

Please check the examination details below before entering your candidate information

Candidate surname					Other names				
Centre Number				Candidate Number					

Pearson Edexcel Level 3 GCE

Monday 15 May 2023

Afternoon (Time: 1 hour 40 minutes) **Paper reference** **8FM0/01**

Further Mathematics
Advanced Subsidiary
PAPER 1: Core Pure Mathematics

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

Total Marks

Candidates may use any calculator allowed 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 10 questions in this question paper. The total mark for this paper is 80.
- 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

- 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.

Turn over ►

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1.

$$\begin{pmatrix} x & 9 \\ y & z \end{pmatrix} - 3 \begin{pmatrix} z & y \\ z & y \end{pmatrix} = k\mathbf{I}$$

where x , y , z and k are constants.

Determine the value of x , the value of y and the value of z .

(4)

$$\begin{pmatrix} x-3z & 9-3y \\ y-3z & z-3y \end{pmatrix} = \begin{pmatrix} k & 0 \\ 0 & k \end{pmatrix}$$

Top right element: $9-3y=0$
 $y=3$ ①

Bottom left element: $y-3z=0$
 $3-3z=0$
 $z=\frac{3}{3}=1$ ①

Top left element: $x-3z=k$
 Bottom right element: $z-3y=k$

$$\begin{aligned} x-3z &= z-3y & \text{①} \\ x &= 4z-3y \\ &= 4(1)-3(3) \\ &= -5 & \text{①} \end{aligned}$$



Question 1 continued

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(Total for Question 1 is 4 marks)



2. $f(z) = z^3 + az^2 + bz + 175$ where a and b are real constants

Given that $-3 + 4i$ is a root of the equation $f(z) = 0$

- (a) determine the value of a and the value of b . (4)
- (b) Show all the roots of the equation $f(z) = 0$ on a single Argand diagram. (2)
- (c) Write down the roots of the equation $f(z + 2) = 0$ (1)

a) let $\alpha = -3 + 4i$ $\alpha + \beta = -6$
 $\beta = -3 - 4i$ $\alpha\beta = 25$

$$\therefore f(z) = (z^2 + 6z + 25)(z - \gamma) = z^3 + az^2 + bz + 175$$

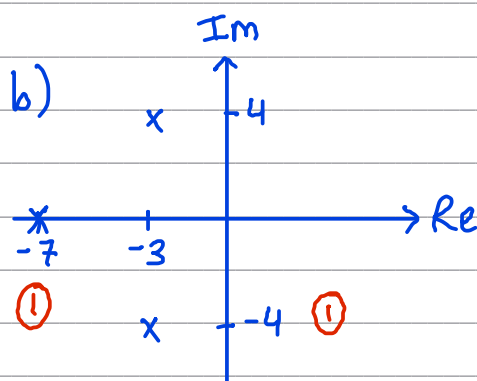
comparing constant: $-25\gamma = 175$
 $\gamma = -7$

$$\therefore f(z) = (z^2 + 6z + 25)(z + 7) = z^3 + az^2 + bz + 175$$

$$z^3 + 7z^2 + 6z^2 + 42z + 25z + 175 = z^3 + az^2 + bz + 175$$

$$z^3 + 13z^2 + 67z + 175 = z^3 + az^2 + bz + 175$$

$$a = 13 \quad b = 67$$



c) roots of $f(z + 2) = 0$: subtract 2 from roots of $f(z) = 0$

$$-5 \pm 4i, -9$$



3.

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

- (a) Describe fully the single geometric transformation A represented by the matrix A . (2)

$$\mathbf{B} = \begin{pmatrix} 1 & 3 & 0 \\ \sqrt{3} & 0 & 5\sqrt{3} \\ 1 & 2 & 0 \end{pmatrix}$$

The transformation B is represented by the matrix B .

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

To determine matrix C , a student attempts the following matrix multiplication.

