Please check the examination details below before entering your candidate information

| Candidate surname | Other names |
|---|---|
| Solved by Mr. Pabitra | |

Centre Number | Candidate Number

# Pearson Edexcel International Advanced Level

## Tuesday 14 January 2025

Afternoon (Time: 1 hour 30 minutes)

Paper reference **WFM01/01**

# Mathematics

## International Advanced Subsidiary/Advanced Level
## Further Pure Mathematics F1

**You must have:**
Mathematical Formulae and Statistical Tables (Yellow), calculator

Total Marks

**Candidates may use any calculator permitted by Pearson regulations. Calculators must not have the facility for symbolic algebra manipulation, differentiation and integration, or have retrievable mathematical formulae stored in them.**

## Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions and ensure that your answers to parts of questions are clearly labelled.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*
- You should show sufficient working to make your methods clear. Answers without working may not gain full credit.
- Inexact answers should be given to three significant figures unless otherwise stated.

## Information

- A booklet 'Mathematical Formulae and Statistical Tables' is provided.
- There are 9 questions in this question paper. The total mark for this paper is 75.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*

## Advice

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- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- If you change your mind about an answer, cross it out and put your new answer and any working underneath.

*Turn over* ▶

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P 7 6 1 9 2 A 0 1 3 2

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**1.** $\mathbf{P} = \begin{pmatrix} p-1 & p+1 \\ -3 & p \end{pmatrix}$ where $p$ is a constant

(a) Determine det **P** in simplest form in terms of $p$.

**(2)**

(b) Hence show that **P** is non-singular for all real values of $p$.

**(2)**

(c) Determine $\mathbf{P}^{-1}$ in terms of $p$.

**(2)**

(a) $\det P = (p-1)p - (p+1)(-3)$

$= p^2 - p + 3p + 3$

$\boxed{\det P = p^2 + 2p + 3}$

(b) $p^2 + 2p + 3 = (p+1)^2 + 2$

$(p+1)^2 \geq 0$ for all real $p$, so $\det P \geq 2 > 0$.

$\det P$ is never 0, so $P$ is non-singular for all real values of $p$.

(c) $P^{-1} = \frac{1}{\det P} \times \begin{pmatrix} p & -(p+1) \\ 3 & p-1 \end{pmatrix}$

$\boxed{P^{-1} = \frac{1}{p^2 + 2p + 3} \begin{pmatrix} p & -p-1 \\ 3 & p-1 \end{pmatrix}}$

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**Question 1 continued**

**(Total for Question 1 is 6 marks)**

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**2.** $$f(x) = x^2 - \frac{7x - 4\sqrt{x}}{x^3} \qquad x > 0$$

(a) Show that the equation $f(x) = 0$ has a root $\alpha$ in the interval [0.3, 0.4]

**(2)**

(b) Determine $f'(x)$.

**(3)**

(c) Using $x_0 = 0.3$ as a first approximation for $\alpha$, apply the Newton–Raphson procedure once to $f(x)$ to determine a second approximation for $\alpha$, giving your answer to 3 decimal places.

**(2)**

The equation $f(x) = 0$ has another root $\beta$ in the interval [1.3, 1.5]

(d) Use linear interpolation once on the interval [1.3, 1.5] to determine an approximation for $\beta$, giving your answer to 3 decimal places.

**(2)**

(a) $f(0.3) = 0.09 - \frac{7(0.3) - 4\sqrt{0.3}}{0.3^3} = 3.456... > 0$

$f(0.4) = 0.16 - \frac{7(0.4) - 4\sqrt{0.4}}{0.4^3} = -4.061... < 0$

There is a change of sign and $f(x)$ is continuous for $x > 0$,
so $f(x) = 0$ has a root $\alpha$ in the interval $[0.3, 0.4]$.

(b) $f(x) = x^2 - \frac{7x}{x^3} + \frac{4x^{1/2}}{x^3} = x^2 - 7x^{-2} + 4x^{-5/2}$

$f'(x) = 2x + 14x^{-3} - 10x^{-7/2}$

(c) $f'(0.3) = 2(0.3) + 14(0.3)^{-3} - 10(0.3)^{-3.5} = -157.082...$

$x_1 = 0.3 - \frac{f(0.3)}{f'(0.3)} = 0.3 - \frac{3.456...}{-157.082...} = 0.32200...$

$x_1 = 0.322$ (3 d.p.)

