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Oxford Cambridge and RSA

Examiners' report

AS LEVEL

FURTHER MATHEMATICS B (MEI)

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

H635

For first teaching in 2017

Y414/01 Summer 2025 series

Version 1

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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.

Paper Y414 series overview

The standard of work seen on this paper remains high, with many candidates demonstrating an excellent grasp of the specification and almost all of the techniques tested. Candidates generally demonstrate a high degree of precision in their work – as is appropriate to numerical methods – but often still lose marks occasionally for slips in accuracy or imprecise use of mathematical language.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• demonstrated deep familiarity with the specification content, including detailed requirements (as noted in the specification and exemplified through past papers) for the format and level of detail required in specific answers • worked precisely, making good use of their calculator to avoid numerical slips (e.g. checking their answers).	• gave explanations that were less precise, made inaccurate use of mathematical language or did not directly address the question • did not work to an appropriate level of precision or, for instance, did not give iterates to a sufficient degree of accuracy to demonstrate the precision of the final answer • relied on their calculator without demonstrating sufficient working to show understanding of the methods tested (especially in 'Determine' or 'Detailed Reasoning' questions).

OCR support

OCR's Subject Advisors have produced a helpful blog post to address some possible misconceptions about the use of calculators in A Level Mathematics and Further Mathematics.

Question 1 (a) and (b)

1 The method of interval bisection is used to find a sequence of approximations to one of the roots of the equation $e^x - x^2 - 3x = 0$.

The table shows the associated spreadsheet output.

	A	B	C	D	E	F
1	a	$f(a)$	b	$f(b)$	c	$f(c)$
2	2	−2.61094	3	2.085537	2.5	−1.56751
3	2.5	−1.56751	3	2.085537	2.75	−0.16987
4	2.75	−0.16987	3	2.085537	2.875	0.834799
5	2.75	−0.16987	2.875	0.834799	2.8125	0.303839
6						

(a) Write down a suitable formula for cell E2. **[1]**

The formula in cell A3 is $\boxed{= \mathrm{IF}(\mathrm{F2} < 0, \mathrm{E2}, \mathrm{A2})}$.

(b) Write down a similar formula for cell C3. **[1]**

Many candidates answered both of these parts well. A small number quoted the secant formula instead. Some candidates omitted the '=' or gave an invalid formula such as 'E2=…'. As in previous years, candidates needed to give their answer in valid spreadsheet notation in order to score. Alternatives are permissible, provided that they would work as a spreadsheet formula (e.g. =(1/2)*(C2+A2) in part (a)).

Question 1 (c)

(c) Complete row 6 of the table in the **Printed Answer Booklet**. **[2]**

This part was generally very well answered, with most candidates scoring both marks for fully correct values. A small number of candidates made an error in their interval bisection leading to incorrect values for E6 and F6 (scoring B1B0). The value 0.06008… is a good example of a case where candidates should be careful with the clarity of their writing – in a number of cases it was unclear which digits a candidate had intended to be a '6' or a '0'. Candidates should also be careful to make sure that their working is correctly associated with the right cell in the table. The space below the table was provided for working, but candidates needed to clearly indicate (e.g. by copying the value, or by drawing an arrow, etc.) which cell their values were associated with.

Question 1 (d)

(d) **Without** doing any more calculations, write down the value of the root correct to the maximum number of decimal places which seems justified. You must explain the precision quoted. **[1]**

Relatively few candidates scored the mark in this part. Candidates needed to demonstrate their understanding of interval bisection to give an appropriate reason for their answer. Most candidates correctly identified 2.8 (1dp) as the appropriate answer, but many gave a reason that was too vague or inappropriate such as 'the best two estimates agree to this precision' or 'all of the values in the last row round to this' – neither of which could be credited. Candidates needed to state that the root lies between 2.75 and 2.78125 (because there is a change of sign in the function between these two value).