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & \frac{\sqrt{3}}{2} & -\frac{1}{2} \\ 0 & \frac{1}{2} & \frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} 1 & 3 & 0 \\ \sqrt{3} & 0 & 5\sqrt{3} \\ 1 & 2 & 0 \end{pmatrix}$$

- (b) State the error made by the student. (1)
- (c) Determine the correct matrix C . (1)

a) Matrix for rotation θ degrees anticlockwise about x -axis:

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{pmatrix} \quad \cos\theta = \frac{\sqrt{3}}{2} \quad \sin\theta = \frac{1}{2}$$

$$\theta = \frac{\pi}{6}, \frac{11\pi}{6} \quad \theta = \frac{\pi}{6}, \frac{5\pi}{6}$$

Rotation of $\frac{\pi}{6}$ degrees anticlockwise about the x -axis (1)



Question 3 continued

b) They have found AB when they should find BA (1)

c)

$$\begin{pmatrix} 1 & 3 & 0 \\ \sqrt{3} & 0 & 5\sqrt{3} \\ 1 & 2 & 0 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \frac{\sqrt{3}}{2} & -\frac{1}{2} \\ 0 & \frac{1}{2} & \frac{\sqrt{3}}{2} \end{pmatrix} = \begin{pmatrix} 1 & \frac{3\sqrt{3}}{2} & -\frac{3}{2} \\ \sqrt{3} & \frac{5\sqrt{3}}{2} & \frac{15}{2} \\ 1 & \sqrt{3} & -1 \end{pmatrix} \quad (1)$$

(Total for Question 3 is 4 marks)



4. (i) (a) Show that

$$\frac{2+3i}{5+i} = k(1+i)$$

where k is a constant to be determined.

(Solutions relying on calculator technology are not acceptable.)

(3)

Given that

- n is a positive integer
- $\left(\frac{2+3i}{5+i}\right)^n$ is a real number

(b) use the answer to part (a) to write down the smallest possible value of n .

(1)

(ii) The complex number $z = a + bi$ where a and b are real constants.

Given that

- $|z^{10}| = 59049$
- $\arg(z^{10}) = -\frac{5\pi}{3}$

determine the value of a and the value of b .

(4)

$$(i) \ a) \ \frac{2+3i}{5+i} \times \frac{5-i}{5-i} = \frac{10-2i+15i+3}{25+1} = \frac{13+13i}{26} \quad (1)$$

$$= \frac{1}{2}(1+i) \quad (1)$$

$$b) \ k^n(1+i)^n \text{ is a real number}$$

$$(1+i)^2 = 2i$$

$$(1+i)^3 = -2+2i$$

$$(1+i)^4 = -4$$

$$\therefore n = 4 \quad (1)$$

$$(ii) \ |z^{10}| = 59049 \Rightarrow |z|^{10} = 59049$$

$$|z| = 3 \quad (1)$$



Question 4 continued

$$\arg(z^{10}) = \arg(\underbrace{z \times z \times \dots \times z}_{10 \text{ times}}) = 10 \arg(z)$$

$$10 \arg(z) = -\frac{5\pi}{3}$$

$$\arg(z) = -\frac{\pi}{6} \text{ (1)}$$

$$z = 3 \left(\cos\left(-\frac{\pi}{6}\right) + i \sin\left(-\frac{\pi}{6}\right) \right) \text{ (1)}$$

$$= \frac{3\sqrt{3}}{2} - \frac{3}{2}i \text{ (1)}$$

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Question 4 continued

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(Total for Question 4 is 8 marks)



5.

In this question you must show all stages of your working.

Solutions relying on calculator technology are not acceptable.