(d) $f(1.3) = -0.37613...$ $f(1.5) = 0.59043...$

$\frac{\beta - 1.3}{0.37613...} = \frac{1.5 - \beta}{0.59043...}$

$0.59043...(\beta - 1.3) = 0.37613...(1.5 - \beta)$

$\beta = \frac{1.3 \times 0.59043... + 1.5 \times 0.37613...}{0.59043... + 0.37613...} = 1.37782...$

$\beta = 1.378$ (3 d.p.)

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**Question 2 continued**

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**Question 2 continued**

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**Question 2 continued**

**(Total for Question 2 is 9 marks)**

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**3.** The quadratic equation

$$3x^2 - 2x + 5 = 0$$

has roots $\alpha$ and $\beta$

Without solving the equation,

(a) write down the value of $(\alpha + \beta)$ and the value of $\alpha\beta$

**(1)**

(b) determine the value of $\alpha^2 + \beta^2$

**(2)**

(c) determine a quadratic equation that has roots

$$\left(\alpha + \frac{1}{\alpha}\right) \text{ and } \left(\beta + \frac{1}{\beta}\right)$$

giving your answer in the form $px^2 + qx + r = 0$ where $p$, $q$ and $r$ are integers.

**(4)**

(a) $3x^2 - 2x + 5 = 0$: $\alpha + \beta = \frac{2}{3}$, $\alpha\beta = \frac{5}{3}$

(b) $\alpha^2 + \beta^2 = (\alpha + \beta)^2 - 2\alpha\beta = \frac{4}{9} - \frac{10}{3} = -\frac{26}{9}$

$$\boxed{\alpha^2 + \beta^2 = -\frac{26}{9}}$$

(c) Sum $= \alpha + \beta + \frac{1}{\alpha} + \frac{1}{\beta} = (\alpha + \beta) + \frac{\alpha + \beta}{\alpha\beta}$

$= \frac{2}{3} + \left(\frac{2}{3} \div \frac{5}{3}\right) = \frac{2}{3} + \frac{2}{5} = \frac{16}{15}$

Product $= (\alpha + \frac{1}{\alpha})(\beta + \frac{1}{\beta}) = \alpha\beta + \frac{\alpha}{\beta} + \frac{\beta}{\alpha} + \frac{1}{\alpha\beta}$

$= \alpha\beta + \frac{\alpha^2 + \beta^2}{\alpha\beta} + \frac{1}{\alpha\beta} = \frac{5}{3} + \left(-\frac{26}{9} \div \frac{5}{3}\right) + \frac{3}{5}$

$= \frac{5}{3} - \frac{26}{15} + \frac{3}{5} = \frac{25 - 26 + 9}{15} = \frac{8}{15}$

Equation: $x^2 - \frac{16}{15}x + \frac{8}{15} = 0$ $\quad (\times 15)$

$$\boxed{15x^2 - 16x + 8 = 0}$$

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**Question 3 continued**

**(Total for Question 3 is 7 marks)**

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**4.** $f(z) = 6z^3 + Az^2 + Bz + C$

where $A$, $B$ and $C$ are integers.

Given that $z = \frac{2}{3} + \frac{\sqrt{17}}{3}i$ is a root of the equation $f(z) = 0$

(a) write down the other complex root of the equation $f(z) = 0$

**(1)**

Given that $z = -\frac{3}{2}$ is also a root of the equation $f(z) = 0$

(b) determine the value of $A$, the value of $B$ and the value of $C$.

**(5)**

(c) Show all the roots of the equation $f(z) = 0$ on a single Argand diagram.

**(2)**

(a) Real coefficients, so the complex conjugate is also a root:

$$z = \frac{2}{3} - \frac{\sqrt{17}}{3}i$$

(b) Sum of complex roots $= \frac{4}{3}$, product $= (\frac{2}{3})^2 + (\frac{\sqrt{17}}{3})^2 = \frac{4}{9} + \frac{17}{9} = \frac{7}{3}$

