Mark Scheme (Results)

January 2017

Pearson Edexcel
International Advanced Subsidiary Level
In Further Pure Mathematics F1 (WFM01)
Paper 01

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications are awarded by Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk. Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

January 2017
Publications Code WFM01_01_1701_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- 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.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- 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 may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate’s response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

PEARSON EDEXCEL IAL MATHEMATICS

General Instructions for Marking

1. The total number of marks for the paper is 75

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 $\sqrt{}$ 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
- o.e. – or equivalent (and appropriate)
- d… or dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- $\ast$ The answer is printed on the paper or ag- answer given
- $\lfloor$ or d… The second mark is dependent on gaining the first mark

4. All A marks are ‘correct answer only’ (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

5. 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.

6. If a candidate makes more than one attempt at any question:
    - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
    - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

7. Ignore wrong working or incorrect statements following a correct answer.

General Principles for Further Pure Mathematics Marking

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

<u>Method mark for solving 3 term quadratic:</u>

1. Factorisation

$(x^2 + bx + c) = (x + p)(x + q), \text{ where} |pq| = |c|$, leading to x = ...

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

2. Formula

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

3. Completing the square

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

<u>Method marks for differentiation and integration:</u>

1. Differentiation

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

2. Integration

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

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.

January 2017
WFM01 Further Pure Mathematics F1
Mark Scheme

Question Number	Scheme	Notes	Marks
1.	$\mathrm{f}(x) = 2^x - 10\sin x - 2$, x measured in radians		
(a)	$\mathrm{f}(2) = -7.092974268...$ $\mathrm{f}(3) = 4.588799919...$	Attempts to find values for both $\mathrm{f}(2)$ and $\mathrm{f}(3)$	M1
	Sign change {negative, positive} {and $\mathrm{f}(x)$ is continuous} therefore {a root} α is between $x = 2$ and $x = 3$	**Both** $\mathrm{f}(2) =$ awrt -7 **and** $\mathrm{f}(3) =$ awrt 5 or truncated 4 or truncated 4.5, sign change and conclusion.	A1 **cso**
			(2)
(b)	$\dfrac{\alpha - 2}{"7.092974268..."} = \dfrac{3 - \alpha}{"4.588799919..."}$ **or** $\dfrac{\alpha - 2}{3 - \alpha} = \dfrac{"7.092974268..."}{"4.588799919..."}$ **or** $\dfrac{\alpha - 2}{"7.092974268..."} = \dfrac{3 - 2}{"4.588799919..." + "7.092974268..."}$	A correct linear interpolation method. Do not allow this mark if a total of one or three negative lengths are used or if either fraction is the wrong way up. This mark may be implied.	M1
	Either $\alpha = \left(\dfrac{(3)("7.092974268...") + (2)("4.588799919...")}{"4.588799919..." + "7.092974268..."}\right)$ **or** $\alpha = 2 + \left(\dfrac{"7.092974268..."}{"4.588799919..." + "7.092974268..."}\right)(1)$ **or** $\alpha = 2 + \left(\dfrac{"-7.092974268..."}{"-4.588799919..." + "-7.092974268..."}\right)(1)$	**dependent on the previous M mark.** Rearranges to make $\alpha = ...$	dM1
	$\{\alpha = 2.607182963...\} \Rightarrow \alpha = 2.607$ (3 dp)	2.607	A1 **cao**
			(3)
(b) **Way 2**	$\dfrac{x}{"7.092974268..."} = \dfrac{1 - x}{"4.588799919..."} \Rightarrow x = \dfrac{"7.092974268..."}{11.68177419...} = 0.6071829632...$		
	$\alpha = 2 + 0.6071829632...$	Finds x using a correct method of similar triangles and applies "2 + their x"	M1 dM1
	$\{\alpha = 2.607182963...\} \Rightarrow \alpha = 2.607$ (3 dp)	2.607	A1 **cao**
(b) **Way 3**	$\dfrac{1 - x}{"7.092974268..."} = \dfrac{x}{"4.588799919..."} \Rightarrow x = \dfrac{"4.588799919..."}{11.68177419...} = 0.3928170366...$		
	$\alpha = 3 - 0.3928170366...$	Finds x using a correct method of similar triangles and applies "3 − their x"	M1 dM1
	$\{\alpha = 2.607182963...\} \Rightarrow \alpha = 2.607$ (3 dp)	2.607	A1 **cao**
			5

	Question 1 Notes	
1. (a)	**A1**	**correct solution only** Candidate needs to state **both** $\mathrm{f}(2) = \text{awrt} - 7$ **and** $\mathrm{f}(3) = \text{awrt } 5$ or truncated 4 or truncated 4.5 along with **a reason and conclusion.** Reference to change of sign **or** e.g. $\mathrm{f}(2) \times \mathrm{f}(3) < 0$ **or** a diagram **or** < 0 and > 0 **or** one negative, one positive are sufficient reasons. There must be a (minimal, not incorrect) conclusion, e.g. root is between 2 and 3, hence root is in the interval, QED and a square are all acceptable. Ignore the presence or absence of any reference to continuity. A minimal acceptable reason and conclusion is "change of sign, hence root".
(a)	**Note** **Note**	In degrees, $\mathrm{f}(2) = 1.651005033...$, $\mathrm{f}(3) = 5.476640438...$ Some candidates will write $\mathrm{f}(2) = 4$, $\mathrm{f}(3) = -0.4147...$

