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Examiners' report

A LEVEL

FURTHER MATHEMATICS B (MEI)

OCR Level 3 Advanced GCE in Further Mathematics B (MEI)

H645

For first teaching in 2017

Y434/01 Summer 2025 series

Version 1

ocr.org.uk/maths

Contents

Introduction

Our examiners’ reports are produced to offer constructive feedback on candidates’ performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates’ performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate responses is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from Teach Cambridge.

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Paper Y434/01 series overview

This optional paper comprises 16⅔ % of the assessment of OCR A Level Further Mathematics B (MEI). There is one examination paper which lasts for 1 hour 15 minutes. Candidates are expected to be familiar with the content of A Level Mathematics and the content of the mandatory Core Pure paper, Y420 (A Level Further Mathematics - H645).

Candidates should be able to use the iterative capability of a calculator in the examination. No credit is given for using equation solvers or numerical integration or differentiation tools to obtain answers.

Candidates should be familiar with the command words used in this specification, in particular that the command word 'Determine' is a signal that sufficient detail of any necessary working must be given in order to earn full credit.

It is expected that candidates will have routinely used a spreadsheet throughout the course. In the examination candidates will be expected to interpret spreadsheet output and to provide simple spreadsheet formulae.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• made efficient use of the iterative capability of their calculator and provided sufficient detail of their working to justify the precision quoted in their answers • presented their answers to the precision requested • understood what they were being asked to explain, and did so concisely and with an appropriate supporting argument • understood the graphical interpretation of algorithms for solving equations numerically, and were able to draw and interpret diagrams appropriately • were able to interpret and give spreadsheet formulae correctly • understood the relationship between the convergence of the ratio of differences and the order of a numerical method or order of convergence of a sequence of approximations in different contexts and were able to communicate this accurately and concisely.	• were able to use the iterative capability of their calculator, but either did not show sufficient detail of their working to earn full credit, or did not appreciate from their working that their answer was not sensible • presented the correct answers to a different precision • understood the principle of what was being asked, but either did not justify their reasoning or were unable to articulate it clearly • understood the graphical interpretation of algorithms for solving equations numerically, but were unable to communicate this adequately or accurately • demonstrated a partial understanding of spreadsheet formulae or were unable to communicate their understanding in sufficiently precise language • had a partial understanding of error analysis using the convergence of the ratio of differences and how it may interpret regarding the order of a numerical method or the order of convergence of a sequence of approximations.

Question 1 (a) and (b)

1 The table shows some values of x and the associated values of $\mathrm{f}(x)$.

x	1.9	2.0	2.1
$\mathrm{f}(x)$	0.216 92	0.2	0.184 84

(a) Determine an estimate of $\mathrm{f}'(2.0)$ using the forward difference method. **[2]**

(b) Determine an estimate of $\mathrm{f}'(2.0)$ using the central difference method. **[2]**

Most candidates earned full marks on this question.

Those who did less well made a slip in the arithmetic or did not show any working.

A very small number of candidates did not do well. This was generally due to not using the specific method required by the question.

Question 2 (a) (i), (ii), (b) and (c)

2 The numbers p and q are approximated by

$P = 323$ and $Q = 162$.

P has been found by **rounding** p to the nearest whole number.

Q has been found by **chopping** q to the nearest whole number.

(a) **(i)** Find the maximum possible relative error in using P to approximate p. **[1]**

(ii) Find the maximum possible relative error in using Q to approximate q. **[1]**

(b) Determine the range of possible values of $R = \frac{200}{p-2q}$. **[3]**

(c) Explain why your answer to part **(b)** is so large. **[1]**

This question was generally very well done.

Candidates who did less well may have used a denominator of 323 or 323.5 in (a) (i) and/or a denominator of 162 or occasionally 162.9 in (a) (ii). Some made a sign error in (a) (ii). In part (b) they may have only obtained one correct bound or not shown sufficient detail of their working to earn the method mark.

Question 3 (a) and (b)

3 Approximations to $\int_{0.5}^{1.3} \sqrt{1+x^3}\,dx$ using the midpoint rule, the trapezium rule and Simpson's rule with $n = 1$ and $n = 2$ are shown in the table. The table is incomplete.

n	M_n	T_n	S_{2n}
1			1.081 111
2	1.074 256		

(a) Complete the copy of the table in the **Printed Answer Booklet**. Give your answers to **6** decimal places. **[4]**

(b) **Without doing any further calculations**, state the value of $\int_{0.5}^{1.3} \sqrt{1+x^3}\,dx$ as accurately as possible. You must justify the precision quoted. **[1]**

This question was very well done by most candidates.

