fraction or recurring decimal $2.\dot{6}1538\dot{4}$ (if given as a decimal correct dot notation oe must be used) • Ignore y value if seen • isw decimals after correct answer seen

Question			Answer	Marks	AO	Guidance
7	(a)		$(k =)\ 1.5$	B1 [1]	3.3	• Allow embedded in equation e.g. $P_{t+1} = \frac{3}{2}P_t$
7	(b)		162	B1 [1]	3.4	• cao
7	(c)	(i)	$48e^{0.4} = 71.6(\approx 72)$ $48e^{0.8} = 106.8(\approx 107)$ Comment comparing *their* values with the data e.g. • Reasonably close • Not exactly right	M1 A1 [2]	3.4 3.5a	• Both values – might not round answers • Allow $106.8 \approx 108$ • Condone incorrect values if $48e^{0.4}$ and $48e^{0.8}$ seen • Must have correct values • e.g. 71.6 is close to 72 and 106.8 is close to 108 • Ignore attempts to compare the two models • Condone e.g. 'close for $t = 1$' **and** 'not close for $t = 2$'
7	(c)	(ii)	$\frac{dQ}{dt} = 19.2e^{0.4t}$ $\frac{dQ}{dt} = 0.4Q$ so the rate of change is proportional to the population	M1 A1 [2]	1.1 2.2a	• Differentiation – might not simplify e.g. $\frac{dQ}{dt} = 19.2e^{0.4t}$ or $\frac{dQ}{dt} = \frac{96}{5}e^{0.4t}$ • Implied by $\frac{dQ}{dt} = ke^{0.4t}$ • Condone poor/no notation • Showing the rate of change is proportional to population e.g. $\frac{dQ}{dt} = 0.4 \times 48e^{0.4t}$ **<u>and</u>** $Q = 48e^{0.4t}$ soi or $\frac{\frac{dQ}{dt}}{48e^{0.4t}} = 0.4$ • 0.4 must be exact and not rounded e.g. from numerical trials • Must see $\frac{dQ}{dt}$ or e.g. Q'

Question			Answer	Marks	AO	Guidance
7	(c)	(iii)	Method to find multiplier for Q At time $t+1$, Q= $48e^{0.4(t+1)}$ $= 48e^{0.4t} \times e^{0.4}$	M1	3.1b	• Use of exponential equation one month later – may award for correct use of equation for Q to find populations for at least 2 consecutive months (for $t = 2$ onwards) For info: $t = 2, Q = 106.8$; $t = 3, Q = 159.4$; $t = 4, Q = 237.7$ to 3 s.f. or better • This **M1** may be implied by finding multiplier of $e^{0.4}$
			$e^{0.4}$ or 1.49 ... (is multiplier for Q)	B1	1.1	• Finding multiplier for Q • If 'multiplier' omitted, then multiplication must be implied by later work
			Multiplier for sequence P is 1.5. Both sequences are equal at $t = 0$ or 1 So ×1.49 each month will give smaller answers than ×1.5	A1	2.4	• Completion with **convincing** general explanation **including** consideration of an early value (could be $P > Q$ at $t = 1$ or both sequences start at 48 or at $t = 2$ the values are 107 for Q and 108 for P)
			Alternative 1 for A1 Model P is $48(1.5)^t$ oe $1.49 \ldots < 1.5$ So, $48(1.49 \ldots)^t < 48(1.5)^t$	A1		• **Convincing** completion, must see '48' or both equal populations at $t = 0$ (or $t = 1$) • oe e.g. showing $\frac{1.5^t}{e^{0.4t}} > 1$ **and** starting values of 48 soi or writing model for P as $48e^{(\ln 1.5)t} = 48\ e^{0.405\ldots t}$
			Alternative 2 for A1 Model P is $48(1.5)^t$ $\frac{dP}{dt} = 48 \times \ln(1.5) \times 1.5^t = \ln(1.5) \times P$ Rate of population growth for P is greater than rate of population growth for Q as $\ln 1.5 > 0.4$ **and** both equal populations at $t = 0$ (or $t = 1$)	A1		• Differentiates may use ln 1.5 or 0.405… • **Convincing** completion

