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

Pearson

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)

$$\begin{bmatrix} x & 9 \\ y & z \end{bmatrix} - 3\begin{bmatrix} z & y \\ z & y \end{bmatrix} = k\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

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

$\therefore x - 3z = k$

$\therefore 9 - 3y = 0$

$\therefore y - 3z = 0$

$\therefore z - 3y = k$

$\therefore y = 3$

$\therefore z = 1$

$\therefore k = -8$

$\therefore x = -5$

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Question 1 continued

(Total for Question 1 is 4 marks)

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

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

(a) determine the value of a and the value of b.

(4)

(b) Show all the roots of the equation $\mathrm{f}(z) = 0$ on a single Argand diagram.

(2)

(c) Write down the roots of the equation $\mathrm{f}(z + 2) = 0$

(1)

(a) IF $z_1 = -3 + 4i$, THEN $z_2 = -3 - 4i$

QUADRATIC FACTOR IS $[z - (-3 + 4i)][z - (-3 - 4i)]$

$\equiv [(z + 3) - 4i][(z + 3) + 4i]$

$\equiv (z + 3)^2 + 16$

$\equiv z^2 + 6z + 25$

$\therefore [z^2 + 6z + 25][z + \alpha] \equiv z^3 + az^2 + bz + 175$

$\therefore 25\alpha = 175$

$\therefore \alpha = 7$

$\therefore [z^2 + 6z + 25][z + 7] \equiv z^3 + az^2 + bz + 175$

$\therefore a = 13, \ b = 67$

$\therefore f(z) = z^3 + 13z^2 + 67z + 175$

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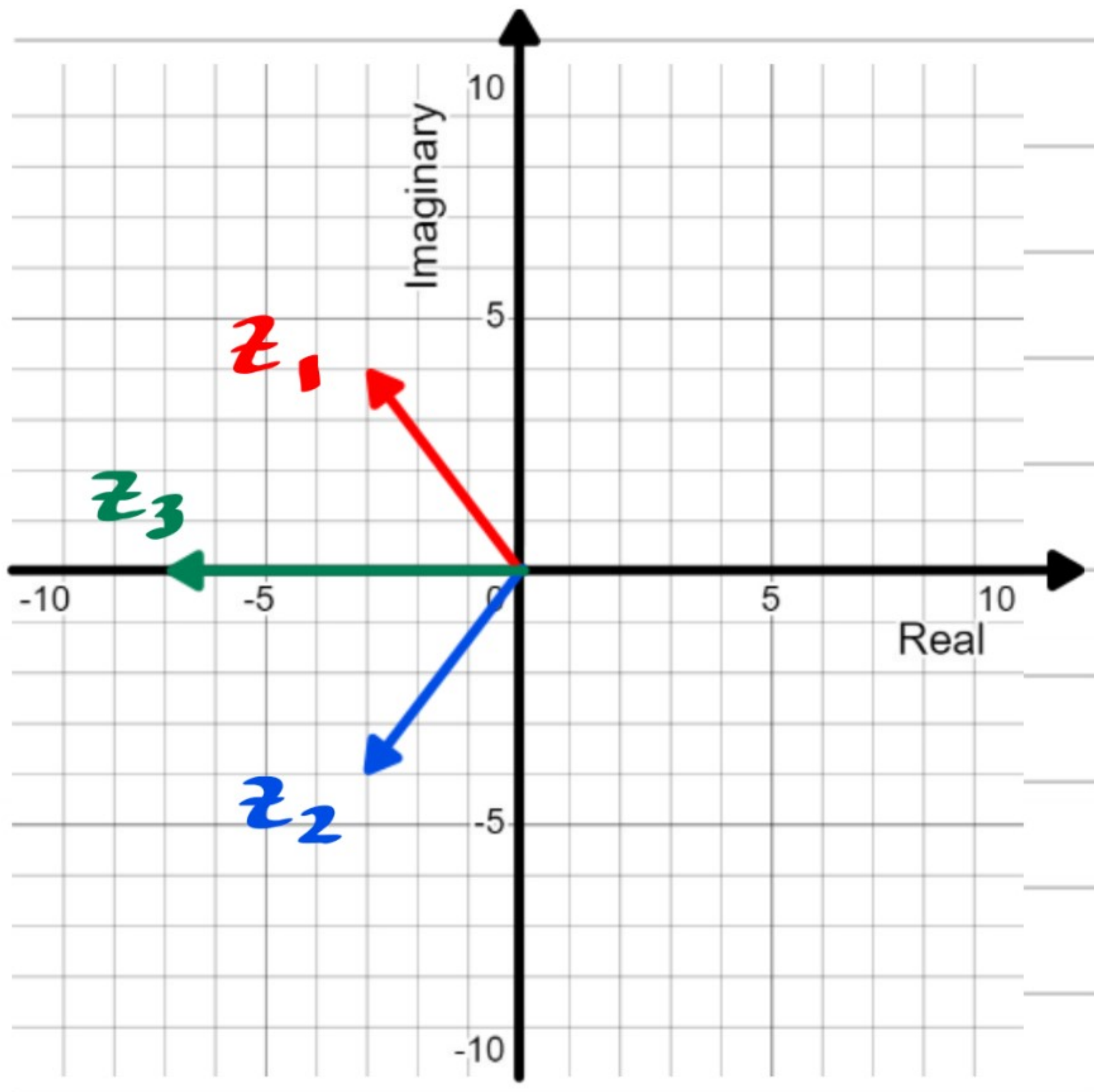
Question 2 continued

