



Mark Scheme (Results)

October 2020

Pearson Edexcel GCE Further Mathematics
Advanced Subsidiary Level
in Further Pure 2 Paper 8FM0_22

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the last candidate in exactly the same way as they mark the first.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification/indicative content will not be exhaustive.

EDEXCEL GCE MATHEMATICS

General Instructions for Marking

1. The total number of marks for the paper is 40.
2. The Edexcel Mathematics mark schemes use the following types of marks:
 - **M** marks: method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
 - **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
 - **B** marks are unconditional accuracy marks (independent of M marks)
 - Marks should not be subdivided.

3. Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes.

- bod – benefit of doubt
 - ft – follow through
 - the symbol $\checkmark$ will be used for correct ft
 - cao – correct answer only
 - cso - correct solution only. There must be no errors in this part of the question to obtain this mark
 - isw – ignore subsequent working
 - awrt – answers which round to
 - SC: special case
 - oe – or equivalent (and appropriate)
 - dep – dependent
 - indep – independent
 - dp decimal places
 - sf significant figures
 - * The answer is printed on the paper
 - $\square$ The second mark is dependent on gaining the first mark
4. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.
 5. Where a candidate has made multiple responses and indicates which response they wish to submit, examiners should mark this response.
If there are several attempts at a question which have not been crossed out, examiners should mark the final answer which is the answer that is the most complete.
 6. Ignore wrong working or incorrect statements following a correct answer.
 7. Mark schemes will firstly show the solution judged to be the most common response expected from candidates. Where appropriate, alternatives answers are provided in the notes. If examiners are not sure if an answer is acceptable, they will check the mark scheme to see if an alternative answer is given for the method used.

General Principles for Further Pure Mathematics Marking

(But note that specific mark schemes may sometimes override these general principles)

Method mark for solving 3 term quadratic:

1. Factorisation

$(x^2 + bx + c) = (x + p)(x + q)$, where $|pq| = |c|$, leading to $x = \dots$

$(ax^2 + bx + c) = (mx + p)(nx + q)$, where $|pq| = |c|$ and $|mn| = |a|$, leading to $x = \dots$

2. Formula

Attempt to use the correct formula (with values for a , b and c)

3. Completing the square

Solving $x^2 + bx + c = 0$: $\left(x \pm \frac{b}{2}\right)^2 \pm q \pm c = 0$, $q \neq 0$, leading to $x = \dots$

Method marks for differentiation and integration:

1. Differentiation

Power of at least one term decreased by 1. ($x^n \rightarrow x^{n-1}$)

2. Integration

Power of at least one term increased by 1. ($x^n \rightarrow x^{n+1}$)

Use of a formula

Where a method involves using a formula that has been learnt, the advice given in recent examiners' reports is that the formula should be quoted first.

Normal marking procedure is as follows:

Method mark for quoting a correct formula and attempting to use it, even if there are small errors in the substitution of values.

Where the formula is not quoted, the method mark can be gained by implication from correct working with values but may be lost if there is any mistake in the working.

Exact answers

Examiners' reports have emphasised that where, for example, an exact answer is asked for, or working with surds is clearly required, marks will normally be lost if the candidate resorts to using rounded decimals.

Question	Scheme							Marks	AOs	
1(a)	1, 9, 11 and 19 are self-inverse							M1 A1	1.1b 1.1b	
		3	7	13	17			B1	1.1b	
		7	3	17	13					
								(3)		
(b)	1	3	7	9	11	13	17	19	M1 A1 A1	1.1b 1.1b 1.1b
	1	4	4	2	2	4	4	2		
								(3)		
(c)	{1, 3, 7, 9} or {1, 9, 13, 17} or {1, 9, 11, 19}							B1	2.5	
								(1)		
(d)	Because 4 is a factor of 8							B1	2.4	
								(1)		
(8 marks)										
Notes										
(a) M1: For any 2 of the self-inverse elements A1: All 4 self-inverse elements correctly identified B1: Correct inverses for the other elements (b) M1: At least 3 correct orders A1: 6 correct orders A1: All correct (c) B1: Describes a correct subgroup of order 4 (d) B1: Correct explanation										

Question	Scheme	Marks	AOs
2(a)	$963 = 657 \times 1 + 306 \quad 657 = 306 \times 2 + 45$	M1	1.2
	$306 = 45 \times 6 + 36$ $45 = 36 \times 1 + 9$ $36 = 9 \times 4 + 0$	A1	1.1b
	$\text{HCF}(963, 657) = 9$ or $c = 9$	A1	1.1b
		(3)	
(b)	$9 = 45 - 36 \times 1 \quad 9 = 45 - (306 - 45 \times 6)$	M1	1.1b
	$9 = 7 \times 45 - 306$ $= 7 \times (657 - 2 \times 306) - 306 = 7 \times 657 - 15 \times 306$ $= 7 \times 657 - 15 \times (963 - 1 \times 657)$	A1	2.1
	$9 = -15 \times 963 + 22 \times 657$	A1	1.1b
		(3)	
(6 marks)			
Notes			
(a) M1: Starts the process by showing 2 correct stages A1: Completes the algorithm correctly A1: Correct HCF (b) M1: Starts the reversal process by completing at least 2 stages A1: Completes the algorithm correctly A1: Correct values for a and b			

