



CANDIDATE  
NAME

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CENTRE  
NUMBER

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CANDIDATE  
NUMBER

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9231/13

October/November 2023

**2 hours**

You must answer on the question paper.

You will need: List of formulae (MF19)

- 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.

- 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) By considering  $(r+1)^2 - r^2$ , use the method of differences to prove that

$$\sum_{r=1}^n r = \frac{1}{2}n(n+1). \quad [4]$$

This image shows a full page of a worksheet designed for handwriting practice. It features approximately 20 evenly spaced horizontal dotted lines across the entire page, providing a guide for letter height and placement. The background is plain white, and there are no other markings or text present.

[3]

[illegible]

**2** Prove by mathematical induction that, for all positive integers  $n$ ,

$$1 + 2x + 3x^2 + \dots + nx^{n-1} = \frac{1 - (n+1)x^n + nx^{n+1}}{(1-x)^2}. \quad [6]$$

[illegible]

- 3** The quartic equation  $x^4 + bx^3 + cx^2 + dx - 2 = 0$  has roots  $\alpha, \beta, \gamma, \delta$ . It is given that

$$\alpha + \beta + \gamma + \delta = 3, \quad \alpha^2 + \beta^2 + \gamma^2 + \delta^2 = 5, \quad \alpha^{-1} + \beta^{-1} + \gamma^{-1} + \delta^{-1} = 6.$$

- (a) Find the values of  $b$ ,  $c$  and  $d$ . [6]

[illegible]

- (b)** Given also that  $\alpha^3 + \beta^3 + \gamma^3 + \delta^3 = -27$ , find the value of  $\alpha^4 + \beta^4 + \gamma^4 + \delta^4$ . [2]

This image shows a full page of white paper with ten horizontal dashed lines, typical of primary school handwriting practice paper. The lines are evenly spaced and extend across the entire width of the page. There is no text or other markings on the paper.

**4** The lines  $l_1$  and  $l_2$  have equations

$$\mathbf{r} = -2\mathbf{i} - 3\mathbf{j} - 5\mathbf{k} + \lambda(-4\mathbf{i} + 3\mathbf{j} + 5\mathbf{k}) \quad \text{and} \quad \mathbf{r} = 2\mathbf{i} - 2\mathbf{j} + 3\mathbf{k} + \mu(2\mathbf{i} - 3\mathbf{j} + \mathbf{k})$$

respectively.

(a) Find the shortest distance between  $l_1$  and  $l_2$ . [5]

[illegible]

The plane  $\Pi$  contains  $l_1$  and the point with position vector  $-\mathbf{i} - 3\mathbf{j} - 4\mathbf{k}$ .

- (b)** Find an equation of  $\Pi$ , giving your answer in the form  $ax + by + cz = d$ . [4]

This image shows a full page of a document template designed for handwriting practice or as a general writing guide. It consists of approximately 20 evenly spaced, horizontal dotted lines running across the width of the page. The background is plain white, and there are no margins, headers, footers, or other markings present.

**5** Let  $k$  be a constant. The matrices **A**, **B** and **C** are given by

$$\mathbf{A} = \begin{pmatrix} 1 & k & 3 \\ 2 & 1 & 3 \\ 3 & 2 & 5 \end{pmatrix}, \quad \mathbf{B} = \begin{pmatrix} 0 & -2 \\ -1 & 3 \\ 0 & 0 \end{pmatrix} \quad \text{and} \quad \mathbf{C} = \begin{pmatrix} -2 & -1 & 1 \\ 1 & 1 & 3 \end{pmatrix}.$$

It is given that  $\mathbf{A}$  is singular.

(a) Show that  $\mathbf{CAB} = \begin{pmatrix} 3 & -7 \\ -9 & 3 \end{pmatrix}$ . [5]

(b) Find the equations of the invariant lines, through the origin, of the transformation in the  $x$ - $y$  plane represented by **CAB**. [5]



- **D** represents an enlargement, centre the origin.
- **E** represents a stretch parallel to the  $x$ -axis.
- **F** represents a reflection in the line  $y = x$ .

[5]

This image shows a single sheet of white paper with horizontal ruling lines. 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) Show that the curve with Cartesian equation

$$\left(x - \frac{1}{2}\right)^2 + y^2 = \frac{1}{4}$$

has polar equation  $r = \cos \theta$ . [3]

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The curves  $C_1$  and  $C_2$  have polar equations

$$r = \cos \theta \quad \text{and} \quad r = \sin 2\theta$$

respectively, where  $0 \leq \theta \leq \frac{1}{2}\pi$ . The curves  $C_1$  and  $C_2$  intersect at the pole and at another point  $P$ .

- (b) Find the polar coordinates of  $P$ . [3]

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- (c) In a single diagram sketch  $C_1$  and  $C_2$ , clearly identifying each curve, and mark the point  $P$ . [3]

- (d)** The region  $R$  is enclosed by  $C_1$  and  $C_2$  and includes the line  $OP$ .

Find, in exact form, the area of  $R$ .

[6]

[illegible]

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

(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  $C$ , stating the coordinates of any intersections with the axes. [3]

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- (d) Sketch the curve with equation  $y = \frac{1}{f(x)}$ . [2]

(e) Find the set of values for which  $\frac{1}{f(x)} < f(x)$ . [4]

[illegible]

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