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FURTHER MATHEMATICS

9231/14

Paper 1 Further Pure Mathematics 1

May/June 2026

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. Do **not** use correction fluid or tape.
- 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. Any blank pages are indicated.



- 1 (a)** Use standard results from the list of formulae (MF19) to show that

$$\sum_{r=1}^n (r-1)^2 = an^3 + bn^2 + cn,$$

where a , b and c are constants to be determined.

[2]





(b) Use the method of differences to find $\sum_{r=2}^n u_r$ in terms of n .

[4]

(c) State the value of $\sum_{r=2}^{\infty} u_r$.

[1]



2 The equation $2x^4 + 3x^3 + x + 1 = 0$ has roots $\alpha, \beta, \gamma, \delta$.

(a) Find a quartic equation whose roots are $\frac{1}{\alpha^3}, \frac{1}{\beta^3}, \frac{1}{\gamma^3}, \frac{1}{\delta^3}$ and state the value of

$$\frac{1}{\alpha^3} + \frac{1}{\beta^3} + \frac{1}{\gamma^3} + \frac{1}{\delta^3}.$$

[5]

(b) Find the value of $\frac{1}{\alpha^6} + \frac{1}{\beta^6} + \frac{1}{\gamma^6} + \frac{1}{\delta^6}$.

[2]





3 The sequence of positive numbers $u_1, u_2, u_3, \dots$ is such that $u_1 > 1$ and, for $n \geq 1$,

$$u_{n+1} = \frac{u_n^2 + 2u_n + 2}{u_n + 4}.$$

(a) By considering $u_{n+1} - 1$, or otherwise, prove by mathematical induction that $u_n > 1$ for all positive integers n .

[5]

(b) Show that $u_{n+1} < u_n$ for $n \geq 1$.

[3]



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

$$\mathbf{A} = \begin{pmatrix} 1 & k & -1 \\ 3 & 1 & k \\ 3 & 1 & -1 \end{pmatrix},$$

where k is a real constant.

(a) Find the values of k for which $\mathbf{A}$ is singular. [3]

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The matrices $\mathbf{B}$ and $\mathbf{C}$ are given by

$$\mathbf{B} = \begin{pmatrix} 1 & 0 \\ 0 & -1 \\ 1 & 0 \end{pmatrix} \text{ and } \mathbf{C} = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \end{pmatrix}.$$

(b) Show that $\mathbf{CAB} = \begin{pmatrix} k+3 & -1 \\ 2 & -k-1 \end{pmatrix}$. [3]

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Show that the transformation in the x - y plane represented by **CAB** has no invariant lines. [5]

[illegible]

5 The points A, B, C have position vectors

$$4\mathbf{i} + 3\mathbf{j} + 3\mathbf{k}, \quad 2\mathbf{i} + 2\mathbf{j} + \mathbf{k}, \quad 5\mathbf{i} + 2\mathbf{j} + 2\mathbf{k},$$

respectively, relative to the origin O .

(a) Find the equation of the plane ABC , giving your answer in the form $ax + by + cz = d$. [5]

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The point D has position vector $2\mathbf{i} + \mathbf{j} + 3\mathbf{k}$.

(b) Find the acute angle between the line OD and the plane ABC . [3]

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(c) Find the shortest distance between the lines AB and CD .

[5]

[illegible]



- 6 The curve C has equation $y = f(x)$, where $f(x) = \frac{2x^2 - x + 1}{2x^2 - 2x}$.

(a) Find the equations of the asymptotes of C .

[2]

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(b) Find the coordinates of any stationary points on C , giving your answers correct to 1 decimal place.

[4]

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(c) Sketch C .

[3]

(d) Sketch the curve with equation $y = \frac{1}{f(x)}$ and state the set of values for which $\frac{1}{f(x)} < f(x)$. [4]

- 7 (a) Show that the curve with Cartesian equation

$$(x^2 + y^2)^{\frac{3}{2}} = xy$$

has polar equation $r = \frac{1}{2} \sin 2\theta$.

[3]

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The curves C_1 and C_2 have polar equations

$$r = \frac{1}{2} \sin 2\theta \quad \text{and} \quad r^2 = \frac{1}{\left(\theta - \frac{1}{4}\pi\right)^2 + 5}$$

respectively, where $0 \leq \theta \leq \frac{1}{2}\pi$.

- (b) Show that C_1 and C_2 intersect where

$$\left(\left(\theta - \frac{1}{4}\pi\right)^2 + 5\right) \sin^2 2\theta = 4$$

and verify by calculation that this equation has a root α between $\theta = 0.5$ and $\theta = 0.6$.

[3]

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- (c) Sketch C_1 and C_2 on the same diagram, clearly identifying each curve and any lines of symmetry.

[4]

- (d)** The region R is enclosed by C_1 and C_2 and includes the pole. Show that the area of R is given by

$$\frac{1}{32}(4\alpha - \sin 4\alpha) + \frac{1}{5}\sqrt{5} \tan^{-1}\left(\frac{1}{5}\sqrt{5}\left(\frac{1}{4}\pi - \alpha\right)\right),$$

where α is the root found in 7(b).

[6]

This image shows a full page of primary-ruled paper. It features ten horizontal rows. Each row is defined by two parallel horizontal dashed lines. Within each row, there are three vertical dotted lines that intersect the horizontal ones, creating a series of small rectangular boxes across the width of the page. This layout is typical for teaching handwriting or basic arithmetic to young children. The entire page is covered by a faint, light blue watermark that reads "PapaCambridge.com".



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