Question Number	Scheme	Notes	Marks
2.	$2x^2 - x + 3 = 0$ has roots a, b		
	Note: Parts (a) and (b) can be marked together.		
(a)	$a + b = \frac{1}{2}$, $ab = \frac{3}{2}$	**Both** $a + b = \frac{1}{2}$ **and** $ab = \frac{3}{2}$	B1
			(1)
(b)	$\frac{1}{a} + \frac{1}{b} = \frac{b+a}{ab} = \frac{\frac{1}{2}}{\frac{3}{2}}$	Attempts to substitute at least one of their $(a + b)$ or their ab into $\frac{b+a}{ab}$	M1
	$= \frac{1}{3}$	$\frac{1}{3}$ **from correct working**	A1 **cso**
			(2)
(c)	Sum $= \left(2a - \frac{1}{b}\right) + \left(2b - \frac{1}{a}\right)$ $= 2(a + b) - \left(\frac{1}{a} + \frac{1}{b}\right)$ $= 2\left(\frac{1}{2}\right) - \left(\frac{1}{3}\right) = \frac{2}{3}$	Uses at least one of $2(\text{their } (a + b))$ or their $\frac{1}{a} + \frac{1}{b}$ in an attempt to find a **numerical value** for the sum of $\left(2a - \frac{1}{b}\right)$ and $\left(2b - \frac{1}{a}\right)$.	M1
	Product $= \left(2a - \frac{1}{b}\right)\left(2b - \frac{1}{a}\right)$ $= 4ab - 2 - 2 + \frac{1}{ab}$ $= 4\left(\frac{3}{2}\right) - 4 + \frac{1}{\left(\frac{3}{2}\right)}$ $= 6 - 4 + \frac{2}{3} = \frac{8}{3}$	Expands $\left(2a - \frac{1}{b}\right)\left(2b - \frac{1}{a}\right)$ and uses their ab at least once in an attempt to find a **numerical value** for the product of $\left(2a - \frac{1}{b}\right)$ and $\left(2b - \frac{1}{a}\right)$.	M1
	$x^2 - \frac{2}{3}x + \frac{8}{3} = 0$	Applies $x^2 - (\text{their sum})x + \text{their product}$ (Can be implied) **Note:** (" = 0" not required for this mark.)	M1
	$3x^2 - 2x + 8 = 0$	Any integer multiple of $3x^2 - 2x + 8 = 0$ including the "= 0"	A1
			(4)
			7

		Question 2 Notes
2. (a)	**Note**	Finding $a+b=\frac{1}{2}, ab=\frac{3}{2}$ by writing down $a, b=\frac{1+\sqrt{23}\,\mathrm{i}}{4}, \frac{1-\sqrt{23}\,\mathrm{i}}{4}$ or by applying $a+b=\left(\frac{1+\sqrt{23}\,\mathrm{i}}{4}\right)+\left(\frac{1-\sqrt{23}\,\mathrm{i}}{4}\right)=\frac{1}{2}$ and $ab=\left(\frac{1+\sqrt{23}\,\mathrm{i}}{4}\right)\left(\frac{1-\sqrt{23}\,\mathrm{i}}{4}\right)=\frac{3}{2}$ scores B0 in part (a).
(b), (c)	**Note**	Those candidates who apply $a+b=\frac{1}{2}, ab=\frac{3}{2}$ in part (b) and/or part (c) having written down/applied $a, b=\frac{1+\sqrt{23}\,\mathrm{i}}{4}, \frac{1-\sqrt{23}\,\mathrm{i}}{4}$ in part (a) will be penalised the final A mark in part (b) **and** penalised the final A mark in part (c).
(b)	**Note**	Applying $a, b=\frac{1+\sqrt{23}\,\mathrm{i}}{4}, \frac{1-\sqrt{23}\,\mathrm{i}}{4}$ explicitly in part (b) will score M0A0. E.g.: Give no credit for $\frac{1}{\frac{1+\sqrt{23}\,\mathrm{i}}{4}}+\frac{1}{\frac{1-\sqrt{23}\,\mathrm{i}}{4}}=\frac{1}{3}$ or for $\frac{1}{a}+\frac{1}{b}=\frac{b+a}{ab}=\left(\left(\frac{1+\sqrt{23}\,\mathrm{i}}{4}\right)+\left(\frac{1-\sqrt{23}\,\mathrm{i}}{4}\right)\right) \div \left(\left(\frac{1+\sqrt{23}\,\mathrm{i}}{4}\right)\left(\frac{1-\sqrt{23}\,\mathrm{i}}{4}\right)\right)=\frac{1}{3}$
(c)	**Note**	Candidates **are not allowed** to apply $a, b=\frac{1+\sqrt{23}\,\mathrm{i}}{4}, \frac{1-\sqrt{23}\,\mathrm{i}}{4}$ explicitly in part (c).
	Note	A correct method leading to a candidate stating $p=3, q=-2, r=8$ without writing a final answer of $3x^2-2x+8=0$ is **final** A0

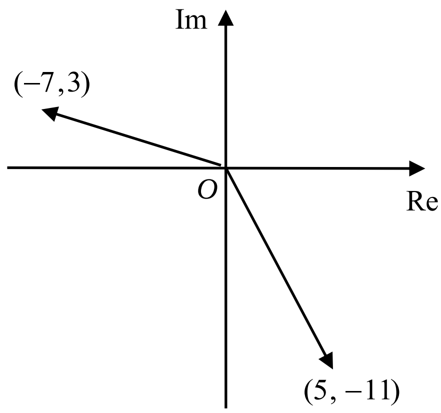
Question Number	Scheme	Notes	Marks
3.	$f(x) = x^4 + 2x^3 + 26x^2 + 32x + 160,\ x_1 = -1 + 3\text{i}$ is given.		
	$x_2 = -1 - 3\text{i}$	Writes down the root $-1-3\text{i}$ **Note:** $-1-3\text{i}$ needs to be stated explicitly somewhere in the candidate's working for B1	B1
	$x^2 + 2x + 10$	Attempt to expand $(x-(-1+3\text{i}))(x-(-1-3\text{i}))$ or $(x-(-1+3\text{i}))(x-(\text{their complex } x_2))$ or any valid method ***to establish a quadratic factor*** e.g. $x = -1 \pm 3\text{i} \Rightarrow x+1 = \pm 3\text{i} \Rightarrow x^2 + 2x + 1 = -9$ or sum of roots -2, product of roots 10 to give $x^2 \pm (\text{their sum})x + (\text{their product})$	M1
		$x^2 + 2x + 10$	A1
	$f(x) = (x^2 + 2x + 10)(x^2 + 16)$	Attempts to find the other quadratic factor. e.g. using long division to get as far as $x^2 + \ldots$ or e.g. $f(x) = (x^2 + 2x + 10)(x^2 + \ldots)$	M1
		$x^2 + 16$	A1
	$\left\{x^2 + 16 = 0 \Rightarrow x = \right\} = \pm\sqrt{16}\,\text{i};\ = \pm 4\text{i}$	**dependent on only the previous M mark** Correct method of solving ***their*** 2nd quadratic factor to give $x = \ldots$.	dM1
		4i **and** -4i	A1
			(7)
			7