(b) $f(z)=0$ HAS ROOTS $z_1=-3+4i$, $z_2=-3-4i$, $z_3=-7$



(c) $f(z) \rightarrow f(z+2)$ IS A TRANSLATION BY $\begin{pmatrix}-2\\0\end{pmatrix}$

$\therefore f(z+2)=0$ HAS ROOTS $z=-5\pm4i, -9$

Question 2 continued

Question 2 continued

(Total for Question 2 is 7 marks)

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 $\mathbf{A}$.

(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 $\mathbf{B}$.
The transformation A followed by the transformation B is the transformation C, which is represented by the matrix $\mathbf{C}$.

To determine matrix $\mathbf{C}$, a student attempts the following matrix multiplication.

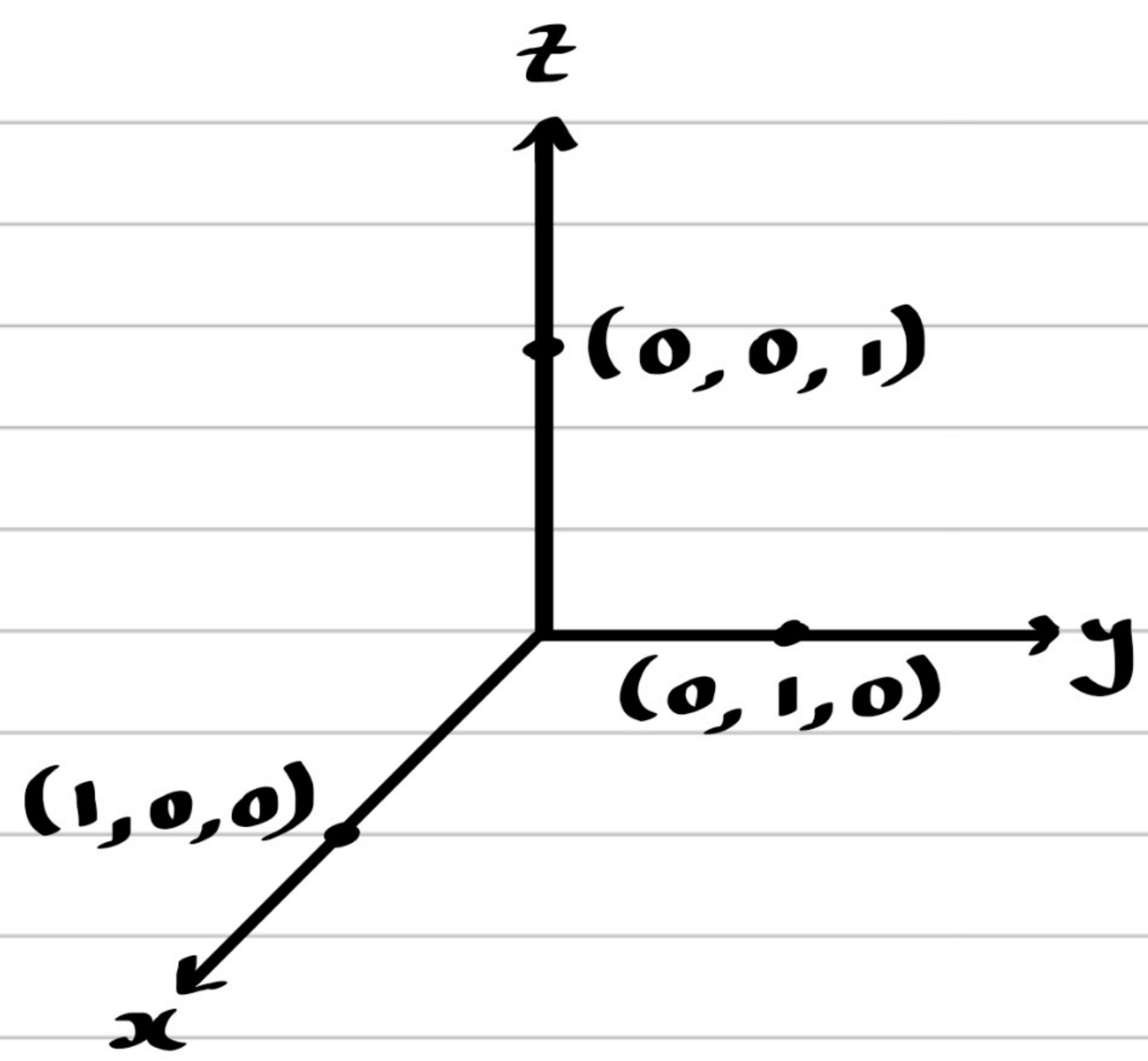
$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & \frac{\sqrt{3}}{2} & -\frac{1}{2} \\ 0 & \frac{1}{2} & \frac{\sqrt{3}}{2} \end{pmatrix}\begin{pmatrix} 1 & 3 & 0 \\ \sqrt{3} & 0 & 5\sqrt{3} \\ 1 & 2 & 0 \end{pmatrix}$$

