CAMBRIDGE
International Education

Cambridge International AS & A Level

FURTHER MATHEMATICS **9231/23**

Paper 2 Further Pure Mathematics 2 **May/June 2026**

MARK SCHEME

Maximum Mark: 75

Published

This mark scheme contains the instructions and marking guidance that our examiners used to mark candidate responses for this component.

Before they start marking, examiners complete a standardisation process. They review a range of candidate responses and discuss the mark scheme in detail to agree which answers can and cannot be accepted. Examiners award marks where it is clear that candidate responses have met the requirements of the mark scheme. These requirements may vary between different components or different versions of the same component, depending on the exact requirements of the question and the candidate responses seen during the standardisation process.

Sometimes, our mark schemes may allow marks to be awarded to responses which contain elements that are factually incorrect or for content not covered by the syllabus. We do this in response to the demands of a specific question to support candidates and make sure that our assessments are fair. However, these allowances should not be used as a guide for teaching and learning.

We cannot discuss the mark scheme with schools, and we recommend that schools read the mark scheme together with the assessment material and the Principal Examiner Report for Teachers.

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General marking principles

All examiners must apply these marking principles when marking candidate responses.

1	Examiners must award marks for each response in line with: • the specific **content** defined in the mark scheme • the specific **skills** defined in the mark scheme or in the level descriptions • the **standard of response** required as exemplified by the standardisation scripts.
2	Examiners must award **whole marks** (not half marks, or other fractions).
3	Examiners must award marks **positively**. This means that: • marks are not deducted for errors or omissions • marks are awarded for correct/valid answers as defined in the mark scheme and also for **other valid answers** which go beyond the scope of the syllabus and mark scheme referring to your team leader as appropriate • the quality of spelling, punctuation and grammar are judged **only** when the mark scheme indicates that these features are **specifically assessed** in the question. However, the meaning of all responses must be unambiguous.
4	Examiners must **consistently** apply the requirements of the mark scheme and any rules for what to do when candidates have not followed instructions correctly.
5	Examiners must use the **full range of marks** defined in the mark scheme, unless limited by the quality of the candidate responses seen.
6	Examiners must award marks according to the mark scheme and **must not** award marks with grade thresholds or grade descriptions in mind.

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Mathematics-Specific Marking Principles

1 Unless a particular method has been specified in the question, full marks may be awarded for any correct method. However, if a calculation is required then no marks will be awarded for a scale drawing.

2 Unless specified in the question, non-integer answers may be given as fractions, decimals or in standard form. Ignore superfluous zeros, provided that the degree of accuracy is not affected.

3 Allow alternative conventions for notation if used consistently throughout the paper, e.g. commas being used as decimal points.

4 Unless otherwise indicated, marks once gained cannot subsequently be lost, e.g. wrong working following a correct form of answer is ignored (isw).

5 Where a candidate has misread a number or sign in the question and used that value consistently throughout, provided that number does not alter the difficulty or the method required, award all marks earned and deduct just 1 A or B mark for the misread.

6 Recovery within working is allowed, e.g. a notation error in the working where the following line of working makes the candidate's intent clear.

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Annotations guidance for centres

Examiners use a system of annotations as a shorthand for communicating their marking decisions to one another. Examiners are trained during the standardisation process on how and when to use annotations. The purpose of annotations is to inform the standardisation and monitoring processes and guide the supervising examiners when they are checking the work of examiners within their team. The meaning of annotations and how they are used is specific to each component and is understood by all examiners who mark the component.

We publish annotations in our mark schemes to help centres understand the annotations they may see on copies of scripts. Note that there may not be a direct correlation between the number of annotations on a script and the mark awarded. Similarly, the use of an annotation may not be an indication of the quality of the response.

The annotations listed below were available to examiners marking this component in this series.