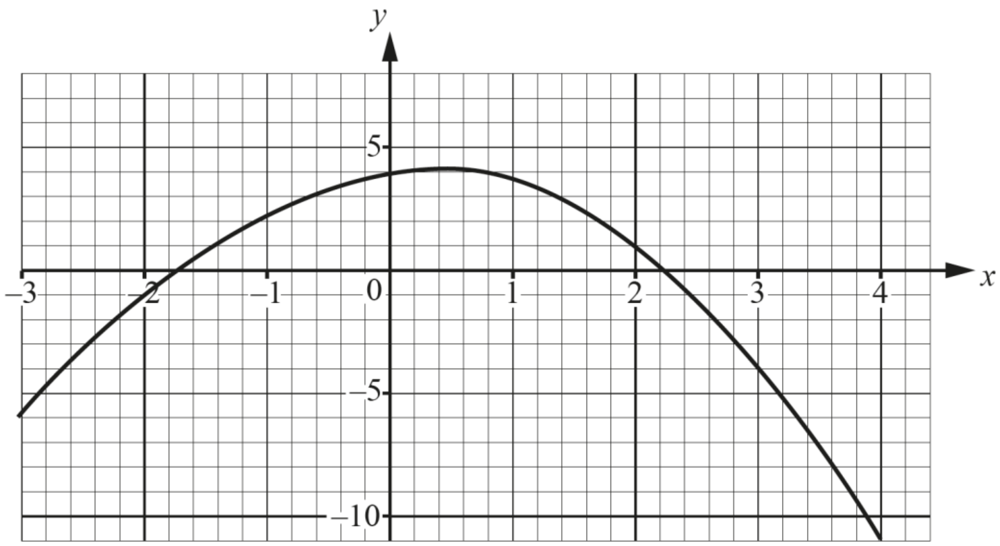
Candidates who did less well sometimes presented their answers to part (a) to a different precision. A small number of candidates calculated S_2 instead of S_4. In part (b) they may have over-stated or understated the likely precision of the best approximation to the interval.

Question 4 (a), (b) and (c)

4 The Newton-Raphson method is to be used to find the positive root of the equation

$\tanh x - x^2 + 4 = 0$.

The diagram shows part of the graph of $y = \tanh x - x^2 + 4$.



(a) On the copy of the diagram in the **Printed Answer Booklet**, show how the Newton-Raphson method works to find x_1 using the starting value $x_0 = 1$. **[1]**

(b) Use the Newton-Raphson method using the starting value $x_0 = 1$ to determine the values of x_1 and x_2 correct to **8** decimal places. **[4]**

(c) Continue the iteration to determine the value of the positive root of the equation $\tanh x - x^2 + 4 = 0$ correct to **7** decimal places. **[2]**

Candidates who did well in this question gave detailed responses to parts (b) and (c) and showed sufficient evidence to justify the requested precision in part (c).

Candidates who did less well may have not identify x_1 on the diagram in part (a) or drawn a tangent which intercepted the *x*-axis outside the required range. In part (b) they may not have shown the iterative formula or perhaps given the iterates to a different precision. In part (c) some candidates either gave too few iterates or presented the iterates to too few decimal places to earn full credit.