Quadratic factor: $z^2 - \frac{4}{3}z + \frac{7}{3}$ or $3z^2 - 4z + 7$

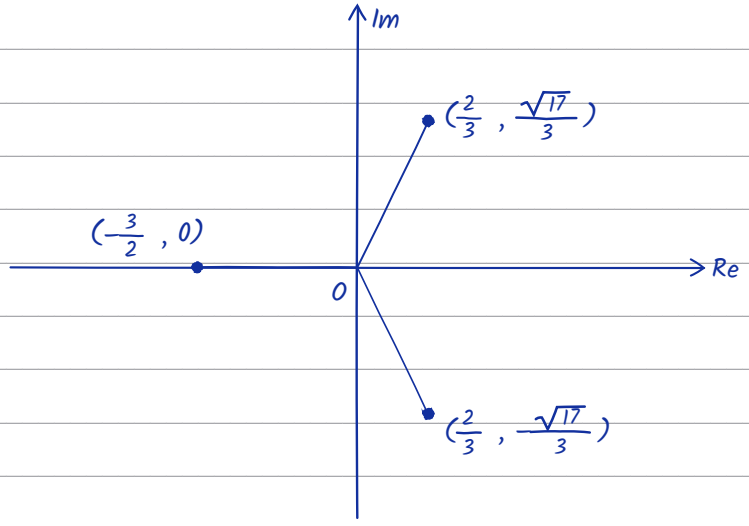
Real root $z = -\frac{3}{2}$ gives the factor $(2z + 3)$

$f(z) = (2z + 3)(3z^2 - 4z + 7)$

$= 6z^3 - 8z^2 + 14z + 9z^2 - 12z + 21 = 6z^3 + z^2 + 2z + 21$

$A = 1, \quad B = 2, \quad C = 21$

(c) Argand diagram




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**Question 4 continued**

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**Question 4 continued**

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**Question 4 continued**

**(Total for Question 4 is 8 marks)**

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**5.** (a) Use the standard results for summations to show that for all positive integers $n$

$$\sum_{r=1}^{n} r(r+1)(r+5) = \frac{1}{4}n(n+a)(n+b)(n+c)$$

where $a$, $b$ and $c$ are integers to be determined.

**(5)**

(b) Hence determine the value of

$$20 \times 21 \times 25 + 21 \times 22 \times 26 + \ldots + 40 \times 41 \times 45$$

**(2)**

(a) $r(r+1)(r+5) = r^3 + 6r^2 + 5r$

$\sum_{r=1}^{n}(r^3 + 6r^2 + 5r) = \frac{1}{4}n^2(n+1)^2 + 6 \times \frac{1}{6}n(n+1)(2n+1) + 5 \times \frac{1}{2}n(n+1)$

$= \frac{1}{4}n(n+1)[n(n+1) + 4(2n+1) + 10]$

$= \frac{1}{4}n(n+1)(n^2 + 9n + 14) = \frac{1}{4}n(n+1)(n+2)(n+7)$

$a = 1, \quad b = 2, \quad c = 7$ (any order)

(b) The sum is $\sum_{r=20}^{40} r(r+1)(r+5) = \sum_{r=1}^{40} - \sum_{r=1}^{19}$

$= \frac{1}{4} \times 40 \times 41 \times 42 \times 47 - \frac{1}{4} \times 19 \times 20 \times 21 \times 26$

$= 809\,340 - 51\,870$

$= 757\,470$

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**Question 5 continued**

**(Total for Question 5 is 7 marks)**

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**6.** The rectangular hyperbola $H$ has equation $xy = 100$

The point $P\left(10t, \frac{10}{t}\right)$, where $t \neq 0$, lies on $H$.

(a) Use calculus to show that the normal to $H$ at $P$ has equation

$$t^3x - ty = 10\left(t^4 - 1\right)$$

**(4)**

The normal to $H$ at $P$ meets the $y$-axis at the point $Q$.

Given that the area of triangle $OPQ$, where $O$ is the origin, is 750

(b) determine both possible pairs of coordinates of the point $P$.

**(5)**

(a) $y = \frac{100}{x}$, $\frac{dy}{dx} = -\frac{100}{x^2}$. At $x = 10t$: $\frac{dy}{dx} = \frac{100}{100t^2} = -\frac{1}{t^2}$

Gradient of normal $= t^2$

Normal: $y - \frac{10}{t} = t^2(x - 10t)$

Multiply by t: $ty - 10 = t^3x - 10t^4$

$t^3x - ty = 10t^4 - 10 = 10(t^4 - 1)$ as required

(b) At Q, $x = 0$: $-ty = 10(t^4 - 1)$, $y = \frac{10(t^4 - 1)}{t}$

Area of $OPQ = \frac{1}{2} \times OQ \times$ (x-coordinate of P) $= \frac{1}{2} \times \frac{10(t^4 - 1)}{t} \times 10t$

$= 50(t^4 - 1) = 750$

$t^4 - 1 = 15$, $t^4 = 16$, $t = \pm 2$

$t = 2$: $P = (20, 5)$ $t = -2$: $P = (-20, -5)$

$P = (20, 5)$ or $P = (-20, -5)$

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**Question 6 continued**

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**Question 6 continued**

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**7.** (i) $\mathbf{A} = \begin{pmatrix} -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{\sqrt{3}}{2} & -\frac{1}{2} \end{pmatrix}$

(a) Describe fully the single transformation represented by the matrix **A**.