Annotations

Annotation	Meaning
	More information required
	Accuracy mark awarded zero
	Accuracy mark awarded one
	Independent accuracy mark awarded zero
	Independent accuracy mark awarded one
	Independent accuracy mark awarded two
	Benefit of the doubt
	Blank Page
	Incorrect
Dep	Used to indicate DM0 or DM1

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Annotation	Meaning
DM1	Dependent on the previous M1 mark(s)
FT	Follow through
	Indicate working that is right or wrong
Highlighter	Highlight a key point in the working
ISW	Ignore subsequent work
J	Judgement
JU	Judgement
M0	Method mark awarded zero
M1	Method mark awarded one
M2	Method mark awarded two
MR	Misread
O	Omission or Other solution
Off-page comment	Allows comments to be entered at the bottom of the RM marking window and then displayed when the associated question item is navigated to.
On-page comment	Allows comments to be entered in speech bubbles on the candidate response.
PE	Judgment made by the PE
Pre	Premature approximation
SC	Special case
SEEN	Indicates that work/page has been seen

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Annotation	Meaning
SF	Error in number of significant figures
	Correct
TE	Transcription error
XP	Correct answer from incorrect working

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Mark Scheme Notes

The following notes are intended to aid interpretation of mark schemes in general, but individual mark schemes may include marks awarded for specific reasons outside the scope of these notes.

Types of mark

M Method mark, awarded for a valid method applied to the problem. Method marks are not 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. Correct application of a formula without the formula being quoted obviously earns the M mark and in some cases an M mark can be implied from a correct answer.

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).

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

DM or **DB** When a part of a question has two or more 'method' steps, the M marks are generally independent unless the scheme specifically says otherwise; and similarly, when there are several B marks allocated. The notation DM or DB is used to indicate that a particular M or B mark is dependent on an earlier M or B (asterisked) mark in the scheme. When two or more steps are run together by the candidate, the earlier marks are implied and full credit is given.

FT Implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A or B marks are given for correct work only.

- A or B marks are given for correct work only (not for results obtained from incorrect working) unless follow through is allowed (see abbreviation FT above).
- For a numerical answer, allow the A or B mark if the answer is correct to 3 significant figures or would be correct to 3 significant figures if rounded (1 decimal place for angles in degrees).
- The total number of marks available for each question is shown at the bottom of the Marks column.
- Wrong or missing units in an answer should not result in loss of marks unless the guidance indicates otherwise.
- Square brackets [ ] around text or numbers show extra information not needed for the mark to be awarded.

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Abbreviations

AEF/OE	Any Equivalent Form (of answer is equally acceptable) / Or Equivalent
AG	Answer Given on the question paper (so extra checking is needed to ensure that the detailed working leading to the result is valid)
CAO	Correct Answer Only (emphasising that no 'follow through' from a previous error is allowed)
CWO	Correct Working Only
ISW	Ignore Subsequent Working
SOI	Seen Or Implied
SC	Special Case (detailing the mark to be given for a specific wrong solution, or a case where some standard marking practice is to be varied in the light of a particular circumstance)
WWW	Without Wrong Working
AWRT	Answer Which Rounds To

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Question	Answer	Marks	Guidance
1	$w^5 = -32 = 32\mathrm{e}^{\mathrm{i}\pi}$	**B1**	Converts to exponential form.
	$z_1 = 2\mathrm{e}^{\mathrm{i}\frac{1}{5}\pi}$	**M1 A1**	Finds one root in required form.
	$z_2 = 2\mathrm{e}^{-\mathrm{i}\frac{1}{5}\pi}$	**A1**	Finds another root.
	$z_3 = 2\mathrm{e}^{\mathrm{i}\frac{3}{5}\pi}$, $z_4 = 2\mathrm{e}^{-\mathrm{i}\frac{3}{5}\pi}$, $z_5 = 2\mathrm{e}^{-\mathrm{i}\pi} = -2$	**A1**	Finds other three roots.
		5	