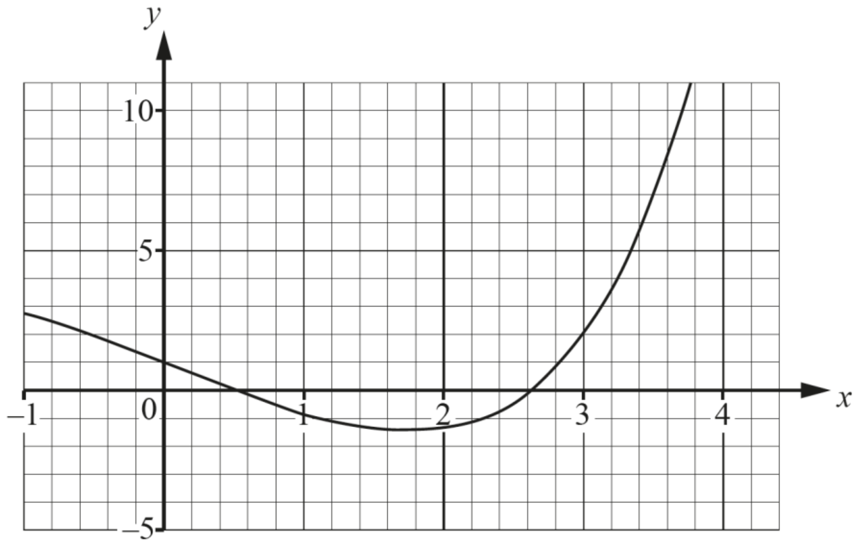
Candidates who did not do well did not draw a tangent in part (a). In part (b) they may have differentiated $\tanh x$ incorrectly ($\ln \cosh x$ was sometimes seen) or made a slip when calculating the iterates, which was seldom recovered in part (c).

Sufficient details for iteration

The command word for part (c) is determine, a signal that some detailed working is required. It must be clear that the iteration has been continued, so to earn M1 seeing x_3 and x_4 to 7 or more decimal places was required. As a final answer correct to 7 decimal places is required, candidates should work to at least 8 decimal places if they choose – as most do – to stop the iteration when the required precision has been confirmed by successive iterates.

Question 5 (a)

5 The diagram shows part of the graph of $y = \sinh x - 3x + 1$.



The largest positive root, α, of the equation $\sinh x - 3x + 1 = 0$ is to be found using the secant method with $x_0 = 2$ and $x_1 = 3$.

Table 5.1 shows the associated spreadsheet output.

Table 5.1

	A	B	C	D	E
2	r	x_r	$f(x_r)$	x_{r+1}	$f(x_{r+1})$
3	0	2	–1.37314	3	2.01787
4	1	3	2.017875	2.404935	–0.7211
5	2	2.404935	–0.72109	2.561598	–0.2451
6	3	2.561598	–0.24513	2.642285	0.06018
7	4	2.642285	0.060175	2.626382	–0.0035
8	5	2.626382	–0.00348	2.627252	–5E-05
9	6	2.627252	–4.5E-05	2.627264	3.5E-08

(a) Write down a suitable formula for cell D4. **[2]**

Most candidates did very well in this question.

Candidates who did less well understood how to apply the formula for the secant method but were unable to express this as a spreadsheet cell formula. The most common slip was to write the formula as a fraction instead of using the / symbol.

Question 5 (b)

(b) State the most accurate approximation to α in the spreadsheet output. **[1]**

Most candidates wrote down the correct answer.

Candidates who did not do well usually wrote down 2.627252 or a rounded version of 2.627264.

Question 5 (c)

(c) Determine whether this approximation is accurate to **6** decimal places. **[2]**

Candidates who did well in this question tested for a sign change, carried out the appropriate calculation successfully and interpreted their answer successfully.

Candidates who did less well may have carried out the calculation correctly but omitted the appropriate deduction.

Candidates who did not do well attempted to justify their answer with a general discussion of values in the table.

Question 5 (d)

(d) Explain what would happen if the initial entry in cell D3 were to be changed from 3 to 1. **[1]**

Candidates who did well in this question understood the graphical interpretation of the secant method and were able to deduce the approximate location of the next iterate and made a conclusion accordingly.

Candidates who did less well commented that the iteration wouldn't converge or would not work.

Question 5 (e)

Table 5.2 shows some further analysis of the sequence of approximations to α.

Table 5.2

A	B	C	D	E
r	x_r	$x_{r+1}-x_r$	$\dfrac{x_{r+2}-x_{r+1}}{x_{r+1}-x_r}$	$\dfrac{x_{r+2}-x_{r+1}}{(x_{r+1}-x_r)^2}$
1	3	–0.5951	–0.2633	0.44242
2	2.404935	0.15666	0.51504	3.28756
3	2.561598	0.08069	–0.1971	–2.4427
4	2.642285	–0.0159	–0.0547	3.44193
5	2.626382	0.00087	0.01315	15.1113
6	2.627252	1.1E-05		
7	2.627264			

(e) Explain what may be inferred from the entries in column D about the order of convergence of this sequence of approximations to α. **[2]**

Candidates who did well observed that the values in column D are decreasing in magnitude and went on to conclude that the order of convergence is higher than first order.

