OCR
Oxford Cambridge and RSA

Friday 12 June 2015 – Morning

AS GCE MATHEMATICS (MEI)

4776/01 Numerical Methods

QUESTION PAPER

Candidates answer on the Printed Answer Book.

OCR supplied materials:
- Printed Answer Book 4776/01
- MEI Examination Formulae and Tables (MF2)

Other materials required:
- Scientific or graphical calculator

Duration: 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

These instructions are the same on the Printed Answer Book and the Question Paper.

- The Question Paper will be found inside the Printed Answer Book.
- Write your name, centre number and candidate number in the spaces provided on the Printed Answer Book. Please write clearly and in capital letters.
- **Write your answer to each question in the space provided in the Printed Answer Book**. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- You are permitted to use a scientific or graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.

INFORMATION FOR CANDIDATES

This information is the same on the Printed Answer Book and the Question Paper.

- The number of marks is given in brackets **[ ]** at the end of each question or part question on the Question Paper.
- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.
- The total number of marks for this paper is **72**.
- The Printed Answer Book consists of **12** pages. The Question Paper consists of **4** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER / INVIGILATOR

- Do not send this Question Paper for marking; it should be retained in the centre or recycled. Please contact OCR Copyright should you wish to re-use this document.

Section A (36 marks)

1 **(i)** Show that the equation

$$x = (\cos x)^3 \qquad (*)$$

where x is in radians, has a root in the interval $(0, 1)$. **[2]**

This root is denoted by α.

(ii) Show numerically that the iteration

$$x_{r+1} = (\cos x_r)^3$$

with $x_0 = 0.6$ does not converge to α. **[2]**

(iii) Show that

$$x = \sqrt{x(\cos x)^3}$$

is a rearrangement of (*). Use the corresponding iteration to find α correct to 4 decimal places. **[4]**

2 An estimate is required of I, where

$$I = \int_0^{0.6} \mathrm{f}(x)\,\mathrm{d}x.$$

The only available values of $\mathrm{f}(x)$ are as follows.

x	0	0.1	0.2	0.4
$\mathrm{f}(x)$	2.3063	2.2769	2.1883	1.8308

(i) Obtain the best possible estimates of $\int_0^{0.2} \mathrm{f}(x)\,\mathrm{d}x$ and $\int_{0.2}^{0.6} \mathrm{f}(x)\,\mathrm{d}x$. Hence give an estimate of I. **[5]**

(ii) State what you would do differently if $\mathrm{f}(0.6)$ became available. **[1]**

3 A computer program is used to calculate values of f where

$$\frac{1}{f} = \frac{1}{u} - \frac{1}{v}.$$

One possible formula for f is

$$f = \frac{1}{\left(\frac{1}{u} - \frac{1}{v}\right)}. \qquad (*)$$

(i) Show that another formula for f is

$$f = \frac{uv}{v-u}. \qquad (**)$$ **[1]**

The program stores and calculates all numbers rounded to 5 significant figures.

(ii) Find the values of f given by the program using (*) and (**) when $u = 11$ and $v = 11.05$.

Show that one of these values is exact and find the relative error in the other. **[6]**

(iii) State what process gives rise to the error in the inexact value. **[1]**

4 The table shows values of a function $\mathrm{f}(x)$ correct to 5 decimal places.

x	1	1.1	1.01	1.001	1.0001	1.000 01
$\mathrm{f}(x)$	0.944 04	0.967 71	0.946 41	0.944 28	0.944 06	0.944 04

(i) Find five estimates of $\mathrm{f}'(1)$ using the forward difference method. **[3]**

(ii) Comment on the accuracy of these estimates.

Give a value for $\mathrm{f}'(1)$ to the accuracy that you consider appropriate. Justify your answer. **[3]**

5 An approximate formula for $\sqrt{x}$ of the form

$$\sqrt{x} \approx a + bx \qquad (*)$$

is required for values of x near to 1.

