IB Math AA HL — Topic 3

Vector Planes

Plane Equations · Line–Plane & Plane–Plane Intersections · Angles · Shortest Distances

Difficulty	EASY	MEDIUM	HARD
Questions	10	10	10
Total Marks	30	40	50

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Name:_____ Date:_____

Score:_____/120

Instructions: Answer all questions. Show all working. Give answers correct to 3 significant figures unless stated otherwise. Each question states whether a calculator is permitted.

Key Formulae

- **Plane (vector form):** $\mathbf{r} = \mathbf{a} + s\mathbf{b} + t\mathbf{c}$, where $\mathbf{a}$ is a point on the plane and $\mathbf{b}$, $\mathbf{c}$ are non-parallel direction vectors lying in the plane.
- **Plane (normal/scalar form):** $\mathbf{r} \cdot \mathbf{n} = \mathbf{a} \cdot \mathbf{n}$; in Cartesian form $ax + by + cz = d$, where $\mathbf{n} = (a, b, c)^{\top}$ and $d = \mathbf{a} \cdot \mathbf{n}$.
- **Normal from three points:** $\mathbf{n} = \overrightarrow{AB} \times \overrightarrow{AC}$; substitute any point to find d.
- **Angle between two planes:** $\cos\theta = \dfrac{|\mathbf{n}_1 \cdot \mathbf{n}_2|}{|\mathbf{n}_1||\mathbf{n}_2|}$ (acute convention, use absolute value).
- **Angle between a line and a plane:** $\sin\phi = \dfrac{|\mathbf{b} \cdot \mathbf{n}|}{|\mathbf{b}||\mathbf{n}|}$, where $\mathbf{b}$ is the line direction and $\mathbf{n}$ is the plane normal.
- **Distance from point P to plane $ax + by + cz = d$:** $\text{dist} = \dfrac{|ax_0 + by_0 + cz_0 - d|}{\sqrt{a^2 + b^2 + c^2}}$.
- **Line of intersection of two planes:** direction $\mathbf{d} = \mathbf{n}_1 \times \mathbf{n}_2$; find a point by setting one variable to zero and solving the 2×2 system.

GDC Tips

- **Cross product:** Enter $\mathbf{n}_1$ and $\mathbf{n}_2$ as lists and use `crossP(n1,n2)` (TI) or `Cross` under the Vector menu (Casio CG50) to find normals and intersection directions without arithmetic errors.
- **Angle between planes/line and plane:** Compute the dot product and magnitudes numerically, then apply $\cos^{-1}$ or $\sin^{-1}$ directly; store intermediate values to avoid rounding mid-calculation.
- **Distance formula:** Store the plane coefficients and point coordinates as variables; evaluate $|ax_0+by_0+cz_0-d|/\sqrt{a^2+b^2+c^2}$ in one expression to get an exact or decimal result.
- **System of equations for intersection:** Use the simultaneous-equation solver (`Poly/Simult` on Casio or `rref` on TI) to find the point where a parametric line meets a plane, or to find a point on the line of intersection of two planes.
- **Three-plane configurations:** Input the augmented matrix $[A|\mathbf{b}]$ and apply `rref`; a row of zeros with non-zero right-hand side indicates inconsistency; a full row of zeros indicates infinite solutions.
- **Verification:** Substitute a computed intersection point back into all plane equations using the GDC's Store and recall to confirm the result satisfies every equation simultaneously.

Common Mistakes to Avoid

1. **Using cosine instead of sine for the line-plane angle.** The angle between a line and a plane is the complement of the angle between the line and the normal; always use $\sin\phi = |\mathbf{b}\cdot\mathbf{n}|/(|\mathbf{b}||\mathbf{n}|)$, not cosine.
2. **Forgetting the absolute value in angle formulas.** Both the line-plane and plane-plane angle formulas require $|\mathbf{b}\cdot\mathbf{n}|$ (or $|\mathbf{n}_1\cdot\mathbf{n}_2|$) to guarantee an acute answer; omitting it can give the obtuse supplement.
3. **Confusing "line parallel to plane" with "line in the plane".** If $\mathbf{b}\cdot\mathbf{n}=0$ the line is either parallel to or lies in the plane; you must test whether a point on the line satisfies the plane equation to distinguish the two cases.
4. **Incorrect normal when the plane is given in vector form.** The normal is $\mathbf{n}=\mathbf{b}\times\mathbf{c}$ (cross product of the two direction vectors), not $\mathbf{b}+\mathbf{c}$ or either direction vector alone.
5. **Sign error in the distance formula.** The formula is $|ax_0+by_0+cz_0-d|/|\mathbf{n}|$; students often use $+d$ instead of $-d$, or forget to divide by $|\mathbf{n}|$ when the normal is not a unit vector.
6. **Arithmetic errors in the cross product for the line of intersection.** Each component of $\mathbf{n}_1\times\mathbf{n}_2$ involves a 2×2 determinant with alternating signs; the middle component carries a minus sign that is frequently dropped, giving a wrong direction vector.