(b) State the error made by the student.

(1)

(c) Determine the correct matrix $\mathbf{C}$.

(1)



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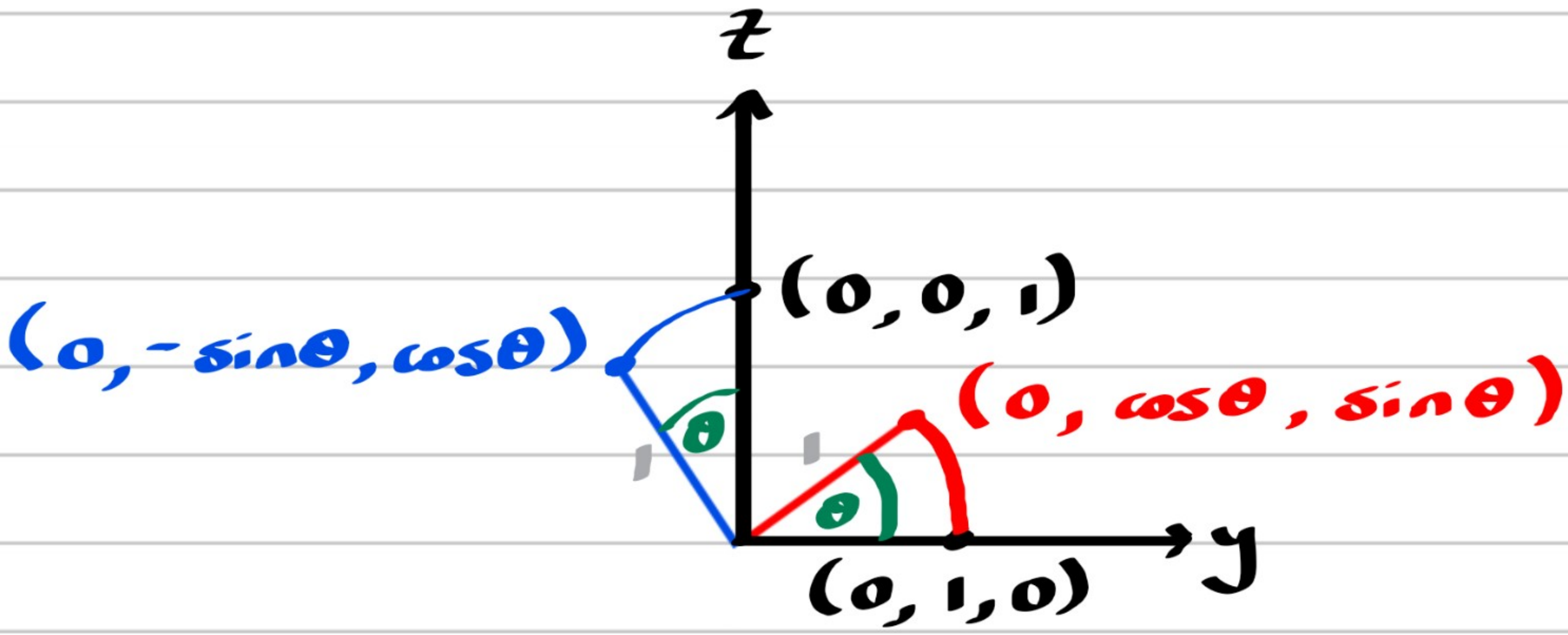
Question 3 continued



∴ ROTATION ABOUT x - AXIS BY θ IS $\begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$

∴ TRANSFORMATION A IS A ROTATION BY 30° IN x - DIR

(b) THE TRANSFORMATIONS ARE BEING MULTIPLIED IN THE WRONG ORDER

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

(Total for Question 3 is 4 marks)

4. (i) (a) Show that

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

where k is a constant to be determined.

(*Solutions relying on calculator technology are not acceptable.*)

(3)

Given that

- n is a positive integer
- $\left(\frac{2 + 3\text{i}}{5 + \text{i}}\right)^n$ 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 $z = a + b\text{i}$ where a and b are real constants.

