OCR RECOGNISING ACHIEVEMENT

Wednesday 16 May 2012 – 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

4715940612

INSTRUCTIONS TO CANDIDATES

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

- The Question Paper will be found in the centre of 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 graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.

INFORMATION FOR CANDIDATES

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- 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.

INSTRUCTIONS 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 Use Lagrange's method to find the equation of the quadratic curve $y = \mathrm{f}(x)$ that passes through the following data points.

x	-1	0	2
y	3	6	-4

Hence find the value of x for which $\mathrm{f}(x)$ is a maximum. **[7]**

2 The number X is an approximation to an exact value x, and $X = x(1 + r)$.

(i) Show that r is the relative error in X. **[2]**

(ii) Use the binomial theorem to show that $X^n \approx x^n(1 + nr)$ provided r is small. **[2]**

(iii) The number Y is an approximation to an exact value y. The relative error in Y is 2%. State the approximate relative errors in

(A) Y^3 as an approximation to y^3,

(B) $\frac{1}{Y}$ as an approximation to $\frac{1}{y}$. **[3]**

3 **(i)** Show that the equation $x^5 = x^4 + 2$ has a root in the interval [1, 2]. **[2]**

(ii) Use the Newton-Raphson method to find this root correct to 6 decimal places. **[6]**

4 The function $\mathrm{g}(x)$ has the values shown in the table.

x	5	5.1	5.2	5.4
$\mathrm{g}(x)$	0.820 86	0.780 82	0.742 73	0.672 05

(i) Find three estimates of $\mathrm{g}'(5)$ using the forward difference method with $h = 0.4, 0.2, 0.1$. **[3]**

(ii) Use these estimates to show that the forward difference method has first order convergence. **[3]**

(iii) Give the value of $\mathrm{g}'(5)$ to the accuracy that is justified, explaining your reasoning. **[2]**

5 The cells of a spreadsheet have the formulae shown in Fig. 5a. The values displayed by the spreadsheet are shown in Fig. 5b.

	A	B	C
1	0.6		
2	=A1–0.2		
3	=A2–0.2		
4	=A3–0.2	=A4+1	=B4–1

Fig. 5a

	A	B	C
1	0.6		
2	0.4		
3	0.2		
4	–5.5E–17	1	0

Fig. 5b

(i) State what the entry in cell A4 of Fig. 5b means. Explain why it is not zero. **[3]**

(ii) What can you deduce about the way the spreadsheet stores and displays numbers from the values shown in cells B4 and C4? **[3]**

Section B (36 marks)

6 The table below gives some values of a function f(x).

x	0	0.25	0.5	0.75	1	1.25	1.5	1.75	2
f(x)	1.000 00	1.060 51	1.116 87	1.168 88	1.216 32	1.259 01	1.296 78	1.329 49	1.357 07

In this question, you are required to find estimates of the integral $\int_0^2 \mathrm{f}(x)\,\mathrm{d}x$.

(i) Find trapezium rule estimates T_1, T_2, T_4, T_8 with $h = 2, 1, 0.5, 0.25$ respectively.

Find the values of $\dfrac{T_4 - T_2}{T_2 - T_1}$ and $\dfrac{T_8 - T_4}{T_4 - T_2}$. State what these values indicate about the trapezium rule. **[7]**

(ii) Use your trapezium rule estimates from part **(i)** to find three Simpson's rule estimates of the integral.

Calculate the ratio of differences for these estimates. What does this value indicate about Simpson's rule? **[6]**

(iii) State, with reasons, the value of the integral to the accuracy that is justified if the given values of f(x) are exact.

Hence give a range within which the value of the integral lies if the given values of f(x) had been rounded to 5 decimal places. **[5]**

7 In this question you are asked to find the roots of the equation $x^2 - 1 = \sin x$, where x is in radians.

(i) Show that the equation has a root in the interval $[-1, 0]$ and another in the interval $[1, 2]$. **[3]**

(ii) Starting with the interval $[-1, 0]$, find the initial estimate of the negative root as given by the method of false position. Apply this method to find two further estimates of the negative root. Discuss briefly the accuracy to which the root has been found. **[7]**

(iii) Starting with $x_0 = 1$ and $x_1 = 2$, find the first estimate of the positive root as given by the secant method. Apply this method to find two further estimates of the positive root. Discuss briefly the accuracy with which the root has been found. **[6]**

(iv) Comment briefly on the relative merits of the method of false position and the secant rule in this case. **[2]**

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RECOGNISING ACHIEVEMENT

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AS GCE MATHEMATICS (MEI)

4776/01 Numerical Methods

PRINTED ANSWER BOOK

Candidates answer on this Printed Answer Book.