Section A — Easy EASY (10 questions × 3 marks = 30 marks)

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1. EASY No Calculator [3 marks]

The plane Π passes through the point $A(3, -1, 2)$ and has normal vector $\mathbf{n} = \begin{pmatrix} 2 \\ 5 \\ -1 \end{pmatrix}$.

Write down the Cartesian equation of Π.

2. EASY Calculator [3 marks]

A plane Π has equation $\mathbf{r} \cdot \begin{pmatrix} 1 \\ -3 \\ 4 \end{pmatrix} = 7$.

Write down a normal vector to Π and state the Cartesian equation of Π.

3. EASY Calculator [3 marks]

The table below shows four points on a solar panel surface. The panel lies in a plane Π with Cartesian equation $ax + by + cz = d$.

Point	P	Q	R	check
Coordinates	$(1, 0, 2)$	$(3, 0, 2)$	$(1, 4, 2)$	$(2, 1, 2)$

Show that the equation of the plane containing P, Q, and R is $z = 2$.

4. **EASY** **No Calculator** **[3 marks]**

The line ℓ is given by $\mathbf{r} = \begin{pmatrix} 1 \\ 2 \\ 0 \end{pmatrix} + t \begin{pmatrix} 3 \\ -1 \\ 2 \end{pmatrix}$, $t \in \mathbb{R}$, and the plane Π has equation $x + 2y - z = 5$.

Find the value of t at which ℓ intersects Π, and state the coordinates of the intersection point.

5. **EASY** **No Calculator** **[3 marks]**

Two planes are given by

$$\Pi_1 : 2x - y + 3z = 4 \qquad \Pi_2 : 4x - 2y + 6z = 9.$$

Show that Π_1 and Π_2 are parallel and find the distance between them.

6. **EASY** **Calculator** **[3 marks]**

A plane Π has equation $3x - 4y + 12z = 26$ and a point B has coordinates $(5, 1, 0)$.

Find the shortest distance from B to Π.

7. **EASY** **Calculator** **[3 marks]**

The planes Π_1 and Π_2 have equations $x - 2y + 2z = 3$ and $2x + y - z = 1$ respectively. The angle between Π_1 and Π_2 is θ.

Find θ, giving your answer in degrees correct to one decimal place.

8. **EASY** **Calculator** **[3 marks]**

A line ℓ has direction vector $\mathbf{b} = \begin{pmatrix} 1 \\ 2 \\ 2 \end{pmatrix}$ and a plane Π has normal vector $\mathbf{n} = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}$.

Find the acute angle between ℓ and Π, giving your answer in degrees correct to one decimal place.

Note: The angle between a line and a plane is found using $\sin\phi = \dfrac{|\mathbf{b} \cdot \mathbf{n}|}{|\mathbf{b}||\mathbf{n}|}$.

9. **EASY** **Calculator** **[3 marks]**

The table below gives information about a ramp at a construction site. The ramp surface lies in a plane Π with normal vector $\mathbf{n}$ and the ramp direction vector is $\mathbf{b}$.

Vector	Components
$\mathbf{b}$ (ramp direction)	$\begin{pmatrix} 4 \\ 0 \\ 1 \end{pmatrix}$
$\mathbf{n}$ (plane normal)	$\begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$

Find the acute angle between the ramp direction and the ramp surface, giving your answer in degrees correct to one decimal place.

Note: Use $\sin\phi = \dfrac{|\mathbf{b} \cdot \mathbf{n}|}{|\mathbf{b}||\mathbf{n}|}$.

10. **EASY** **No Calculator** **[3 marks]**

The plane Π passes through the three points $A(1, 0, 0)$, $B(0, 2, 0)$, and $C(0, 0, 3)$.
Find the Cartesian equation of Π, giving it in the form $ax + by + cz = d$ where $a, b, c, d \in \mathbb{Z}^+$.

Section B — Medium MEDIUM (10 questions × 4 marks = 40 marks)

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11. MEDIUM No Calculator [4 marks]

A plane Π passes through the points $A(1, 0, 2)$, $B(3, 1, 1)$ and $C(0, 2, 4)$.

(a) Find a normal vector to Π. [2]

(b) Hence write down the Cartesian equation of Π. [2]

12. MEDIUM No Calculator [4 marks]

A plane Π has equation $2x - y + 3z = 12$. The line L has parametric equations

$$x = 1 + 4t, \qquad y = 2 - t, \qquad z = t, \qquad t \in \mathbb{R}.$$

Find the coordinates of the point where L meets Π.

13. MEDIUM Calculator **[4 marks]**

Two planes are defined by

$$\Pi_1 : 3x - y + 2z = 5 \qquad \text{and} \qquad \Pi_2 : x + 2y - z = 4.$$

(a) Find the direction vector of the line of intersection of Π_1 and Π_2 by computing $\mathbf{n}_1 \times \mathbf{n}_2$, where $\mathbf{n}_1$ and $\mathbf{n}_2$ are the normals to Π_1 and Π_2 respectively. [2]

(b) Find a point that lies on the line of intersection by setting $z = 0$ and solving the resulting system. [2]

14. MEDIUM Calculator **[4 marks]**

The plane Π has equation $\mathbf{r} \cdot \begin{pmatrix} 2 \\ 1 \\ -2 \end{pmatrix} = 9$. Point P has coordinates $(5, 1, -1)$.