	Question 3 Notes	
3.	**Note**	$x_1 = -1 + 3\text{i}$, $x_2 = -1 - 3\text{i}$ leading to $(x-1+3\text{i})(x-1-3\text{i})$ is 1st M0 1st A0
	Note	Give 3rd M1 for $x^2 + k = 0,\ k > 0 \Rightarrow$ **at least one of either** $x = \sqrt{k}\,\text{i}$ **or** $x = -\sqrt{k}\,\text{i}$ Therefore $x^2 + 16 = 0$ leading to a final answer of $x = \sqrt{16}\,\text{i}$ only is 3rd M1.
	Note	$x^2 + 16 = 0$ leading to $x = \pm\sqrt{(16\text{i})}$ unless recovered is 3rd M0 3rd A0.
	Note	Give 3rd M0 for $x^2 + k = 0,\ k > 0 \Rightarrow x = \pm k\text{i}$
	Note	Give 3rd M0 for $x^2 + k = 0,\ k > 0 \Rightarrow x = \pm k$ or $x = \pm\sqrt{k}$ Therefore $x^2 + 16 = 0$ leading to $x = \pm 4$ is 3rd M0. Therefore $x^2 + 16 = 0$ leading to $(x+4)(x-4) = 0 \Rightarrow x = \pm 4$ is 3rd M0.
	Note	No working leading to $x = -1-3\text{i}, 4\text{i}, -4\text{i}$ is B1M0A0M0A0M0A0.
	Note	Candidates can go from $x^2 + 16 = 0$ to $x = \pm 4\text{i}$ for the final dM1A1 marks.
	3rd dM1	You can give this mark for a correct method for solving ***their*** quadratic $\neq x^2 + k,\ k > 0$ which can be a 3TQ.
	Note	e.g. their 2nd quadratic is $x^2 - 16 = 0$ leading to $(x+4)(x-4) = 0 \Rightarrow x = \pm 4$ gets 3rd M1.

Question Number	Scheme	Notes	Marks
4. (a)	$\left\{\sum_{r=1}^{n} r(2r+1)(3r+1) = \right\} \sum_{r=1}^{n} (\underline{6r^3 + 5r^2 + r})$	$6r^3 + 5r^2 + r$	B1
	$= 6\left(\frac{1}{4}n^2(n+1)^2\right) + 5\left(\frac{1}{6}n(n+1)(2n+1)\right) + \left(\frac{1}{2}n(n+1)\right)$	Attempts to expand $r(2r+1)(3r+1)$ and attempts to substitute at least one correct standard formula into their resulting expression.	M1
		Correct expression (or equivalent)	A1
	$= \frac{1}{6}n(n+1)\big(9n(n+1) + 5(2n+1) + 3\big)$	**dependent on the previous M mark** Attempt to factorise at least $n(n+1)$ having attempted to substitute all three standard formulae.	dM1
	$= \frac{1}{6}n(n+1)(9n^2 + 19n + 8)$	Correct completion with no errors. **Note:** $a = 9, b = 19, c = 8$	A1 **cso**
			(5)
(b)	Let $\mathrm{f}(n) = \frac{1}{6}n(n+1)(9n^2 + 19n + 8)$. So $\sum_{r=10}^{20} r(2r+1)(3r+1) = \mathrm{f}(20) - \mathrm{f}(9)$		
	$= \left(\frac{1}{6}(20)(20+1)(9(20)^2 + 19(20) + 8)\right) - \left(\frac{1}{6}(9)(9+1)(9(9)^2 + 19(9) + 8)\right)$	Attempts to find either $\mathrm{f}(20) - \mathrm{f}(9)$ or $\mathrm{f}(20) - \mathrm{f}(10)$	M1
	$\left\{= \left(\frac{1}{6}(20)(21)(3988)\right) - \left(\frac{1}{6}(9)(10)(908)\right) = 279160 - 13620\right\} = 265540$	265540	A1
			(2)
			7

Question 4 Notes

4. (a)	**Note**	Applying e.g. $n = 1, n = 2, n = 3$ to the printed equation without applying the standard formulae to give $a = 9, b = 19, c = 8$ is B0M0A0M0A0.
	Alt 1 **dM1** **A1 cso**	**Alt Method 1:** Using $\frac{3}{2}n^4 + \frac{14}{3}n^3 + \frac{9}{2}n^2 + \frac{4}{3}n \equiv \frac{1}{6}an^4 + \frac{1}{6}(a+b)n^3 + \frac{1}{6}(b+c)n^2 + \frac{1}{6}cn$ o.e. Equating coefficients and finds at least two of $a = 9, b = 19, c = 8$ Finds $a = 9, b = 19, c = 8$ and demonstrates the identity works for all of its terms.
	Alt 2 **dM1** **A1**	**Alt Method 2:** $6\left(\frac{1}{4}n^2(n+1)^2\right) + 5\left(\frac{1}{6}n(n+1)(2n+1)\right) + \left(\frac{1}{2}n(n+1)\right) \equiv \frac{1}{6}n(n+1)(an^2 + bn + c)$ Substitutes $n = 1, n = 2, n = 3$ into this identity o.e. and finds at least two of $a = 9, b = 19, c = 8$ Finds $a = 9, b = 19, c = 8$.
	Note	Allow final dM1A1 for $\frac{3}{2}n^4 + \frac{14}{3}n^3 + \frac{9}{2}n^2 + \frac{4}{3}n$ or $\frac{1}{6}n(9n^3 + 28n^2 + 27n + 8)$ or $\frac{1}{6}(9n^4 + 28n^3 + 27n^2 + 8n) \rightarrow \frac{1}{6}n(n+1)(9n^2 + 19n + 8)$, from no incorrect working.
(b)	**Note**	Give M1A0 for applying $\mathrm{f}(20) - \mathrm{f}(10)$. i.e. $279160 - 20130 \{= 259030\}$
	Note	Give M0A0 for applying $20(41)(61) - 9(19)(28) = 50020 - 4788 = 45232$
	Note	Give M0A0 for applying $20(41)(61) - 10(21)(31) = 50020 - 6510 = 43510$
	Note	Give M0A0 for listing individual terms. e.g. $6510 + 8602 + \ldots + 42978 + 50020 = 265540$

