Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER					

0510102257

FURTHER MATHEMATICS **9231/22**

Paper 2 Further Pure Mathematics 2 **October/November 2022**

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 **16** pages.

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1 **(a)** Find the set of values of k for which the system of equations

$$\begin{aligned} x + 2y + 3z &= 1, \\ kx + 4y + 6z &= 0, \\ 7x + 8y + 9z &= 3, \end{aligned}$$

has a unique solution. [3]

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(b) Interpret the situation geometrically in the case where the system of equations does not have a unique solution. [2]

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2 A curve has equation

$$(x+1)y+y^2 = 2.$$

(a) Show that $\frac{dy}{dx} = -\frac{2}{3}$ at the point $(0, -2)$. [3]

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(b) Find the value of $\frac{d^2y}{dx^2}$ at the point $(0, -2)$. [4]

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3 **(a)** A curve has equation $y = e^x + \frac{1}{4}e^{-x}$, for $0 \leqslant x \leqslant 1$. Find, in terms of π and e, the area of the surface generated when the curve is rotated through 2π radians about the x-axis. [6]

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(b) Using standard results from the list of formulae (MF19), or otherwise, find the Maclaurin's series for $e^x + \frac{1}{4}e^{-x}$ up to and including the term in x^2. [2]

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4 Find the solution of the differential equation

$$(4t^2 - 1)\frac{dx}{dt} + 4x = 4t^2 - 1$$

for which $x = 3$ when $t = 1$. Give your answer in the form $x = f(t)$. [9]

5 **(a)** Write down the fourth roots of unity. [1]

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(b) Use de Moivre's theorem to show that

$$\cos 4\theta = 8\cos^4\theta - 8\cos^2\theta + 1.$$ [4]

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(c) Hence obtain the real roots of the equation

$$16(8x^4 - 8x^2 + 1)^4 - 9 = 0$$

in the form $\cos(q\pi)$, where q is a rational number. [5]

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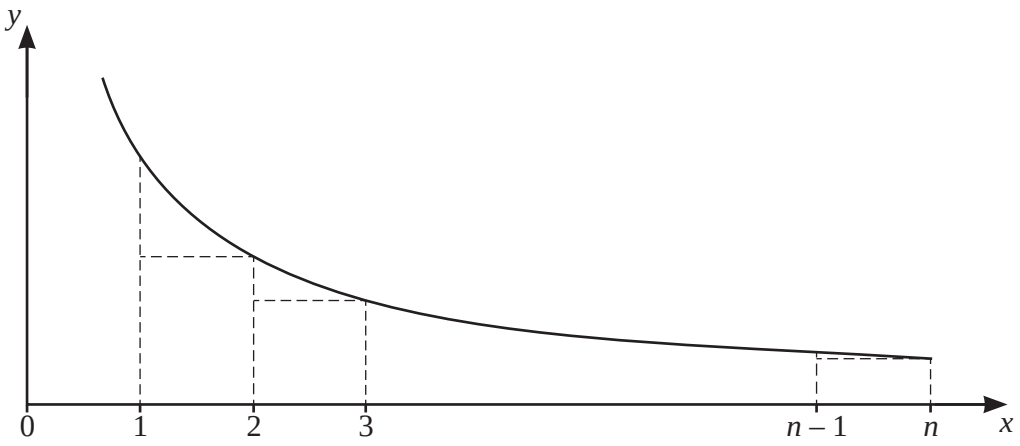

The diagram shows the curve $y = \dfrac{1}{\sqrt{x^2+2x}}$ for $x > 0$, together with a set of $(n-1)$ rectangles of unit width.

By considering the sum of the areas of these rectangles, show that

$$\sum_{r=1}^{n} \frac{1}{\sqrt{r^2+2r}} < \ln\left(n+1+\sqrt{n^2+2n}\right) + \tfrac{1}{3}\sqrt{3} - \ln\left(2+\sqrt{3}\right). \qquad [10]$$

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

Show that λ^{-1} is an eigenvalue of $\mathbf{A}^{-1}$ for which $\mathbf{e}$ is a corresponding eigenvector. [2]

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

$$\mathbf{A} = \begin{pmatrix} 2 & 0 & 3 \\ 15 & -4 & 3 \\ 3 & 0 & 2 \end{pmatrix}.$$

(b) Given that -1 is an eigenvalue of $\mathbf{A}$, find a corresponding eigenvector. [2]

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(c) It is also given that $\begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}$ and $\begin{pmatrix} 1 \\ 2 \\ 1 \end{pmatrix}$ are eigenvectors of $\mathbf{A}$. Find the corresponding eigenvalues. [2]

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(d) Hence find a matrix **P** and a diagonal matrix **D** such that $\mathbf{A}^{-1} = \mathbf{PDP}^{-1}$. [2]

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(e) Use the characteristic equation of **A** to show that $\mathbf{A}^{-1} = p\mathbf{A}^2 + q\mathbf{I}$, where p and q are rational numbers to be determined. [4]

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8 It is given that $y = \cosh u$, where $u > 0$, and

$$\sqrt{\cosh^2 u - 1}\left(\frac{d^2u}{dx^2} + \frac{du}{dx}\right) + \cosh u\left(\frac{du}{dx}\right)^2 - 2\cosh u = 4e^{-x}.$$

(a) Show that

$$\frac{d^2y}{dx^2} + \frac{dy}{dx} - 2y = 4e^{-x}.$$ [4]

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(b) Find u in terms of x, given that, when $x = 0$, $u = \ln 3$ and $\frac{du}{dx} = 3$. [10]

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Additional page

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