(a) Show that P does not lie on Π. [1]

(b) Find the perpendicular distance from P to Π. [3]

15. MEDIUM Calculator **[4 marks]**

A line L has equation $\mathbf{r} = \begin{pmatrix} 1 \\ 0 \\ 3 \end{pmatrix} + t \begin{pmatrix} 2 \\ -1 \\ 2 \end{pmatrix}$, $t \in \mathbb{R}$, and a plane Π has equation $4x - 2y + z = 10$.

Find the acute angle between L and Π, giving your answer to 3 significant figures.

16. **MEDIUM** **Calculator** **[4 marks]**

The table below gives two aircraft positions (in km) relative to a fixed control tower at the origin O, recorded at times $t = 0$ and $t = 1$ hour.

Time (hours)	x (km)	y (km)	z (km)
$t = 0$	3	1	5
$t = 1$	7	3	9

The aircraft travels in a straight line. A restricted airspace region lies on the plane $\Pi : 2x - y + 2z = 30$.

(a) Write down the vector equation of the aircraft's path. [1]

(b) Find the coordinates of the point where the aircraft enters Π. [3]

17. **MEDIUM** **Calculator** **[4 marks]**

Two planes are given by

$$\Pi_1 : \mathbf{r} \cdot \begin{pmatrix} 1 \\ 2 \\ -1 \end{pmatrix} = 6 \qquad \text{and} \qquad \Pi_2 : \mathbf{r} \cdot \begin{pmatrix} 2 \\ -1 \\ 3 \end{pmatrix} = 4.$$

Find the acute angle between Π_1 and Π_2, giving your answer in degrees to 3 significant figures.

18. MEDIUM Calculator **[4 marks]**

A plane Π passes through point $Q(2, -1, 3)$ and is parallel to the plane $\Pi_0 : x - 3y + 2z = 7$.

(a) Write down the Cartesian equation of Π. [2]

(b) Hence find the perpendicular distance between Π and Π_0. [2]

19. MEDIUM No Calculator **[4 marks]**

The plane Π has equation $3x + 2y - 6z = 12$. The line L has equation

$$\frac{x-1}{3} = \frac{y+2}{2} = \frac{z-1}{-6}.$$

Determine whether L lies in Π, is parallel to Π but not in it, or intersects Π at a single point. Justify your answer fully.

20. MEDIUM Calculator **[4 marks]**

A solar panel is modelled as lying in the plane $\Pi : 2x + y - 2z = 0$. Sunlight travels in the direction $\mathbf{d} = \begin{pmatrix} 1 \\ 2 \\ -2 \end{pmatrix}$.

Find the angle between the sunlight direction and the solar panel, giving your answer in degrees to 3 significant figures.

Note: the angle between a line and a plane is the complement of the angle between the line and the normal to the plane.

Section C — Hard HARD (10 questions × 5 marks = 50 marks)

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21. HARD No Calculator [5 marks]

The plane Π_1 passes through the points $A(1, 0, 1)$, $B(2, 2, 0)$ and $C(0, 1, 3)$.

(a) Show that the normal to Π_1 is $\mathbf{n} = \begin{pmatrix} 5 \\ -1 \\ 3 \end{pmatrix}$. [2]

(b) Hence find the Cartesian equation of Π_1. [1]

(c) The plane Π_2 has equation $2x - y + z = 3$. Find the Cartesian equation of the line of intersection of Π_1 and Π_2, giving the direction vector and a point on the line. [2]

22. HARD Calculator [5 marks]

The plane Π has equation $2x - y + 2z = 9$. The line ℓ is given by $\mathbf{r} = \begin{pmatrix} 1 \\ 3 \\ 0 \end{pmatrix} + t \begin{pmatrix} 1 \\ -1 \\ 2 \end{pmatrix}$, $t \in \mathbb{R}$.

(a) Find the acute angle between ℓ and Π, giving your answer in degrees to three significant figures. [3]

(b) Find the coordinates of the point where ℓ intersects Π. [2]

23. **HARD** **Calculator** **[5 marks]**

A solar panel is modelled as a rectangular section of the plane $\Pi : 3x - 4y + z = 12$. Sunlight travels in the direction $\mathbf{d} = \begin{pmatrix} 1 \\ -1 \\ -3 \end{pmatrix}$.

(a) Find the acute angle between the sunlight direction $\mathbf{d}$ and the plane Π, giving your answer in degrees to three significant figures. [3]

(b) The point $P(4, 0, 0)$ lies on Π. A support rod runs perpendicularly from P to the ground plane $z = 0$. Find the length of the rod. [2]

24. **HARD** **Calculator** **[5 marks]**

Three planes are defined by:

$$\Pi_1 : x + 2y - z = 3, \qquad \Pi_2 : 2x - y + 3z = 1, \qquad \Pi_3 : x + 2y + kz = 5$$

where $k \in \mathbb{R}$.