(i) Find the values of a and b for which (*) is exact when $x = 1$ and $x = 1.21$. **[4]**

(ii) With these values of a and b, find the absolute and relative errors in (*) when $x = 0.81$. **[4]**

Section B (36 marks)

6 The variables p and q are known to take the following values.

p	1	2	3
q	2.2	2.8	5.2

(i) Plot these points and draw, by eye, a smooth curve through them. **[2]**

(ii) Use Newton's forward difference interpolation formula to obtain a quadratic expression for q in terms of p. Give your answer in simplified form. **[6]**

(iii) Estimate q when $p = 2.5$. Let this estimate be denoted by α. **[2]**

(iv) Now suppose that a quadratic expression for p in terms of q is required. Explain why Newton's formula could not be used for this purpose. Use Lagrange's method to write down an expression for this quadratic. (You are not required to simplify this expression.) **[5]**

(v) Estimate p when q is equal to the value α found in part **(iii)**. Comment on your answer. **[3]**

7 **(i)** Show that the equation

$$3x^4 + x - 2 = 0 \qquad (*)$$

has a root, α, in the interval $(0, 1)$.

Show that (*) does not have any other positive roots. **[3]**

(ii) Sketch the curve $y = 3x^4 + x - 2$ for $0 \leqslant x \leqslant 1$. **[2]**

The secant method, with $x_0 = 0$ and $x_1 = 1$ is used to find α.

(iii) Find x_2 exactly, and calculate x_3 and x_4 correct to 6 significant figures.

Show, by means of appropriate lines on your graph, how the secant method produces these values. **[8]**

(iv) Iterate the secant method further to find α correct to 3 significant figures. Show that you have obtained the required accuracy. **[5]**

END OF QUESTION PAPER

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PRINTED ANSWER BOOK

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OCR supplied materials:
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- MEI Examination Formulae and Tables (MF2)

Other materials required:
- Scientific or graphical calculator

Duration: 1 hour 30 minutes

* 4 7 7 6 0 1 *

* 3 1 6 7 8 1 6 6 5 8 *

Candidate forename		Candidate surname	

Centre number						Candidate number				

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Section A (36 marks)

1 (i)	
1 (ii)	
1 (iii)	

2 (i)

2 (ii)

3 (i)

3 (ii)

3 (iii)

4 (i)

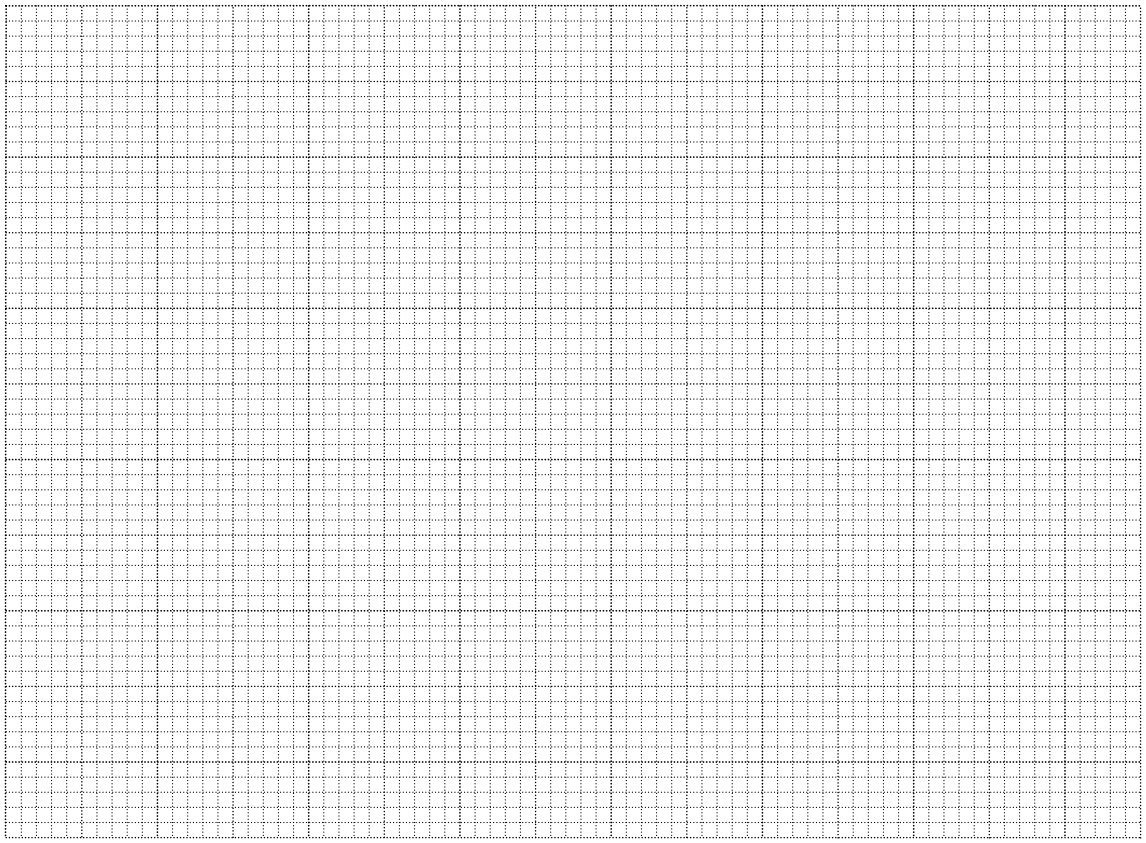
4 (ii)