Question			Answer	Marks	AO	Guidance
			Alternative method using inequalities Model for P is 48×1.5^t $(48)e^{0.4t} < (48 \times)1.5^t$ oe $0.4t < \ln 1.5^t$ $0.4t < t \ln 1.5$ True for $t > 1$ since $\ln 1.5 = 0.405\ldots > 0.4$	**B1** **M1** **A1**		• B1 for finding correct model for P • Forming inequality for P and Q • **Convincing** completion
				[3]		

Question			Answer	Marks	AO	Guidance
8	**(a)**		10.1	**B1** **[1]**	**1.1**	cao
8	**(b)**		223.378	**B1** **[1]**	**1.1**	cao
8	**(c)**		226.2	**B1** **[1]**	**2.2a**	cao

Question			Answer	Marks	AO	Guidance
9	(a)		$(\mathrm{f}'(x) =)\ \ 3x^2 + 3\mathrm{e}^{3x}$	B1 B1 [2]	1.1 1.1	• $3x^2$ or $k\mathrm{e}^{3x}$ where $k = 1, 3$ or $\frac{1}{3}$ • Implied by correct answer • Fully correct derivative
9	(b)		$(0, 1)$	B1 [1]	1.1	• Or $x = 0$, $y = 1$. • 1 alone is **not** sufficient. • Condone omission of brackets
9	(c)		$\frac{\mathrm{d}y}{\mathrm{d}x} = \frac{1}{\frac{\mathrm{d}x}{\mathrm{d}y}}$ so gradient is $\frac{1}{\textit{their}\text{ gradient of } y=\mathrm{f}(x)\text{(where it crosses } y\text{-axis)}}$	M1	3.1a	• Consideration of relationship between gradients of the two curves where they cross the relevant axes. May be shown in a diagram with sketch of any increasing function reflected in $y = x$ • Implied by correct answer • **FT** *their* derivative
			Alternative method for M1 $x = y^3 + \mathrm{e}^{3y}$ $1 = 3y^2\frac{\mathrm{d}y}{\mathrm{d}x} + 3\mathrm{e}^{3y}\frac{\mathrm{d}y}{\mathrm{d}x}$ $\frac{\mathrm{d}y}{\mathrm{d}x} = \frac{1}{3y^2+3\mathrm{e}^{3y}}$	M1		• Clear attempt to use implicit differentiation to find $\frac{\mathrm{d}y}{\mathrm{d}x}$ • Implied by correct answer
			$\frac{1}{3}$	A1 [2]	1.1	• nfww

Question			Answer	Marks	AO	Guidance
10			$4^2 + 1^2 + x^2$	B1	1.1	• Use of Pythagoras implied by $17 + x^2$
			$17 + x^2 = n^2$ OR $n^2 - x^2 = 17$	B1	1.1	• Understanding that $17 + x^2$ is a square number soi e.g. by equating to at least one square number $17 + x^2 = 25$ • Allow e.g. $n = \sqrt{17 + x^2}$ and n integer soi e.g. by equating to an integer
			$(n - x)(n + x) = 17$	M1	3.1a	• Rearranging to get *their* 17 on one side and factorising
			$n - x = 1$ **and** $n + x = 17$ AND $n - x = -1$ **and** $n + x = -17$	A1	2.2a	• OR $n - x = 17$ **and** $n + x = 1$ AND $n - x = -17$ **and** $n + x = -1$ • Implies **M1.** If the final **B2** is earned following only one pair of correct equations then award **A1**
			Alternative method 1 for M1 A1 Evidence of adding square numbers to 17 to try to get a square number Or subtracting 17 from square numbers to get a square number Or $x^2 = 64$	M1		• At least two different square numbers added to *their* 17 e.g. two from: $17 + 1$, $17 + 4$, $17 + 9$, $17 + 16$ $17 + 25$, $17 + 49$, $17 + 64$, $17 + 81$ and so on • Or tested two using $17 + x^2 = 25$, $17 + x^2 = 36$, $17 + x^2 = 49$, $17 + x^2 = 64$, $17 + x^2 = 81$ and so on
			Explanation of why there will be no further values	A1		• e.g. Since 64 and 17 + 64 are adjacent square numbers there will be no larger values of x^2
			Alternative method 2 for M1 A1 $(x + 1)^2 - x^2 = 17$	M1		• Uses adjacent square numbers • Implied by $2x + 1 = 17$ • Condone not testing earlier squares for this **M1**
			$2x + 1 = 17$ and $(x - 1)^2 - x^2 = 17$	A1		• If the final **B2** is earned following **M1** then award **A1**
			8 and -8	B2 [6]	1.1	• Both values and no others • **B1** if only one value given (ignore extras)

