



CANDIDATE
NAME

CENTRE
NUMBER

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CANDIDATE
NUMBER

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9231/12

May/June 2021

2 hours

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.

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- 1 Prove by mathematical induction that $2^{4n} + 31^n - 2$ is divisible by 15 for all positive integers n . [6]

This image shows a full page of white paper with horizontal dashed 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 (a) Use standard results from the List of formulae (MF19) to find $\sum_{r=1}^n (1-r-r^2)$ in terms of n , simplifying your answer. [3]

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

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

(a) Find a quartic equation whose roots are α^3 , β^3 , γ^3 , δ^3 and state the value of $\alpha^3 + \beta^3 + \gamma^3 + \delta^3$. [4]

[illegible]

- (b)** Find the value of $\frac{1}{\alpha^3} + \frac{1}{\beta^3} + \frac{1}{\gamma^3} + \frac{1}{\delta^3}$. [3]

[illegible]

- (c) Find the value of $\alpha^4 + \beta^4 + \gamma^4 + \delta^4$. [2]

[illegible]

- 4 The matrix $\mathbf{M}$ represents the sequence of two transformations in the x - y plane given by a rotation of 60° anticlockwise about the origin followed by a one-way stretch in the x -direction, scale factor d ($d \neq 0$).

(a) Find $\mathbf{M}$ in terms of d . [4]

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(b) The unit square in the x - y plane is transformed by $\mathbf{M}$ onto a parallelogram of area $\frac{1}{2}d^2$ units².

Show that $d = 2$. [2]

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The matrix $\mathbf{N}$ is such that $\mathbf{MN} = \begin{pmatrix} 1 & 1 \\ \frac{1}{2} & \frac{1}{2} \end{pmatrix}$.

(c) Find $\mathbf{N}$.

[3]

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(d) Find the equations of the invariant lines, through the origin, of the transformation in the x - y plane represented by $\mathbf{MN}$.

[5]

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- 5 The curve C has polar equation $r = a \cot\left(\frac{1}{3}\pi - \theta\right)$, where a is a positive constant and $0 \leq \theta \leq \frac{1}{6}\pi$.

It is given that the greatest distance of a point on C from the pole is $2\sqrt{3}$.

- (a) Sketch C and show that $a = 2$. [3]

- (b) Find the exact value of the area of the region bounded by C , the initial line and the half-line $\theta = \frac{1}{6}\pi$. [4]

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.

- (c) Show that C has Cartesian equation $2(x + y\sqrt{3}) = (x\sqrt{3} - y)\sqrt{x^2 + y^2}$. [3]

6 Let t be a positive constant.

The line l_1 passes through the point with position vector $t\mathbf{i} + \mathbf{j}$ and is parallel to the vector $-2\mathbf{i} - \mathbf{j}$. The line l_2 passes through the point with position vector $\mathbf{j} + t\mathbf{k}$ and is parallel to the vector $-2\mathbf{j} + \mathbf{k}$.

It is given that the shortest distance between the lines l_1 and l_2 is $\sqrt{21}$.

(a) Find the value of t . [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.

The plane Π_1 contains l_1 and is parallel to l_2 .

(b) Write down an equation of Π_1 , giving your answer in the form $\mathbf{r} = \mathbf{a} + \lambda\mathbf{b} + \mu\mathbf{c}$. [1]

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The plane Π_2 has Cartesian equation $5x - 6y + 7z = 0$.

- (c) Find the acute angle between l_2 and Π_2 . [3]

[illegible]

- (d) Find the acute angle between Π_1 and Π_2 . [3]

This image shows a full page of white paper with horizontal dashed lines, typical of primary school handwriting practice 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.

7 The curve C has equation $y = \frac{x^2 + x + 9}{x + 1}$.

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

[3]

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(b) Find the coordinates of the stationary points on C .

[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 $y = \left| \frac{x^2 + x + 9}{x + 1} \right|$ and find the set of values of x for which $2|x^2 + x + 9| > 13|x + 1|$. [5]

This image shows a full page of white paper with horizontal dotted lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting or typing. There are no margins, text, or other markings on the page.

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