Question Number	Scheme	Notes	Marks
5.	$z = -7 + 3\mathrm{i};\quad \dfrac{z}{1+\mathrm{i}} + w = 3 - 6\mathrm{i}$		
(a)	$\left\{\lvert z\rvert = \sqrt{(-7)^2 + (3)^2}\right\} = \sqrt{58}$ or $7.61577...$	$\sqrt{58}$ or awrt 7.62	B1
			(1)
(b)	$\arg z = \pi - \arctan\left(\dfrac{3}{7}\right)$ or $= \dfrac{\pi}{2} + \arctan\left(\dfrac{7}{3}\right)$ or $= -\pi - \arctan\left(\dfrac{3}{7}\right)$	Uses trigonometry in order to find an angle in the 2^{nd} quadrant. i.e. in the range of either $(1.57..., 3.14...)$ or $(-3.14, -4.71...)$ or $(90°, 180°)$ or $(-180°, -270°)$. **Note:** $\arctan\left(-\dfrac{3}{7}\right)$ by itself is not sufficient for M1.	M1
	$\{= \pi - 0.40489...\} = 2.7367...\ \{= 2.74\ (2\text{ dp})\}$ **or** $\{= -\pi - 0.40489...\} = -3.5464...\{= -3.55\ (2\text{ dp})\}$	either awrt 2.74 or awrt -3.55	A1 o.e.
	{**Note:** $\arg z = 156.8014...°$ or $-203.1985...°$}		**(2)**
(c) **Way 1**	$\dfrac{(-7+3\mathrm{i})}{(1+\mathrm{i})}\dfrac{(1-\mathrm{i})}{(1-\mathrm{i})} + w = 3 - 6\mathrm{i}$	$\dfrac{(-7+3\mathrm{i})}{(1+\mathrm{i})}\dfrac{(1-\mathrm{i})}{(1-\mathrm{i})} + w = 3 - 6\mathrm{i}$ or $\dfrac{z}{(1+\mathrm{i})}\dfrac{(1-\mathrm{i})}{(1-\mathrm{i})} + w = 3 - 6\mathrm{i}$ or can be implied by $-2 + 5\mathrm{i} + w = 3 - 6\mathrm{i}$	M1
	$-2 + 5\mathrm{i} + w = 3 - 6\mathrm{i}$		
	$w = 5 - 11\mathrm{i}$	**dependent on the previous M mark** Rearranges to make $w = \ldots$	dM1
		$5 - 11\mathrm{i}$	A1
			(3)
(c) **Way 2**	$z + w(1+\mathrm{i}) = (3 - 6\mathrm{i})(1+\mathrm{i})$	Fully correct method of multiplying each term by $(1+\mathrm{i})$	M1
	$w(1+\mathrm{i}) = (9 - 3\mathrm{i}) - (-7 + 3\mathrm{i})$		
	$w = \dfrac{(16 - 6\mathrm{i})}{(1+\mathrm{i})}\dfrac{(1-\mathrm{i})}{(1-\mathrm{i})}$	**dependent on the previous M mark** Rearranges to make $w = ...$ and multiplies by $\dfrac{(1-\mathrm{i})}{(1-\mathrm{i})}$	dM1
	$w = 5 - 11\mathrm{i}$	$5 - 11\mathrm{i}$	A1
			(3)
(d)		Plotting $-7 + 3\mathrm{i}$ correctly. The point must be indicated by a scale (could be ticks on the axes) **or** labelled with coordinates or a complex number z.	B1
		Plotting their w correctly. The point must be indicated by a scale (could be ticks on the axes) **or** labelled with coordinates or a complex number w.	B1ft
		<u>Special Case</u> Award SC B1B0 if both $-7 + 3\mathrm{i}$ and their w are plotted correctly relative to each other without any scale or labelled coordinates.	
			8

Question Number	Scheme	Notes	Marks
6.	$f(x)=x^3-\dfrac{1}{2x}+x^{\frac{3}{2}}, \quad x>0$		
(a)	$f'(x)=3x^2+\dfrac{1}{2}x^{-2}+\dfrac{3}{2}x^{\frac{1}{2}}$ **or** $f'(x)=3x^2+(2x)^{-2}(2)+\dfrac{3}{2}x^{\frac{1}{2}}$	At least one of either $x^3 \to \pm Ax^2$ or $-\dfrac{1}{2x} \to \pm Bx^{-2}$ or $x^{\frac{3}{2}} \to \pm Cx^{\frac{1}{2}}$ where A, B and C are non-zero constants.	M1
		At least 2 differentiated terms are correct	A1
		Correct differentiation.	A1
	$\left\{\alpha \simeq 0.6-\dfrac{f(0.6)}{f'(0.6)}\right\} \Rightarrow \alpha \simeq 0.6-\dfrac{-0.1525753318...}{3.630783893...}$	**dependent on the previous M mark** Valid attempt at Newton-Raphson using their values of $f(0.6)$ and $f'(0.6)$	dM1
	$\{\alpha=0.6420226971...\} \Rightarrow \alpha=0.642$ (3 dp)	**dependent on all 4 previous marks** 0.642 on their first iteration (Ignore any subsequent iterations)	A1 **cso cao**
	Correct differentiation followed by a correct answer scores full marks in (a) **Correct answer with <u>no</u> working scores no marks in (a)**		
			(5)
(b) **Way 1**	$f(0.6415)=-0.001630649...$ $f(0.6425)=\ 0.002020826...$	Chooses a suitable interval for x, which is within ±0.0005 of their answer to (a) and at least one attempt to evaluate $f(x)$.	M1
	Sign change {negative, positive} {and $f(x)$ is continuous} therefore {a root} $\alpha=0.642$ (3 dp)	Both values correct awrt (or truncated) to 1 sf, sign change and conclusion.	A1 **cso**
			(2)
(b) **Way 2**	**Applying Newton-Raphson again** Using $\alpha=0.642$ or better e.g. $\alpha=0.64200226971...$		
	• $\alpha \simeq 0.642-\dfrac{0.0001949626...}{3.651474882...}\ \{=0.641946607...\}$ • $\alpha \simeq 0.642022697-\dfrac{0.0002778408...}{3.651497787...}\ \{=0.641946608...\}$	Evidence of applying Newton-Raphson for a second time on their answer to part (a)	M1
	$\alpha=0.642$ (3 dp)	$\alpha=0.642$ (3 dp)	A1 **cso**
	Note: You can recover work for Way 2 in part (a)		**(2)**
			7

		Question 6 Notes
6. (a)	**Note**	Incorrect differentiation followed by their estimate of α with no evidence of applying the NR formula is final dM0A0.
	Final dM1	This mark can be implied by applying at least one correct ***value*** of either $f(0.6)$ or $f'(0.6)$ in $0.6-\dfrac{f(0.6)}{f'(0.6)}$. So just $0.6-\dfrac{f(0.6)}{f'(0.6)}$ with an incorrect answer and no other evidence scores final dM0A0.
	Note	If a candidate writes $0.6-\dfrac{f(0.6)}{f'(0.6)}=0.642$ with no differentiation, send the response to review.