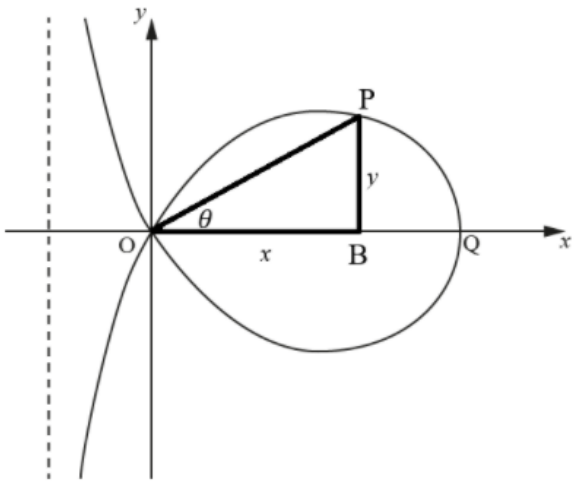
Question			Answer	Marks	AO	Guidance
11	(a)		$\dfrac{\sqrt{n+1}+1-\left(\sqrt{n+1}-1\right)}{\left(\sqrt{n+1}-1\right)\left(\sqrt{n+1}+1\right)}$	M1	3.1a	• Finding common denominator or attempt to rationalise denominator for at least one fraction e.g. $\frac{1}{\sqrt{n+1}-1}\cdot\frac{\sqrt{n+1}+1}{\sqrt{n+1}+1}-\frac{1}{\sqrt{n+1}+1}\cdot\frac{\sqrt{n+1}-1}{\sqrt{n+1}-1}$ *or* $\frac{\sqrt{n+1}+1}{n}-\frac{\left(\sqrt{n+1}-1\right)}{n}$ oe • Condone consistently considering any general term in the sequence e.g. a_{k+1} for all marks $\dfrac{1}{\sqrt{k+2}-1}\cdot\dfrac{\sqrt{k+2}+1}{\sqrt{k+2}+1}-\dfrac{1}{\sqrt{k+2}+1}\cdot\dfrac{\sqrt{k+2}-1}{\sqrt{k+2}-1}$
			$\dfrac{2}{(n+1)-1}=\dfrac{2}{n}$	A1	2.1	• Correct simplification • a_{k+1} leads to $\frac{2}{k+1}$
			Numerator and denominator are integers (and denominator is not zero) so this is rational	A1	2.2a	• nfww • Correct explanation of why the general term must be rational e.g. in form $\frac{p}{q}$ oe p, q integers • Condone rational as n an integer or k integer • '$\frac{2}{n}$ is rational' alone is **A0** - <u>must</u> include comment that n is an integer
				[3]		