(a) Find the line of intersection of Π_1 and Π_2, expressing your answer in the form $\mathbf{r} = \mathbf{a} + t\mathbf{b}$. [3]

(b) Find the value of k for which the three planes do **not** share a unique common point, and determine whether the three planes then have no common point at all or share a common line. [2]

25. **HARD** **No Calculator** **[5 marks]**

The plane Π has equation $\mathbf{r} \cdot \begin{pmatrix} 2 \\ -1 \\ 2 \end{pmatrix} = 6$. The point Q has coordinates $(5, 1, -2)$.

(a) Show that the perpendicular distance from Q to Π is $\frac{1}{3}$. [3]

(b) Find the coordinates of the foot of the perpendicular from Q to Π. [2]

26. **HARD** **Calculator** **[5 marks]**

Consider the planes $\Pi_1 : 3x - y + 2z = 7$ and $\Pi_2 : x + 2y - z = 4$.

(a) Show that the direction vector of the line of intersection of Π_1 and Π_2 is $\mathbf{d} = \begin{pmatrix} -3 \\ 5 \\ 7 \end{pmatrix}$. [2]

(b) Find the acute angle between Π_1 and Π_2, giving your answer in degrees to three significant figures. [2]

(c) The point $R(2, -1, 0)$ lies on Π_1. Verify that R does not lie on Π_2, and hence find the distance from R to the plane Π_2. [1]

27. **HARD** **Calculator** **[5 marks]**

A particle moves so that its position at time $t \geq 0$ (in seconds) is given by the table below, where distances are in metres.

t (s)	0	1	2	3
Position	$(1, 2, 0)$	$(3, 1, 2)$	$(5, 0, 4)$	$(7, -1, 6)$

The particle travels in a straight line. The plane Π has equation $2x + 3y - z = 6$.

(a) Write down the vector equation of the particle's path. [1]

(b) Find the acute angle between the particle's path and Π, in degrees to three significant figures. [2]

(c) Find the time at which the particle crosses Π, and state the coordinates of the crossing point. [2]

28. **HARD** **No Calculator** **[5 marks]**

The plane Π has equation $x - 2y + 2z = 5$. The point S has coordinates $(3, -1, 4)$.

(a) Show that S does not lie on Π. [1]

(b) Find the reflection S' of S in the plane Π. [4]

29. **HARD** **Calculator** **[5 marks]**

The planes $\Pi_1 : ax + 2y - z = 3$ and $\Pi_2 : 2x - y + az = 5$, where $a \in \mathbb{R}$, are given.

(a) Find the value of a for which Π_1 and Π_2 are perpendicular. [2]

(b) For the value of a found in (a), find the acute angle between the line of intersection of Π_1 and Π_2 and the z-axis, in degrees to three significant figures. [3]

30. **HARD** **Calculator** **[5 marks]**

The line ℓ has equation $\mathbf{r} = \begin{pmatrix} 2 \\ -1 \\ 3 \end{pmatrix} + t \begin{pmatrix} 1 \\ 1 \\ -1 \end{pmatrix}$, $t \in \mathbb{R}$, and the plane Π has equation $3x - y + 2z = 12$.

(a) Show that ℓ is parallel to Π but does not lie in Π. [2]

(b) A second line m passes through the point $T(4, 1, 2)$ and is parallel to the normal of Π. Find the coordinates of the point where m meets Π, and hence find the distance from T to Π. [3]

Mark Schemes

Q1 — Cartesian Equation from Point and Normal EASY

Substituting into $\mathbf{r} \cdot \mathbf{n} = \mathbf{a} \cdot \mathbf{n}$: **M1**

$\mathbf{a} \cdot \mathbf{n} = (3)(2) + (-1)(5) + (2)(-1) = 6 - 5 - 2 = -1$ **A1**

Cartesian equation: $2x + 5y - z = -1$ **A1**

Q2 — Normal Vector and Cartesian Form from Vector Equation EASY

Normal vector: $\mathbf{n} = \begin{pmatrix} 1 \\ -3 \\ 4 \end{pmatrix}$ **A1**

The dot product $\mathbf{r} \cdot \mathbf{n} = 7$ expands as $x - 3y + 4z = 7$ **M1**

Cartesian equation: $x - 3y + 4z = 7$ **A1**

Q3 — Plane Through Three Collinear-z Points EASY

$\overrightarrow{PQ} = \begin{pmatrix} 2 \\ 0 \\ 0 \end{pmatrix}, \overrightarrow{PR} = \begin{pmatrix} 0 \\ 4 \\ 0 \end{pmatrix}$ **M1**

Normal $\mathbf{n} = \overrightarrow{PQ} \times \overrightarrow{PR} = \begin{pmatrix} (0)(0) - (0)(4) \\ (0)(0) - (2)(0) \\ (2)(4) - (0)(0) \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 8 \end{pmatrix}$, so $\mathbf{n} \parallel \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$ **A1**