Question 2

2 The table gives three values of x and the associated values of y.

x	-1	2	3
y	-3.39	0.18	0.45

Use Lagrange's form of the interpolating polynomial to construct a polynomial of degree 2 for the values in the table. Give your answer in the form

$y = ax^2 + bx + c$,

where a, b and c are constants to be determined. **[4]**

This question was well answered, with most candidates obtaining all (or nearly all) of the correct coefficients. As is always the case, to obtain full marks candidates needed to give their answer in the correct form and in the right variables i.e. y =… in terms of x. Many candidates omitted the y = and so did not gain the final A mark, even with correct coefficients.

Question 3 (a) and (b)

3 **(a)** Find the relative error when π is **chopped** to **3** decimal places. **[2]**

(b) Find the relative error when π is **rounded** to **3** decimal places. **[2]**

Both of these parts were well answered, with most candidates gaining at least the M mark in both parts. Some candidates had the terms in the numerator the wrong way around, leading to a sign error in the answer (typically in both parts), which could score M1A0 in each. As these questions were 'Find', the method mark could be implied by a correct final answer – but most candidates included appropriate working.

Some candidates' working did not distinguish clearly between the exact value of π and the [chopped/rounded] approximation 3.141 [or 3.142] (e.g. writing 3.141… or an apparently terminating decimal). Provided the correct answer was obtained, this was condoned on this occasion, but candidates should be reminded to carefully distinguish between exact values and approximations in their working throughout these papers.

Question 3 (c)

You are given that $y = \pi^2 - 5$ and $z = (\pi - 5)^2$.

You are also given the following information.

- Y is an approximation to y.
- Z is an approximation to z.
- Y and Z are found by using $\pi = 3.14$.

A student states that the relative error in using Y to approximate y is exactly the same as the relative error in using Z to approximate z, because in each case the calculation involves squaring and subtracting 5.

(c) **Without** doing any calculations, explain whether the student is correct. **[1]**

Most candidates answered this question well, with many giving the 'standard' answer (as shown in the scheme) referring to a different order of operations. Some candidates made a similar argument by describing the calculations, which was entirely acceptable provided that **both** calculations were described in sufficient detail to make a clear comparison. (For instance, vague statements like 'in one of the calculations you get an extra π term' were not enough on their own). The question specified '**without** doing any calculations' – a small number of candidates evaluated both y and z which was not creditable (although if these calculations were seen alongside a creditable answer it did not 'spoil' that answer – it is of course good practice for students to make use of their calculator to help them understand the situation).

Question 4 (a)

4 A student is using a spreadsheet to investigate the curve $y = f(x)$ at the point where $x = 2$. Some of the spreadsheet output is shown below.

Table 4.1 shows some values of x and the associated values of $f(x)$.

Table 4.2 shows **two** approximations to $f'(2)$ found using the same method with $h = 0.001$ and $h = 0.01$.

	E	F	G	H	I	J
2						
3		**Table 4.1**				
4		x	2	2.001	2.01	
5		$f(x)$	0.30103	0.30125	0.3032	
6						
7						
8		**Table 4.2**				
9		h	0.001	0.01		
10		$f'(2)$	0.21709	0.21661		
11						

(a) The formula in cell G10 is $\boxed{= (\text{H5} - \text{G5})/\text{G9}}$.

The formula in cell H10 is $\boxed{= (\text{I5} - \text{G5})/\text{H9}}$.

State the method being used to find these approximations to $f'(2)$. **[1]**

This question was answered correctly by almost all candidates.

Question 4 (b)

(b) • Calculate $\frac{0.30125-0.30103}{0.001}$.

• Explain why your answer is not the same as the value displayed in cell G10. **[3]**

Here, almost all candidates correctly evaluated the given expression, gaining B1. Most candidates went on to correctly quote the (general) fact that the spreadsheet 'stores values to a greater precision than displayed' – or similar, gaining the next B1. However, fewer candidates described in sufficient detail (for the third mark) why this meant that their answer was different from the value displayed in G10. Candidates needed to give a specific answer here, in the context of the question – i.e. referring to the specific cell references involved in the calculation. Candidates should (as always with this type of question) be reminded that the values stored in the spreadsheet are not necessarily 'exact' but are more precise than those that are displayed – this is an important distinction in numerical methods.