Question			Answer	Marks	AO	Guidance
11	(b)		(Since $n > 0$) as n increases, $\frac{2}{n}$ decreases Or $\frac{2}{n+1} - \frac{2}{n} = -\frac{2}{n(n+1)}$	M1	2.2a	• Must relate to $\frac{2}{n}$, $a_n \to 0$ is not sufficient • Allow "($n > 0$ and) $\lim_{n\to\infty} \frac{2}{n} = 0$" • Condone omission of $n > 0$ • May find the difference between 2 terms or use inequalities • Allow $f(x) = \frac{2}{x} \Rightarrow f'(x) = -\frac{2}{x^2} < 0$ (condone n instead of x) • Condone listing terms for **M1 A0** • **FT** *their* $\frac{2}{n}$ provided in the form $\frac{b}{n+c}$ where b, c integers
			$\Rightarrow$ sequence is decreasing	A1	2.5	**See appendix** • **Convincing** conclusion e.g. difference between terms is negative, so sequence is decreasing or $\frac{2}{n+1} < \frac{2}{n}$, so decreasing or function $f(x)$ is decreasing therefore sequence a_n decreasing • **A1** is only available if *their* $\frac{2}{n}$ is correct for *their* term e.g. $\frac{2}{k+1}$ from considering a_{k+1} • **SC B1** for 'decreasing' following **M0** for a correct but incomplete argument. But not just for 'decreasing' unsupported.
				[2]		

Question			Answer	Marks	AO	Guidance
12	(a)		$\frac{3a-x}{a+x}=\frac{3a}{a}=3\geq 0$	B1 [1]	2.1	• AG • Or complete argument e.g. $a>0$ so $\frac{3a}{a}\geq 0$ • Condone $3>0$ or $\frac{3a}{a}>0$ • No wrong working seen
12	(b)		$y^2\geq 0$ and $x^2>0$ Since $y^2=\frac{x^2(3a-x)}{a+x}$ then $\frac{(3a-x)}{a+x}\geq 0$	B1 [1]	2.1	• AG • Clear explanation, must be based on y^2 non-negative (≥ 0) and x^2 positive (>0) • Condone $\frac{y^2}{x^2}\geq 0$ then $\frac{(3a-x)}{a+x}\geq 0$ from rearranging
12	(c)		$x+a$ cannot be 0 [as then the value of y^2 is undefined] $3a-x\leq 0$ and $a+x<0$ ($3a-x\geq 0$ and $a+x>0$) If $3a-x\leq 0$ and $a+x<0$ then $3a\leq x$ and $x<-a$ These cannot both be true when a is positive so $3a-x\geq 0$ and $a+x>0$	B1 B1 B1	2.2a 2.2a 2.3	• Dismissing zero value for $x+a$ • Allow e.g. $x+a>0$ **and** $x+a<0$ • Condone e.g. " $x+a>0$ as denominator cannot be 0" • Condone "both positive or both negative" • Considering negative case • Condone e.g. $3a-x<0$ and $a+x<0$ for this mark • AG • Dismissing the "both negative" case • Dep on previous two B1 marks • Inequality signs must be correct
			Alternative method for 3rd B1 If $3a-x\leq 0$ and $a+x<0$ then $3a-x+a+x<0\Rightarrow 4a<0$ but this is impossible as $a>0$ so $3a-x\geq 0$ and $a+x>0$	B1		• AG • Dismissing the "both negative" case • Dep on previous two B1 marks • Inequality signs must be correct
				[3]		

Question			Answer	Marks	AO	Guidance
12	(d)		$3a \geq x$ and $x > -a$ OR $-a < x \leq 3a$	B1 [1]	3.1a	• Any equivalent inequality/inequalities with x as a subject • Both inequality signs must be correct • Condone e.g. comma for 'and'
12	(e)		(Asymptote is) $x = -a$	B1 [1]	2.2a	• $-a$ alone is insufficient. • oe e.g. $x + a = 0$