Plane equation: $0(x-1) + 0(y-0) + 1(z-2) = 0 \implies z = 2$ **AG**

Q4 — Line-Plane Intersection EASY

Substitute parametric form into the plane equation: **M1**

$(1 + 3t) + 2(2 - t) - (2t) = 5$

$1 + 3t + 4 - 2t - 2t = 5 \implies 5 - t = 5 \implies t = 0$ **A1**

Intersection point: $(1, 2, 0)$ **A1**

Q5 — Parallel Planes and Distance Between Them EASY

$\mathbf{n}_1 = \begin{pmatrix} 2 \\ -1 \\ 3 \end{pmatrix}$, $\mathbf{n}_2 = \begin{pmatrix} 4 \\ -2 \\ 6 \end{pmatrix} = 2\mathbf{n}_1$, so the planes are parallel (normals are scalar multiples). **R1**

Rewrite Π_1 as $4x - 2y + 6z = 8$; both planes now share normal $\begin{pmatrix} 4 \\ -2 \\ 6 \end{pmatrix}$. **M1**

$$\text{Distance} = \frac{|9 - 8|}{\sqrt{4^2 + (-2)^2 + 6^2}} = \frac{1}{\sqrt{56}} = \frac{1}{2\sqrt{14}} \approx 0.134$$ **A1**

Q6 — Distance from Point to Plane EASY

Use the formula $d = \dfrac{|ax_0 + by_0 + cz_0 - d|}{|\mathbf{n}|}$ with $B(5, 1, 0)$: **M1**

Numerator: $|3(5) - 4(1) + 12(0) - 26| = |15 - 4 + 0 - 26| = |-15| = 15$ **A1**

$|\mathbf{n}| = \sqrt{9 + 16 + 144} = \sqrt{169} = 13$; distance $= \dfrac{15}{13} \approx 1.15$ **A1**

Q7 — Angle Between Two Planes EASY

$\mathbf{n}_1 = \begin{pmatrix} 1 \\ -2 \\ 2 \end{pmatrix}$, $\mathbf{n}_2 = \begin{pmatrix} 2 \\ 1 \\ -1 \end{pmatrix}$; use $\cos\theta = \dfrac{|\mathbf{n}_1 \cdot \mathbf{n}_2|}{|\mathbf{n}_1||\mathbf{n}_2|}$ **M1**

$\mathbf{n}_1 \cdot \mathbf{n}_2 = 2 - 2 - 2 = -2$; $|\mathbf{n}_1| = 3$, $|\mathbf{n}_2| = \sqrt{6}$

$\cos\theta = \dfrac{|-2|}{3\sqrt{6}} = \dfrac{2}{3\sqrt{6}}$ (unrounded: $0.27217\ldots$) **A1**

$\theta = \arccos(0.27217\ldots) = 74.2°$ **A1**

Q8 — Angle Between Line and Plane EASY

Use $\sin\phi = \dfrac{|\mathbf{b} \cdot \mathbf{n}|}{|\mathbf{b}||\mathbf{n}|}$ **M1**

$\mathbf{b} \cdot \mathbf{n} = (1)(0) + (2)(1) + (2)(0) = 2$; $|\mathbf{b}| = \sqrt{1 + 4 + 4} = 3$, $|\mathbf{n}| = 1$

$\sin\phi = \dfrac{2}{3}$ (unrounded: $0.66\overline{6}$) **A1**

$\phi = \arcsin\left(\dfrac{2}{3}\right) = 41.8°$ **A1**

Q9 — Angle Between Ramp Direction and Ramp Surface EASY

Use $\sin\phi = \dfrac{|\mathbf{b}\cdot\mathbf{n}|}{|\mathbf{b}||\mathbf{n}|}$ **M1**

$\mathbf{b}\cdot\mathbf{n} = (4)(0)+(0)(0)+(1)(1) = 1$; $|\mathbf{b}| = \sqrt{16+0+1} = \sqrt{17}$, $|\mathbf{n}| = 1$

$\sin\phi = \dfrac{1}{\sqrt{17}}$ (unrounded: $0.24254\ldots$) **A1**

$\phi = \arcsin\left(\dfrac{1}{\sqrt{17}}\right) = 14.0°$ **A1**

Q10 — Plane Through Intercept Points EASY

Use intercept form: $\dfrac{x}{1}+\dfrac{y}{2}+\dfrac{z}{3}=1$ **M1**

Multiply through by 6: $6x+3y+2z=6$ **A1**

Cartesian equation: $6x+3y+2z=6$ **A1**

Q11 — Normal from Three Points and Cartesian Equation MEDIUM

(a) Direction vectors in the plane: $\overrightarrow{AB} = \begin{pmatrix}2\\1\\-1\end{pmatrix}$, $\overrightarrow{AC} = \begin{pmatrix}-1\\2\\2\end{pmatrix}$

