Mark Scheme (Results)

Summer 2013

GCE Further Pure Mathematics 1 (6667/01R)

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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.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

EDEXCEL GCE 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
- oe – or equivalent (and appropriate)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- * The answer is printed on the paper
- ⌈ 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.

8. In some instances, the mark distributions (e.g. M1, B1 and A1) printed on the candidate's response may differ from the final mark scheme

General Principles for 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 =

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

2. Formula

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

3. Completing the square

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

Method marks for differentiation and integration:

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 mistakes 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.

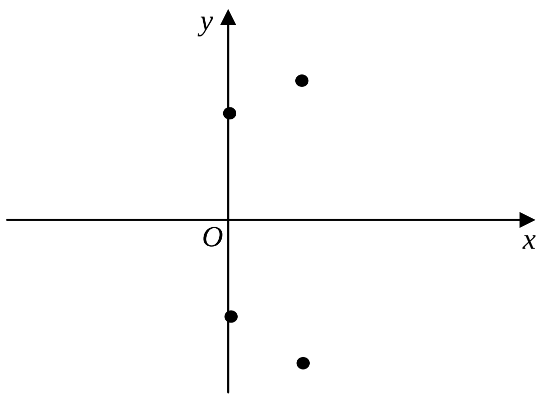
Answers without working

The rubric says that these may not gain full credit. Individual mark schemes will give details of what happens in particular cases. General policy is that if it could be done "in your head", detailed working would not be required.

Question Number	Scheme		Marks
1.	$z = 8 + 3\text{i}, \quad w = -2\text{i}$		
(a)	$z - w \left\{= (8 + 3\text{i}) - (-2\text{i})\right\} = 8 + 5\text{i}$	$8 + 5\text{i}$	B1
			[1]
(b)	$zw \left\{= (8 + 3\text{i})(-2\text{i})\right\} = 6 - 16\text{i}$	Either the real or imaginary part is correct.	M1
		$6 - 16\text{i}$	A1
			[2]
			3

Question Number	Scheme		Marks
2.	$\mathbf{A} = \begin{pmatrix} 2k+1 & k \\ -3 & -5 \end{pmatrix}$, $\mathbf{B} = \mathbf{A} + 3\mathbf{I}$		
(i)(a)	$\mathbf{B} = \mathbf{A} + 3\mathbf{I} = \begin{pmatrix} 2k+1 & k \\ -3 & -5 \end{pmatrix} + 3\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$	For applying $\mathbf{A} + 3\mathbf{I}$. Can be implied by three out of four correct elements in candidate's final answer. Solution must come from addition.	M1
	$= \begin{pmatrix} 2k+4 & k \\ -3 & -2 \end{pmatrix}$	Correct answer.	A1
			[2]
(b)	**B** is singular $\Rightarrow \det \mathbf{B} = 0$.		
	$-2(2k+4) - (-3k) = 0$	Applies "$ad - bc$" to **B** and equates to 0	M1
	$-4k - 8 + 3k = 0$		
	$k = -8$	$k = -8$	A1cao
			[2]
(ii)	$\mathbf{C} = \begin{pmatrix} 2 \\ -3 \\ 4 \end{pmatrix}$, $\mathbf{D} = \begin{pmatrix} 2 & -1 & 5 \end{pmatrix}$, $\mathbf{E} = \mathbf{CD}$		
	$\mathbf{E} = \begin{pmatrix} 2 \\ -3 \\ 4 \end{pmatrix} \begin{pmatrix} 2 & -1 & 5 \end{pmatrix} = \begin{pmatrix} 4 & -2 & 10 \\ -6 & 3 & -15 \\ 8 & -4 & 20 \end{pmatrix}$	Candidate writes down a 3×3 matrix.	M1
		Correct answer.	A1
			[2] 6