Question			Answer	Marks	AO	Guidance
13			$\tan(2\theta) = \frac{2t}{1-t^2}$	B1	1.1	• OR $\tan(3\theta) = \tan(2\theta + \theta) = \frac{\tan 2\theta + \tan\theta}{1 - \tan 2\theta \tan\theta}$ • Formula for $\tan(2\theta)$ in terms of t or $\tan\theta$ • Allow embedded
			$(\tan(3\theta) = \tan(2\theta + \theta) =)\ \dfrac{\frac{2t}{1-t^2} + t}{1 - \frac{2t^2}{1-t^2}}$	M1	3.1a	• Must be in terms of $\tan\theta$ or t only • Condone considering numerator and denominator separately • Using *their* $\tan(2\theta)$ provided from using double angle formula
			$\tan(3\theta) = \dfrac{2t + t(1-t^2)}{1 - t^2 - 2t^2}$ $= \dfrac{3t - t^3}{1 - 3t^2}$ $= \dfrac{t(3 - t^2)}{1 - 3t^2}$	A1 [3]	2.1	• AG • Correct completion to given result in terms of t. • Must see at least one step of working after M1 awarded and no errors or omissions

Question			Answer	Marks	AO	Guidance
14	(a)			B1 [1]	3.1a	• Triangle POB drawn, where B is the point on the x- axis such that PB is perpendicular to the x-axis. • P may be anywhere on curve in 1st quadrant. • The points P and B need not be labelled • Vertical and horizontal sides should be labelled y and x OR x and y clearly indicated on the axes OR Point on curve labelled (x, y) • Allow angle θ not labelled • Condone good freehand – mark intent
14	(b)		$(3a - x =)\ 3a - \dfrac{a(3-t^2)}{1+t^2}$ $= \dfrac{3a + 3at^2 - 3a + at^2}{1+t^2}$ $= \dfrac{4at^2}{1+t^2}$	B1 [1]	2.1	AG • Correct completion to given result. • Must see at least one step of working and no errors or omissions
14	(c)		$(a + x =)\ \dfrac{4a}{1+t^2}$	B1 [1]	3.1a	• Correct expression in terms of a and t • Must be simplified

Question			Answer	Marks	AO	Guidance
14	(d)		$\frac{3a-x}{a+x} = \frac{\frac{4at^2}{1+t^2}}{\frac{4a}{1+t^2}}$	M1	3.1a	• Dividing the correct expressions for $3a-x$ and $a+x$
			$= t^2$ $\Rightarrow \frac{3a-x}{a+x} = \frac{y^2}{x^2}$ $\Rightarrow \frac{x^2(3a-x)}{a+x} = y^2$	A1	2.1	AG • Simplifying to t^2 • Using $t = \frac{y}{x}$ to give a correct completion to given result • Must have at least one line of working and no incorrect work seen
			Alternative method 1 $\frac{x^2(3a-x)}{a+x} = \frac{x^2 \times \frac{4at^2}{1+t^2}}{\frac{4a}{1+t^2}}$	M1		• Substituting correct expressions for $3a-x$ and $a+x$ into $y^2 = \frac{x^2(3a-x)}{a+x}$
			$= \frac{x^2 \times t^2}{1}$ $= y^2$ (since $t = \frac{y}{x}$)	A1		AG • Simplifying to x^2t^2 • Using $t = \frac{y}{x}$ to give a correct completion to given result • Must have at least one line of working and no incorrect work seen

