



CANDIDATE
NAME

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CENTRE
NUMBER

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9231/12

October/November 2020

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 [].

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- 1** The cubic equation $x^3 + bx^2 + cx + d = 0$, where b , c and d are constants, has roots α , β , γ . It is given that $\alpha\beta\gamma = -1$.

(a) State the value of d . [1]

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(b) Find a cubic equation, with coefficients in terms of b and c , whose roots are $\alpha + 1$, $\beta + 1$, $\gamma + 1$. [3]

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(c) Given also that $\gamma + 1 = -\alpha - 1$, deduce that $(c - 2b + 3)(b - 3) = b - c$. [4]

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- 2** Prove by mathematical induction that $7^{2n} - 1$ is divisible by 12 for every positive integer n . [5]

[illegible]

- 3 (a)** By simplifying $(x^n - \sqrt{x^{2n} + 1})(x^n + \sqrt{x^{2n} + 1})$, show that $\frac{1}{x^n - \sqrt{x^{2n} + 1}} = -x^n - \sqrt{x^{2n} + 1}$. [1]

$$\text{Let } u_n = x^{n+1} + \sqrt{x^{2n+2} + 1} + \frac{1}{x^n - \sqrt{x^{2n} + 1}}.$$

- (b)** Use the method of differences to find $\sum_{n=1}^N u_n$ in terms of N and x . [3]

- (c) Deduce the set of values of x for which the infinite series

$$u_1 + u_2 + u_3 + \dots$$

- is convergent and give the sum to infinity when this exists. [3]

4 The matrices **A** and **B** are given by

$$\mathbf{A} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \text{ and } \mathbf{B} = \begin{pmatrix} \frac{1}{2} & -\frac{1}{2}\sqrt{3} \\ \frac{1}{2}\sqrt{3} & \frac{1}{2} \end{pmatrix}.$$

- (a) Give full details of the geometrical transformation in the x - y plane represented by **A**. [1]

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- (b) Give full details of the geometrical transformation in the x - y plane represented by **B**. [2]

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The triangle DEF in the x - y plane is transformed by **AB** onto triangle PQR .

- (c) Show that the triangles DEF and PQR have the same area. [3]

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- (d) Find the matrix which transforms triangle PQR onto triangle DEF . [2]

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

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- 5** The curve C has polar equation $r = \ln(1 + \pi - \theta)$, for $0 \leq \theta \leq \pi$.

- (a) Sketch C and state the polar coordinates of the point of C furthest from the pole. [3]

- (b) Using the substitution $u = 1 + \pi - \theta$, or otherwise, show that the area of the region enclosed by C and the initial line is

$$\frac{1}{2}(1+\pi)\ln(1+\pi)(\ln(1+\pi)-2)+\pi. \quad [6]$$

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- (c) Show that, at the point of C furthest from the initial line,

$$(1 + \pi - \theta) \ln(1 + \pi - \theta) - \tan \theta = 0$$

and verify that this equation has a root between 1.2 and 1.3.

[5]

6 Let a be a positive constant.

(a) The curve C_1 has equation $y = \frac{x-a}{x-2a}$. [2]

Sketch C_1 .

The curve C_2 has equation $y = \left(\frac{x-a}{x-2a}\right)^2$. The curve C_3 has equation $y = \left|\frac{x-a}{x-2a}\right|$.

(b) (i) Find the coordinates of any stationary points of C_2 . [3]

[illegible]

- (ii) Find also the coordinates of any points of intersection of C_2 and C_3 . [3]

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- (c) Sketch C_2 and C_3 on a single diagram, clearly identifying each curve. Hence find the set of values of x for which $\left(\frac{x-a}{x-2a}\right)^2 \leq \left|\frac{x-a}{x-2a}\right|$. [5]

7 The points A, B, C have position vectors

$$-2\mathbf{i} + 2\mathbf{j} - \mathbf{k}, \quad -2\mathbf{i} + \mathbf{j} + 2\mathbf{k}, \quad -2\mathbf{j} + \mathbf{k},$$

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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- (b)** Find the acute angle between the planes OBC and ABC . [4]

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The point D has position vector $t\mathbf{i} - \mathbf{j}$.

(c) Given that the shortest distance between the lines AB and CD is $\sqrt{10}$, find the value of t . [6]

Additional Page

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