5 (i)

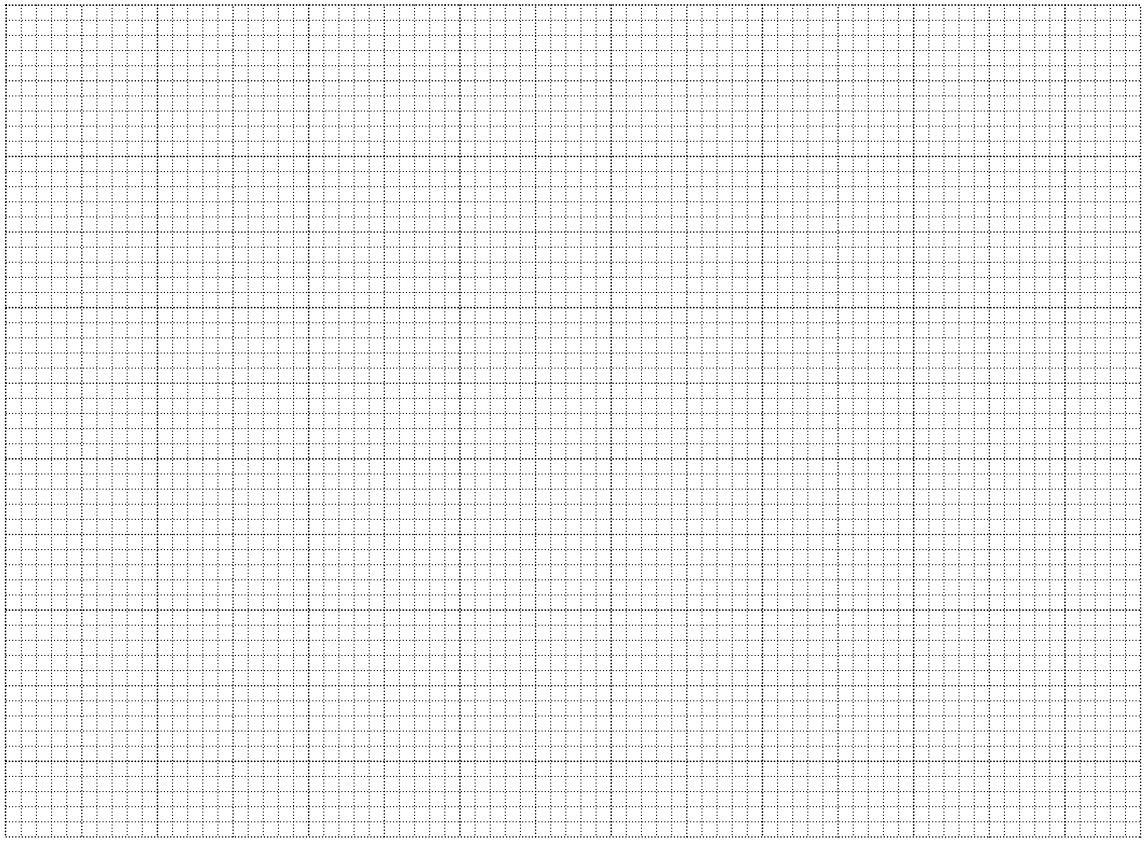
5 (ii)