<table>
<tr><td></td><td colspan="2">Question 6 Notes</td></tr>
<tr><td rowspan="5">6. (b)</td><td>A1</td><td>Way 1: correct solution only
Candidate needs to state both of their values for $f(x)$ to awrt (or truncated) 1 sf along with a reason and conclusion. Reference to change of sign or e.g. $f(0.6415) \times f(0.6425) < 0$ or a diagram or < 0 and > 0 or one negative, one positive are sufficient reasons. There must be a correct conclusion, e.g. $\alpha = 0.642$ (3 dp). Ignore the presence or absence of any reference to continuity. A minimal acceptable reason and conclusion is “change of sign, so $\alpha = 0.642$ (3 dp).”</td></tr>
<tr><td>Note</td><td>Stating “root is in between 0.6415 and 0.6425” without some reference to $\alpha = 0.642$ (3 dp) is not sufficient for A1.</td></tr>
<tr><td>Note</td><td>The root of $f(x) = 0$ is $0.6419466...$, so candidates can also choose x_1 which is less than $0.6419466...$ and choose x_2 which is greater than $0.6419466...$ with both x_1 and x_2 lying in the interval $\left[0.6415, 0.6425\right]$ and evaluate $f(x_1)$ and $f(x_2)$.</td></tr>
<tr><td>Note</td><td><u>Conclusions to part (b)</u>
Their conclusion needs to convey that they understand that $\alpha = 0.642$ to 3 decimal places.
Therefore acceptable conclusions are:
e.g. 1: $\alpha = 0.642$ (3 dp)
e.g. 2: (a) is correct to 3 dp {Note: their answer to part (a) must be 0.642}
e.g. 3: my answer to part (a) is correct to 3 dp {Note: their answer to part (a) must be 0.642}
e.g. 4: the answer is correct to 3 d.p. {Note: their answer to part (a) must be 0.642}
Note that saying “α is correct to 3 dp” or “0.642 is correct” or "$\alpha = 0.642$"are not acceptable conclusions.</td></tr>
<tr><td>Note</td><td>$0.642 - \frac{f(0.642)}{f'(0.642)} = 0.642$ (3 dp) is sufficient for M1A1 in part (b).</td></tr>
<tr><td>6. (b)</td><td>Note</td><td><u>Helpful Table</u>
<table>
<tr><th>x</th><th>$f(x)$</th></tr>
<tr><td>0.6415</td><td>-0.001630649</td></tr>
<tr><td>0.6416</td><td>-0.001265547</td></tr>
<tr><td>0.6417</td><td>-0.000900435</td></tr>
<tr><td>0.6418</td><td>-0.000535312</td></tr>
<tr><td>0.6419</td><td>-0.000170180</td></tr>
<tr><td>0.6420</td><td>0.000194963</td></tr>
<tr><td>0.6421</td><td>0.000560115</td></tr>
<tr><td>0.6422</td><td>0.000925278</td></tr>
<tr><td>0.6423</td><td>0.001290451</td></tr>
<tr><td>0.6424</td><td>0.001655634</td></tr>
<tr><td>0.6425</td><td>0.002020827</td></tr>
</table>
</td></tr>
</table>

Question Number	Scheme	Notes	Marks
7. (i)(a)	Reflection	Reflection	B1
	in the y-axis.	**dependent on the previous B mark** Allow y-axis **or** $x = 0$	dB1
			(2)
(i)(a) **Way 2**	Stretch scale factor -1	Stretch scale factor -1	B1
	parallel to the x-axis	**dependent on the previous B mark** parallel to the x-axis	dB1
			(2)
(b)	$\{\mathbf{B} =\}\begin{pmatrix} 3 & 0 \\ 0 & 1 \end{pmatrix}$	$\begin{pmatrix} 3 & \ldots \\ \ldots & 1 \end{pmatrix}$ or $\begin{pmatrix} 1 & \ldots \\ \ldots & 3 \end{pmatrix}$	M1
		Correct matrix	A1
			(2)
	Note: Parts (ii)(a) and (ii)(b) can be marked together.		
(ii)(a)	$\{k =\}\ \sqrt{(-4)^2 - (3)(-3)}\,;= 5$ **or** $k\cos\theta = -4,\ k\sin\theta = -3$ to give $\theta = \ldots$ and then $k = \ldots$	Attempts $\sqrt{\pm 16 \pm 9}$ **or** uses full method of trigonometry to find $k = \ldots$	M1;
		5 only	A1 **cao**
			(2)
(b)	$5\cos\theta = -4,\ 5\sin\theta = -3,\ \tan\theta = \dfrac{3}{4}$ or $\tan^{-1}\left(\dfrac{3}{4}\right)$ and e.g. $\theta = \pi + \tan^{-1}\left(\dfrac{3}{4}\right)$	Uses trigonometry to find an expression in the range $(3.14\ldots, 4.71\ldots)$ or $(-3.14\ldots, -1.57\ldots)$ or $(180°, 270°)$ or $(-180°, -90°)$	M1
	$\{\theta = \pi + 0.64350\ldots\} = 3.78509\ldots \{= 3.79 \text{ (2 dp)}\}$	awrt 3.79 or awrt -2.50	A1
			(2)
(c)	$\{\mathbf{M}^{-1} =\}\ \dfrac{1}{25}\begin{pmatrix} -4 & -3 \\ 3 & -4 \end{pmatrix}$	$\dfrac{1}{25}$ or $\begin{pmatrix} -4 & -3 \\ 3 & -4 \end{pmatrix}$	M1
		$\dfrac{1}{25}\begin{pmatrix} -4 & -3 \\ 3 & -4 \end{pmatrix}$ or $\begin{pmatrix} -0.16 & -0.12 \\ 0.12 & -0.16 \end{pmatrix}$ o.e.	A1 o.e.
			(2)
			10