Question Number	Scheme		Marks
3.	$\text{f}(x) = \frac{1}{2}x^4 - x^3 + x - 3$		
(a)	$\text{f}(2) = -1$ $\text{f}(2.5) = 3.40625$	Either any one of $\text{f}(2) = -1$ or $\text{f}(2.5) =$ awrt 3.4	M1
	Sign change (and $\text{f}(x)$ is continuous) therefore a root α exists between $x = 2$ and $x = 2.5$	both values correct, sign change and conclusion	A1
			[2]
(b)	$\text{f}(2.25) = 0.673828125 \left\{= \frac{345}{512}\right\}$ $\{\Rightarrow 2 \leqslant \alpha \leqslant 2.25\}$	$\text{f}(2.25) =$ awrt 0.7	B1
		Attempt to find $\text{f}(2.125)$	M1
	$\text{f}(2.125) = -0.2752685547...$ $\Rightarrow 2.125 \leqslant \alpha \leqslant 2.25$	$\text{f}(2.125) =$ awrt -0.3 with $2.125 \leqslant \alpha \leqslant 2.25$ or $2.125 < \alpha < 2.25$ or $[2.125, 2.25]$ or $(2.125, 2.25)$.	A1
			[3]
(c)	$\text{f}'(x) = 2x^3 - 3x^2 + 1 \{+ 0\}$	At least two of the four terms differentiated correctly.	M1
		Correct derivative.	A1
	$\text{f}(-1.5) = 1.40625 \ \left(= 1\frac{13}{32}\right)$ $\{\text{f}'(-1.5) = -12.5\}$	$\text{f}(-1.5) =$ awrt 1.41	B1
	$\beta_2 = -1.5 - \left(\frac{\text{"}1.40625\text{"}}{\text{"}-12.5\text{"}}\right)$	Correct application of Newton-Raphson using their values.	M1
	$= -1.3875 \quad \left(= -1\frac{31}{80}\right)$	-1.3875 seen as answer to first iteration, award M1A1B1M1	
	$= -1.39$ (2 dp)	–1.39	A1 **cao**
			[5] **10**

Question Number	Scheme		Marks
4.	$\mathrm{f}(x) = (4x^2 + 9)(x^2 - 2x + 5) = 0$		
(a)	$(4x^2 + 9) = 0 \Rightarrow x = \frac{3i}{2}, -\frac{3i}{2}$	An attempt to solve $(4x^2 + 9) = 0$ which involves i.	M1
		$\frac{3i}{2}, -\frac{3i}{2}$	A1
	$(x^2 - 2x + 5) = 0 \Rightarrow x = \frac{2 \pm \sqrt{4 - 4(1)(5)}}{2(1)}$	Solves the 3TQ	M1
	$\Rightarrow x = \frac{2 \pm \sqrt{-16}}{2}$		
	$\Rightarrow x = 1 \pm 2i$	$1 \pm 2i$	A1
			[4]
(b)		Any two of their roots plotted correctly on a single diagram, which have been found in part (a).	B1ft
		Both sets of their roots plotted correctly on a single diagram with symmetry about $y = 0$.	B1ft
			[2] **6**
	Method mark for solving 3 term quadratic: 1. <u>Factorisation</u> $(x^2 + bx + c) = (x + p)(x + q)$, where $\lvert pq \rvert = \lvert c \rvert$, leading to x = $(ax^2 + bx + c) = (mx + p)(nx + q)$, where $\lvert pq \rvert = \lvert c \rvert$ and $\lvert mn \rvert = \lvert a \rvert$, leading to x = 2. <u>Formula</u> Attempt to use <u>correct</u> formula (with values for a, b and c). 3. <u>Completing the square</u> Solving $x^2 + bx + c = 0$: $\left(x \pm \frac{b}{2}\right)^2 \pm q \pm c, \quad q \neq 0$, leading to x =...		

Question Number	Scheme		Marks
	Ignore part labels and mark part (a) and part (b) together		
5.	$H: x = 3t,\ y = \frac{3}{t},\quad L: 6y = 4x - 15$		
(a)	$H = L \Rightarrow 6\left(\frac{3}{t}\right) = 4(3t) - 15$	An attempt to substitute $x = 3t$ and $y = \frac{3}{t}$ into L Correct equation in t.	M1 A1
	$\Rightarrow 18 = 12t^2 - 15t \Rightarrow 12t^2 - 15t - 18 = 0$		
	$\Rightarrow 4t^2 - 5t - 6 = 0$ *	Correct solution only, involving at least one intermediate step to given answer.	A1 **cso**
			[3]
(b)	$(t-2)(4t+3)\{=0\}$	A valid attempt at solving the quadratic.	M1
	$\Rightarrow t = 2, -\frac{3}{4}$	Both $t = 2$ and $t = -\frac{3}{4}$	A1
	When $t = 2$, $x = 3(2) = 6,\ y = \frac{3}{2} \Rightarrow \left(6, \frac{3}{2}\right)$	An attempt to use one of their t-values to find one of either x or y.	M1
	When $t = -\frac{3}{4}$,	One set of coordinates correct or both x-values are correct.	A1
	$x = 3\left(-\frac{3}{4}\right) = -\frac{9}{4},\ y = \frac{3}{\left(-\frac{3}{4}\right)} = -4 \Rightarrow \left(-\frac{9}{4}, -4\right)$	Both sets of values correct.	A1
			[5] **8**
(b)	**Alt Method:** An attempt to eliminate either x or y from $xy = 9$ and $6y = 4x - 15$ 1st M1: A full method to obtain a quadratic equation in either x or y. 1st A1: For either $4x^2 - 15x - 54 = 0$ or $6y^2 + 15y - 36 = 0$ or equivalent. 2nd M1: A valid attempt at solving the quadratic. 2nd A1: For either $x = 6, -\frac{9}{4}$ or $y = \frac{3}{2}, -4$ 3rd A1: Both $\left(6, \frac{3}{2}\right)$ and $\left(-\frac{9}{4}, -4\right)$.		