Given that

- $|z^{10}| = 59\,049$
- $\arg(z^{10}) = -\frac{5\pi}{3}$

determine the value of a and the value of b.

(4)

(i)(a) $\frac{2+3i}{5+i} = \frac{2+3i}{5+i} \times \frac{5-i}{5-i}$

$= \frac{10 - 2i + 15i + 3}{25 + 1}$

$= \frac{13 + 13i}{26}$

$= \frac{1+i}{2}$

$\therefore k = \frac{1}{2}$

(b) $\left[\frac{2+3i}{5+i}\right]^4 = \frac{1}{4}$

Question 4 continued

$\therefore n = 4$

(ii) IF $z = a + bi$, THEN $z^{10} = (a+bi)^{10}$

$= [r(\cos\theta + i\sin\theta)]^{10}$

$= r^{10}(\cos 10\theta + i\sin 10\theta)$

AS $\arg(z^{10}) = -\frac{5\pi}{3}$ $\therefore 10\theta = -\frac{5\pi}{3}$ $\therefore \theta = -\frac{\pi}{6}$

AS $|z^{10}| = 59049$ $\therefore r = |z| = 59049^{\frac{1}{10}} = 3$

$\therefore z = 3\left[\cos\left(-\frac{\pi}{6}\right) + i\sin\left(-\frac{\pi}{6}\right)\right]$

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

$\therefore a = \frac{3\sqrt{3}}{2}, \; b = -\frac{3}{2}$

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Question 4 continued

Question 4 continued

(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.

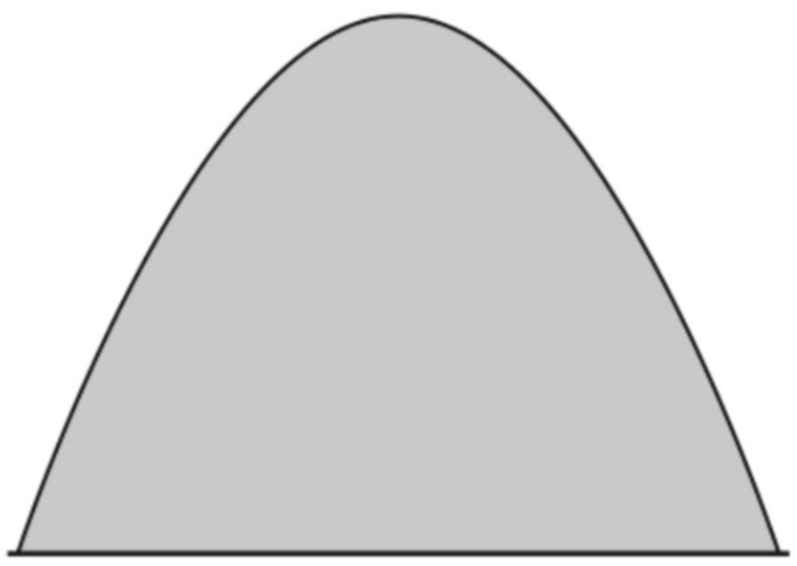

Figure 1

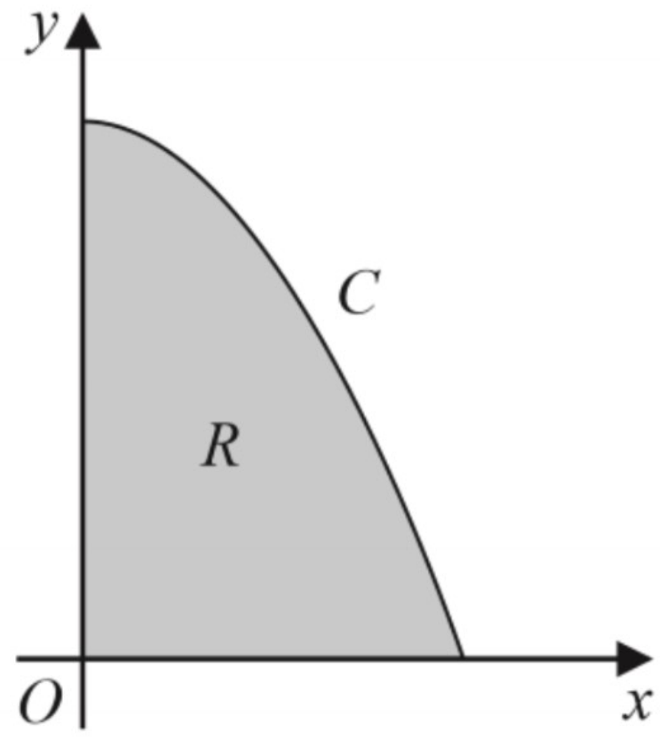

Figure 2

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

$$y + x^2 = 2 \qquad 0 \leqslant x \leqslant \sqrt{2}$$

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 $900\,\text{kg}\,\text{m}^{-3}$