Candidates who did less well either commented that the values in column D are not constant or that the convergence was not first order.

Question 5 (f)

(f) Explain what may be inferred from the entries in column E about the order of convergence of this sequence of approximations to α. **[2]**

Candidates who did well observed that the values in column E are increasing in magnitude and went on to conclude that the order of convergence is lower than second order (or both).

Candidates who did less well either commented that the values in column E are not constant or that the convergence was not second order (or both).

Question 6 (a)

6 The midpoint rule is used to find a sequence of approximations to $\int_0^1 \sqrt{\sin x}\,dx$.

The associated spreadsheet output, together with some further analysis, is shown in the table.

n	M_n	difference	ratio
1	0.6924056		
2	0.6615057	–0.0308999	
4	0.6498274	–0.0116782	0.37794
8	0.6454773	–0.0043501	0.3725
16	0.6438811	–0.0015962	0.36692
32	0.643302	–0.0005791	0.36281
64	0.6430936	–0.0002085	0.35996
128	0.6430189	–7.463E-05	0.35801

(a) Explain what the entries in the ratio column tell you about the order of the midpoint rule in this case. **[2]**

Candidates who did well in this question observed that the ratios seem to be converging to 0.358 and went on to note that this is between 0.25 and 0.5, which suggests the order of the method is between first and second order in this case.

Candidates who did less well neglected to compare the ratios with 0.25 and 0.5 or were unable to communicate their deduction in concise terms.

Convergence of ratio of differences

Candidates need to comment on whether the ratio of differences is **converging**. Commenting such as 'the ratios are approximately equal' or 'the ratios are approximately constant' is insufficient.

Question 6 (b)

(b) Use the information in the table to determine the most accurate estimate of $\int_0^1 \sqrt{\sin x}\,dx$ possible. You must justify the precision quoted. **[5]**

Candidates who did well in this question worked with M_{128} and -7.463×10^{-5}, and extrapolated to infinity with an appropriate value for *r*. They completed the calculation accurately and were usually able to deduce an appropriate level of precision for their final answer. A minority of candidates compared two extrapolated values to justify their final answer, which did not earn the last mark. Some candidates were over ambitious or too cautious (see exemplar 1) with the final precision quoted.

Candidates who did less well earned the method marks but did not gain the accuracy marks for one of three reasons. Some candidates made a sign error and worked with $-(-7.463 \times 10^{-5})$ to M_{128}. The two most common reasons for losing the first – and therefore subsequent – A marks are highlighted in exemplars 2 and 3.

A small number of candidates worked with the theoretical ratios and earned 1 or 2 marks.

Candidates who did not do well used the integration function on their calculator or simply provided a commentary on the values in the table.

Exemplar 1

6(b)

$= 0{\cdot}6430189 - 7{\cdot}463\times10^{-5} \times \dfrac{0{\cdot}35801}{1-0{\cdot}35801}$

$= 0{\cdot}6429772821.$

$= \boxed{0{\cdot}643}$ as both extrapolated value and M_{128} are this to 3dp

M1M1A1 is earned on the first line of working for extrapolating to infinity from M_{128} with the correct difference and an appropriate ratio. A1 is then awarded on the next line for obtaining a value within the specified range. However, it's possible to deduce a greater precision than the one quoted by the candidate, so the final A mark is not earned.

Exemplar 2

6(b)	
	$-7.463\times10^{-5} + 0.35801(-7.463\times10^{-5}) + 0.35801^2 \ldots$
	$a = -7.463\times10^{-5}$ $\quad S_\infty = \frac{a}{1-r}$
	$r = 0.35801$
	$\frac{-7.463\times10^{-5}}{1-0.35801} = -0.000116$
	$0.6430189 - 0.000116 = 0.6429026S$
	$\int_0^1 \sqrt{\sin x}\,dx \approx 0.643$
	as the last calculated value and extrapolated to ∞ value agree to 3 decimal places

This candidate has taken -7.463×10^{-5} to be $M_{256} - M_{128}$ not $M_{128} - M_{64}$. Extrapolation to infinity takes place, but with a first term of -7.463×10^{-5} instead of $-7.463 \times 10^{-5} \times r$. On line 5 this is combined with M_{128} to earn M1M1A0. Note that this is equivalent to $M_n + d \times \frac{1}{1-r}$ as mentioned in the guidance in the mark scheme.