Normal $\mathbf{n} = \overrightarrow{AB}\times\overrightarrow{AC}$: **M1**

$\mathbf{n} = \begin{pmatrix}(1)(2)-(-1)(2)\\(-1)(-1)-(2)(2)\\(2)(2)-(1)(-1)\end{pmatrix} = \begin{pmatrix}4\\-3\\5\end{pmatrix} = (4,-3,5)$ **A1**

(b) Using point $A(1,0,2)$: $d = \begin{pmatrix}4\\-3\\5\end{pmatrix}\cdot\begin{pmatrix}1\\0\\2\end{pmatrix} = 4+0+10 = 14$ **M1**

$4x-3y+5z=14$ **A1**

Q12 — Exact Line-Plane Intersection MEDIUM

Substitute parametric equations into $2x-y+3z=12$: **M1**

$2(1+4t)-(2-t)+3(t)=12$

$2+8t-2+t+3t=12 \implies 12t=12 \implies t=1$ **A1**

Coordinates at $t=1$: $x=5,\ y=1,\ z=1$ **M1**

$(5,1,1)$ **A1**

Q13 — Line of Intersection of Two Planes MEDIUM

(a) $\mathbf{n}_1 = \begin{pmatrix} 3 \\ -1 \\ 2 \end{pmatrix}$, $\mathbf{n}_2 = \begin{pmatrix} 1 \\ 2 \\ -1 \end{pmatrix}$ **M1**

$\mathbf{n}_1 \times \mathbf{n}_2 = \begin{pmatrix} (-1)(-1) - (2)(2) \\ (2)(1) - (3)(-1) \\ (3)(2) - (-1)(1) \end{pmatrix} = \begin{pmatrix} -3 \\ 5 \\ 7 \end{pmatrix} = (-3, 5, 7)$ **A1**

(b) Set $z = 0$: solve $3x - y = 5$ and $x + 2y = 4$. **M1**

From first: $y = 3x - 5$. Substitute: $x + 2(3x - 5) = 4 \implies 7x = 14 \implies x = 2,\ y = 1$.
$(2, 1, 0)$ **A1**

Q14 — Distance from Point to Plane MEDIUM

(a) Substituting $P(5, 1, -1)$ into $2x + y - 2z$: $2(5) + 1 - 2(-1) = 10 + 1 + 2 = 13 \neq 9$
so P does not lie on Π. **R1**

(b) The plane in Cartesian form is $2x + y - 2z = 9$. **M1**

Formula: $d = \dfrac{|2(5) + 1(1) - 2(-1) - 9|}{\sqrt{2^2 + 1^2 + (-2)^2}}$ **M1**

$d = \dfrac{|10 + 1 + 2 - 9|}{\sqrt{4 + 1 + 4}} = \dfrac{4}{3} \approx 1.33$ units **A1**

Q15 — Angle Between Line and Plane MEDIUM

Direction vector $\mathbf{b} = \begin{pmatrix} 2 \\ -1 \\ 2 \end{pmatrix}$, normal $\mathbf{n} = \begin{pmatrix} 4 \\ -2 \\ 1 \end{pmatrix}$. **M1**

Using $\sin\theta = \dfrac{|\mathbf{b} \cdot \mathbf{n}|}{|\mathbf{b}||\mathbf{n}|}$: **M1**

$\mathbf{b} \cdot \mathbf{n} = 8 + 2 + 2 = 12$, $|\mathbf{b}| = \sqrt{4 + 1 + 4} = 3$, $|\mathbf{n}| = \sqrt{16 + 4 + 1} = \sqrt{21}$

$\sin\theta = \dfrac{12}{3\sqrt{21}} = \dfrac{4}{\sqrt{21}}$ **A1**

$\theta = \arcsin\left(\dfrac{4}{\sqrt{21}}\right) = 60.7941\ldots^\circ$ (GDC)

$\theta \approx 60.8^\circ$ (3 s.f.) **A1**

Note: using cos instead of sin gives the angle with the normal (the complement); this is a common error. Keep full GDC precision until the final rounding step.

Q16 — Aircraft Path Meets a Restricted Plane MEDIUM

(a) Direction: $\begin{pmatrix}7\\3\\9\end{pmatrix}-\begin{pmatrix}3\\1\\5\end{pmatrix}=\begin{pmatrix}4\\2\\4\end{pmatrix}$.