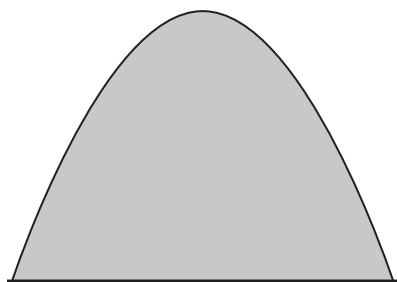


Figure 1

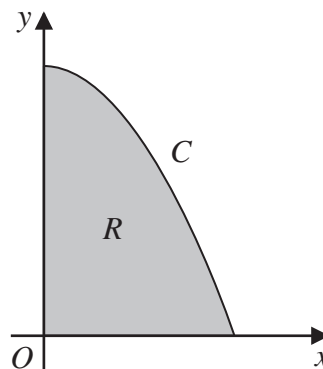


Figure 2

A large pile of concrete waste is created on a building site.

Figure 1 shows a central vertical cross-section of the concrete waste.

The curve C , shown in Figure 2, has equation

$$y + x^2 = 2 \quad 0 \leq x \leq \sqrt{2}$$

The region R , shown shaded in Figure 2, is bounded by the y -axis, the x -axis and the curve C .

The volume of concrete waste is modelled by the volume of revolution formed when R is rotated through 360° about the y -axis. The units are metres.

The density of the concrete waste is 900 kg m^{-3}

- (a) Use the model to estimate the mass of the concrete waste. Give your answer to 2 significant figures. (6)
- (b) Give a limitation of the model. (1)

The mass of the concrete waste is approximately 5500 kg.

- (c) Use this information and your answer to part (a) to evaluate the model, giving a reason for your answer. (1)

a) mass = density \times volume

$$\text{Volume} = \pi \int_{\alpha}^{\beta} x^2 dy = \pi \int_0^2 (2-y) dy \quad \textcircled{1}$$

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Question 5 continued

$$= \pi \left[2y - \frac{1}{2}y^2 \right]_0^2 \quad (1)$$

$$= \pi \left(2(2) - \frac{1}{2}(2)^2 - 0 \right) \quad (1)$$

$$= 2\pi$$

$$\therefore \text{mass} = 900 \text{ kg m}^{-3} \times 2\pi \text{ m}^3 = 5700 \text{ kg (2sf)} \quad (1)$$

b) The surface will not be perfectly smooth (1)

c) There is a 200kg difference so it is not a very good model (1)

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Question 5 continued

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Question 5 continued

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(Total for Question 5 is 8 marks)



6. The line l_1 has equation $\mathbf{r} = \begin{pmatrix} -2 \\ 2 \\ 0 \end{pmatrix} + \lambda \begin{pmatrix} 3 \\ 0 \\ 1 \end{pmatrix}$ where λ is a scalar parameter.

The line l_2 is parallel to $\begin{pmatrix} 1 \\ 2 \\ -3 \end{pmatrix}$

(a) Show that l_1 and l_2 are perpendicular.

(2)

The plane Π contains the line l_1 and is perpendicular to $\begin{pmatrix} 1 \\ 2 \\ -3 \end{pmatrix}$

(b) Determine a Cartesian equation of Π

(2)

(c) Verify that the point $A(3, 1, 1)$ lies on Π

(1)

Given that

- the point of intersection of Π and l_2 has coordinates $(2, 3, 2)$
- the point $B(p, q, r)$ lies on l_2
- the distance AB is $2\sqrt{5}$
- p, q and r are positive integers

(d) determine the coordinates of B .

(6)

a) $\begin{pmatrix} 3 \\ 0 \\ 1 \end{pmatrix} \cdot \begin{pmatrix} 1 \\ 2 \\ -3 \end{pmatrix} = 3 + 0 - 3 = 0$ so the lines are perpendicular

b) using $\mathbf{r} \cdot \mathbf{n} = \mathbf{a} \cdot \mathbf{n}$ \mathbf{a} is a point on the plane

$$\mathbf{r} \cdot \begin{pmatrix} 1 \\ 2 \\ -3 \end{pmatrix} = \begin{pmatrix} -2 \\ 2 \\ 0 \end{pmatrix} \cdot \begin{pmatrix} 1 \\ 2 \\ -3 \end{pmatrix} = -2 + 4 + 0$$

$$x + 2y - 3z = 2$$



Question 6 continued

c) $3 + 2(1) - 3(1) = 2$ ✓ so A lies on the plane ①

d) equation of l_2 : $\underline{r} = \begin{pmatrix} 2 \\ 3 \\ 2 \end{pmatrix} + \mu \begin{pmatrix} 1 \\ 2 \\ -3 \end{pmatrix}$ a point on the line