**(2)**

The matrix **B** represents a stretch scale factor 2 parallel to the $x$-axis.

(b) Write down the matrix **B**.

**(1)**

The transformation represented by matrix **B** followed by the transformation represented by matrix **A** is the transformation represented by the matrix **C**.

(c) Determine **C**.

**(2)**

(ii) $\mathbf{M} = \begin{pmatrix} k & -2 \\ -1 & 2k \end{pmatrix}$ where $k$ is a constant

Given that the transformation represented by matrix **M** maps the point $(k, k)$ onto the point $(35, 91)$

(a) determine the value of $k$.

**(4)**

A quadrilateral $Q$ is transformed to another quadrilateral $Q'$ by the matrix **M**.

Given that $Q'$ has area 336

(b) use the value of $k$ found in part (ii)(a) to determine the area of $Q$.

**(2)**

(i)(a) $\cos\theta = -\frac{1}{2}$, $\sin\theta = -\frac{\sqrt{3}}{2}$ $\left(A = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}\right)$

$\theta = 240°$ so rotation of 240° anticlockwise (120° clockwise) about the origin

(i)(b)

$B = \begin{pmatrix} 2 & 0 \\ 0 & 1 \end{pmatrix}$

(i)(c) B followed by A: $C = AB$

$C = \begin{pmatrix} -1/2 & \sqrt{3}/2 \\ -\sqrt{3}/2 & -1/2 \end{pmatrix}\begin{pmatrix} 2 & 0 \\ 0 & 1 \end{pmatrix} = \begin{pmatrix} -1 & \sqrt{3}/2 \\ -\sqrt{3} & -1/2 \end{pmatrix}$

(ii)(a) $\begin{pmatrix} k & -2 \\ -1 & 2k \end{pmatrix}\begin{pmatrix} k \\ k \end{pmatrix} = \begin{pmatrix} k^2 - 2k \\ 2k^2 - k \end{pmatrix} = \begin{pmatrix} 35 \\ 91 \end{pmatrix}$

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**Question 7 continued**

$k^2 - 2k - 35 = 0$ $\quad (k - 7)(k + 5) = 0,$ $\quad k = 7$ or $k = -5$

$2k^2 - k - 91 = 0$ $\quad (2k + 13)(k - 7) = 0,$ $\quad k = 7$ or $k = -\frac{13}{2}$

$k = 7$ (the only value that works in both)

(ii)(b) $\det M = 7 \times 14 - (-2)(-1) = 98 - 2 = 96$

Area of $Q'$ $= |\det M| \times$ area of $Q$: $\quad$ area of $Q = \frac{336}{96} = 3.5$

Area of $Q = 3.5$

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**Question 7 continued**

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**Question 7 continued**

**(Total for Question 7 is 11 marks)**

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**8.** (i) Prove by induction that, for $n \in \mathbb{Z}^+$

$$\begin{pmatrix} -2 & 9 \\ -1 & 4 \end{pmatrix}^n = \begin{pmatrix} 1-3n & 9n \\ -n & 3n+1 \end{pmatrix}$$

**(5)**

(ii) A sequence of numbers is defined by

$$u_1 = 1 \qquad u_2 = 4$$

$$u_{n+2} = 6u_{n+1} - 9u_n \qquad n \geqslant 1$$

Prove by induction that, for $n \in \mathbb{Z}^+$

$$u_n = 3^{n-2}(n+2)$$

**(5)**

(i) $n = 1$: $RHS = \begin{pmatrix} 1-3 & 9 \\ -1 & 3+1 \end{pmatrix} = \begin{pmatrix} -2 & 9 \\ -1 & 4 \end{pmatrix} = LHS$, so true for $n = 1$

Assume true for $n = k$: $\begin{pmatrix} -2 & 9 \\ -1 & 4 \end{pmatrix}^k = \begin{pmatrix} 1-3k & 9k \\ -k & 3k+1 \end{pmatrix}$

Then $\begin{pmatrix} -2 & 9 \\ -1 & 4 \end{pmatrix}^{k+1} = \begin{pmatrix} 1-3k & 9k \\ -k & 3k+1 \end{pmatrix}\begin{pmatrix} -2 & 9 \\ -1 & 4 \end{pmatrix}$

$$= \begin{pmatrix} -2+6k-9k & 9-27k+36k \\ 2k-3k-1 & -9k+12k+4 \end{pmatrix} = \begin{pmatrix} -2-3k & 9+9k \\ -k-1 & 3k+4 \end{pmatrix}$$

$$= \begin{pmatrix} 1-3(k+1) & 9(k+1) \\ -(k+1) & 3(k+1)+1 \end{pmatrix}$$

which is the result with $n = k + 1$.