			Alternative method 2 $\frac{x^2(3a-x)}{a+x} = \left(\frac{a(3-t^2)}{1+t^2}\right)^2 \times \frac{1}{a+\frac{a(3-t^2)}{1+t^2}} \times \frac{4at^2}{1+t^2}$	**M1**		• Substituting $x = \frac{a(3-t^2)}{1+t^2}$ and $3a - x = \frac{4at^2}{1+t^2}$ into $y^2 = \frac{x^2(3a-x)}{a+x}$
			$= \frac{a^2(3-t^2)^2}{(1+t^2)^2} \times \frac{4at^2}{a(1+t^2)+a(3-t^2)}$ $= \frac{a^2(3-t^2)^2}{(1+t^2)^2} \times \frac{4t^2}{1+t^2+3-t^2}$ $= \frac{a^2(3-t^2)^2}{(1+t^2)^2} \times \frac{4t^2}{4} = \frac{a^2(3-t^2)^2t^2}{(1+t^2)^2}$ $= \left(\frac{a(3-t^2)t}{(1+t^2)}\right)^2 = y^2$	**A1**		AG • Simplifying and showing $y^2 = (xt)^2$ to give a correct completion to given result • Must have at least one line of working and no incorrect work seen
			Alternative method 3 $x = \frac{a(3-t^2)}{1+t^2}$ $\Rightarrow x + xt^2 = 3a - at^2$ $\Rightarrow t^2(x+a) = 3a - x$ $\Rightarrow t^2 = \frac{3a-x}{a+x}$	**M1**		• Making t^2 the subject of $x = \frac{a(3-t^2)}{1+t^2}$ as far as $t^2 = \ldots$ • Condone algebraic or sign slips
			$y = xt \Rightarrow y^2 = x^2t^2 = \frac{x^2(3a-x)}{a+x}$	**A1**		AG • Using $t = \frac{y}{x}$ to give a correct completion to given result • No incorrect work seen
				[2]		

Appendix

Question 5a

REMEMBER: It is not possible to have an award of M0A1

After M1 has been awarded the following comments would earn A1
There is a sign change therefore the curve crosses the x-axis therefore a root is between 1 and 2
Change of sign and root must be between 1 and 2
$-1 < 0$ and $12 > 0$
-1 is negative and 12 is positive
Change of sign then there is a root between 1.2 and 1.3, which also lies between 1 and 2

After M1 has been awarded the following comments would earn A0
$x = 1, y = -1$ and $x = 2, y = 8$, sign change suggests a root between these values **A0 as $y = 8$ is incorrect**
There is a root between 1 and 2 **A0 as no mention of sign change**

Question 6a

The following comments earn B1
The graph has two roots between 2 and 3 but since the y values and both 2 and 3 are positive, no change in sign will be detected so the student will not find the roots.
The change of sign would go unnoticed between 2 and 3 on the x axis
Both roots are between the positive integers 2 and 3 therefore a change of sign will not be observed.
x=2 , f(x) = 0.933 x = 3, f(x) = 0.147 so there is no change of sign so no roots determined

The following comments earn B0
Student uses integer which when you use f(2) and f(3) both values are positive therefore it could not be used to locate a root **B0 as no explicit mention of change of sign**
As he may skip over the exact moment f(x)=0 due to the interval change/resolution of the spreadsheet data. **B0 as change of sign not mentioned or that there are two roots between 2 and 3**
She uses integer values the roots are between the integers 2 and 3 the graph f(x) is always positive at these values. **B0 as no explicit mention of change of sign or 2 roots**
It has 2 roots. **B0 as no explicit mention of change of sign or 2 roots between integers 2 and 3**
Because there is a ln term in the equation. **B0 as no mention of change of sign or 2 roots**
The student might miss an x value that correlates to f(x)=0 **B0 as no mention of change of sign or 2 roots between 2 and 3.**

Question 11b

These would earn M1A1
As n tends towards infinity $\frac{2}{n}$ will tend towards zero. Decreasing.
$a_{n+1} = \frac{2}{n+1} < \frac{2}{n} = a_n$ So $a_{n+1} < a_n$ so the sequence is decreasing
As k increases $\frac{2}{k+1}$ decreasing, therefore the sequence is decreasing **Note: This is follow through from their answer in 11a as noted in the guidance column.**

This would earn SCB1
$n = 1 \rightarrow a_1 = 2$ $n = 2 \rightarrow a_2 = 1$ $n = 2 \rightarrow a_3 = \frac{2}{3}$ $n = 4 \rightarrow a_4 = \frac{1}{2}$ It is decreasing. **This is insufficient for the award of M1A1 marks as they are using numerical values, however would earn SCB1.**

This would earn M0A0
The sequence is decreasing **No special case awarded as 'decreasing' is unsupported.**

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