Question 4 (c)

(c) State the value of $f'(2)$ as accurately as you can. You must justify the precision quoted. **[1]**

Most candidates gave an acceptable answer to this part. A small number of candidates made a mistake when rounding or tried to justify a more/less precise value, which could not be credited here. Candidates should always be encouraged to be as specific as possible when identifying the values they have used to obtain their answer – here specifying at least 'the two approximations' (as there were only two in the spreadsheet).

Question 4 (d)

(d) Hence determine an estimate for the error when $f(2)$ is used as an approximation to $f(2.1)$. **[2]**

Most candidates obtained the correct value here. Note that, as this was a 'Determine' question, candidates needed to show working to justify their answer (at least the expression for the calculation, as given in the scheme). Candidates who did not show any working could score a maximum of 1 mark under the Special Case.

Question 4 (e)

(e) Explain whether your answer to part **(d)** is likely to be an over-estimate or an under-estimate. **[1]**

This part was much less well answered than those above. Very few candidates correctly identified that the value in part (d) was likely to be an under-estimate and provided a sufficient justification. Many candidates tried to argue based on 'rounding down' which was not specific enough to gain the mark. Candidates could argue based on *h* decreasing or increasing (depending on whether they read left-right or right-left in the spreadsheet), but either way needed to describe this, and the corresponding trend in approximations to justify their answer.

Question 5 (a)

5 The spreadsheet output shows a sequence of approximations to $\int_{0.5}^{1.5} \mathrm{f}(x)\,\mathrm{d}x$ using the trapezium rule and Simpson's rule, together with some further analysis of the approximations found using Simpson's rule.

	F	G	H	I	J
21	n	T_n	S_n	difference	ratio
22	1	0.84557616			
23	2	0.88144672	0.89340357		
24	4	0.89066651	0.89373977	0.00034	
25	8	0.89299453	0.89377054	3.1E-05	0.092
26	16	0.89357822	0.89377279	2.2E-06	0.073
27	32	0.89372426	0.89377294	1.5E-07	0.066
28	64	0.89376077	0.89377295	9.4E-09	0.063
29	128	0.8937699	0.89377295	5.9E-10	0.063

(a) Write down the value displayed in cell I25 using standard mathematical notation. **[1]**

Almost all candidates provided a correct answer to this part.

Question 5 (b)

(b) State the value of $\int_{0.5}^{1.5} \mathrm{f}(x)\,\mathrm{d}x$ as accurately as you can. You must justify the precision quoted. **[1]**

Most candidates answered this correctly, giving the required value and an appropriate justification. Candidates needed to give a clear justification that referred specifically (e.g. using cell references or correct notation S_{128}, S_{64}) to the Simpson's estimates. As the table also contained approximations from the trapezium rule, it was not sufficient simply to say 'the best two estimates'. Some candidates tried to argue using T_{128} and S_{128} which was not creditable (since Simpson's rule is more accurate than the trapezium rule). Candidates should be reminded not to over-assert (e.g. here, the last two Simpson's estimates have the same displayed value because they agree to at least that precision, strictly they are unlikely to be exactly the same value). Answers that went on to say something like this, or e.g. 'they are equal' could still score in this case.

Question 5 (c)

(c) Write down a suitable formula for cell H23. **[2]**

Similarly to the earlier questions on spreadsheet formulae, this was generally well answered – with most, but not all, candidates giving an answer in an appropriate spreadsheet form. In this case there were 2 marks available, with the M1 being scored for an appropriate expression (with some allowable deviation in the cell references), and the A1 requiring the spreadsheet notation to be fully correct.

Question 5 (d) (i)

(d) (i) Explain what the values in column J tell you about the order of Simpson's rule in this case. **[2]**

Most candidates answered this part well. Many candidates scored the first mark for stating that the ratios were converging – although this mark was not given for imprecise or incorrect statements such as 'the ratios are approximately equal' – it is the fact that the ratios appear to be converging that is relevant. The second mark (which could be given independently) was more commonly scored, with most candidates recalling that the apparent limit of $0.063 \approx 0.0625 = \frac{1}{16}$ suggests that the method is fourth order.