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

Other materials required:
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Duration: 1 hour 30 minutes

Candidate forename		Candidate surname	

Centre number						Candidate number				

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Turn over

1

2 (i)	
2 (ii)	
2 (iii) (*A*)	
2 (iii) (*B*)	

3 (i)	
3 (ii)	

4 (i)	
4 (ii)	
4 (iii)	

5 (i)	
5 (ii)	

6 (i)	

6 (ii)

6 (iii)	

7 (i)	
7 (ii)	

7 (ii)	**(continued)**
7 (iii)	
	(answer space continued overleaf)

7 (iii)	**(continued)**
7 (iv)	

RECOGNISING ACHIEVEMENT

GCE

Mathematics (MEI)

Advanced Subsidiary GCE

Unit **4776:** Numerical Methods

Mark Scheme for June 2012

Oxford Cambridge and RSA Examinations

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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

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			$y = 3x(x-2)/(-1)(-3) + 6(x+1)(x-2)/(1)(-2) - 4(x+1)x/(3)(2)$ $y = (x^2-2x) - 3(x^2-x-2) - ⅔(x^2+x)$ $y = ⅓(-8x^2+x+18)$ $y' = ⅓(-16x+1) = 0$ when $x = 1/16$	B1B1B1 A1 A1 M1A1 **[7]**	 M1 for diffn, A1 cao	
2	(i)		rearrange convincingly to $r = (X-x)/x$	M1A1 **[2]**	No further explanation required	
2	(ii)		$(1+r)^n = 1 + nr + n(n-1)r^2/2 + \ldots$ result given	M1 E1 **[2]**	Need to see correct r^2 term For saying r^2 negligible	
2	(iii)		(A) n=3 6% (B) n=1 –2%	B1 B2 **[3]**	 B1 for 2%	
3	(i)		x LHS RHS 1 1 < 3 2 32 > 18 Or equivalent	M1A1 **[2]**	No explanation required	
3	(ii)		$f(x) = x^5 - x^4 - 2$ $f'(x) = 5x^4 - 4x^3$ hence N-R formula r: 0, 1, 2, 3, 4 x_r: 1.5, 1.455026, 1.451113, 1.4510851, 1.4510851 hence root is 1.451085 to 6 decimal places	M1A1 M1A1A1 A1 **[6]**	May be implied by subsequent work M1 1st application, A1 2nd, A1 for 2 successive values agreeing to 6 dp	
4	(i) & (ii)		h g'(5) 0.4 –0.37203 0.2 –0.39065 –0.01863 0.1 –0.40040 –0.00975 0.52349 (or 'the differences approx. halve') approx 0.5 (as h is halved) so first order	M1A1A1 **[3]** M1A1 E1	Estimates M1 diffs, A1 ratio (may be implied)	

Question			Answer	Marks	Guidance	
				[3]		
4	**(iii)**		Some way off convergence, so accept –0.4 (or an argument by extrapolation to –0.41)	E1A1 **[2]**	A1for –0.4 or for –0.41 with extrapolation, E1 for a reason	
5	**(i)**		It means -5.5×10^{-17} It is not zero because of rounding errors in the representation of numbers like 0.6, 0.4, 0.2 (or in the calculations)	E1 E2,1,0 **[3]**	(Or 0.6 was not exact)	
5	**(ii)**		Cell B4 displays 1 either because the spreadsheet does not show enough dp or because adding 1 pushes the error beyond the sf the spreadsheet stores. The zero in C4 shows that the error must have been lost in B4	E1 E1 E1 **[3]**		
6	**(i)**		T1 2.357070 diffs ratios T2 2.394855 0.037785 T4 2.404253 0.009397 0.248710 T8 2.406599 0.002346 0.249667 both approximately 0.25 indicates 2nd order method	M1A1 A1 A1 B1 E1 E1 **[7]**	Any T value 2 further T values All T values Ratios explanation	
6	**(ii)**		Using ⅓ $(4{*}T_{2n} - T_n)$ to obtain Simpson's rule estimates S1 2.407450 diffs ratios S2 2.407385 –6.5E–05 S4 2.407381 –4.2E–06 0.064103 approximately 1/16 indicates 4th order method	M1 A1 A1 B1 E1 E1 **[6]**	(Or via M values) Any S value All S values Ratio Explanation	
6	**(iii)**		Convergence of the Simpson's rule estimates suggests 2.40738 (or even 2.407381 by extrapolation) If data are rounded to 5 dp, there is an error in the range ± 0.000 005 in each value Since the integral is over a range of 2 units the correct value will lie within ± 0.000 01 of the value given previously.	 A1E1 B1 A1E1 **[5]**	 Either answer Sight of $f(x)$ + or – 0.000 005	

