GCE

Further Mathematics B MEI

Y414/01: Numerical Methods

AS Level

Mark Scheme for June 2023

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

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

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

MARKING INSTRUCTIONS

PREPARATION FOR MARKING
RM ASSESSOR

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

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

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

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

MARKING

1. Mark strictly to the mark scheme.

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

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

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

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

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

Multiple Choice Question Responses

When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).

When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses

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

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**)

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

Short Answer Questions (requiring a more developed response, worth **two or more marks**)

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

Longer Answer Questions (requiring a developed response)

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

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there, then add a tick to confirm that the work has been seen.

7. Award No Response (NR) if:
    - there is nothing written in the answer space

Award Zero '0' if:
    - anything is written in the answer space and is not worthy of credit (this includes text and symbols).

Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

8. The RM Assessor **comments box** is used by your team leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**
If you have any questions or comments for your team leader, use the phone, the RM Assessor messaging system, or e-mail.

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

10. For answers marked by levels of response:
    a. **To determine the level** – start at the highest level and work down until you reach the level that matches the answer
    b. **To determine the mark within the level**, consider the following

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

11. **Annotations**

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

Other abbreviations in mark scheme	Meaning
E1	Mark for explaining a result or establishing a given result
dep*	Mark dependent on a previous mark, indicated by *. The * may be omitted if only one previous M mark
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
www	Without wrong working
AG	Answer given
awrt	Anything which rounds to
BC	By Calculator
DR	This question included the instruction: In this question you must show detailed reasoning.
BP	Blank Page
Seen	
Highlighting	

12. **Subject Specific Marking Instructions**

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

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

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

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

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

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

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

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

c. The following types of marks are available.

M

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

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

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

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

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, e.g. wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

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

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

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

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

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

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

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

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

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

Question			Answer	Mark	AO	Guidance
1	(a)	(i)	1.30258×10^{-9} or 0.000 000 001 302 58	B1	1.1	
				[1]		
1	(a)	(ii)	Because the values in **L22** and **M22** are stored to a **higher precision** than they are displayed	B1	1.1	Accept 'greater accuracy' but do not allow e.g. 'the spreadsheet stores values to a different degree of accuracy than it displays'
			And they are not equal	B1	1.1	Accept "they are **both** not equal to 1"
				[2]		
1	(b)	(i)	1.051… **soi**	B1	1.1	
			–0.000 271 (096 376) to 3 or more sf	B1	1.1	Condone 0.000 271
				[2]		
1	(b)	(ii)	It will be different because (although the numbers and operations are the same) the order of operations is different	B1	1.2	Must be a written explanation
				[1]		
2			$\frac{(x-5)(x-8)}{(3-5)(3-8)} \times 9.26 + \frac{(x-3)(x-8)}{(5-3)(5-8)} \times 19.3 + \frac{(x-3)(x-5)}{(8-3)(8-5)} \times 37.96$	M1	1.1	Allow sign errors and one substitution error
				A1	1.1	All substitutions correct, may be implied by later work
			$y = 0.24x^2 + 3.1x - 2.2$	A1	1.1	2 terms correct
				A1	1.1	All correct in the required form in terms of x, with y = seen cao
				[4]	1.1	
3	(a)		$\frac{43.2}{2.145+2.175}$ or $\frac{43.2}{2.135+2.165}$	M1	1.1a	For either expression correct, may be implied by 10 or 10.047
			$10 < P \leq 10.047$	A1	1.1	10.047 to at least 5sf ($10.0465116279 = \frac{432}{43}$) Allow < or ≤ for either, or interval notation / words. ISW
				[2]		
3	(b)		$\frac{43.2}{2.175-2.135}$ or $\frac{43.2}{2.165-2.145}$	M1	1.1a	For either expression correct, may be implied by 1080 or 2160
			$1080 < Q < 2160$	A1	1.1	Allow < or ≤ for either, or interval notation / words. ISW
				[2]		
3	(c)		There is such a big difference because the **denominator** of Q involves the **subtraction of nearly equal numbers**	B1	2.4	allow eg division by subtraction of nearly equal numbers
				[1]		