	Question 7 Notes	
7. (i)	**Note**	Give B1B0 for "Reflection in the y-axis about $(0, 0)$".
(i)	**Note**	Send to review a response which states, e.g. "enlargement parallel to the x-axis"
(ii)(b)	**Note**	Allow M1 (implied) for awrt $217°$ or awrt $-143°$
(ii)(b)	**Note**	$\begin{pmatrix} k\cos\theta & -k\sin\theta \\ k\sin\theta & k\cos\theta \end{pmatrix} = \begin{pmatrix} -4 & 3 \\ -3 & -4 \end{pmatrix}$
(ii) (c)	**Note**	Allow M1 for $\begin{pmatrix} -0.8 & -0.6 \\ 0.6 & -0.8 \end{pmatrix}$

Question Number	Scheme	Notes	Marks
8.	$C: y^2 = 4ax$, a is a positive constant. $P(at^2, 2at)$ lies on C; k, p, q are constants.		
(a)	$y = 2a^{\frac{1}{2}}x^{\frac{1}{2}} \Rightarrow \frac{\mathrm{d}y}{\mathrm{d}x} = \frac{1}{2}(2)a^{\frac{1}{2}}x^{-\frac{1}{2}} = \frac{\sqrt{a}}{\sqrt{x}}$	$\frac{\mathrm{d}y}{\mathrm{d}x} = \pm kx^{-\frac{1}{2}}$	
	$y^2 = 4ax \Rightarrow 2y\frac{\mathrm{d}y}{\mathrm{d}x} = 4a$	$py\frac{\mathrm{d}y}{\mathrm{d}x} = q$	M1
	$\frac{\mathrm{d}y}{\mathrm{d}x} = \frac{\mathrm{d}y}{\mathrm{d}t}.\frac{\mathrm{d}t}{\mathrm{d}x} = 2a\left(\frac{1}{2at}\right)$	their $\frac{\mathrm{d}y}{\mathrm{d}t} \times \frac{1}{\text{their } \frac{\mathrm{d}x}{\mathrm{d}t}}$	
	$\frac{\mathrm{d}y}{\mathrm{d}x} = a^{\frac{1}{2}}x^{-\frac{1}{2}}$ or $2y\frac{\mathrm{d}y}{\mathrm{d}x} = 4a$ or $\frac{\mathrm{d}y}{\mathrm{d}x} = 2a\left(\frac{1}{2at}\right)$	Correct differentiation	A1
	So, $m_N = -t$	Applies $m_N = \frac{-1}{m_T}$, where m_T is found from using calculus. **Can be implied by later working**	M1
	$y - 2at = -t(x - at^2)$ **or** $y = -tx + 2at + at^3$	Correct straight line method for an equation of a **normal** where $m_N \left(\neq m_T\right)$ is found from using calculus.	M1
	leading to $y + tx = at^3 + 2at$ (*)	Correct solution only	A1
	Note: m_N must be a function of t for the 2nd M1 and the 3rd M1 mark.		**(5)**
(b)	Coordinates of B are $(5a, 0)$	$(5a, 0)$. Condone $x = 5a$ if coordinates are not stated.	B1
			(1)
(c)	$\left\{\text{their } (5a, 0) \text{ into } y + tx = at^3 + 2at \Rightarrow\right\}$ $5at = at^3 + 2at$		
	$\left\{m_{BP} =\right\}$ $\frac{2at - 0}{at^2 - 5a} = -t$		
	$PB^2 = (at^2 - 5a)^2 + (2at)^2 \Rightarrow \frac{\mathrm{d}(PB^2)}{\mathrm{d}t} = 2(at^2 - 5a)2at + 2(2at)2a = 0$		M1
	$PB^2 = a^2t^4 - 10a^2t^2 + 25a^2 + 4a^2t^2 = a^2t^4 - 6a^2t^2 + 25a^2 \Rightarrow \frac{\mathrm{d}(PB^2)}{\mathrm{d}t} = 4a^2t^3 - 12a^2t = 0$		
	Substitutes their coordinates of B into the normal equation **or** finds m_{BP} and sets this equal to their m_N **or** minimises PB or PB^2 **to obtain an equation in *a* and *t* only**. **Note:** $t \equiv \theta$ or p.		
	$t^3 - 3t = 0$ or $t^2 - 3 = 0 \Rightarrow t = ...$	**dependent on the previous M mark** Solves to find $t = ...$	dM1
	$\{Q, R$ are$\}$ $(3a, 2\sqrt{3}a)$ and $(3a, -2\sqrt{3}a)$	At least one set of coordinates is correct.	A1
		Both sets of coordinates are correct.	A1
			(4)
(d)	Area $BQR = \frac{1}{2}(2(2a\sqrt{3}))(5a - 3a)$ or $= \frac{1}{2}\begin{vmatrix} 5a & 3a & 3a & 5a \\ 0 & 2\sqrt{3}a & -2\sqrt{3}a & 0 \end{vmatrix}$	Points are in the form $B(ka, 0)$, $Q(a, b)$ and $R(a, -b)$, $k \neq 0$ **and** applies either $\frac{1}{2}\left(\left\|(ka - a)\right\|\right)(2b)$ **or** writes down a correct ft determinant statement.	M1
	$= 4a^2\sqrt{3}$	$4a^2\sqrt{3}$	A1
			(2)
			12