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>7</td><td>(i)</td><td></td><td>

x	LHS		RHS
–1	0	>	-0.84147
0	–1	<	0
1	0	<	0.841471
2	3	>	0.909297

or equivalent
no explicit explanation reqd.</td><td>M1A1A1
[3]</td><td></td></tr>
<tr><td>7</td><td>(ii)</td><td></td><td>

a	b	f(a)	f(b)	x	f(x)
–1	0	0.841471	–1	–0.54304	–0.18836
–1	–0.54304	0.841471	–0.18836	–0.62662	–0.02093
–1	–0.62662	0.841471	–0.02093	–0.63568	

The sequence of values of x has not converged: –0.6 is the only safe estimate.</td><td>M1A1
M1A1
A1

E1A1

[7]</td><td>M1 is for correct end-points</td></tr>
<tr><td>7</td><td>(iii)</td><td></td><td>

x	1	2	1.286979	1.377411	1.412046
f(x)	–0.84147	2.090703	–0.30368	–0.0841	0.006448

The sequence of values of x has not converged, but 1.4 appears safe</td><td>M1A1A1A1

E1A1
[6]</td><td></td></tr>
<tr><td>7</td><td>(iv)</td><td></td><td>The rules converge at about the same rate
The rules converge slowly
Secant rule involves less calculation at each step (but may be harder to implement on a calculator)</td><td>E2,1

[2]</td><td>Reward other appropriate comments</td></tr>
</table>

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4776 Numerical Methods (Written Examination)

General Comments

The purely computational parts of this paper were found straightforward by most candidates. Theoretical parts were found more challenging, and interpreting results was difficult for all but the very best candidates.

The standard of presentation of work, and in particular the systematic setting out of numerical algorithms, seems to have improved somewhat. However some candidates frequently resort to scattering calculations on the page, making it difficult for examiners to detect and reward any correct work.

Comments on Individual Questions

1) **Lagrange's interpolation formula**
This question attracted many correct solutions. However marks were lost by those who confused the x and f(x) values, and by those who could not simplify the quadratic.

2) **Relative errors**
The algebra required in parts (i) proved very straightforward, but only a minority were able to use the binomial theorem correctly in part (ii). Part (iii) required the understanding of relative error but was not well answered.

3) **Solution of an equation, Newton-Raphson method**
This was a very straightforward question, with very many candidates scoring full marks.

4) **Numerical differentiation**
Parts (i) and (ii), finding the estimates and demonstrating that the forward difference method is first order, were done well by most candidates. Part (iii), giving the answer to the accuracy that is justified, proved tricky for quite a few. One surprisingly common error was to drop the negative sign.

5) **Errors in the representation and storage of numbers**
Almost all candidates were able to interpret the spreadsheet notation in part (i). The explanation expected for the 'dirty zero' result in cell A4 was that the spreadsheet does not store numbers such as 0.6 exactly; hence a calculation which would give exactly zero on paper may not give zero when carried out on a computer. The most common answer, however, was that the value entered in cell A1 is not 0.6. This is a possibility, of course, but it rather misses the point. Very few candidates were able to make the required inferences in part (ii). Adding 1 causes the significant figures shown in cell A4 to be hidden in cell B4. Subtracting 1 again to get a clean zero shows that these figures were lost altogether.