Question	Scheme	Marks	AOs
3(i)(a)	$\begin{vmatrix} 1-\lambda & -2 \\ 1 & 4-\lambda \end{vmatrix} = (1-\lambda)(4-\lambda) + 2 = 0$	M1	1.1b
	$\Rightarrow 4 - 5\lambda + \lambda^2 + 2 = 0 \Rightarrow \lambda^2 - 5\lambda + 6 = 0^*$	A1*	1.1b
		(2)	
(b)	$\mathbf{A}^2 - 5\mathbf{A} + 6\mathbf{I} = 0$	M1	1.1b
	$\mathbf{A}^3 - 5\mathbf{A}^2 + 6\mathbf{A} = 0 \Rightarrow \mathbf{A}^3 = 5(5\mathbf{A} - 6\mathbf{I}) - 6\mathbf{A}$	M1	3.1a
	$\mathbf{A}^3 = 19\mathbf{A} - 30\mathbf{I}$	A1	1.1b
		(3)	
	Alternative to part (b)		
	$\lambda^2 - 5\lambda + 6 = 0 \Rightarrow \lambda^3 - 5\lambda^2 + 6\lambda = 0 \Rightarrow \lambda^3 = 5(5\lambda - 6) - 6\lambda$	M1	3.1a
	$\mathbf{A}^3 = 5(5\mathbf{A} - 6\mathbf{I}) - 6\mathbf{A}$	M1	1.1b
	$\mathbf{A}^3 = 19\mathbf{A} - 30\mathbf{I}$	A1	1.1b
		(3)	
(ii)	$\mathbf{M} = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \Rightarrow \begin{pmatrix} a & b \\ c & d \end{pmatrix} \begin{pmatrix} 1 \\ 2-i \end{pmatrix} = (-1+i) \begin{pmatrix} 1 \\ 2-i \end{pmatrix}$ or $\mathbf{M} = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \Rightarrow \begin{pmatrix} a & b \\ c & d \end{pmatrix} \begin{pmatrix} 1 \\ 2+i \end{pmatrix} = (-1-i) \begin{pmatrix} 1 \\ 2+i \end{pmatrix}$	M1	1.1b
	$a+b(2-i) = -1+i \quad a+b(2+i) = -1-i$ $c+d(2-i) = -1+3i \quad c+d(2+i) = -1-3i$	A1	1.1b
	$a+b(2-i) = -1+i, a+b(2+i) = -1-i \Rightarrow a=1, b=-1$ or $c+d(2-i) = -1+3i, c+d(2+i) = -1-3i \Rightarrow c=5, d=-3$	M1 A1	3.1a 1.1b
	$\mathbf{M} = \begin{pmatrix} 1 & -1 \\ 5 & -3 \end{pmatrix}$	A1	2.2a
		(5)	
	Alternative to part (ii)		
	$\mathbf{P} = \begin{pmatrix} 1 & 1 \\ 2-i & 2+i \end{pmatrix} \Rightarrow \mathbf{P}^{-1} = \frac{1}{2i} \begin{pmatrix} 2+i & -1 \\ i-2 & 1 \end{pmatrix}$	M1 A1	1.1b 1.1b
	$\mathbf{D} = \mathbf{P}^{-1}\mathbf{M}\mathbf{P} \Rightarrow \mathbf{M} = \mathbf{P}\mathbf{D}\mathbf{P}^{-1}$		
	$\mathbf{M} = \frac{1}{2i} \begin{pmatrix} 1 & 1 \\ 2-i & 2+i \end{pmatrix} \begin{pmatrix} -1+i & 0 \\ 0 & -1-i \end{pmatrix} \begin{pmatrix} 2+i & -1 \\ i-2 & 1 \end{pmatrix} = \dots$	M1	3.1a
	$\mathbf{M} = \begin{pmatrix} 1 & -1 \\ 5 & -3 \end{pmatrix}$	A1 A1	1.1b 2.2a
		(5)	
(10 marks)			
Notes			

(i)(a)

M1: Attempts the determinant of $\mathbf{A} - \lambda \mathbf{I}$

A1*: Fully correct proof

(i)(b)

M1: Applies the Cayley-Hamilton theorem to the equation given in (a)(i)

M1: A full method leading to $\mathbf{A}^3$ by multiplying by $\mathbf{A}$ and substituting for $\mathbf{A}^2$