(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) $x = 0,\ y = 2$

$x = \sqrt{2},\ y = 0$

$y + x^2 = 2 \therefore x^2 = 2 - y$

VOLUME $= \pi \int_0^2 x^2 \, dy$

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Question 5 continued

$= \pi \int_0^2 (2 - y)\, dy$

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

$= 2\pi \text{ m}^3$

$\therefore$ MASS $= 2\pi \times 900$

$= 1800\pi$

$= 5700$ kg (2sf)

(b) THE PILE OF CONCRETE WASTE IS UNLIKELY TO BE PERFECTLY SYMMETRICAL

(c) % ERROR $= \frac{1800\pi - 5500}{5500} \times 100$

$= 2.81\ldots\%$

$\therefore$ GOOD MODEL TO USE

Question 5 continued

Question 5 continued

(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

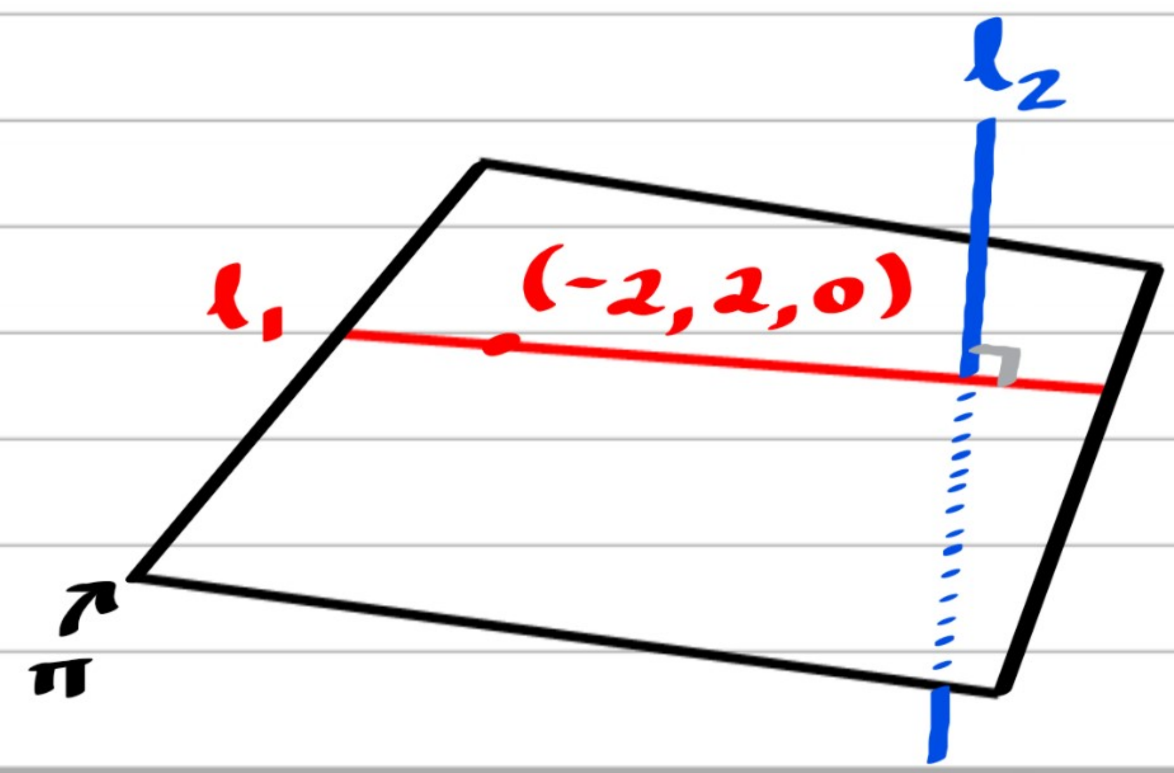
(d) determine the coordinates of B.

(6)

$$\begin{bmatrix} 1 \\ 2 \\ -3 \end{bmatrix} \cdot \begin{bmatrix} 3 \\ 0 \\ 1 \end{bmatrix} = 1 \times 3 + 2 \times 0 + -3 \times 1 = 0$$

$\therefore$ LINES ARE PERPENDICULAR

(b)