Exemplar 3

6(b) best estimate + difference × $\frac{r}{1-r}$

0.6430189 ~~th~~ $- 0.00007463 \times \frac{0.36}{1-0.36}$

$= 0.6429769206$ comparison with M_{128}

0.643 because this is the precision the best two estimates agree to

extrapolation and M_{128}

It should be clear from the table that the ratio is both decreasing in magnitude and converging. Candidates should therefore appreciate that *r* will converge to something less than 0.36, and that 0.35 is very unlikely. Consequently, the most precise estimate from the given information will be obtained by using a value for *r* between 0.358 and 0.35801. In this case the candidate earns M1M1 on the second line of working, but A0 for using *r* = 0.36.

Question 7 (a)

7 The equation $8\ln(x+2)-3x+1=0$ has a positive root, γ, and a negative root, δ.

It is proposed that the iterative formula

$x_{n+1}=\mathrm{g}(x_n)$, where $\mathrm{g}(x)=8\ln(x+2)-2x+1$,

should be used to find γ.

It is found that $\mathrm{g}'(\gamma)\approx -0.977$.

(a) Explain what this tells you about the speed of convergence of the sequence of approximations to γ which would be generated by $x_{n+1}=\mathrm{g}(x_n)$. **[2]**

Candidates who did well in this question observed the proximity of -0.997 to -1 and commented that the speed of convergence would be slow.

Candidates who did less well referred to 'the gradient' instead of -0.997 or $g'(\gamma)$, or they may have concluded that the iteration would converge quickly.

Candidates who did not do well commented that $-0.997>-1$ so the iteration will converge.

Question 7 (b)

The relaxed iteration

$x_{n+1} = (1-\lambda)x_n + \lambda g(x_n)$ with $\lambda = 0.506$

is used to find a sequence of approximations to γ.

The spreadsheet output is shown in the table, together with the values of $f(x_r) = 8\ln(x_r+2) - 3x_r + 1$ for $r = 0, 1, 2, 3, 4$.

	E	F	G
1	r	x_r	$f(x_r)$
2	0	5	1.567281192
3	1	5.7930443	0.046719768
4	2	5.8166845	3.04288E-05
5	3	5.8166999	–4.07401E-09
6	4	5.8166999	5.47118E-13

(b) State the value of γ as accurately as you can, justifying the precision quoted. **[1]**

Candidates who did well wrote down 5.8166999 and justified their answer by comparing x_3 and x_4.

Some candidates who did not do well wrote down the correct answer but offered no justification; others offered an incorrect justification such as a comparison of x_5 and x_6 and a few suggested a rounded version of 5.8166999.

Question 7 (c)

(c) Explain why the values displayed in cells F5 and F6 are the same as each other, but the values in cells G5 and G6 are different to each other. **[2]**

Candidates who did well in this question clearly stated that the values in the spreadsheet are stored in F5 and F6 to a higher precision than they are displayed, and that the (different) stored values are used to calculate the values in cells in G5 and G6, which is why they are different.

Candidates who did less well gave the generic answer that the spreadsheet stores numbers to a greater precision than that to which they are displayed, but didn't clearly explain how the different values displayed in G5 and G6 had arisen.

Question 7 (d)

The negative root of the equation $8\ln(x+2)-3x+1=0$, δ, is close to -1.

It is found that $g'(\delta)\approx 13.9$.

(d) Explain why the iterative formula

$x_{n+1}=g(x_n)$ with $x_0=-1$

may **not** be used to find δ. **[1]**

Candidates who did well in this question related 13.9 to the criterion for convergence of a fixed point iterative formula. This was expressed correctly in a variety of different ways.

Candidates who did not do well gave vague answers such as 'the gradient isn't less than 1'.

Question 7 (e) (i)

(e) **(i)** Use the relaxed iteration

$x_{n+1}=(1-\lambda)x_n+\lambda g(x_n)$ with $\lambda=0.506$ and $x_0=-1$

to find x_1, x_2, x_3 and x_4, giving your answers correct to **3** decimal places. **[2]**

Candidates who did well in this question applied the iterative formula correctly and presented their answers to the requested precision.