Question Number	Scheme		Marks
6.	$\mathbf{A}=\begin{pmatrix}0 & 1\\ -1 & 0\end{pmatrix}$, $\mathbf{B}=\begin{pmatrix}2 & 3\\ 1 & 4\end{pmatrix}$		
(a)	$\mathbf{P}=\mathbf{AB}\left\{=\begin{pmatrix}0 & 1\\ -1 & 0\end{pmatrix}\begin{pmatrix}2 & 3\\ 1 & 4\end{pmatrix}\right\}$	$\mathbf{P}=\mathbf{AB}$, seen or implied.	M1
	$\mathbf{P}=\begin{pmatrix}1 & 4\\ -2 & -3\end{pmatrix}$	Correct answer.	A1
			[2]
(b)	$\det\mathbf{P}=1(-3)-(4)(-2)\ \{=-3+8=5\}$	Applies "$ad-bc$".	M1
	$\text{Area}(T)=\underline{\dfrac{24}{5}}\ (\text{units})^2$	$\dfrac{24}{\text{their }\det\mathbf{P}}$, dependent on previous M	dM1
		$\underline{\dfrac{24}{5}}$ or $\underline{4.8}$	A1ft
			[3]
(c)	$\mathbf{QP}=\mathbf{I}\Rightarrow\mathbf{QPP}^{-1}=\mathbf{IP}^{-1}\Rightarrow\mathbf{Q}=\mathbf{P}^{-1}$		
	$\mathbf{Q}=\mathbf{P}^{-1}=\dfrac{1}{5}\begin{pmatrix}-3 & -4\\ 2 & 1\end{pmatrix}$	$\mathbf{Q}=\mathbf{P}^{-1}$ stated or an attempt to find $\mathbf{P}^{-1}$. Correct ft inverse matrix.	M1 A1ft
			[2] **7**
	Using **BA,** area is the same in (b) and inverse is $\dfrac{1}{5}\begin{pmatrix}1 & -2\\ 4 & -3\end{pmatrix}$ in (c) and could gain ft marks.		

Question Number	Scheme		Marks
7.	$y^2 = 4ax$, at $P\left(at^2, 2at\right)$.		
(a)	$y = 2\sqrt{a}\,x^{\frac{1}{2}} \Rightarrow \frac{dy}{dx} = \sqrt{a}\,x^{-\frac{1}{2}}$ or (implicitly) $2y\frac{dy}{dx} = 4a$ or (chain rule) $\frac{dy}{dx} = 2a \times \frac{1}{2at}$	$\frac{dy}{dx} = \pm k x^{-\frac{1}{2}}$ or $ky\frac{dy}{dx} = c$ or $\frac{\text{their } \frac{dy}{dt}}{\text{their } \frac{dx}{dt}}$	M1
	When $x = at^2$, $\frac{dy}{dx} = \frac{\sqrt{a}}{\sqrt{at^2}} = \frac{\sqrt{a}}{\sqrt{a}\,t} = \frac{1}{t}$ or $\frac{dy}{dx} = \frac{4a}{2(2at)} = \frac{1}{t}$	$\frac{dy}{dx} = \frac{1}{t}$	A1
	T: $y - 2at = \frac{1}{t}\left(x - at^2\right)$	Applies $y - 2at =$ their $m_T\left(x - at^2\right)$ **Their m_T must be a function of t from calculus.**	M1
	T: $ty - 2at^2 = x - at^2$		
	T: $ty = x + at^2$	Correct solution.	A1 **cso** *
			[4]
(b)	At Q, $x = 0 \Rightarrow y = \frac{at^2}{t} = at \Rightarrow Q(0, at)$	$y = at$ or $Q(0, at)$	B1
			[1]
(c)	$S(a, 0)$		
	$\text{m}(PQ) = \frac{at - 2at}{0 - at^2} = \frac{-at}{-at^2} = \frac{1}{t}$	A correct method for finding either $\text{m}(PQ)$ or $\text{m}(SQ)$ for their Q or S.	M1
	$\text{m}(SQ) = \frac{at - 0}{0 - a} = \frac{at}{-a} = -t$	$\text{m}(PQ) = \frac{1}{t}$ and $\text{m}(SQ) = -t$	A1
	$\text{m}(PQ) \times \text{m}(SQ) = \frac{1}{t} \times -t = -1 \Rightarrow PQ \perp SQ$	Shows $\text{m}(PQ) \times \text{m}(SQ) = -1$ and conclusion.	A1 **cso**
			[3] **8**