B(p, q, r) lies on l_2 : $\begin{pmatrix} p \\ q \\ r \end{pmatrix} = \begin{pmatrix} 2 \\ 3 \\ 2 \end{pmatrix} + \mu \begin{pmatrix} 1 \\ 2 \\ -3 \end{pmatrix}$ ①

$$\begin{aligned} \therefore p &= 2 + \mu \\ q &= 3 + 2\mu \\ r &= 2 - 3\mu \end{aligned}$$

Distance AB is $2\sqrt{5}$

$$AB = \begin{pmatrix} p \\ q \\ r \end{pmatrix} - \begin{pmatrix} 3 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} p-3 \\ q-1 \\ r-1 \end{pmatrix}$$

$$(p-3)^2 + (q-1)^2 + (r-1)^2 = (2\sqrt{5})^2 \quad \text{get in terms of } \mu$$

$$((2+\mu)-3)^2 + ((3+2\mu)-1)^2 + ((2-3\mu)-1)^2 = 20$$

$$(-1+\mu)^2 + (2+2\mu)^2 + (1-3\mu)^2 = 20 \quad \text{①}$$

$$1 - 2\mu + \mu^2 + 4 + 8\mu + 4\mu^2 + 1 - 6\mu + 9\mu^2 - 20 = 0$$

$$14\mu^2 - 14 = 0 \quad \text{①} \Rightarrow \mu = \pm 1 \quad \text{①}$$

using $\mu = 1$:

$$B = \begin{pmatrix} 3 \\ 5 \\ -1 \end{pmatrix} \quad \times \text{ r is not positive}$$

using $\mu = -1$: ①

$$B = \begin{pmatrix} 2-1 \\ 3+2(-1) \\ 2-3(-1) \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 5 \end{pmatrix} \quad \checkmark \quad \text{①}$$



Question 6 continued

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Question 6 continued

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(Total for Question 6 is 11 marks)



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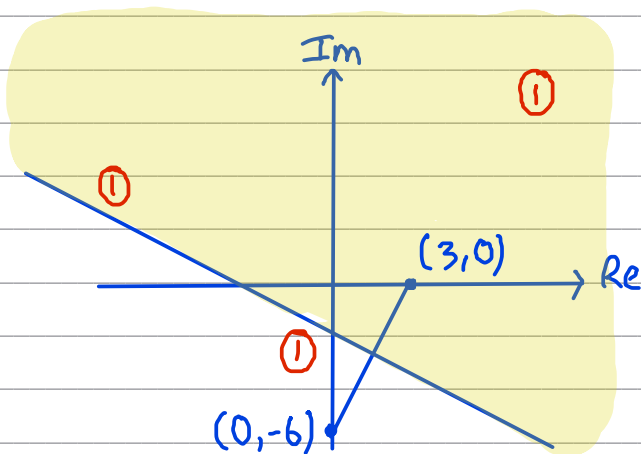
7. (i) Shade, on an Argand diagram, the set of points for which

$$|z - 3| \leq |z + 6i| \quad (3)$$

- (ii) Determine the exact complex number w which satisfies both

$$\arg(w - 2) = \frac{\pi}{3} \quad \text{and} \quad \arg(w + 1) = \frac{\pi}{6} \quad (6)$$