Question 5 (d) (ii)

(ii) Explain whether this is usual. **[1]**

This part was also well answered, with the mark scheme allowing follow-through from part (d)(i) provided that the correct fact (that Simpson's rule is generally a fourth order method) was quoted. Some candidates quoted the right fact but did not include a clear statement about whether it was 'usual' or 'unusual'. Candidates should be reminded to always make sure that their answer to the question is clear and complete.

Question 6 (a)

6 The equation $0.5\ln x + x^2 - x - 2 = 0$ has a root α, such that $1 < \alpha < 2$.

A student attempts to find α using the iterative formula

$x_{n+1} = \mathrm{g}(x_n)$ with $x_0 = 1$, where $\mathrm{g}(x) = 0.5\ln x + x^2 - 2$.

The associated spreadsheet output is shown in the table.

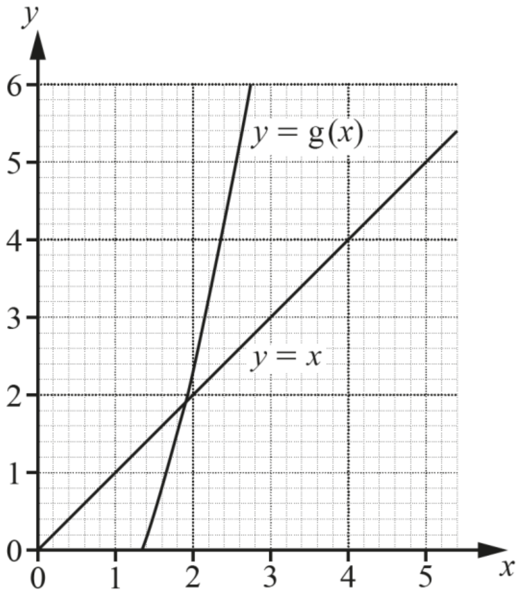
	K	L
1	n	x_n
2	0	1
3	1	-1
4	2	#NUM!

(a) Explain why #NUM! is displayed in cell L4. **[1]**

Most candidates answered this part well. Candidates needed to identify the ln *x* term in the given function as the cause of this error when $x_1 = -1$, e.g. by saying 'you cannot take the log of a negative number' or similar. Some candidates correctly pointed out that $\ln(-1)$ is imaginary, which was credited. Candidates needed to be specific so merely stating that 'there is a math/calculation error' or 'the spreadsheet cannot compute this value' alone was not sufficient.

Question 6 (b)

The graph shows part of the graphs of $y = x$ and $y = \mathrm{g}(x)$.



(b) On the copy of the graph in the **Printed Answer Booklet** show how the iterative formula $x_{n+1} = \mathrm{g}(x_n)$ with $x_0 = 2$ finds x_1 and x_2. **[1]**

This part was very well answered, with most candidates providing a good diagram with adequate labelling. A small number of candidates omitted the labels for x_1, x_2 or mistakenly drew the iterations as going leftwards rather than rightwards.

Question 6 (c)

(c) Explain why the iterative formula $x_{n+1} = \mathrm{g}(x_n)$ may **not** be used to successfully find α, whatever the value of x_0. **[1]**

Many candidates gave an acceptable answer to this standard question. However, quite a few candidates did not score this mark because their answer was insufficiently specific. As is almost always the case, candidates needed to refer to the **gradient** of **g** at the point α (either in words, or in symbols) and state that this is >1.

Question 6 (d)

(d) Use the relaxed iteration

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

with $\lambda = -0.328$ and $x_0 = 1$, to determine the value of α correct to **6** decimal places. **[3]**

Most candidates gave a good answer here, with a few making numerical errors. Candidates should be reminded that, in order to justify the root to 6dp, their iterations need to be given to at least 7dp – or, if not, then the accuracy needs to be verified with a change of sign or similar. A few candidates omitted x_1 , which was required (to at least 3dp) or did not show sufficient iterates so – even if they obtained an appropriate value for the root, could not score as a result. The instruction in the question is quite specific and candidates must show these iterations to demonstrate that they are using the correct iteration and that they have determined the root to the required degree of accuracy.