Question	Answer	Marks	Guidance
2	$\sqrt{1+\left(\frac{1}{2}x^{-\frac{1}{2}}\right)^2} = \sqrt{1+\frac{1}{4}x^{-1}}$	**B1**	Finds $\sqrt{1+\left(\frac{\mathrm{d}y}{\mathrm{d}x}\right)^2}$.
	$2\pi\int_0^2 \sqrt{x}\sqrt{1+\frac{1}{4}x^{-1}}\,\mathrm{d}x$	**M1**	Correct formula for surface area with limits. Integral must be in terms of x.
	$= 2\pi\int_0^2 \sqrt{x+\frac{1}{4}}\,\mathrm{d}x$ or $\pi\int_0^2 \sqrt{4x+1}\,\mathrm{d}x$	**A1**	Integrand simplified correctly.
	$= 2\pi\left[\frac{2}{3}\left(x+\frac{1}{4}\right)^{\frac{3}{2}}\right]_0^2$ or $\frac{\pi}{6}\left[(4x+1)^{\frac{3}{2}}\right]_0^2$	**M1**	Integrates and substitutes limits. Integrand must be of the form $(px+a)^n$ with a and p nonzero and consistent with previous working and $n \neq 1$.
	$= \frac{13}{3}\pi$	**A1**	AEF.
		5	

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Question	Answer	Marks	Guidance
3(a)	**EITHER:** $\frac{\mathrm{d}}{\mathrm{d}x}\left((x+1)\ln^n(x+1)\right) = n(x+1)\frac{\ln^{n-1}(x+1)}{(x+1)} + \ln^n(x+1)$	**(B1**	CAO (AEF).
	$\left[(x+1)\ln^n(x+1)\right]_0^a = nI_{n-1} + I_n$	**M1**	Integrates both sides using the limits given.
	$I_n = (a+1)\ln^n(a+1) - nI_{n-1}$	**A1)**	Substitutes limits and rearranges. AG.
	OR: **Alternative method for question 3(a)**		
	$I_n = \int_0^a \ln^n(x+1)\,\mathrm{d}x = \left[x\ln^n(x+1)\right]_0^a - n\int_0^a \frac{x\ln^{n-1}(x+1)}{(x+1)}\,\mathrm{d}x$	**(B1**	CAO (Condone missing limits).
	$\left[= a\ln^n(a+1) - n\int_0^a \ln^{n-1}(x+1)\,\mathrm{d}x + n\int_0^a \frac{\ln^{n-1}(x+1)}{(x+1)}\right]$ $= a\ln^n(a+1) - n\mathrm{I}_{n-1} + \left[\ln^n(x+1)\right]_0^a$	**M1**	Expression needs to be fully integrated and in terms of a and I_{n-1}.
	$I_n = (a+1)\ln^n(a+1) - nI_{n-1}$	**A1)**	Substitutes limits, convincing work to AG.
	Available marks	**3**	
3(b)	$I_1 = (a+1)\ln(a+1) - a$	**B1**	CAO.
	$I_2 = (a+1)\ln^2(a+1) - 2I_1$	**M1**	Applies reduction formula to find I_2.
	$I_2 = (a+1)\ln^2(a+1) - 2(a+1)\ln(a+1) + 2a$	**A1**	
		3	

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Question	Answer	Marks	Guidance
4	$49m^2+14m+1=0 \Rightarrow m=-\frac{1}{7}$	**M1**	Auxiliary equation.
	$x=\mathrm{e}^{-\frac{1}{7}t}\left(At+B\right)$	**A1**	Complimentary function.
	$x=k\mathrm{e}^{\frac{1}{7}t} \Rightarrow x'=\frac{1}{7}k\mathrm{e}^{\frac{1}{7}t} \Rightarrow x''=\frac{1}{49}k\mathrm{e}^{\frac{1}{7}t}$	**B1**	Particular integral and its derivatives.
	$k\mathrm{e}^{\frac{1}{7}t}+2k\mathrm{e}^{\frac{1}{7}t}+k\mathrm{e}^{\frac{1}{7}t}=196\mathrm{e}^{\frac{1}{7}t} \Rightarrow 4k=196$	**M1**	Substitutes and equates coefficients.
	$k=49$	**A1**	
	$x=\mathrm{e}^{-\frac{1}{7}t}\left(At+B\right)+49\mathrm{e}^{\frac{1}{7}t}$	**A1**	General solution.
	$x'=A\mathrm{e}^{-\frac{1}{7}t}-\frac{1}{7}\mathrm{e}^{-\frac{1}{7}t}\left(At+B\right)+7\mathrm{e}^{\frac{1}{7}t}$	**M1***	General solution must be of correct form for any further marks.
	$7=B+49 \quad 0=A-\frac{1}{7}B+7 \Rightarrow A=-13, \quad B=-42$	**dM1 A1**	Substitutes initial conditions to find A and B.
	$x=\mathrm{e}^{-\frac{1}{7}t}\left(-13t-42\right)+49\mathrm{e}^{\frac{1}{7}t}$	**A1**	
		10	