Question			Answer	Mark	AO	Guidance
4	(a)		0.002 × 0.576 error ≈ 0.00115	M1 A1	1.1 2.2b	Use of g(1.802) ≈ g(1.8) + 0.002× $g'(1.8)$, may see 0.001152 Mark the final answer, must be rounded correctly to 3sf **SCB1** for 0.00115 without working
			Alternative Method: g(1.8) – g(1.802) calculated (±) 0.00115	 M1 A1		 May be implied by sight of –0.00115088631 (from using given expression for g(x) from later part of question) Mark the final answer, must be rounded correctly to 3sf
				[2]		
4	(b)		x_0 =1.8 x_1 =1.80082266922 x_2 =1.80129614714 x_3 =1.8015686022 x_4 =1.80172536548 x_5 =1.80181555739 x_6 =1.80186744644 x_7 =1.80189729856 x_8 =1.80191447248 x_9 =1.80192435258 x_{10} =1.80193003654 x_{11} =1.80193330648 x_{12} =1.80193518765 x_{13} =1.80193626988 (x_{14} =1.80193689247) 1.80194 **cao**	M1 M1 A1	1.1 1.1 2.2a	x_1, x_2 seen to 5 or more dp (ignore labelling) x_3, x_4 or any 2 further correct iterations seen to 6 or more dp (ignore labelling) Correct answer to 5dp, supported by at least 4 correct iterations. Must be seen separately from their list of iterations as a clear final answer.
				[3]		
4	(c)		Because the condition –1 < $g'(0.445)$ < 1 is not satisfied	B1	2.4	Allow eg because $g'(0.445)$ > 1, must reference the point (x ≈)0.445 or β (not just 'because the gradient is more than 1')
				[1]		

Question			Answer	Mark	AO	Guidance
4	(d)		$x_{n+1} = \big(1-(-0.258)\big)x_n + (-0.258)\mathrm{g}(x_n)$	B1	1.1	Sight of the correct relaxed iteration formula with given values. May see $g(x_n) = \sqrt[3]{x_n^2 + 2x_n - 1}$, may be seen in working.
			x_0 =0.445 x_1 =0.44504176118 x_2 =0.445041867581 x_3 =0.445041867912 x_4 =0.445041867913 x_5 =0.445041867913	M1	1.1	x_2, x_3 seen to 6 or more dp (ignore labelling)
			0.44504187 **cao**	A1	2.2a	Correct answer to 8dp, supported by at least 3 correct iterations. Must be seen separately from their list of iterations as a clear final answer.
				[3]		
5	(a)		$\frac{1.30258554+1.28983372}{2}$	M1	1.1	
			1.29620963	A1	1.1	Must be correctly rounded to 8dp. **SCB1** for correct answer without working.
				[2]		
5	(b)		$\frac{2\times1.30258554+1.28983372}{3}$ or $\frac{2\times1.29948881+\text{their } 1.29620963}{3}$	M1	3.1a	Or equivalent correct working
			[S_2 =] 1.29833493…	A1	1.1	Accept rounded correctly to 6dp or more **SCB1** for correct answer without working.
			[S_4 =] 1.29839575	A1	1.1	Accept rounded correctly to 6dp or more **SCB1** for correct answer without working.
				[3]		
5	(c)		1.298 (is secure) because S_4 and S_2 agree to 3dp	B1	2.2b	Allow 'by comparison of S_4 with S_2' or '1.2984 (is probable) because S_4 is (more accurate / better) than S_2' but not referencing T/M values.
				[1]		
5	(d)		$\frac{16\times1.29839575-1.29833493}{15}$	M1	3.1a	May be implied by 1.29839980467 Allow partial extrapolation for this mark only
			1.298399 to 1.2984	A1	1.1	
			1.29840 by comparison with S_4	A1	2.2b	www, allow 1.298400 or 1.2984000 Accept 'because extrapolation increases accuracy'

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Mark</th><th>AO</th><th>Guidance</th></tr>
<tr><td></td><td></td><td></td><td></td><td>[3]</td><td></td><td></td></tr>
<tr><td>6</td><td>(a)</td><td></td><td>
<table>
<tr><td>t</td><td>W</td><td>ΔW</td><td>ΔW²</td><td>ΔW³</td></tr>
<tr><td>0</td><td>35.90</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>–1.99</td><td></td><td></td></tr>
<tr><td>1</td><td>33.91</td><td></td><td>0.46</td><td></td></tr>
<tr><td></td><td></td><td>–1.53</td><td></td><td>–0.06</td></tr>
<tr><td>2</td><td>32.38</td><td></td><td>0.40</td><td></td></tr>
<tr><td></td><td></td><td>–1.13</td><td></td><td>–0.06</td></tr>
<tr><td>3</td><td>31.25</td><td></td><td>0.34</td><td></td></tr>
<tr><td></td><td></td><td>–0.79</td><td></td><td></td></tr>
<tr><td>4</td><td>30.46</td><td></td><td></td><td></td></tr>
</table>
</td><td>M1