$\mathbf{r}=\begin{pmatrix}3\\1\\5\end{pmatrix}+t\begin{pmatrix}4\\2\\4\end{pmatrix}, t\in\mathbb{R}$ **A1**

(b) Substitute into $2x-y+2z=30$ (GDC or by hand): **M1**

$2(3+4t)-(1+2t)+2(5+4t)=30$

$6+8t-1-2t+10+8t=30 \implies 14t=15 \implies t=\dfrac{15}{14}$

$x=3+\dfrac{60}{14}=\dfrac{42+60}{14}=\dfrac{102}{14}=\dfrac{51}{7}, \quad y=1+\dfrac{30}{14}=\dfrac{14+30}{14}=\dfrac{44}{14}=\dfrac{22}{7}, \quad z=5+\dfrac{60}{14}=\dfrac{70+60}{14}=\dfrac{130}{14}=\dfrac{65}{7}$

$\left(\dfrac{51}{7},\dfrac{22}{7},\dfrac{65}{7}\right)=(51/7,\ 22/7,\ 65/7)\approx(7.29, 3.14, 9.29)$ km **A1**

Note: $x=3+\frac{60}{14}=\frac{102}{14}=\frac{51}{7}$ and $y=1+\frac{30}{14}=\frac{44}{14}=\frac{22}{7}$; take care combining the whole-number part with the fraction over a common denominator of 14.

Q17 — Angle Between Two Planes MEDIUM

$\mathbf{n}_1=\begin{pmatrix}1\\2\\-1\end{pmatrix}, \mathbf{n}_2=\begin{pmatrix}2\\-1\\3\end{pmatrix}$. **M1**

$\mathbf{n}_1\cdot\mathbf{n}_2=2-2-3=-3$

$|\mathbf{n}_1|=\sqrt{1+4+1}=\sqrt{6}, |\mathbf{n}_2|=\sqrt{4+1+9}=\sqrt{14}$ **M1**

$\cos\phi=\dfrac{|\mathbf{n}_1\cdot\mathbf{n}_2|}{|\mathbf{n}_1||\mathbf{n}_2|}=\dfrac{3}{\sqrt{6}\cdot\sqrt{14}}=\dfrac{3}{\sqrt{84}}\approx 0.32733\ldots$ **A1**

$\phi=\arccos(0.32733\ldots)\approx 70.9^\circ$ (GDC) **A1**

Note: the absolute value of the dot product gives the acute angle between the planes.

Q18 — Parallel Planes and Distance Between Them MEDIUM

(a) Since $\Pi\parallel\Pi_0$, its normal is $\begin{pmatrix}1\\-3\\2\end{pmatrix}$. Using $Q(2,-1,3)$: **M1**

$d=1(2)-3(-1)+2(3)=2+3+6=11$

$\Pi: x-3y+2z=11$ **A1**

(b) Distance between parallel planes $ax + by + cz = d_1$ and $ax + by + cz = d_2$: **M1**

$$D = \frac{|d_1 - d_2|}{|\mathbf{n}|} = \frac{|11 - 7|}{\sqrt{1+9+4}} = \frac{4}{\sqrt{14}} \approx 1.07 \text{ units (GDC)}$$ **A1**

Q19 — Classify Line Relative to Plane MEDIUM

Direction vector of L: $\mathbf{b} = \begin{pmatrix} 3 \\ 2 \\ -6 \end{pmatrix}$. Normal to Π: $\mathbf{n} = \begin{pmatrix} 3 \\ 2 \\ -6 \end{pmatrix}$. **M1**

$\mathbf{b} \cdot \mathbf{n} = 9 + 4 + 36 = 49 \neq 0$
Since **b** is parallel to **n** (in fact $\mathbf{b} = \mathbf{n}$), we have $\mathbf{b} \cdot \mathbf{n} \neq 0$, so L is not parallel to Π. **R1**

Note: we must check whether **b** *is perpendicular to* **n** *(line parallel to plane) or not.*

Test the point on L at $t = 0$: $(1, -2, 1)$. Check in Π: **M1**

$3(1) + 2(-2) - 6(1) = 3 - 4 - 6 = -7 \neq 12$
Since $\mathbf{b} \cdot \mathbf{n} \neq 0$, the line intersects Π at a single point. **A1**

Q20 — Angle Between Sunlight Direction and Solar Panel MEDIUM

$\mathbf{d} = \begin{pmatrix} 1 \\ 2 \\ -2 \end{pmatrix}$, $\mathbf{n} = \begin{pmatrix} 2 \\ 1 \\ -2 \end{pmatrix}$ (normal to Π). **M1**

First find angle α between **d** and **n**: **M1**

$$\cos\alpha = \frac{|\mathbf{d} \cdot \mathbf{n}|}{|\mathbf{d}||\mathbf{n}|} = \frac{|2 + 2 + 4|}{\sqrt{1+4+4} \cdot \sqrt{4+1+4}} = \frac{8}{3 \cdot 3} = \frac{8}{9}$$ **A1**

Angle between line and plane $= 90° - \alpha$:

$\alpha = \arccos\left(\frac{8}{9}\right) \approx 27.266\ldots°$, $\theta = 90° - 27.266\ldots° \approx 62.7°$ (GDC) **A1**

Note: the angle between a line and a plane uses $\sin\theta = |\mathbf{d} \cdot \mathbf{n}|/(|\mathbf{d}||\mathbf{n}|)$ *equivalently; using cos directly gives the complement (the angle with the normal), which is a common error.*