Question 6 continued

$\Pi : x + 2y - 3z = d$

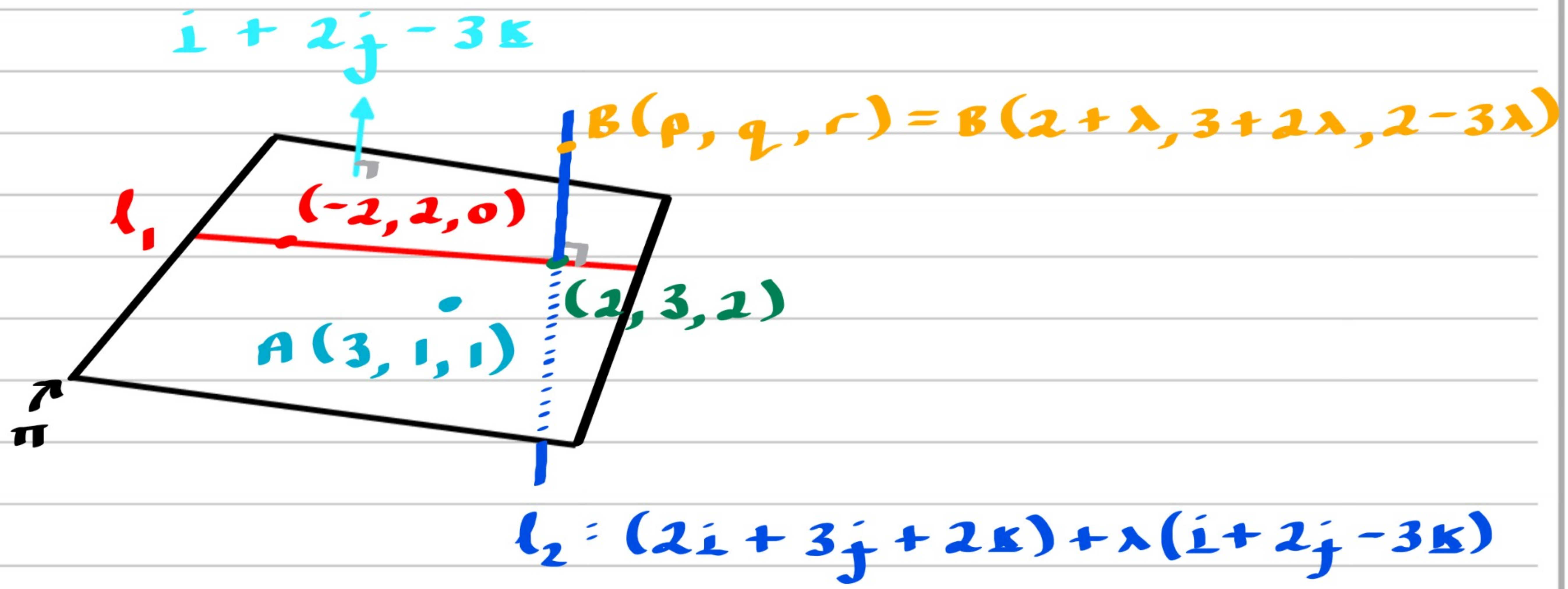
AS $(-2,2,0)$ LIES ON Π : $d = (-2)+2(2)-3(0) = 2$

$\therefore \Pi : x + 2y - 3z = 2$

(c) $A(3,1,1)$: LHS $= 3 + 2\times 1 - 3\times 1 = 2 =$ RHS

$\therefore A(3,1,1)$ LIES ON PLANE

(d)



$$\overrightarrow{AB} = \begin{bmatrix} 2+\lambda-3 \\ 3+2\lambda-1 \\ 2-3\lambda-1 \end{bmatrix} = \begin{bmatrix} -1+\lambda \\ 2+2\lambda \\ 1-3\lambda \end{bmatrix}$$

$$|\overrightarrow{AB}| = \sqrt{(-1+\lambda)^2 + (2+2\lambda)^2 + (1-3\lambda)^2} = 5\sqrt{2}$$

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

$\therefore \lambda^2 - 2\lambda + 1 + 4\lambda^2 + 8\lambda + 4 + 9\lambda^2 - 6\lambda + 1 = 20$

$\therefore 14\lambda^2 = 14$

$\therefore \lambda = \pm 1$, BUT AS $p, q, r > 0 \therefore \lambda = -1$

$\therefore B(1,1,5)$

P 7 2 8 0 6 A 0 1 9 3 6

Turn over

Question 6 continued

Question 6 continued

(Total for Question 6 is 11 marks)

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

$$|z - 3| \leqslant |z + 6\mathrm{i}|$$

(3)

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

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

(6)