Question Number	Scheme		Marks
8. (a)	$\sum_{r=1}^{n} r(2r-1) = \frac{1}{6}n(n+1)(4n-1)$		
	$n=1$; LHS $= \sum_{r=1}^{1} r(2r-1) = 1$ RHS $= \frac{1}{6}(1)(2)(3) = 1$ As LHS = RHS, the summation formula is true for $n = 1$.	$\frac{1}{6}(1)(2)(3) = 1$ seen	B1
	Assume that the summation formula is true for $n = k$.		
	ie. $\sum_{r=1}^{k} r(2r-1) = \frac{1}{6}k(k+1)(4k-1)$.		
	With $n = k+1$ terms the summation formula becomes:		
	$\sum_{r=1}^{k+1} r(2r-1) = \underline{\frac{1}{6}k(k+1)(4k-1) + (k+1)(2(k+1)-1)}$	$S_{k+1} = S_k + u_{k+1}$ with $S_k = \frac{1}{6}k(k+1)(4k-1)$.	M1
	$= \frac{1}{6}k(k+1)(4k-1) + (k+1)(2k+1)$		
	$= \frac{1}{6}(k+1)\left(k(4k-1) + 6(2k+1)\right)$	Factorise by $\frac{1}{6}(k+1)$	dM1
	$= \frac{1}{6}(k+1)\left(4k^2 + 11k + 6\right)$	$\left(4k^2 + 11k + 6\right)$ or equivalent quadratic seen	A1
	$= \frac{1}{6}(k+1)(k+2)(4k+3)$		
	$= \frac{1}{6}(k+1)(k+1+1)(4(k+1)-1)$	Correct completion to S_{k+1} in terms of $k+1$ dependent on both Ms.	dM1
	If the summation formula is <u>true for $n = k$</u>, then it is shown to be <u>true for $n = k+1$</u>. As the result is <u>true for $n = 1$</u>, it is now also <u>true for all n</u> and $n \in \mathbb{Z}^+$ by mathematical induction.	Conclusion with all 4 underlined elements that can be seen anywhere in the solution	A1 cso
			[6]

Question Number	Scheme		Marks
8. (b)	$\sum_{r=n+1}^{3n} r(2r-1) = S_{3n} - S_n$		
	$= \frac{1}{6}.3n(3n+1)(12n-1) - \frac{1}{6}n(n+1)(4n-1)$	Use of $S_{3n} - S_n$ or $S_{3n} - S_{n+1}$ with the result from (a) used at least once. Correct un-simplified expression.	M1 A1
	$= \frac{1}{6}n\{3(3n+1)(12n-1) - (n+1)(4n-1)\}$		
	$= \frac{1}{6}n\{3(36n^2 + 9n - 1) - (4n^2 + 3n - 1)\}$	Factorises out $\frac{1}{6}n$ or $\frac{1}{3}n$ and an attempt to open up the brackets.	dM1
	$= \frac{1}{6}n\{108n^2 + 27n - 3 - 4n^2 - 3n + 1\}$		
	$= \frac{1}{6}n\{104n^2 + 24n - 2\}$		
	$= \frac{1}{3}n(52n^2 + 12n - 1)$ $\{a = 52, b = 12, c = -1\}$	$= \frac{1}{3}n(52n^2 + 12n - 1)$	A1 **[4]** **10**