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Question	Answer	Marks	Guidance
5(a)	$\operatorname{sech} t = \dfrac{2}{e^t + e^{-t}} \quad \tanh t = \dfrac{e^t - e^{-t}}{e^t + e^{-t}}$	**B1**	
	$1 - \left(\dfrac{2}{e^t + e^{-t}}\right)^2 = \dfrac{\left(e^t + e^{-t}\right)^2 - 4}{\left(e^t + e^{-t}\right)^2} = \dfrac{e^{2t} + 2 + e^{-2t} - 4}{\left(e^t + e^{-t}\right)^2} = \dfrac{\left(e^t - e^{-t}\right)^2}{\left(e^t + e^{-t}\right)^2}$	**M1 A1**	Expands, gets to $\dfrac{e^{2t} + 2 + e^{-2t} - 4}{\left(e^t + e^{-t}\right)^2}$ for M1, AG. Variable used must be consistent throughout. A0 if a mixture of variables is used.
		3	
5(b)	$\dfrac{dy}{dt} = t\sinh t + \cosh t\,, \ \dfrac{dx}{dt} = t\cosh t + \sinh t$	**B1**	CAO
	$\dfrac{dy}{dx} = \dfrac{dy}{dt} \times \dfrac{dt}{dx} = \dfrac{t\sinh t + \cosh t}{t\cosh t + \sinh t}$	**M1**	Uses chain rule.
	$\dfrac{t\sinh t + \cosh t}{t\cosh t + \sinh t} \times \dfrac{\operatorname{sech} t}{\operatorname{sech} t} = \dfrac{t\tanh t + 1}{t + \tanh t}$	**A1**	Divides numerator and denominator by $\cosh t$, AG.
		3	

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Question	Answer	Marks	Guidance
5(c)	$\frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\mathrm{d}y}{\mathrm{d}x}\right)=\frac{(t+\tanh t)\left(t\operatorname{sech}^2 t+\tanh t\right)-(t\tanh t+1)\left(1+\operatorname{sech}^2 t\right)}{(t+\tanh t)^2}$	***M1 A1**	Applies quotient rule.
	$\left[\frac{t^2\operatorname{sech}^2 t+t\tanh t+t\operatorname{sech}^2 t\tanh t+\tanh^2 t-t\tanh t-t\tanh t\operatorname{sech}^2 t-1-\operatorname{sech}^2 t}{(t+\tanh t)^2}\right]$ $\left[\frac{t^2\operatorname{sech}^2 t+\tanh^2 t-\operatorname{sech}^2 t-1}{(t+\tanh t)^2}\right]$ $\frac{t^2\operatorname{sech}^2 t+\left(1-\operatorname{sech}^2 t\right)-\operatorname{sech}^2 t-1}{(t+\tanh t)^2}$	**M1**	Simplifies numerator to the form $\left(\mathrm{t}^2-2\right)\operatorname{sech}^n t$ by applying $\tanh^2 t=1-\operatorname{sech}^2 t$.
	$=\frac{\left(t^2-2\right)\operatorname{sech}^2 t}{(t+\tanh t)^2}$	**A1**	
	$\frac{\mathrm{d}^2y}{\mathrm{d}x^2}=\frac{\left(t^2-2\right)\operatorname{sech}^2 t}{(t+\tanh t)^2}\times\frac{1}{t\cosh t+\sinh t}=\frac{\left(t^2-2\right)\operatorname{sech}^3 t}{(t+\tanh t)^3}$	**dM1 A1**	Uses chain rule, multiplies by their $\frac{\mathrm{d}t}{\mathrm{d}x}$ for M1. Convincing argument to final result for A1
		6	