(a) $|z-(3+0i)| \leq |z-(0-6i)|$

WE REQUIRE PERPENDICULAR BISECTOR

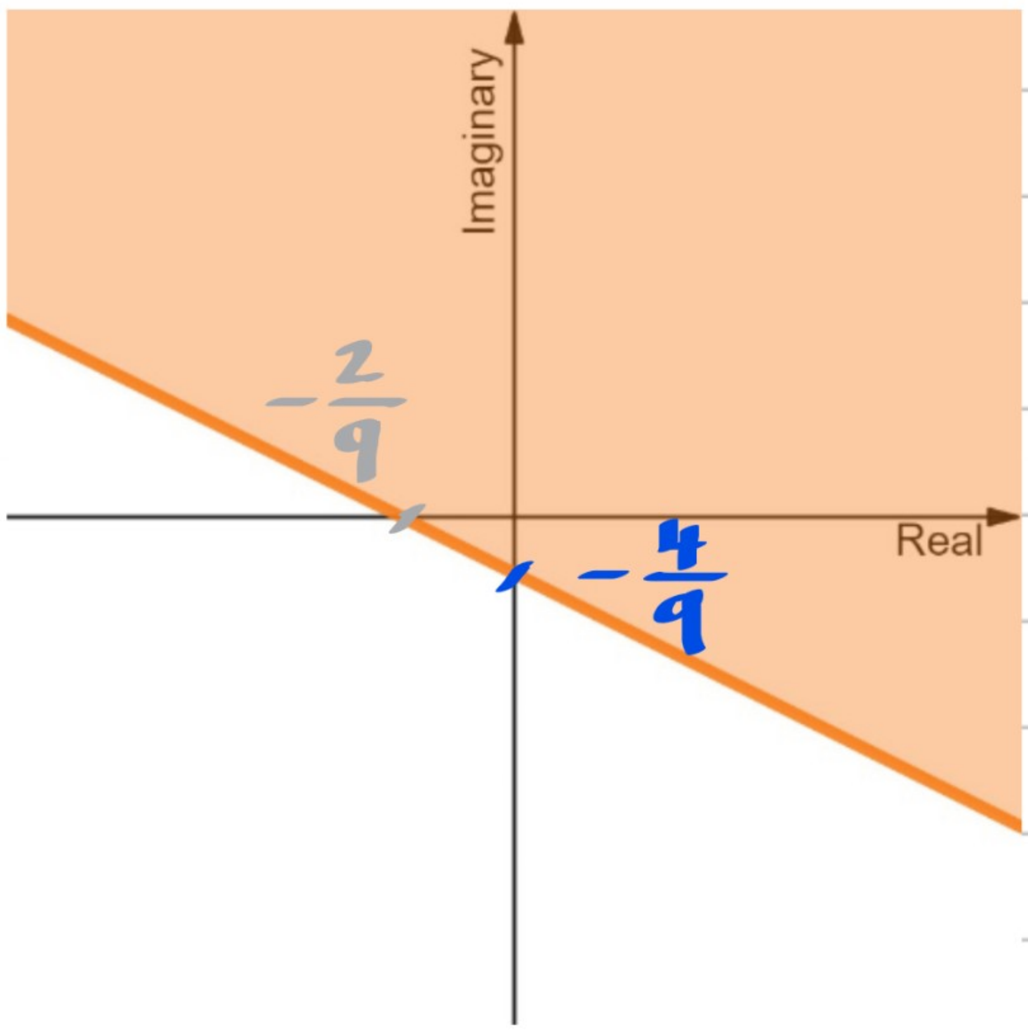
$\therefore$ GRADIENT $= \dfrac{0--6}{3-0} = 2$

$\therefore$ PERPENDICULAR GRADIENT $= -\dfrac{1}{2}$

$\therefore$ MIDPOINT, $M\left[\dfrac{3+0}{2}, \dfrac{0+-6}{2}\right] = M\left[\dfrac{3}{2}, -3\right]$

i.e. $y--3 = -\dfrac{1}{2}\left[x-\dfrac{3}{2}\right]$

$\therefore$ PERPENDICULAR BISECTOR HAS EQUATION $y=-\dfrac{1}{2}x-\dfrac{9}{4}$



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Question 7 continued

(b) $\arg(w-2) = \frac{\pi}{3} \therefore y = \sqrt{3}[x-2]$ ①

$\arg(w+1) = \frac{\pi}{6} \therefore y = \frac{\sqrt{3}}{3}\left[x+1\right]$ ②

SOLVE ① AND ② SIMULTANEOUSLY:

$\therefore \sqrt{3}[x-2] = \frac{\sqrt{3}}{3}\left[x+1\right]$

$\therefore 3[x-2] = x+1$

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

$\therefore x = \frac{7}{2}$

$\therefore y = \frac{\sqrt{3}}{3}\left[\frac{7}{2}+1\right] = \frac{3\sqrt{3}}{2}$

$\therefore w = \frac{7}{2} + \frac{3\sqrt{3}}{2}i$

Question 7 continued

Question 7 continued

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

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

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

$= 4\left[\frac{1}{6}n(n+1)(2n+1)\right]$

$-4\left[\frac{1}{2}n(n+1)\right] + n$

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

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

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

$= \frac{n}{3}\left[4n^2 - 1\right]$

$\therefore a = 4$

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Question 8 continued

(b) SUM OF SQUARES OF POSITIVE ODD THREE-DIGIT NUMBERS

$= [101 + 103 + 105 + 107 + \cdots + 995 + 997 + 999]^2$

$= \sum_{r=51}^{500} [2r-1]^2$

$= \sum_{r=1}^{500} [2r-1]^2 - \sum_{r=1}^{50} [2r-1]^2$

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

$= 166\ 499\ 850$

(Total for Question 8 is 8 marks)

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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 **P** is non-singular for all real values of k.

