



# Cambridge International AS & A Level

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## FURTHER MATHEMATICS

9231/22

Paper 2 Further Pure Mathematics 2

May/June 2025

2 hours

You must answer on the question paper.

You will need: List of formulae (MF19)

### INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- If additional space is needed, you should use the lined page at the end of this booklet; the question number or numbers must be clearly shown.
- You should use a calculator where appropriate.
- You must show all necessary working clearly; no marks will be given for unsupported answers from a calculator.
- Give non-exact numerical answers correct to 3 significant figures, or 1 decimal place for angles in degrees, unless a different level of accuracy is specified in the question.

### INFORMATION

- The total mark for this paper is 75.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **20** pages. Any blank pages are indicated.

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- This image shows a full page of white paper with horizontal dotted lines, typical of primary school writing paper. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.



2 Let  $I_n = \int_0^1 (1-x)^n \sinh x \, dx$ , where  $n$  is a non-negative integer.

(a) Show that, for  $n \geq 2$ ,  $I_n = -1 + n(n-1)I_{n-2}$ . [4]

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(b) Find the exact value of  $I_2$ . [3]

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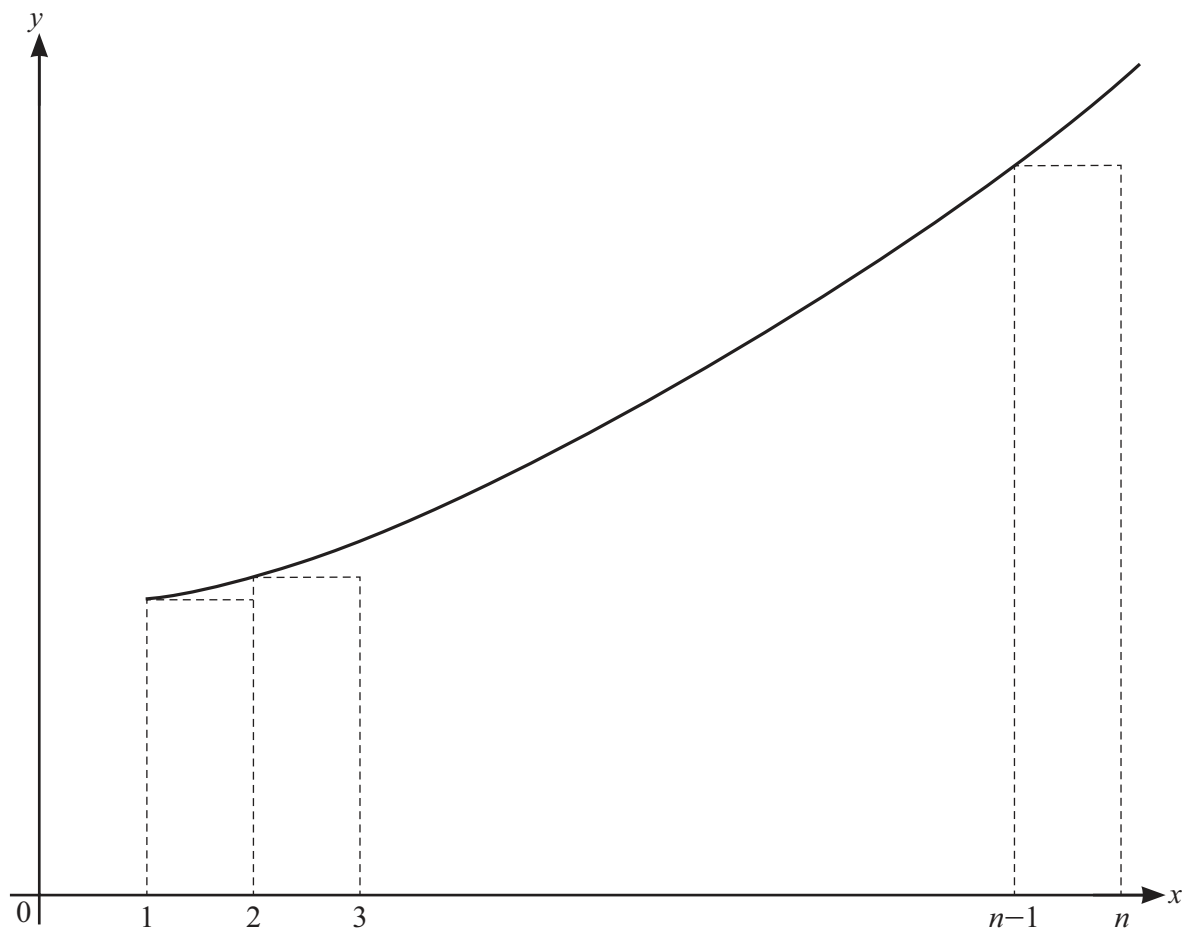
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[6]

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4



The diagram shows the curve with equation  $y = \frac{1}{\sqrt{x}}e^{\sqrt{x}}$  for  $x \geq 1$ , together with a set of  $n-1$  rectangles of unit width.

(a) By considering the sum of the areas of these rectangles, show that

$$\sum_{r=1}^n \frac{1}{\sqrt{r}} e^{\sqrt{r}} < \left(2 + \frac{1}{\sqrt{n}}\right) e^{\sqrt{n}} - 2e. \quad [5]$$

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- (b) Use a similar method to find, in terms of  $n$ , a lower bound for  $\sum_{r=1}^n \frac{1}{\sqrt{r}} e^{\sqrt{r}}$ . [4]



5

$$6 \frac{d^2 x}{dt^2} + 3 \frac{dx}{dt} + 6x = e^{-t},$$

given that, when  $t = 0$ ,  $x = \frac{dx}{dt} = 0$ . [10]

This image shows a full page of white paper with horizontal dashed lines, typical of primary-ruled notebook paper. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.





- 6 (a) Starting from the definitions of  $\tanh$  and  $\operatorname{sech}$  in terms of exponentials, prove that

$$1 - \tanh^2 u = \operatorname{sech}^2 u. \quad [3]$$

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- (b) Show that  $\frac{d}{dt}(\operatorname{sech}^{-1} t) = -\frac{1}{t\sqrt{1-t^2}}.$  [4]

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It is given that

$$x = \tanh^{-1} t \quad \text{and} \quad y = t \operatorname{sech}^{-1} t, \quad \text{for } 0 < t < 1.$$

- (c) Show that  $\frac{dy}{dx} = -\sqrt{1-t^2} + (1-t^2)\operatorname{sech}^{-1} t$ . [4]

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- (d) Find  $\frac{d^2 y}{dx^2}$  in terms of  $t$ . [4]

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$$\frac{dy}{dx} - \frac{x+5}{x^2+10x+61}y = 1,$$

[10]

[illegible]





- 8 (a) It is given that  $\lambda$  is an eigenvalue of the non-singular square matrix  $\mathbf{A}$ , with corresponding eigenvector  $\mathbf{e}$ .

Show that  $\mathbf{e}$  is an eigenvector of  $\mathbf{A}^3$  with corresponding eigenvalue  $\lambda^3$ . [2]

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The matrix  $\mathbf{A}$  is given by

$$\mathbf{A} = \begin{pmatrix} -1 & 3 & 4 \\ 0 & 1 & 0 \\ 0 & -2 & 5 \end{pmatrix}.$$

- (b) Show that the eigenvalues of  $\mathbf{A}$  are  $-1$ ,  $1$  and  $5$ . [2]

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[6]

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[3]

[illegible]

[illegible]









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