Question 7 (a)

7 A student makes a cup of tea and investigates how long it takes to reach room temperature. The student places the cup of tea on a table in the kitchen and records the temperature T°C of the tea t minutes after it was made, at **5** minute intervals starting with $t = 5$. The data collected are shown in the table.

Time after tea was made t (minutes)	5	10	15	20
Temperature of tea T (°C)	78.5	68.1	58.7	50.3

(a) Show that a quadratic polynomial would be a reasonable model for these data. **[3]**

This part was very well answered, with most candidates receiving full marks. Most candidates recognised the need to setup and complete a difference table and only a few made a numerical error in doing so. For the final mark, a specific conclusion was required – giving a clear reason why a quadratic model is reasonable.

Question 7 (b)

(b) Use Newton's forward difference interpolation method to determine a suitable quadratic polynomial for these data. **[4]**

This part was also well answered, with almost all candidates setting up an appropriate polynomial of the right form. Most candidates were able to simplify their expression to reach correct coefficients but – as earlier – quite a few were unable to score the final A mark because they did not give their polynomial in the required form (i.e. T=··· in terms of t). Some candidates made an error with the denominators (e.g. 25 instead of 50).

Question 7 (c) (i) and (c) (ii)

(c) The temperature in the kitchen is 19°C. It takes one hour for the tea to cool to room temperature.

(i) Use the model to find an estimate of the temperature of the tea after 1 hour. **[1]**

(ii) Use the model to find an estimate of the temperature of the tea after an hour and a half. **[1]**

These two parts were very well answered, with follow-through from candidate's polynomial in part (b).

Question 7 (c) (iii)

(iii) Hence identify a limitation of the model. **[1]**

This part was well answered, with most candidates giving an appropriate explanation in context. Here, candidates needed to note a relevant limitation of the quadratic model in context (e.g. by referring to the temperature of the tea over time). The two earlier parts gave them some indicative data points to work from, although they did not need to refer to these in their answer. Candidates who gave answers that were too generic, e.g. 'unrealistic values past a certain point' did not score the mark here – their answer needed to be relevant to the model and in context.

Question 8 (a)

8 **Table 8.1** shows some values of x and the associated values of $\mathrm{f}(x)$.

Table 8.1

x	0.5	0.9	1.3
$\mathrm{f}(x)$	1.41421	1.09947	0.71101

(a) Use the central difference method to determine an approximation to $\mathrm{f}'(0.9)$. **[2]**

Most candidates gave a good answer here. As the question was 'Determine', working needed to be seen (with a Special Case available for unsupported answers) – but most candidates did show this. As this was an approximation to the gradient, the sign needed to be correct.

Question 8 (b)

Table 8.2 shows a sequence of approximations to $\mathrm{f}'(0.9)$ for different values of the step length, h, together with some further analysis.

Table 8.2

h	0.2	0.1	0.05	0.025	0.0125
$\mathrm{f}'(0.9)$	−0.957 844	−0.977 203	−0.982 021	−0.983 225	−0.983 525
difference		−0.019 360	−0.004 818	−0.001 203	−0.000 301
ratio			0.248 882	0.249 719	0.249 930

(b) Use extrapolation to determine the value of $\mathrm{f}'(0.9)$ as accurately as you can. You must justify the precision quoted. **[5]**

Many candidates made a good attempt at the extrapolation to infinity here, but few scored full marks. Candidates should be encouraged to set out their working clearly in these questions. Some candidates appeared to have the right setup but did not write down their answer to a sufficient degree of accuracy to demonstrate success. Some candidates incorrectly claimed (following correct extrapolation) that the value could be -0.983 (rounding error). Candidates should be reminded to be clear and specific with their conclusion here – if comparing to a value in the table then they should be clear which value they are referring to. Sign errors were common, both in the extrapolation formula and in the final answer. A small number of candidates computed their own difference instead of using the value given in the table, which resulted in a slight loss of accuracy (because they were using displayed values to do so).