6) **Numerical integration**
The numerical work in first two parts was done well by the vast majority of candidates. It was pleasing to see so many correctly dealing with the orders of the trapezium rule and Simpson's rule. Part (iii) was found more difficult: in particular, very few could estimate the effect of the values of f(x) being approximate. If each f(x) may be in error by ±0.000 005, and the range of integration is of length 2, then a sensible estimate of the error in the integral is the product of these two numbers, i.e. ±0.000 01. (A few resolute candidates arrived at this conclusion by re-working all their calculations.)

7) **Solution of an equation, false position and secant methods**

Locating the roots in part (i) was well answered, but the modal score for each of the other three parts was zero. It seems that the false position and secant methods are not as well known as they should be – and indeed that they are frequently confused. (Of course the two methods use essentially the same formula to get from two estimates of the root to a third: the difference lies in what is done with the third estimate. It is an important feature of the false position method that, at every stage, we have two estimates which bracket the root; it is an important feature of the secant method that we pay no attention to whether the current two estimates do or do not bracket the root.)

GCE Mathematics (MEI)

			Max Mark	a	b	c	d	e	u
4751/01	(C1) MEI Introduction to Advanced Mathematics	Raw	72	57	50	44	38	32	0
		UMS	100	80	70	60	50	40	0
4752/01	(C2) MEI Concepts for Advanced Mathematics	Raw	72	54	48	42	36	31	0
		UMS	100	80	70	60	50	40	0
4753/01	(C3) MEI Methods for Advanced Mathematics with Coursework: Written Paper	Raw	72	60	53	47	41	34	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
4753	(C3) MEI Methods for Advanced Mathematics with Coursework	UMS	100	80	70	60	50	40	0
4754/01	(C4) MEI Applications of Advanced Mathematics	Raw	90	65	57	50	43	36	0
		UMS	100	80	70	60	50	40	0
4755/01	(FP1) MEI Further Concepts for Advanced Mathematics	Raw	72	63	56	49	42	35	0
		UMS	100	80	70	60	50	40	0
4756/01	(FP2) MEI Further Methods for Advanced Mathematics	Raw	72	61	53	46	39	32	0
		UMS	100	80	70	60	50	40	0
4757/01	(FP3) MEI Further Applications of Advanced Mathematics	Raw	72	54	47	40	34	28	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	39	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
4758	(DE) MEI Differential Equations with Coursework	UMS	100	80	70	60	50	40	0
4761/01	(M1) MEI Mechanics 1	Raw	72	58	50	42	34	27	0
		UMS	100	80	70	60	50	40	0
4762/01	(M2) MEI Mechanics 2	Raw	72	58	51	44	38	32	0
		UMS	100	80	70	60	50	40	0
4763/01	(M3) MEI Mechanics 3	Raw	72	63	56	50	44	38	0
		UMS	100	80	70	60	50	40	0
4764/01	(M4) MEI Mechanics 4	Raw	72	56	49	42	35	29	0
		UMS	100	80	70	60	50	40	0
4766/01	(S1) MEI Statistics 1	Raw	72	54	46	38	30	23	0
		UMS	100	80	70	60	50	40	0
4767/01	(S2) MEI Statistics 2	Raw	72	61	55	49	43	38	0
		UMS	100	80	70	60	50	40	0
4768/01	(S3) MEI Statistics 3	Raw	72	58	51	44	38	32	0
		UMS	100	80	70	60	50	40	0
4769/01	(S4) MEI Statistics 4	Raw	72	56	49	42	35	28	0
		UMS	100	80	70	60	50	40	0
4771/01	(D1) MEI Decision Mathematics 1	Raw	72	53	47	42	37	32	0
		UMS	100	80	70	60	50	40	0
4772/01	(D2) MEI Decision Mathematics 2	Raw	72	56	50	44	39	34	0
		UMS	100	80	70	60	50	40	0
4773/01	(DC) MEI Decision Mathematics Computation	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	50	44	38	33	27	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
4776	(NM) MEI Numerical Methods with Coursework	UMS	100	80	70	60	50	40	0
4777/01	(NC) MEI Numerical Computation	Raw	72	55	47	39	32	25	0
		UMS	100	80	70	60	50	40	0