Section B (36 marks)

6 (i) **There is a spare copy of this graph paper below.**



Spare copy of graph paper for question 6 (i)



6 (ii)

6 (iii)

6 (iv)

(answer space continued on next page)

6 (iv)	**(continued)**
6 (v)	

7 (i)	

PLEASE DO NOT WRITE IN THIS SPACE

7 (ii) & (iii)

7 (iv)	

1. **Annotations and abbreviations**

Annotation in scoris	**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
Highlighting	
Other abbreviations in mark scheme	**Meaning**
E1	Mark for explaining
U1	Mark for correct units
G1	Mark for a correct feature on a graph
M1 dep*	Method mark dependent on a previous mark, indicated by *
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working

2. Subject-specific Marking Instructions for GCE Mathematics (MEI) Pure strand

a Annotations should be used whenever appropriate during your marking.

The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded either 0 or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

For subsequent marking you must make it clear how you have arrived at the mark you have awarded.

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 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, award marks according to the spirit of the basic scheme; if you are in any doubt whatsoever (especially if several marks or candidates are involved) 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, eg 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
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.

E

A given result is to be established or a result has to be explained. This usually requires more working or explanation than the establishment of an unknown result.

Unless otherwise indicated, marks once gained cannot subsequently be lost, eg 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, exactly what is acceptable will be detailed in the mark scheme rationale. If this is not the case please consult your Team Leader.

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 Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise. Candidates are expected to give numerical answers to an appropriate degree of accuracy, with 3 significant figures often being the norm. Small variations in the degree of accuracy to which an answer is given (e.g. 2 or 4 significant figures where 3 is expected) should not normally be penalised, while answers which are grossly over- or under-specified should normally result in the loss of a mark. The situation regarding any particular cases where the accuracy of the answer may be a marking issue should be detailed in the mark scheme rationale. If in doubt, contact your Team Leader.

g Rules for replaced work

If a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests.

If there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others.

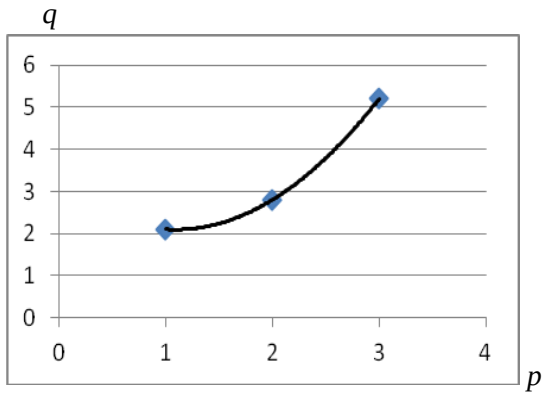
NB Follow these maths-specific instructions rather than those in the assessor handbook.