Exemplar 1

8(b)

$M_h + d \times \frac{r}{1-r}$

$-0.983525 - 0.000301 \times \frac{0.249930}{1-0.249930}$

$= -0.9836252459$

$= -0.983$, as when -0.983525 and -0.9836252459 are both chopped to 3 d.p., they are the same.

This is an example of a candidate response where the initial extrapolation is done correctly, achieving a value in the required range for accuracy, but where the candidate has then gone on to make an error in their final value – attempting to justify this based on chopping rather than rounding.

Question 9 (a)

9 In this question you must show detailed reasoning

The equation $0.2x^4 + 0.8x - 0.2 = 0$ has a root α such that $0 < \alpha < 1$.

(a) Use the Newton-Raphson method with $x_0 = 1$ to determine the value of α correct to **6** decimal places. **[5]**

This question was generally well answered. Noting the DR instruction, candidates needed to clearly set out and demonstrate how they obtained their Newton-Raphson formula. Most candidates did this, but those who did not show this working did not gain one or both of the first 2 marks (although, in this case, they could go on to score the later marks with correct iterations). As with all questions of this type, candidates should be encouraged to set out their working clearly and show a sufficient level of precision to justify the answer required. Candidates should be encouraged to show their iterative formula in full (ideally with correct subscript notation), especially when the question asks candidates to show detailed reasoning.

Exemplar 2

9(a)

$f(x) = 0.2x^4 + 0.8x - 0.2$ (Sign change needed)

$f'(x) = 0.8x^3 + 0.8$

$x_{n+1} = x_n - \frac{f(x)}{f'(x)}$

$x_0 = 1$

$x_1 = 0.5$

$x_2 = 0.263888888...$

$x_3 = 0.2490601605$

$x_4 = 0.249038764$

$x_5 = 0.249038764$

$x_6 = 0.249038764$

$\therefore 0.249038$ 6 dp

Sign change:

$f(0.2490375) = -7.11947693 \times 10^{-7}$

$f(0.2490385) = 1.00403561 \times 10^{-7}$

Change of sign hence the root is 0.249038 to 6 dp.

This candidate has successfully completed the Newton-Raphson iteration and achieved the correct value to 6dp, but did not demonstrate their understanding of the method (because they did not show the iterative formula used in full) sufficiently. They scored B1 for differentiation, B0 and then M1A1A1 for correct iterates and conclusion.

OCR support

This OCR blog discusses the instruction 'in this question you must show detailed reasoning' and gives some further detail as to what is likely to be expected (especially in contexts such as numerical methods, where it is still reasonable to offload some of the calculation to a calculator).

Question 9 (b) (i)

The equation $0.2x^4 + 0.8x - 0.2 = 0$ has another root β such that $-2 < \beta < -1$.

The Newton-Raphson method is used to find a sequence of approximations to β.
The associated spreadsheet output is shown in the table below, together with some further analysis.

A	B	C	D
r	x_r	difference	ratio
0	−2		
1	−1.75	0.25	
2	−1.670923	0.079077	0.3163082
3	−1.663319	0.007604	0.096159
4	−1.663252	6.7E-05	0.0088147
5	−1.663252	5.18E-09	7.724E-05

(b) (i) Explain what the values in column D suggest about the order of convergence of this sequence of approximations. **[2]**

This part was very well answered, with most candidates giving both statements correctly. As is usual with these questions, candidates needed to be reasonably precise with their language – the mark scheme gives a list of terms which were and were not accepted.

Question 9 (b) (ii)

(ii) Explain whether this is usual. **[1]**

Most candidates gave a good answer here. As earlier, candidates could follow-through their answer from (b)(i) provided that they stated the correct fact about Newton-Raphson in their answer here and drew an appropriate comparison. Candidates needed to state whether they determined this to be usual or unusual.

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