A1: Deduces the correct expression or correct values for p and q

Alternative

M1: A full method leading to λ^3 in terms of λ

M1: Applies the Cayley-Hamilton theorem

A1: Deduces the correct expression or correct values for p and q

(ii)

M1: Uses a general matrix and sets up at least one matrix equation using the information given in the question

A1: Correct equations in terms of a, b, c and d

M1: Solves simultaneously to find values for all of a, b, c and d

A1: One correct pair of values

A1: Deduces the correct matrix $\mathbf{M}$

Alternative:

M1: Attempts to find the inverse of the matrix of eigenvectors

A1: Correct matrix

M1: Attempts $\mathbf{PDP}^{-1}$ where $\mathbf{D}$ is the diagonal matrix of eigenvalues

A1: At least 2 elements correct

A1: Deduces the correct matrix $\mathbf{M}$

Question	Scheme	Marks	AOs
4(a)	$A_{n+1} = 1.05A_n - F$	B1	3.3
		(1)	
(b)	$n = 1 \Rightarrow A_1 = (10\,000 - 20F)1.05^{1-1} + 20F$ $n = 1 \Rightarrow A_1 = 10\,000 - 20F + 20F = 10\,000$ So true for $n = 1$	B1	2.1
	Assume true for $n = k$ so that $A_k = (10\,000 - 20F)1.05^{k-1} + 20F$ $A_{k+1} = \dots$	M1	2.4
	$A_{k+1} = 1.05((10\,000 - 20F)1.05^{k-1} + 20F) - F$	A1ft	1.1b
	$A_{k+1} = (10\,000 - 20F)1.05^k + 21F - F$ $= (10\,000 - 20F)1.05^k + 20F$	A1	1.1b
	So the result holds for $n = k + 1$ and so $A_n = (10\,000 - 20F)1.05^{n-1} + 20F$ is true for all $n \geq 1$	A1	2.2a
		(5)	
(c)	$(10\,000 - 20F)1.05^{16-1} + 20F \leq 0$	M1	3.1b
	$10\,000 \times 1.05^{15} \leq 20F(1.05^{15} - 1) \Rightarrow F \geq \dots$	M1	2.1
	$F \geq \frac{10\,000 \times 1.05^{15}}{20(1.05^{15} - 1)}$	A1	1.1b
	So the smallest value of F is £963.43 or So the smallest value of F is £964	A1	3.2a
		(4)	
(10 marks)			
Notes			
(a) B1: Correct equation (b) B1: Demonstrates that the result is true for $n = 1$ M1: Makes a statement that assumes the result is true for some value of n A1ft: Correct expression for A_{k+1} A1: Reaches the correct statement for $k + 1$ in the required form A1: Completes the inductive argument (c) M1: Identifies a correct strategy using $n = 16$ to obtain an equation in F M1: Proceeds to obtain a value for the minimum value of F A1: Correct numerical expression for F A1: Correct answer (allow to the nearest penny or nearest £)			

Question	Scheme	Marks	AOs
5(a)	$p = \frac{\pi}{4}$ and $q = \pi$ or $\frac{\pi}{4} \leq \arg z \leq \pi$	B1	1.1b
	$r = 2$ or $ z \leq 2$	B1	1.1b
		(2)	
(b)	Position for z is at intersection in quadrant 1	B1	3.1a
	Angle between $y = x$ and “ OW ” is $\frac{\pi}{3} + \frac{\pi}{4}$	B1	2.2a
	$d^2 = 4^2 + 2^2 - 2 \times 4 \times 2 \cos\left(\frac{\pi}{3} + \frac{\pi}{4}\right)$	M1	1.1b
	$= 20 - 4\sqrt{2} + 4\sqrt{6}$	A1	2.2a
		(4)	
	Alternative for (b):		
	Position for z is at intersection in quadrant 1	B1	3.1a
	$y = x$ intersects $x^2 + y^2 = 4$ at $(\sqrt{2}, \sqrt{2})$	B1	2.2a
	$d^2 = (\sqrt{2} + 2\sqrt{3})^2 + (\sqrt{2} - 2)^2$	M1	1.1b
	$= 20 - 4\sqrt{2} + 4\sqrt{6}$	A1	2.2a
		(4)	
(6 marks)			
Notes			
(a) B1: Correct values or correct loci B1: Correct value or correct loci (b) B1: Realises that the position for z is at the intersection in quadrant 1 and makes progress in finding the distance B1: Deduces from the information given that the angle between $y = x$ and “OW” is $\pi/4 + \pi/3$ M1: Correct use of the cosine rule in order to find the required length² A1: Deduces the required value in a simplified and exact form Alternative: B1: Realises that the position for z is at the intersection in quadrant 1 and makes progress in finding the distance B1: Deduces from the information given the correct coordinates for z M1: Correct use of Pythagoras in order to find the required length² A1: Deduces the required value in a simplified and exact form			