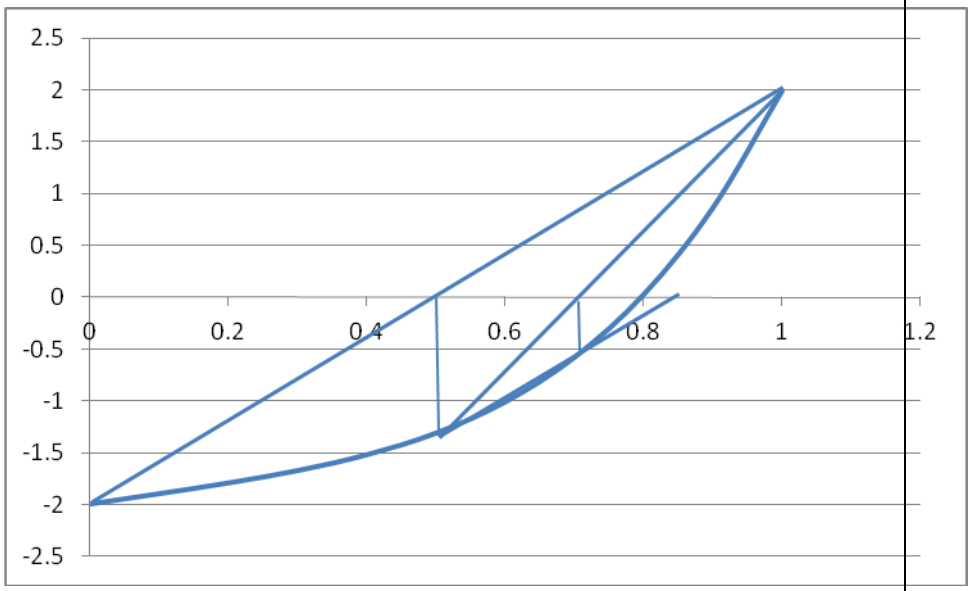
h For a *genuine* misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some units. This is achieved by withholding one A mark in the question.

Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

Question			Answer	Marks	Guidance	
1	(i)		x LHS RHS 0 0 < 1 1 1 > 0.1577	M1A1 **[2]**	Or equivalent	±0.8423
1	(ii)		First few iterates are: 0.6 0.562201 0.605676 0.555651 0.613166 (clearly not converging)	M1A1 **[2]**	At least 4 values required No explanation required	
1	(iii)		Convincing algebra: e.g. multiply by x and take square root First few iterates are: 0.6 0.580793 0.582561 0.582431 0.582441 Root is 0.5824 to 4 dp	B1 M1A1 A1 **[4]**	Accept reverse argument Cao. SC: A1 for correct answer with no iterations shown	
2	(i)		Use Simpson's rule for (0, 0.2), mid-point rule for (0.2, 0.6) S = 0.45341, M = 0.73232, I = 1.18573	M1M1 A1A1A1 **[5]**	Stated or used Accept 4 or more dp for I	
2	(ii)		Use a second Simpson's rule	E1 **[1]**		
3	(i)		Convincing algebra: eg common denominator then reciprocal	B1 **[1]**	Accept reverse argument	
3	(ii)		To 5 dp, 1/11 = 0.090909, 1/11.05 = 0.090498 Hence (*) gives2433.1 And (**) gives 2431, which is the correct answer The relative error in (*) is 0.00086 (or 0.086%)	M1A1 A1 B1E1 B1 **[6]**	 It's exact because >5dp not required	
3	(iii)		Subtraction of nearly equal rounded quantities	B1 **[1]**	Must say rounding + nearly equal	

Question			Answer	Marks	Guidance	
4	(i)		h f '(1) 0.1 0.2367 0.01 0.237 0.001 0.24 0.0001 0.2 0.00001 0	M1A1A1 **[3]**	M1 for first value A1 two more A1 all	
	(ii)		Estimates become less precise as h reduces so it is difficult to comment on accuracy. But 0.237 or 0.24 seem best - agreement before precision lost	E1 B1E1 **[3]**	Must refer to reducing h for 2nd E1 Accept either	
5	(i)		$x = 1$: $1 = a + b$ $x = 1.21$ $1.1 = a + 1.21\,b$ Hence $a = 11/21 = 0.523\,81$ and $b = 10/21 = 0.476\,19$	B1 B1 M1A1 **[4]**	Either equation Other equation Cao	
5	(ii)		$x = 0.81$: exact 0.9, approximate 0.909 52 Absolute error 0.009 52 Relative error 0.010 58	B1B1 B1 B1 **[4]**		

