

PURE MATHEMATICS A-LEVEL PAPER I

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 AL(C1) answer book.
- Answer any FOUR questions in Section B, using the AL(C2) answer book.

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

- Show that $x^3 + 3x^2 + ax + b = 0$ and $3x^2 + x + a = 0$.
- Using (a), or otherwise, show that

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

$$(ii) \quad x = \frac{3a - 9b}{2(3a - 4)} \text{ if } a = \frac{4}{3}.$$

(7 marks)

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

- 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?

- Let P be a 3×3 real matrix such that $Q^{-1}PQ = \begin{pmatrix} a & 0 & 0 \\ 0 & b & 0 \\ 0 & 0 & c \end{pmatrix}$ for some 3×3 real matrix Q .

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

(7 marks)

SECTION A (40 marks)

Answer ALL questions in this section.

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

1. Let x_1, x_2, \dots, x_n be arbitrary complex numbers.

$$(a) \quad \text{Prove that } x_1 \overline{x_2} + x_2 \overline{x_1} \geq x_1 x_2 + \overline{x_1 x_2}.$$

$$(b) \quad \text{Using (a), or otherwise, show that } |x_1|^2 + |x_2|^2 + \dots + |x_n|^2 \geq \operatorname{Re}(x_1 x_2 + x_2 x_3 + \dots + x_{n-1} x_n + x_n x_1).$$

(4 marks)

2. Let $\{a_n\}$ be a sequence of real numbers, where

$$a_0 = 1, \quad a_1 = 6, \quad a_2 = 45 \quad \text{and}$$

$$a_n - a_{n-1} + \frac{1}{3}a_{n-2} - \frac{1}{27}a_{n-3} = 0 \quad \text{for } n = 0, 1, 2, \dots$$

Using mathematical induction, or otherwise, show that

$$a_n = 3^n(n^2 + 1) \quad \text{for } n = 0, 1, 2, \dots$$

(4 marks)

3. Suppose the system of linear equations

$$(*) : \begin{cases} 4x + 4y = 0 \\ -2y + z = 0 \\ x + 4y + z = 0 \end{cases}$$

has nontrivial solutions.

$$(a) \quad \text{Show that } \lambda \text{ satisfies the equation } \lambda^2 + k\lambda - k = 0.$$

$$(b) \quad \text{If the quadratic equation in } \lambda \text{ in (a) has equal roots, find } k. \\ \text{Solve } (*) \text{ for each of these values of } k.$$

(5 marks)

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6. Let $a = (2, 3-x, 1)$, $b = (1-x, 2, 3)$ and $c = (0, 4, 2-x)$.

- Show that b and c are linearly independent for all real values of x .
- Show that there is only one real number x so that a, b and c are linearly dependent.

For this value of x , express a as a linear combination of b and c .

(3 marks)

7. (a) Let A be a 3×3 non-singular matrix. Show that

$$\det(A^{-1} - xI) = -\frac{x^3}{\det A} \det(A - x^{-1}I).$$

$$(b) \quad \text{Let } A = \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 4 & -17 & 6 \end{pmatrix}.$$

(i) Show that 4 is a root of $\det(A - xI) = 0$ and hence find the other roots in surd form.

$$(ii) \quad \text{Solve } \det(A^{-1} - xI) = 0.$$

(7 marks)

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Felix Flügel



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