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Question	Answer	Marks	Guidance
6(a)	$\frac{\mathrm{d}y}{\mathrm{d}x}+\frac{y}{1-x^2}=\sqrt{1-x}$	**B1**	Divides through by $1-x^2$.
	$\mathrm{e}^{\int\frac{1}{1-x^2}\mathrm{d}x}\left[=\mathrm{e}^{\tanh^{-1}x}\ or\ \mathrm{e}^{\frac{1}{2}\ln\left(\frac{1+x}{1-x}\right)}\right]$	**M1 A1**	Finds integrating factor. Allow $\mathrm{e}^{\int\frac{a}{1-x^2}\mathrm{d}x}$ for M1.
	$=\mathrm{e}^{\frac{1}{2}\ln\left(\frac{1+x}{1-x}\right)}=\sqrt{\frac{1+x}{1-x}}$	**A1**	AG. Must have obtained all previous marks.
		4	
6(b)	$\frac{\mathrm{d}}{\mathrm{d}x}\left(y\sqrt{\frac{1+x}{1-x}}\right)=\sqrt{1+x}$	**M1 A1**	Correct form on LHS and RHS.
	$y\sqrt{\frac{1+x}{1-x}}=\frac{2}{3}(1+x)^{\frac{3}{2}}+C$	**M1 A1**	Integrates RHS.
	$1=\frac{2}{3}+C\Rightarrow C=\frac{1}{3}$	**M1**	Substitutes initial conditions.
	$y\sqrt{\frac{1+x}{1-x}}=\frac{2}{3}(1+x)^{\frac{3}{2}}+\frac{1}{3}$	**A1**	$y=\frac{2}{3}(1+x)(1-x)^{\frac{1}{2}}+\frac{1}{3}(1+x)^{-\frac{1}{2}}(1-x)^{\frac{1}{2}}$. Final answer must be in terms of x and not be in terms of integrating factor.
		6	

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Question	Answer	Marks	Guidance
7(a)	$\int \frac{x}{\sqrt{1-x^2}}\,\mathrm{d}x = -\frac{1}{2}\int \frac{1}{\sqrt{u}}\,\mathrm{d}u$	**M1 A1**	Applies given substitution. Allow $\int \frac{a}{\sqrt{u}}\,\mathrm{d}u$ for M1.
	$= -\sqrt{1-x^2}$ $[+C]$	**A1**	Accept without '$+C$'. Must be in terms of x.
		3	
7(b)	$\left[\frac{1}{n}\sin^{-1}\frac{1}{n} + \frac{1}{n}\sin^{-1}\frac{2}{n} + \ldots + \frac{1}{n}\sin^{-1}\frac{n}{n}\right] = \sum_{r=1}^{n}\frac{1}{n}\sin^{-1}\left(\frac{r}{n}\right) \geqslant \int_0^1 \sin^{-1}x\,\mathrm{d}x$	**M1**	M1 correct comparison (no limits required)
		A1	A1 correct limits on both sides
	$\int_0^1 \sin^{-1}x\,\mathrm{d}x = \left[x\sin^{-1}x\right]_0^1 - \int_0^1 \frac{x}{\sqrt{1-x^2}}\,\mathrm{d}x$	**M1**	Integrates by parts.
	$\left[x\sin^{-1}x + \sqrt{1-x^2}\right]_0^1$	**A1**	CAO with correct signs
	$= \frac{1}{2}\pi - 1$	**A1**	Clear substitution of limits to given result
		5	

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Question	Answer	Marks	Guidance
7(c)	$\frac{1}{n}\sin^{-1}\frac{1}{n}+\frac{1}{n}\sin^{-1}\frac{2}{n}+\ldots+\frac{1}{n}\sin^{-1}\frac{n-1}{n}=\sum_{r=1}^{n-1}\frac{1}{n}\sin^{-1}\left(\frac{r}{n}\right)$	**M1**	Forms the sum of the areas of appropriate rectangles.
	$\sum_{r=1}^{n-1}\frac{1}{n}\sin^{-1}\left(\frac{r}{n}\right)=\sum_{r=1}^{n}\frac{1}{n}\sin^{-1}\left(\frac{r}{n}\right)-\left(\frac{1}{n}\right)\left(\frac{\pi}{2}\right)$	**A1**	Adjusts summation with reference to missing term.
	$\left[\sum_{r=1}^{n-1}\frac{1}{n}\sin^{-1}\left(\frac{r}{n}\right)\leqslant\int_0^1\sin^{-1}x\,\mathrm{d}x\right]$ $\sum_{r=1}^{n}\frac{1}{n}\sin^{-1}\left(\frac{r}{n}\right)\leqslant\frac{1}{2}\pi-1+\frac{\pi}{2n}$	**A1**	CAO
		3	
7(d)	$\frac{1}{2}\pi-1$	**B1**	Dependent on obtaining full marks in 7(c).
		1	