It is true for $n = 1$, and if it is true for $n = k$ then it is true for $n = k + 1$.

So by mathematical induction it is true for all positive integers $n$.

(ii) $n = 1$: $3^{-1}(1+2) = 1 = u_1$ $\qquad$ $n = 2$: $3^0(2+2) = 4 = u_2$

so it is true for $n = 1$ and $n = 2$

Assume true for $n = k$ and $n = k + 1$: $u_k = 3^{k-2}(k+2)$, $\quad u_{k+1} = 3^{k-1}(k+3)$

$u_{k+2} = 6u_{k+1} - 9u_k = 6 \times 3^{k-1}(k+3) - 9 \times 3^{k-2}(k+2)$

$= 2 \times 3^k(k+3) - 3^k(k+2) = 3^k(2k+6-k-2) = 3^k(k+4)$

$= 3^{(k+2)-2}((k+2)+2)$ $\qquad$ which is the result with $n = k + 2$.

It is true for $n = 1$ and $n = 2$, and if it is true for $n = k$ and $n = k + 1$

then it is true for $n = k + 2$. So by induction it is true for all positive integers $n$.

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**Question 8 continued**

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**Question 8 continued**

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**Question 8 continued**

**(Total for Question 8 is 10 marks)**

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**9.** The parabola $C$ has equation $y^2 = \frac{1}{2}x$

The point $P\left(\frac{t^2}{8}, \frac{t}{4}\right)$, where $t \neq 0$, lies on $C$.

(a) Use calculus to show that the tangent to $C$ at $P$ has equation

$$8yt - 8x = t^2$$

**(3)**

Given that

- the tangent to $C$ at $P$ meets the $y$-axis at the point $A$
- the line $l_1$ is the perpendicular bisector of the line segment $OA$ where $O$ is the origin
- the line $l_2$ is the perpendicular bisector of the line segment $AP$
- $l_1$ and $l_2$ intersect at the point $Q$

(b) show that, as $t$ varies, the coordinates of $Q$ satisfy the equation

$$y^2 = \alpha x + \beta$$

where $\alpha$ and $\beta$ are constants to be determined.

**(5)**

(a) $y^2 = \frac{1}{2}x$: $2y\frac{dy}{dx} = \frac{1}{2}$, $\frac{dy}{dx} = \frac{1}{4y}$

At P, $y = \frac{t}{4}$: $\frac{dy}{dx} = \frac{1}{t}$

Tangent: $y - \frac{t}{4} = \frac{1}{t}\left(x - \frac{t^2}{8}\right)$

Multiply by 8t: $8ty - 2t^2 = 8x - t^2$

$8yt - 8x = t^2$ as required

(b) At A, $x = 0$: $8yt = t^2$, $y = \frac{t}{8}$. $A = \left(0, \frac{t}{8}\right)$

$l_1$ is the perpendicular bisector of OA: $y = \frac{t}{16}$

Midpoint of AP $= \left(\frac{t^2}{16}, \left(\frac{t}{8} + \frac{t}{4}\right) \div 2\right) = \left(\frac{t^2}{16}, \frac{3t}{16}\right)$

AP is along the tangent (gradient $\frac{1}{t}$), so $l_2$ has gradient $-t$

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**Question 9 continued**

$l_2$: $y - \frac{3t}{16} = -t\left(x - \frac{t^2}{16}\right)$

At Q, $y = \frac{t}{16}$: $\frac{t}{16} - \frac{3t}{16} = -tx + \frac{t^3}{16}$

$-\frac{2}{16} = -x + \frac{t^2}{16}$ so $x = \frac{2 + t^2}{16}$

At Q, $t = 16y$: $x = \frac{2 + 256y^2}{16}$ so $16x = 2 + 256y^2$

$y^2 = \frac{16x - 2}{256} = \frac{1}{16}x - \frac{1}{128}$

$$y^2 = \frac{1}{16}x - \frac{1}{128}, \quad \alpha = \frac{1}{16}, \quad \beta = -\frac{1}{128}$$

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**Question 9 continued**

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**Question 9 continued**

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**Question 9 continued**

**(Total for Question 9 is 8 marks)**

**TOTAL FOR PAPER IS 75 MARKS**

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