- (i) perpendicular bisector of $(3, 0)$ and $(0, -6)$



$$(ii) \arg(w - (2 + 0i)) = \frac{\pi}{3} \quad \arg(w - (-1 + 0i)) = \frac{\pi}{6}$$

$$\frac{y-0}{x-2} = \tan \frac{\pi}{3} \quad (1)$$

$$\frac{y-0}{x+1} = \tan \frac{\pi}{6}$$

$$\arg(w - (a + bi)) = \theta \Rightarrow \frac{y-b}{x-a} = \tan \theta$$

$$y = \sqrt{3}(x-2) \quad (1)$$

$$y = \frac{1}{\sqrt{3}}(x+1) \quad (1)$$

set equal:

$$\sqrt{3}(x-2) = \frac{1}{\sqrt{3}}(x+1) \Rightarrow 3(x-2) = x+1$$

$$3x - 6 = x + 1$$

$$2x = 7$$

$$x = \frac{7}{2} \quad (1)$$



Question 7 continued

$$y = \sqrt{3} \left(\frac{7}{2} - 2 \right) = \frac{3\sqrt{3}}{2} \quad (1)$$

$$w = \frac{7}{2} + \frac{3\sqrt{3}}{2}i \quad (1)$$

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P 7 2 8 0 6 A 0 2 3 3 6

Question 7 continued

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Question 7 continued

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(Total for Question 7 is 9 marks)



8. (a) Use the standard results for $\sum_{r=1}^n r^2$ and $\sum_{r=1}^n r$ to show that, for all positive integers n ,

$$\sum_{r=1}^n (2r-1)^2 = \frac{n}{3}(an^2 - 1)$$

where a is a constant to be determined.

(5)

- (b) Hence determine the sum of the squares of all positive odd three-digit integers.

(3)

a) $(2r-1)^2 = 4r^2 - 4r + 1$ ①

$$\sum_{r=1}^n (2r-1)^2 = 4 \sum_{r=1}^n r^2 - 4 \sum_{r=1}^n r + \sum_{r=1}^n 1$$
 ①

$$= \frac{4n}{6}(n+1)(2n+1) - \frac{4n}{2}(n+1) + n$$
 ①

$$= \frac{n}{3} [2(n+1)(2n+1) - 6(n+1) + 3]$$
 ①

$$= \frac{n}{3} [2(2n^2 + 3n + 1) - 6n - 6 + 3]$$

$$= \frac{n}{3} [4n^2 + 6n + 2 - 6n - 6 + 3]$$

$$= \frac{n}{3} (4n^2 - 1)$$
 ①

- b) first 3-digit odd number: 101 $2r-1 = 101 \Rightarrow r = 51$
 last 3-digit odd number: 999 $2r-1 = 999 \Rightarrow r = 500$

$$\sum_{r=51}^{500} (2r-1)^2 = \sum_{r=1}^{500} (2r-1)^2 - \sum_{r=1}^{50} (2r-1)^2$$
 ①

$$= \frac{500}{3} (4(500)^2 - 1) - \frac{50}{3} (4(50)^2 - 1)$$
 ①

$$= 166,499,850$$
 ①



Question 8 continued

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(Total for Question 8 is 8 marks)



9. (i)
$$\mathbf{P} = \begin{pmatrix} k & -2 & 7 \\ -3 & -5 & 2 \\ k & k & 4 \end{pmatrix} \quad \text{where } k \text{ is a constant}$$

Show that \mathbf{P} is non-singular for all real values of k .

(4)

(ii)
$$\mathbf{Q} = \begin{pmatrix} 2 & -1 \\ -3 & 0 \end{pmatrix}$$

The matrix \mathbf{Q} represents a linear transformation T

Under T , the point $A(a, 2)$ and the point $B(4, -a)$, where a is a constant, are transformed to the points A' and B' respectively.

Given that the distance $A'B'$ is $\sqrt{58}$, determine the possible values of a .