Candidates who did less well may have only found x_1 correctly, or (very occasionally) they may have given their answers to a different precision.

Candidates who did not do well worked with $x_{n+1}=(1-\lambda)x_n+\lambda f(x_n)$ instead of

$x_{n+1}=(1-\lambda)x_n+\lambda g(x_n)$.

Question 7 (e) (ii)

(ii) State what would happen if the iteration in part **(e)(i)** were to be continued. **[1]**

Candidates who were successful in part (i) nearly always correctly observed that the iteration would converge to 5.8166…

Candidates who did not do well in this question concluded that the iteration would not work, or that it would (eventually) converge to the negative root, or that it would converge to an incorrect positive root.

Question 7 (f)

(f) Use the relaxed iteration

$$x_{n+1} = (1-\lambda)x_n + \lambda g(x_n) \text{ with } \lambda = -0.078 \text{ and } x_0 = -1$$

to determine the value of δ correct to **7** decimal places. **[2]**

Candidates who did well in this question gave x_1, x_2 and usually x_3 to 3 decimal places or more, and then (usually) x_5 and x_6 to 8 decimal places before giving the correct answer to the required precision. A small number of candidates justified the final accuracy with a change of sign.

Candidates who did less well may have worked throughout to 7 or fewer decimal places or they may have quoted x_1, x_2 and then (for example) x_5 and x_{10}.

Candidates who did not do well worked with $x_{n+1} = (1-\lambda)x_n + \lambda f(x_n)$ or gave insufficient detail to earn M1. Very occasionally the correct answer was written down with no supporting working.

Question 8 (a) and (b)

8 Following an injury an athlete returns to training in preparation for a regional competition. At the end of each week the athlete's trainer records the time, t seconds, the athlete takes to run 100 metres.

Table 8.1 shows some of the times recorded at the end of week W.

Table 8.1

W	0	2	3
t	18.00	17.68	16.83

The trainer uses the information in the table to construct a polynomial of degree 2 to model these data.

(a) Use Lagrange's interpolating polynomial of degree 2 to obtain the trainer's model. **[3]**

Subsequently it is found that when $W = 4$, $t = 15.44$.

(b) Determine whether the model is a good fit for these values. **[1]**

Most candidates earned full marks in parts (a) and (b).

Candidates who did less well left their answer to part (a) in terms of *x* or presented the answer as a function of *t* rather than a function of *W.*

Candidates who did not do well substituted the *t* values where they should have substituted the *W* values, and vice versa, when finding the equation of the polynomial.

Question 8 (c), (d), (e) and (f)

The trainer decides to use the three most recent data points, when $W = 2$, 3 and 4, to construct a new model using Newton's forward difference interpolation formula.

Table 8.2 shows the difference table for these data.

Table 8.2

W	t		
2	17.68		
		–0.85	
3	16.83		–0.54
		–1.39	
4	15.44		

(c) The trainer obtains the interpolation formula

$t = -0.27W^2 + BW + C$, where B and C are constants.

- Determine the value of B.
- Determine the value of C. **[3]**

(d) Explain why the new model is a refinement of the model found in part **(a)**. **[1]**

At the regional competition, the athlete needs to run 100 metres in less than 11 seconds in order to qualify for a national competition. The regional competition takes place when $W = 6$.

(e) Determine whether, according to the new model, the athlete will qualify for the national competition. **[1]**

(f) Explain whether it would be appropriate to use the new model to predict the athlete's times for $W \geqslant 7$. **[1]**

Candidates who did well in parts c to f obtained the values of *B* and *C* successfully and were able to use their results to answer parts e and f successfully. A minority of candidates understood that the new model is a refinement because it uses the most recent values. In parts e and f they made specific comments about the outcomes predicted by the model.

Candidates who did less well may have made a slip in part c. In part d they may have speculated incorrectly that Newton's Interpolating polynomial is more accurate than Lagrange's polynomial or reasoned that the new model works for $W = 4$. In part e a few candidates calculated the predicted value of t correctly, but then either reached an incorrect conclusion or made no conclusion at all. In part f some candidates simply gave the generic answer that extrapolation is unreliable, which was insufficient to earn the mark, or they may have neglected to state that the model is unsuitable $W > 6$.

Candidates who did not do well made incorrect substitutions in part c and often made no further progress.

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