Question Number	Scheme	Notes	Marks
8. (c) **Way 2**	$y^2 = 4ax$ into $(x - 5a)^2 + y^2 = r^2$ $(x - 5a)^2 + 4ax = r^2$ $x^2 - 10ax + 25a^2 + 4ax = r^2$ $x^2 - 6ax + 25a^2 - r^2 = 0$ $\left\{"b^2 - 4ac = 0" \Rightarrow\right\}\ 36a^2 - 4(1)(25a^2 - r^2) = 0$	Substitutes $y^2 = 4ax$ into $(x - \text{their } x_A)^2 + y^2 = r^2$ and applies $"b^2 - 4ac = 0"$ to the resulting quadratic equation.	M1
	$36a^2 - 100a^2 + 4r^2 = 0$ $4r^2 = 64a^2 \Rightarrow r^2 = 16a^2 \Rightarrow r = 4a$ So $r = 4a$ gives $x^2 - 6ax + 25a^2 - 16a^2 = 0$ $x^2 - 6ax + 9a^2 = 0 \Rightarrow (x - 3a)(x - 3a) = 0$ $\Rightarrow x = 3a$	**dependent on the previous M mark** Obtains $r = ka$, $k > 0$, where k is a constant and uses this result to form and solve a quadratic to find x which is in terms of a.	dM1
	$\left\{y^2 = 4ax \Rightarrow\right\}\ y^2 = 4a(3a) = 12a^2 \Rightarrow y = \pm 2\sqrt{3}\,a$		
	$\{Q, R \text{ are}\}\ (3a, 2\sqrt{3}\,a)$ and $(3a, -2\sqrt{3}\,a)$	At least one set of coordinates is correct.	A1
		Both sets of coordinates are correct.	A1
			(4)

	Question 8 Notes	
8. (c)	**A marks**	Allow $(3a, \sqrt{12}\,a)$ and $(3a, -\sqrt{12}\,a)$ as exact alternatives to $(3a, 2\sqrt{3}\,a)$ and $(3a, -2\sqrt{3}\,a)$ respectively.

Question Number	Scheme	Notes	Marks
9.	(i) $\sum_{r=1}^{n}(4r^3-3r^2+r)=n^3(n+1)$; (ii) $\mathrm{f}(n)=5^{2n}+3n-1$ is divisible by 9		
(i)	$n=1:\text{LHS}=4-3+1=2$, $\text{RHS}=1^3(1+1)=2$	Shows or states **both** LHS $=2$ **and** RHS $=2$ **or** states LHS $=$ RHS $=2$	B1
	(Assume the result is true for $n=k$)		
	$\sum_{r=1}^{k+1}(4r^3-3r^2+r)=k^3(k+1)+4(k+1)^3-3(k+1)^2+(k+1)$	Adds the $(k+1)^{\text{th}}$ term to the sum of k terms	M1
	$=(k+1)\left[k^3+4(k+1)^2-3(k+1)+1\right]$ or $(k+1)\left[k^3+4k^2+5k+2\right]$ or $(k+2)\left[k^3+3k^2+3k+1\right]$	**dependent on the previous M mark**. Takes out a factor of either $(k+1)$ or $(k+2)$	dM1
	$=(k+1)(k+1)(k+1)(k+2)$	**dependent on both the previous M marks**. Factorises out and obtains either $(k+1)(k+1)(....)$ or $(k+1)(k+2)(....)$	ddM1
	$=(k+1)^3(k+1+1)$ or $=(k+1)^3(k+2)$	Achieves this result with no errors.	A1
	If the result is true for $n=k$, then it is true for $n=k+1$. As the result has been shown to be true for $n=1$, then the result is true for all n $(\in \mathbb{Z}^+)$		A1 **cso**
	Note: Expanded quartic is $k^4+5k^3+9k^2+7k+2$		**6**
(ii) **Way 1**	$\mathrm{f}(1)=5^2+3-1=27$	$\mathrm{f}(1)=27$ is the minimum	B1
	$\mathrm{f}(k+1)-\mathrm{f}(k)=(5^{2(k+1)}+3(k+1)-1)-(5^{2k}+3k-1)$	Attempts $\mathrm{f}(k+1)-\mathrm{f}(k)$	M1
	$\mathrm{f}(k+1)-\mathrm{f}(k)=24(5^{2k})+3$		
	$=24(5^{2k}+3k-1)-9(8k-3)$	$24(5^{2k}+3k-1)$ or $24\mathrm{f}(k)$	A1
	or $=24(5^{2k}+3k-1)-72k+27$	$-9(8k-3)$ or $-72k+27$	A1
	$\mathrm{f}(k+1)=24\mathrm{f}(k)-9(8k-3)+\mathrm{f}(k)$ or $\mathrm{f}(k+1)=24\mathrm{f}(k)-72k+27+\mathrm{f}(k)$ or $\mathrm{f}(k+1)=25(5^{2k}+3k-1)-72k+27$	**dependent on at least one of the previous accuracy marks being awarded.** Makes $\mathrm{f}(k+1)$ the subject and expresses it in terms of $\mathrm{f}(k)$ or $(5^{2k}+3k-1)$	dM1
	If the result is true for $n=k$, then it is true for $n=k+1$, As the result has been shown to be true for $n=1$, then the result is true for all n $(\in \mathbb{Z}^+)$		A1 **cso**
			(6)
(ii) **Way 2**	$\mathrm{f}(1)=5^2+3-1=27$	$\mathrm{f}(1)=27$ is the minimum	B1
	$\mathrm{f}(k+1)=5^{2(k+1)}+3(k+1)-1$	Attempts $\mathrm{f}(k+1)$	M1
	$\mathrm{f}(k+1)=25(5^{2k})+3k+2$		
	$=25(5^{2k}+3k-1)-9(8k-3)$	$25(5^{2k}+3k-1)$ or $25\mathrm{f}(k)$	A1
	or $=25(5^{2k}+3k-1)-72k+27$	$-9(8k-3)$ or $-72k+27$	A1
	$\mathrm{f}(k+1)=25\mathrm{f}(k)-9(8k-3)$ or $\mathrm{f}(k+1)=25\mathrm{f}(k)-72k+27$ or $\mathrm{f}(k+1)=25(5^{2k}+3k-1)-72k+27$	**dependent on at least one of the previous accuracy marks being awarded.** Makes $\mathrm{f}(k+1)$ the subject and expresses it in terms of $\mathrm{f}(k)$ or $(5^{2k}+3k-1)$	dM1
	If the result is true for $n=k$, then it is true for $n=k+1$, As the result has been shown to be true for $n=1$, then the result is true for all n $(\in \mathbb{Z}^+)$		A1 **cso**
			12