(5)

$$(i) \det P = k \begin{vmatrix} -5 & 2 \\ k & 4 \end{vmatrix} + 2 \begin{vmatrix} -3 & 2 \\ k & 4 \end{vmatrix} + 7 \begin{vmatrix} -3 & -5 \\ k & k \end{vmatrix}$$

$$= k(-20 - 2k) + 2(-12 - 2k) + 7(-3k + 5k) \quad (1)$$

$$= -20k - 2k^2 - 24 - 4k - 21k + 35k$$

$$= -2k^2 - 10k - 24 \quad (1)$$

If P is singular, $\det P = 0 \Rightarrow -2k^2 - 10k - 24 = 0$

considering determinant: $(-10)^2 - 4(-2)(-24) = -92 < 0 \quad (1)$
 \therefore no real roots so P is non-singular (1)

(ii) finding transformed coordinates:

$$\begin{pmatrix} 2 & -1 \\ -3 & 0 \end{pmatrix} \begin{pmatrix} a & 4 \\ 2 & -a \end{pmatrix} = \begin{pmatrix} 2a-2 & 8+a \\ -3a & -12 \end{pmatrix} \quad (1)$$

$$\Rightarrow A' = \begin{pmatrix} 2a-2 \\ -3a \end{pmatrix} \quad B' = \begin{pmatrix} 8+a \\ -12 \end{pmatrix}$$

Distance $A'B' = \sqrt{58}$

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Question 9 continued

$$((8+a) - (2a-2))^2 + ((-12) - (-3a))^2 = 58 \quad \textcircled{1}$$

$$(10-a)^2 + (3a-12)^2 = 58$$

$$100 - 20a + a^2 + 9a^2 - 72a + 144 - 58 = 0$$

$$10a^2 - 92a + 186 = 0 \quad \textcircled{1}$$

$$a = 3 \text{ or } a = 6.2 \quad \textcircled{1}$$

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Question 9 continued

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(Total for Question 9 is 9 marks)



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10. In this question you must show all stages of your working.

Solutions relying on calculator technology are not acceptable.

(i) The quartic equation

$$z^4 + 5z^2 - 30 = 0$$

has roots p, q, r and s .

Without solving the equation, determine the quartic equation whose roots are

$$(3p - 1), (3q - 1), (3r - 1) \text{ and } (3s - 1)$$

Give your answer in the form $w^4 + aw^3 + bw^2 + cw + d = 0$, where a, b, c and d are integers to be found.

(5)

(ii) The roots of the cubic equation

$$4x^3 + nx + 81 = 0 \quad \text{where } n \text{ is a real constant}$$

are $\alpha, 2\alpha$ and $\alpha - \beta$

Determine

(a) the values of the roots of the equation,

(5)

(b) the value of n .

(2)

$$(i) \quad w = 3z - 1 \Rightarrow z = \frac{w + 1}{3} \quad (1)$$

$$\left(\frac{w + 1}{3}\right)^4 + 5\left(\frac{w + 1}{3}\right)^2 - 30 = 0 \quad (1)$$

$$\frac{1}{81}(w^4 + 4w^3 + 6w^2 + 4w + 1) + \frac{5}{9}(w^2 + 2w + 1) - 30 = 0 \quad (1)$$

$$(w^4 + 4w^3 + 6w^2 + 4w + 1) + 45(w^2 + 2w + 1) - 2430 = 0$$

$$w^4 + 4w^3 + 51w^2 + 94w - 2384 = 0$$

(1) (1)

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Question 10 continued

$$(ii) a) \alpha + 2\alpha + \alpha - \beta = \frac{-b}{a} = 0 \Rightarrow 4\alpha - \beta = 0$$

$$\beta = 4\alpha$$

$$\alpha(2\alpha)(\alpha - \beta) = \frac{-d}{a} = \frac{-81}{4} = -20.25$$

$$\text{sub } \beta = 4\alpha \text{ into } 2\alpha^2(\alpha - \beta) = -20.25$$

$$2\alpha^2(-3\alpha) = -20.25$$

$$6\alpha^3 = 20.25$$

$$\alpha = 1.5 \Rightarrow \beta = 6$$

$$\text{roots are } 1.5, 3, -4.5$$

$$b) \text{ pair sum: } 1.5(3) - 1.5(4.5) - 3(1.5) = \frac{n}{4}$$

$$n = -63$$