A1</td><td>1.1

1.1</td><td>Differences found, with at least three correct in first column

All correct</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[2]</td><td></td><td></td></tr>
<tr><td>6</td><td>(b)</td><td></td><td>The third differences are equal</td><td>B1</td><td>2.4</td><td>Allow third differences are constant or fourth differences are zero</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[1]</td><td></td><td></td></tr>
<tr><td>6</td><td>(c)</td><td></td><td>$35.9 + t \times -1.99 + \frac{t(t-1)}{2!} \times 0.46 + \frac{t(t-1)(t-2)}{3!} \times -0.06$
$W = -0.01t^3 + 0.26t^2 - 2.24t + 35.9$</td><td>M1
A1
A1
A1</td><td>3.3
1.1
1.1
3.3</td><td>Allow sign errors in substitution or one numerical error
At least 2 terms correctly substituted
3 terms correct
All correct; A0 if different variable used or “W =” omitted</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[4]</td><td></td><td></td></tr>
<tr><td>6</td><td>(d)</td><td></td><td>$t = 6, W = 29.66$ (which is ≈ 29.8) so model is a good fit</td><td>B1ft</td><td>3.4</td><td>Ft $W\vert_{t=6}$ in their equation from (c)</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[1]</td><td></td><td></td></tr>
<tr><td>6</td><td>(e)</td><td></td><td>In the long run model predicts weight decreases forever oe</td><td>B1</td><td>3.5b</td><td>Allow ‘modelled weight will eventually be negative’</td></tr>
<tr><td></td><td></td><td></td><td></td><td>[1]</td><td></td><td></td></tr>
<tr><td>7</td><td>(a)</td><td></td><td>$16.17x^2 - 4.34x - 1.11$ seen
$x - \frac{\mathrm{f}(x)}{\text{their f}'(x)}$ used</td><td>M1*
M1 dep*</td><td>3.1a
1.1</td><td>Allow one slip in differentiation
Need to see at least 3 iterates, including their x_1 and x_2 May be implied by correct iterates.</td></tr>
</table>

Question			Answer	Mark	AO	Guidance
			(x_0 =–0.5) x_1 = –0.458598726 x_2 = –0.454582156 x_3 = –0.454545458 x_4 = –0.454545455 (x_5 = –0.454545455)	**M1**	**1.1**	x_3, x_4 seen to 6 or more dp (ignore labelling)
			–0.4545455	**A1**	**3.2a**	Correct answer to 7dp, supported by at least 4 correct iterations. Must be seen separately from their list of iterations as a clear final answer.
				[4]		
7	**(b)**	**(i)**	= B10 – B9	**B1**	**2.2a**	
				[1]		
7	**(b)**	**(ii)**	= C12/C11	**B1**	**2.2a**	
				[1]		
7	**(c)**		Ratio of differences is **converging to** 0.5 So convergence appears to be 1st order Unusual because Newton-Raphson method usually has 2nd order convergence	**B1** **B1** **B1**	**2.2b** **2.2b** **2.3**	Accept ‘approaching 0.5’ but not ‘is constant’ or ‘=0.5’
				[3]		
8	**(a)**		$\frac{1.4439304-1.3258177}{0.8}$ 0.147640875	**M1** **A1**	**1.1** **1.1**	Accept rounded correctly to 6dp or more. **SCB1** for correct answer without working.
				[2]		
8	**(b)**		$\frac{1.4439304-0.9638087}{1.6}$ 0.3000760625 (at least 6dp)	**M1** **A1**	**1.1** **1.1**	Accept rounded correctly to 6dp or more. **SCB1** for correct answer without working.
				[2]		

Question			Answer	Mark	AO	Guidance
8	(c)		Answer to part (b) likely to be closer to true value since central difference method is (generally) a **2nd order** method, whereas forward difference method is (generally) **1st order** method	**B1**	**2.4**	Allow answer to part (b) probably closer to true value since central difference approximation takes values either side of 2 but forward difference (uses a step in the positive x-direction only) just takes a value to the right **oe** Explanation must mention both methods
				[1]		
8	(d)		$0.2355276 + (-0.0007017) \times \frac{0.25}{0.75}$ 0.2352937 to 0.2352962 allow 0.235, 0.2353, 0.23529 or 0.235294 because extrapolation improves accuracy significantly **oe**	**M1** **A1** **A1** **A1**	**3.1a** **2.1** **1.1** **3.2a**	allow slip in substitution 0.25 or any rounded version of 0.2484204 www Allow 0.24 **is certain** by comparison of extrapolated value with 0.2355276 if **M0** allow **SC2** for $0.2355276 + (-0.0007017) \times 0.2484204 \approx 0.235$ as final answer; allow rounded versions of difference and ratio
				[4]		

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