Question Number	Scheme	Notes	Marks
	(ii) $f(n) = 5^{2n} + 3n - 1$ is divisible by 9		
(ii) **Way 3**	**General Method:** Using $f(k+1) - mf(k)$; where m is an integer		
	$f(1) = 5^2 + 3 - 1 = 27$	$f(1) = 27$ is the minimum	B1
	$f(k+1) - mf(k) = (5^{2(k+1)} + 3(k+1) - 1) - m(5^{2k} + 3k - 1)$	Attempts $f(k+1) - mf(k)$	M1
	$f(k+1) - mf(k) = (25 - m)(5^{2k}) + 3k(1 - m) + (2 + m)$		
	$= (25 - m)(5^{2k} + 3k - 1) - 9(8k - 3)$	$(25 - m)(5^{2k} + 3k - 1)$ or $(25 - m)f(k)$	A1
	or $= (25 - m)(5^{2k} + 3k - 1) - 72k + 27$	$-9(8k - 3)$ or $-72k + 27$	A1
	$f(k+1) = (25 - m)f(k) - 9(8k - 3) + mf(k)$ or $f(k+1) = (25 - m)f(k) - 72k + 27 + mf(k)$	**dependent on at least one of the previous accuracy marks being awarded.** Makes $f(k+1)$ the subject and expresses it in terms of $f(k)$ or $(5^{2k} + 3k - 1)$	dM1
	If the result is true for $n = k$, then it is true for $n = k+1$, As the result has been shown to be true for $n = 1$, then the result is is true for all n $(\in \mathbb{Z}^+)$		A1 **cso**
(ii) **Way 4**	**General Method:** Using $f(k+1) - mf(k)$		
	$f(1) = 5^2 + 3 - 1 = 27$	$f(1) = 27$ is the minimum	B1
	$f(k+1) - mf(k) = (5^{2(k+1)} + 3(k+1) - 1) - m(5^{2k} + 3k - 1)$	Attempts $f(k+1) - mf(k)$	M1
	$f(k+1) - mf(k) = (25 - m)(5^{2k}) + 3k(1 - m) + (2 + m)$		
	e.g. $m = -2 \Rightarrow f(k+1) + 2f(k) = 27(5^{2k}) + 9k$	$m = -2$ and $27(5^{2k})$	A1
		$m = -2$ and $9k$	A1
	$f(k+1) = 27(5^{2k}) + 9k - 2f(k)$	**dependent on at least one of the previous accuracy marks being awarded.** Makes $f(k+1)$ the subject and expresses it in terms of $f(k)$ or $(5^{2k} + 3k - 1)$	dM1
	If the result is true for $n = k$, then it is true for $n = k+1$, As the result has been shown to be true for $n = 1$, then the result is true for all n $(\in \mathbb{Z}^+)$		A1 **cso**
	Note	Some candidates may set $f(k) = 9M$ and so may prove the following general result • $\{f(k+1) = 25f(k) - 9(8k - 3)\} \Rightarrow f(k+1) = 225M - 9(8k - 3)$ • $\{f(k+1) = 25f(k) - 72k + 27\} \Rightarrow f(k+1) = 225M - 72k + 27$	
	Question 9 Notes		
(i)	**Note**	LHS = RHS by itself is not sufficient for the 1st B1 mark in part (i).	
(i) & (ii)	**Note**	**Final A1 for parts (i) and (ii)** is dependent on all previous marks being scored in that part. It is gained by candidates conveying the ideas of **all** four underlined points **either** at the end of their solution **or** as a narrative in their solution.	
(ii)	**Note**	In part (ii), Way 4 there are many alternatives where candidates focus on isolating $b(5^{2k})$, where b is a multiple of 9. Listed below are some alternative results: $f(k+1) = 36(5^{2k}) - 11f(k) + 36k - 9$ $f(k+1) = 18(5^{2k}) + 7f(k) - 18k + 9$ $f(k+1) = 27(5^{2k}) - 2f(k) + 9k$ $f(k+1) = 9(5^{2k}) + 16f(k) - 45k + 18$ See the next page for how these are derived.	

	Question 9 Notes Continued			
	(ii) $f(n) = 5^{2n} + 3n - 1$ is divisible by 9			
9. (ii)	**The A1A1dM1 marks for Alternatives using** $f(k+1) - mf(k)$			
	Way 4.1	$f(k+1) = 25(5^{2k}) + 3k + 2$		
		$= 36(5^{2k}) - 11(5^{2k}) + 3k + 2$		
		$= 36(5^{2k}) - 11[(5^{2k}) + 3k - 1] + 36k - 9$	$m = -11$ and $36(5^{2k})$	A1
			$m = -11$ and $36k - 9$	A1
		$f(k+1) = 36(5^{2k}) - 11f(k) + 36k - 9$ or $f(k+1) = 36(5^{2k}) - 11[(5^{2k}) + 3k - 1] + 36k - 9$	as before	dM1
	Way 4.2	$f(k+1) = 25(5^{2k}) + 3k + 2$		
		$= 27(5^{2k}) - 2(5^{2k}) + 3k + 2$		
		$= 27(5^{2k}) - 2[(5^{2k}) + 3k - 1] + 9k$	$m = -2$ and $27(5^{2k})$	A1
			$m = -2$ and $9k$	A1
		$f(k+1) = 27(5^{2k}) - 2f(k) + 9k$ or $f(k+1) = 27(5^{2k}) - 2[(5^{2k}) + 3k - 1] + 9k$	as before	dM1
	Way 4.3	$f(k+1) = 25(5^{2k}) + 3k + 2$		
		$= 18(5^{2k}) + 7(5^{2k}) + 3k + 2$		
		$= 18(5^{2k}) + 7[(5^{2k}) + 3k - 1] - 18k + 9$	$m = 7$ and $18(5^{2k})$	A1
			$m = 7$ and $-18k + 9$	A1
		$f(k+1) = 18(5^{2k}) + 7f(k) - 18k + 9$ or $f(k+1) = 18(5^{2k}) + 7[(5^{2k}) + 3k - 1] - 18k + 9$	as before	dM1
	Way 4.4	$f(k+1) = 25(5^{2k}) + 3k + 2$		
		$= 9(5^{2k}) + 16(5^{2k}) + 3k + 2$		
		$= 9(5^{2k}) + 16[(5^{2k}) + 3k - 1] - 45k + 18$	$m = 16$ and $9(5^{2k})$	A1
			$m = 16$ and $-45k + 18$	A1
		$f(k+1) = 9(5^{2k}) + 16f(k) - 45k + 18$ or $f(k+1) = 9(5^{2k}) + 16[(5^{2k}) + 3k - 1] - 45k + 18$	as before	dM1

Pearson Education Limited. Registered company number 872828
with its registered office at 80 Strand, London, WC2R 0RL, United Kingdom