Question			Answer	Marks	Guidance	
6	(i)			G1 G1 **[2]**	Points Smooth curve Accept axes interchanged	
6	(ii)		1 2.2 1st diffs 2nd diff 2 2.8 0.6 3 5.2 2.4 1.8 $q = 2.2 + 0.6\,(p - 1) + 1.8\,(p - 1)(p - 2) / 2$ $q = 0.9\,p^2 - 2.1\,p + 3.4$	M1A1 B1B1B1 B1 **[6]**	Table Each term Cao	
6	(iii)		Substitute $p = 2.5$ into q = ... from part **(ii)** Obtain $q = 3.775$	M1 A1 **[2]**	FT sub'n into incorrect quadratic Cao	
6	(iv)		Unequal differences in values of q $p = 1\,(q - 2.8)\,(q - 5.2) / (2.2 - 2.8)\,(2.2 - 5.2)$ $+ 2\,(q - 2.2)\,(q - 5.2) / (2.8 - 2.2)\,(2.8 - 5.2)$ $+ 3\,(q - 2.2)\,(q - 2.8) / (5.2 - 2.2)\,(5.2 - 2.8)$	E1 M1A1 A1 A1 **[5]**	 One term correct Two terms Three terms	

Question			Answer	Marks	Guidance	
6	(v)		Substitute $q = 3.775$ into $p =$ from part **(iii)** Obtain $p = 2.985...$ Not 2.5 (or more sophisticated comments about inverse interpolation!)	M1 A1 E1 **[3]**	Allow sub'n of their q Cao Must be from correct p, q	
7	(i)		$x = 0$, LHS $= -2$, $x = 1$, LHS $= 2$ (hence root) Gradient is $12x^3 + 1$ which is positive for x positive (hence no more positive roots)	B1 M1 E1 **[3]**	Accept +ve, -ve Or, eg, for $x > 1$ f$(x) > 0$	
7	(ii)		Sketch of curve (see below)	G2 **[2]**	G1 points G1 smooth curve	
7	(iii)		$x_2 = 0.5$, $x_3 = 0.698\,113$, $x_4 = 0.859\,557$  	M1A1A1A1 A1 A1 A1 A1 **[8]**	M1 for secant rule A for cao Use of f-p gets M0A1A1M0 (sc) each correct construction line accurate location of roots	

Question			Answer	Marks	Guidance	
7	(iv)		Further iterates: 0.785 679, 0.794 930, 0.795959, 0.795 942, ... Root is 0.796 to 3 dp Check: f(0.7955) = –0.003 12, f(0.7965) = 0.003 94	M1A1 A1 M1 A1 **[5]**	Must be using secant method Cao. SC M0A0A1 for other methods	

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GCE Mathematics (MEI)

