

PURE MATHEMATICS A-LEVEL PAPER 1

9.00 am–12.00 noon (3 hours)
This paper must be answered in English.

- This paper consists of Section A and Section B.
- Answer ALL questions in Section A, using the ALU(C1) answer book.
- Answer any FOUR questions in Section B, using the ALU(C2) answer book.

ALU-ALL-PURPOSE MATTERS 1-1

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4. Suppose $x + \sqrt{r}$ is a root of the cubic equation $x^3 + ax + b = 0$, where a , b , x are rational numbers and \sqrt{r} is not a rational number.

(a) Show that $x^2 + 3x^2 + ax + b = 0$ and $3x^2 + x + a = 0$.

(b) Using (a), or otherwise, show that

(i) $x - \sqrt{r}$ is also a root of the equation, and

$$(ii) x = \frac{3a - 3b}{2(3a + 4)} \text{ if } a \neq \frac{b}{3}.$$

(7 marks)

5. Let a , b and c be positive numbers.

(a) Using A.M. \geq G.M., show that $(1+a)(1+b)(1+c) \geq (1+\sqrt[3]{abc})^3$. Under what condition on a , b and c will the equality hold?

(b) Let J^3 be a 3×3 real matrix such that $J^3 \cdot PQ = \begin{pmatrix} a & 0 & 0 \\ 0 & b & 0 \\ 0 & 0 & c \end{pmatrix}$ for some 3×3 real matrix Q .

Using (a), show that $(\det(J + J^2))^{\frac{1}{3}} \geq 1 + (\det(J))^{\frac{1}{3}}$.

(7 marks)

SECTION A (40 marks)

Answer ALL questions in this section.

Write your answers in the ALU(C1) answer book.

- Let x_1, x_2, \dots, x_n be arbitrary complex numbers.
 - Prove that $x_1 \bar{x}_2 + x_2 \bar{x}_3 + \dots + x_n \bar{x}_1 = \bar{x}_1 x_2 + \bar{x}_2 x_3 + \dots$
 - Using (a), or otherwise, show that $(x_1)^2 + (x_2)^2 + \dots + (x_n)^2 \geq \text{Re}(x_1 x_1 + x_2 x_2 + \dots + x_n x_n + \bar{x}_1 x_1)$. (4 marks)
- Let $\{a_n\}$ be a sequence of real numbers, where $a_0 = 1$, $a_1 = 6$, $a_2 = 45$, and $a_n = a_{n-1} + \frac{1}{3}a_{n-2} - \frac{1}{27}a_{n-3} = 0$ for $n = 3, 4, 5, \dots$. Using mathematical induction, or otherwise, show that $a_n = 3^n(a^2 + 1)$ for $n = 0, 1, 2, \dots$. (6 marks)
- Suppose the system of linear equations

$$(*) : \begin{cases} 3x + 2y = 0 \\ -2x + y = 0 \\ x + 2y + z = 0 \end{cases}$$
 has non-trivial solutions.
 - Show that λ satisfies the equation $\lambda^3 + 3\lambda^2 - 8\lambda = 0$.
 - If the quadratic equation in λ in (a) has equal roots, find λ . Solve $(*)$ for each of these values of λ . (6 marks)

ALU-ALL-PURPOSE MATTERS 1-2

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- Let $\mathbf{a} = (1, 2, 3 - x, 3)$, $\mathbf{b} = (1, 1 - x, 2, 3)$ and $\mathbf{c} = (0, 0, 2 - x)$.
- Show that \mathbf{b} and \mathbf{c} are linearly independent for all real values of x .
- Show that there is only one real number x so that \mathbf{a} , \mathbf{b} and \mathbf{c} are linearly dependent.

(For this value of x , express \mathbf{a} as a linear combination of \mathbf{b} and \mathbf{c}). (3 marks)

- (a) Let A be a 3×3 non-singular matrix. Show that $\det(A^{-1} - \alpha I) = -\frac{\alpha^3}{\det A} \det(A - \alpha^{-1} I)$.
- Let $A = \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & -1 & 0 \end{pmatrix}$.
 - Show that A is a root of $\det(A - \alpha I) = 0$ and hence find the other roots in surd form.
 - Solve $\det(A^{-1} - \alpha I) = 0$. (7 marks)

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Felix Flügel

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