(4)

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

The matrix **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) $\det(P) = \begin{vmatrix} K & -2 & 7 \\ -3 & -5 & 2 \\ K & K & 4 \end{vmatrix}$

$= K\begin{vmatrix} -5 & 2 \\ K & 4 \end{vmatrix} - -2\begin{vmatrix} -3 & 2 \\ K & 4 \end{vmatrix} + 7\begin{vmatrix} -3 & -5 \\ K & K \end{vmatrix}$

$= K[-20 - 2K] + 2[-12 - 2K] + 7[-3K + 5K]$

$= -2K^2 - 10K - 24$

DISCRIMINANT $= (-10)^2 - 4(-2)(-24)$

$= -92 < 0$

$\therefore -2K^2 - 10K - 24 \neq 0$ FOR $K \in \mathbb{R}$

$\therefore$ P IS NON-SINGULAR

(b) $\begin{bmatrix} x_A' \\ y_A' \end{bmatrix} = \begin{bmatrix} 2 & -1 \\ -3 & 0 \end{bmatrix}\begin{bmatrix} a \\ 2 \end{bmatrix}$

$\therefore A'[2a - 2, -3a]$

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Question 9 continued

$$\begin{bmatrix} x_B' \\ y_B' \end{bmatrix} = \begin{bmatrix} 2 & -1 \\ -3 & 0 \end{bmatrix} \begin{bmatrix} 4 \\ -a \end{bmatrix}$$

$\therefore B' [8 + a, -12]$

$$\therefore \overrightarrow{A'B'} = \begin{bmatrix} 8 + a \\ -12 \end{bmatrix} - \begin{bmatrix} 2a - 2 \\ -3a \end{bmatrix}$$

$$= \begin{bmatrix} 10 - a \\ -12 + 3a \end{bmatrix}$$

$$\therefore \sqrt{(10 - a)^2 + (-12 + 3a)^2} = \sqrt{58}$$

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

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

$$\therefore 10a^2 - 92a + 186 = 0$$

$$\therefore a = 3, a = \frac{31}{5}$$

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Question 9 continued

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Question 9 continued

(Total for Question 9 is 9 marks)

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

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

are α, 2α and $\alpha - \beta$

Determine

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

(5)

(b) the value of n.

(2)

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

$\therefore$ NEW EQUATION IS: $\left[\frac{w+1}{3}\right]^4 + 5\left[\frac{w+1}{3}\right]^2 - 30 = 0$

$\therefore [w+1]^4 + 45[w+1]^2 - 2430 = 0$

$\therefore w^4 + 4w^3 + 6w^2 + 4w + 1 + 45[w^2 + 2w + 1]$

$- 2430 = 0$

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

Question 10 continued

$\therefore a = 4,\ b = 51,\ c = 94,\ d = -2384$

(ii)(a) $4x^3 + 0x^2 + nx + 81 = 0$

$x^3 + 0x^2 + \frac{n}{4}x + \frac{81}{4} = 0$

SUM OF ROOTS: $\alpha + 2\alpha + (\alpha - \beta) = -0$

$\therefore \beta = 4\alpha$

PRODUCT OF ROOTS: $(\alpha)(2\alpha)(\alpha - \beta) = -\frac{81}{4}$

$\therefore (\alpha)(2\alpha)(\alpha - 4\alpha) = -\frac{81}{4}$

$\therefore -6\alpha^3 = -\frac{81}{4}$

$\therefore \alpha = \frac{3}{2}$

i.e. $2\alpha = 2 \times \frac{3}{2} = 3$

$\beta = 4\alpha = 4 \times \frac{3}{2} = 6$

$\alpha - \beta = \frac{3}{2} - 6 = -\frac{9}{2}$

$\therefore$ ROOTS ARE: $\frac{3}{2}, 3, -\frac{9}{2}$

Question 10 continued

(b) $\therefore \left[x - \frac{3}{2}\right]\left[x - 3\right]\left[x - - \frac{9}{2}\right] = 0$

$\therefore [2x - 3][x - 3][2x + 9] = 0$

$\therefore [2x^2 - 9x + 9][2x + 9] = 0$

$\therefore 4x^3 + 18x^2 - 18x^2 - 81x + 18x + 81 = 0$

$\therefore 4x^3 - 63x + 81 = 0$

$\therefore n = -63$

Question 10 continued

Question 10 continued

(Total for Question 10 is 12 marks)

TOTAL FOR PAPER IS 80 MARKS