				Max Mark	a	b	c	d	e	u
4751	01	C1 – MEI Introduction to advanced mathematics (AS)	Raw	72	63	58	53	48	43	0
			UMS	100	80	70	60	50	40	0
4752	01	C2 – MEI Concepts for advanced mathematics (AS)	Raw	72	56	50	44	39	34	0
			UMS	100	80	70	60	50	40	0
4753	01	(C3) MEI Methods for Advanced Mathematics with Coursework: Written Paper	Raw	72	56	51	46	41	36	0
4753	02	(C3) MEI Methods for Advanced Mathematics with Coursework: Coursework	Raw	18	15	13	11	9	8	0
4753	82	(C3) MEI Methods for Advanced Mathematics with Coursework: Carried Forward Coursework Mark	Raw	18	15	13	11	9	8	0
			UMS	100	80	70	60	50	40	0
4754	01	C4 – MEI Applications of advanced mathematics (A2)	Raw	90	74	67	60	54	48	0
			UMS	100	80	70	60	50	40	0
4755	01	FP1 – MEI Further concepts for advanced mathematics (AS)	Raw	72	62	57	53	49	45	0
			UMS	100	80	70	60	50	40	0
4756	01	FP2 – MEI Further methods for advanced mathematics (A2)	Raw	72	65	58	52	46	40	0
			UMS	100	80	70	60	50	40	0
4757	01	FP3 – MEI Further applications of advanced mathematics (A2)	Raw	72	59	52	46	40	34	0
			UMS	100	80	70	60	50	40	0
4758	01	(DE) MEI Differential Equations with Coursework: Written Paper	Raw	72	63	57	51	45	38	0
4758	02	(DE) MEI Differential Equations with Coursework: Coursework	Raw	18	15	13	11	9	8	0
4758	82	(DE) MEI Differential Equations with Coursework: Carried Forward Coursework Mark	Raw	18	15	13	11	9	8	0
			UMS	100	80	70	60	50	40	0
4761	01	M1 – MEI Mechanics 1 (AS)	Raw	72	62	54	46	39	32	0
			UMS	100	80	70	60	50	40	0
4762	01	M2 – MEI Mechanics 2 (A2)	Raw	72	54	47	40	33	27	0
			UMS	100	80	70	60	50	40	0
4763	01	M3 – MEI Mechanics 3 (A2)	Raw	72	64	56	48	41	34	0
			UMS	100	80	70	60	50	40	0
4764	01	M4 – MEI Mechanics 4 (A2)	Raw	72	53	45	38	31	24	0
			UMS	100	80	70	60	50	40	0
4766	01	S1 – MEI Statistics 1 (AS)	Raw	72	61	54	47	41	35	0
			UMS	100	80	70	60	50	40	0
4767	01	S2 – MEI Statistics 2 (A2)	Raw	72	65	60	55	50	46	0
			UMS	100	80	70	60	50	40	0
4768	01	S3 – MEI Statistics 3 (A2)	Raw	72	64	58	52	47	42	0
			UMS	100	80	70	60	50	40	0
4769	01	S4 – MEI Statistics 4 (A2)	Raw	72	56	49	42	35	28	0
			UMS	100	80	70	60	50	40	0
4771	01	D1 – MEI Decision mathematics 1 (AS)	Raw	72	56	51	46	41	37	0
			UMS	100	80	70	60	50	40	0
4772	01	D2 – MEI Decision mathematics 2 (A2)	Raw	72	54	49	44	39	34	0
			UMS	100	80	70	60	50	40	0
4773	01	DC – MEI Decision mathematics computation (A2)	Raw	72	46	40	34	29	24	0
			UMS	100	80	70	60	50	40	0
4776	01	(NM) MEI Numerical Methods with Coursework: Written Paper	Raw	72	56	50	45	40	34	0
4776	02	(NM) MEI Numerical Methods with Coursework: Coursework	Raw	18	14	12	10	8	7	0
4776	82	(NM) MEI Numerical Methods with Coursework: Carried Forward Coursework Mark	Raw	18	14	12	10	8	7	0
			UMS	100	80	70	60	50	40	0
4777	01	NC – MEI Numerical computation (A2)	Raw	72	55	47	39	32	25	0
			UMS	100	80	70	60	50	40	0
4798	01	FPT - Further pure mathematics with technology (A2)	Raw	72	57	49	41	33	26	0
			UMS	100	80	70	60	50	40	0

GCE Statistics (MEI)									
			Max Mark	a	b	c	d	e	u
G241	01 Statistics 1 MEI (Z1)	Raw	72	61	54	47	41	35	0
		UMS	100	80	70	60	50	40	0
G242	01 Statistics 2 MEI (Z2)	Raw	72	55	48	41	34	27	0
		UMS	100	80	70	60	50	40	0
G243	01 Statistics 3 MEI (Z3)	Raw	72	56	48	41	34	27	0
		UMS	100	80	70	60	50	40	0

GCE Quantitative Methods (MEI)									
			Max Mark	a	b	c	d	e	u
G244	01 Introduction to Quantitative Methods MEI	Raw	72	58	50	43	36	28	0
G244	02 Introduction to Quantitative Methods MEI	Raw	18	14	12	10	8	7	0
		UMS	100	80	70	60	50	40	0
G245	01 Statistics 1 MEI	Raw	72	61	54	47	41	35	0
		UMS	100	80	70	60	50	40	0
G246	01 Decision 1 MEI	Raw	72	56	51	46	41	37	0
		UMS	100	80	70	60	50	40	0