Question Number	Scheme		Marks
9.	$w = 10 - 5\text{i}$		
(a)	$\lvert w\rvert = \left\{\sqrt{10^2 + (-5)^2}\right\} = \sqrt{125}$ or $5\sqrt{5}$ or $11.1803...$	$\underline{\sqrt{125}}$ or $\underline{5\sqrt{5}}$ or <u>awrt 11.2</u>	B1
			[1]
(b)	$\arg w = -\tan^{-1}\left(\frac{5}{10}\right)$	Use of $\tan^{-1}$ or $\tan$	M1
	$= -0.463647609... = -0.46$ (2 dp)	awrt -0.46 or awrt 5.82	A1 oe
			[2]
	$(2+\text{i})(z+3\text{i}) = w$		
(c)	$z + 3\text{i} = \dfrac{10-5\text{i}}{(2+\text{i})}$	Simplifies to give $* = \dfrac{\text{complex no.}}{(2+\text{i})}$	B1
	$z + 3\text{i} = \dfrac{(10-5\text{i})}{(2+\text{i})} \times \dfrac{(2-\text{i})}{(2-\text{i})}$	Multiplies by $\dfrac{\text{their } (2-\text{i})}{\text{their } (2-\text{i})}$	M1
	$z + 3\text{i} = \dfrac{20 - 10\text{i} - 10\text{i} - 5}{1+4}$	Simplifies realising that a real number is needed on the denominator and applies $\text{i}^2 = -1$ on their numerator expression and denominator expression.	M1
	$z + 3\text{i} = \dfrac{15 - 20\text{i}}{5}$		
	$z + 3\text{i} = 3 - 4\text{i}$ $z = 3 - 7\text{i}$ (Note: $a = 3, b = -7$.)	$z = 3 - 7\text{i}$	A1
			[4]
	$\arg(\lambda + 9\text{i} + w) = \dfrac{\pi}{4}$		
(d)	$\lambda + 9\text{i} + w = \lambda + 9\text{i} + 10 - 5\text{i} = (\lambda + 10) + 4\text{i}$		
	$\arg(\lambda + 9\text{i} + w) = \dfrac{\pi}{4} \Rightarrow \lambda + 10 = 4$	Combines real and imaginary parts and puts "Real part = Imaginary part" i.e. $\dfrac{\lambda+10}{4} = 1$ or $\dfrac{4}{\lambda+10} = 1$ o.e.	M1
	So, $\lambda = -6$	-6	A1
			[2] **9**
(c) (c)	<u>**Alt 1: Scheme as above:**</u> $(2+\text{i})z + 6\text{i} + 3\text{i}^2 = 10 - 5\text{i} \Rightarrow (2+\text{i})z = 13 - 11\text{i}$ B1 for $z = \dfrac{13-11\text{i}}{2+\text{i}}$; M1 for $z = \dfrac{(13-11\text{i})}{(2+\text{i})} \times \dfrac{(2-\text{i})}{(2-\text{i})}$; M1 for $z = \dfrac{26 - 13\text{i} - 22\text{i} - 11}{4+1}$; A1 for $z = 3 - 7\text{i}$ <u>**Alt 2:**</u> **Let** $z = a + \text{i}b$ gives $(2+i)(a + \text{i}b + 3\text{i}) = 10 - 5\text{i}$ for B1 Equating real and imaginary parts to form two equations both involving a and b for M1 Solves simultaneous equations as far as a= or b= for M1 a=3, b=-7 or $z = 3 - 7\text{i}$ for A1		

Question Number	Scheme		Marks
10.	$\sum_{r=1}^{24}\left(r^3 - 4r\right)$		
(i)	$= \frac{1}{4}24^2(24+1)^2 - 4.\frac{1}{2}24(24+1)$	An attempt to use at least one of the standard formulae correctly and substitute 24.	M1
	$\{= 90000 - 1200\}$		
	$= 88800$	88800	A1 **cao**
			[2]
(ii)	$\sum_{r=0}^{n}\left(r^2 - 2r + 2n + 1\right)$		
	$= \underline{\frac{1}{6}n(n+1)(2n+1) - 2.\frac{1}{2}n(n+1)} + 2n(n+1) + (n+1)$	An attempt to use at least one of the standard formulae correctly.	M1
		<u>Correct underlined expression.</u>	A1
		$2n \rightarrow 2n(n+1)$	B1
		$1 \rightarrow (n+1)$	B1
	$= \frac{1}{6}(n+1)\left\{2n^2 + n - 6n + 12n + 6\right\}$	An attempt to factorise out $\frac{1}{6}(n+1)$ or $\frac{1}{6}n$.	M1
	$= \frac{1}{6}(n+1)\left\{2n^2 + 7n + 6\right\}$		
	$= \frac{1}{6}(n+1)(n+2)(2n+3)$	Correct answer. (Note: $a = 2$, $b = 2$, $c = 3$.)	A1
			[6]
			8

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