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Question	Answer	Marks	Guidance
8(a)	**EITHER:** $\begin{vmatrix} 6 & -12 & -12 \\ a & 4 & 1 \\ 2 & b & -8 \end{vmatrix} = -12ab - 96a - 6b - 120 = 0$	**(M1A1**	Finds determinant in terms of a and b.
	$a = -\dfrac{b+20}{2(b+8)}$ $[b \neq -8.]$	**A1)**	
	OR: **Alternative method for 8(a)**		
	$(6+12a)x + 36y = 25$ (R1+12R2) $(2+8a)x + (b+32)y = 19$ (R3+8R2)	**(M1**	Row eliminates z from two of the equations and forms an equation from resulting coefficients being in ratio.
	$\dfrac{6+12a}{2+8a} = \dfrac{36}{b+32}$	**A1**	Correct ratio equation
	$a = -\dfrac{b+20}{2(b+8)}$ $[b \neq -8.]$	**A1)**	CAO
	Available marks	**3**	

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Question	Answer	Marks	Guidance
8(b)	$\begin{aligned} 6x - 12y - 12z &= 1, \\ -\tfrac{1}{4}x + 4y + z &= 2, \Rightarrow -8(2) = 3 \\ 2x - 32y - 8z &= 3, \end{aligned}$	**B1**	Must show an inconsistent system.
	Two distinct parallel planes. Other plane not parallel.	**B1 B1**	Accept a clear sketch for parallel planes and third plane intersecting both.
		3	
8(c)	$\begin{pmatrix} 6 & -12 & -12 \\ -1 & 4 & 1 \\ 2 & -8 & -8 \end{pmatrix}\begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix} = \begin{pmatrix} -6 \\ 0 \\ -6 \end{pmatrix} = -6\begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$	**M1**	Multiplies **A** with given eigenvector.
	-6	**A1**	
		2	

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Question	Answer	Marks	Guidance
8(d)	$\begin{vmatrix} 6-\lambda & -12 & -12 \\ -1 & 4-\lambda & 1 \\ 2 & -8 & -8-\lambda \end{vmatrix} = -\lambda^3 + 2\lambda^2 + 36\lambda - 72$	**M1**	Characteristic equation.
	$\lambda = 2, 6, -6$	**A1**	
	$\lambda = 2$: $\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 4 & -12 & -12 \\ -1 & 2 & 1 \end{vmatrix} = \begin{pmatrix} 12 \\ 8 \\ -4 \end{pmatrix} \sim \begin{pmatrix} 3 \\ 2 \\ -1 \end{pmatrix}$	**M1 A1**	Uses vector product (or equations) to find corresponding eigenvectors.
	$\lambda = 6$: $\begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 0 & -12 & -12 \\ -1 & -2 & 1 \end{vmatrix} = \begin{pmatrix} -36 \\ 12 \\ -12 \end{pmatrix} \sim \begin{pmatrix} -3 \\ 1 \\ -1 \end{pmatrix}$	**A1**	
	Thus $\mathbf{P} = \begin{pmatrix} 3 & -3 & 1 \\ 2 & 1 & 0 \\ -1 & -1 & 1 \end{pmatrix}$ and $\mathbf{D} = \begin{pmatrix} 2 & 0 & 0 \\ 0 & 6 & 0 \\ 0 & 0 & -6 \end{pmatrix}$	**M1 A1**	Or correctly matched permutations of columns. M0A0 if a zero eigenvector is included.
		7	

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