Q21 — Plane Through Three Points; Line of Intersection HARD

(a) $\overrightarrow{AB} = \begin{pmatrix} 1 \\ 2 \\ -1 \end{pmatrix}$, $\overrightarrow{AC} = \begin{pmatrix} -1 \\ 1 \\ 2 \end{pmatrix}$ **M1**

$$\mathbf{n} = \overrightarrow{AB} \times \overrightarrow{AC} = \begin{pmatrix} (2)(2) - (-1)(1) \\ (-1)(-1) - (1)(2) \\ (1)(1) - (2)(-1) \end{pmatrix} = \begin{pmatrix} 5 \\ -1 \\ 3 \end{pmatrix} = (5, -1, 3)$$ **A1 AG**

(b) Using point $A(1,0,1)$: $5(1)+(-1)(0)+3(1)=5+3=8$, so $\Pi_1: 5x-y+3z=8$ **A1**

(c) Direction of intersection: $\mathbf{d}=\mathbf{n}_1\times\mathbf{n}_2=\begin{pmatrix}5\\-1\\3\end{pmatrix}\times\begin{pmatrix}2\\-1\\1\end{pmatrix}=\begin{pmatrix}(-1)(1)-(3)(-1)\\(3)(2)-(5)(1)\\(5)(-1)-(-1)(2)\end{pmatrix}=\begin{pmatrix}2\\1\\-3\end{pmatrix}=(2,1,-3)$ **M1**

Point $A(1,0,1)$ satisfies both planes ($5(1)-0+3(1)=8$; $2(1)-0+1=3$), so it lies on the line of intersection.

Line: $\mathbf{r}=\begin{pmatrix}1\\0\\1\end{pmatrix}+t\begin{pmatrix}2\\1\\-3\end{pmatrix}$, $t\in\mathbb{R}$, i.e. through point $(1,0,1)$ with direction $(2,1,-3)$ **A1**

Note: Accept any scalar multiple of the direction vector; accept any valid point on both planes.

Q22 — Angle Between Line and Plane; Intersection Point HARD

(a) Direction of ℓ: $\mathbf{b}=\begin{pmatrix}1\\-1\\2\end{pmatrix}$; normal of Π: $\mathbf{n}=\begin{pmatrix}2\\-1\\2\end{pmatrix}$. **M1**

$$\sin\theta=\frac{|\mathbf{b}\cdot\mathbf{n}|}{|\mathbf{b}||\mathbf{n}|}=\frac{|2+1+4|}{\sqrt{6}\cdot 3}=\frac{7}{3\sqrt{6}}$$

GDC: $\theta=\arcsin\left(\frac{7}{3\sqrt{6}}\right)=\arcsin(0.95346\ldots)=72.2845\ldots^\circ$

$\theta\approx 72.3^\circ$ (3 s.f.) **A1A1**

Note: Award A1 for correct sine formula setup, A1 for final answer. Complement error (cos instead of sin) loses second A1. Keep full GDC precision until the final rounding step.

(b) Substitute $\mathbf{r}$ into plane: $2(1+t)-(3-t)+2(2t)=9$ **M1**

$$2+2t-3+t+4t=9\implies 7t=10\implies t=\frac{10}{7}$$

Point: $\left(1+\frac{10}{7},3-\frac{10}{7},\frac{20}{7}\right)=\left(\frac{17}{7},\frac{11}{7},\frac{20}{7}\right)$ **A1**

Q23 — Sunlight Angle on a Plane; Perpendicular Rod Length HARD

(a) $\mathbf{d}=\begin{pmatrix}1\\-1\\-3\end{pmatrix}$; $\mathbf{n}=\begin{pmatrix}3\\-4\\1\end{pmatrix}$. **M1**

$$\sin\theta=\frac{|\mathbf{d}\cdot\mathbf{n}|}{|\mathbf{d}||\mathbf{n}|}=\frac{|3+4-3|}{\sqrt{11}\cdot\sqrt{26}}=\frac{4}{\sqrt{286}}$$

GDC: $\theta = \arcsin\left(\dfrac{4}{\sqrt{286}}\right) = \arcsin(0.23645\ldots) = 13.7°$ (3 s.f.) **A1A1**

Note: The angle between a line and a plane uses $\sin\theta = |\mathbf{d}\cdot\mathbf{n}|/(|\mathbf{d}||\mathbf{n}|)$*; using cos gives the complement and is penalised.*

(b) $P = (4,0,0)$ lies on Π since $3(4) - 4(0) + 0 = 12$. **(M1)**

The support rod runs from $P(4,0,0)$ perpendicular to $z = 0$; it is vertical, so length $=$ z-coordinate of $P = 0$ m.

Since P already has $z = 0$, the rod has zero length; that is, P lies on the ground plane. **A1**

Note: Award A1 for correctly identifying length $= 0$ *with justification.*

Q24 — Three Planes; Line of Intersection and a Critical Value of k HARD

(a) Direction: $\mathbf{d} = \mathbf{n}_1 \times \mathbf{n}_2 = \begin{pmatrix}1\\2\\-1\end{pmatrix} \times \begin{pmatrix}2\\-1\\3\end{pmatrix} = \begin{pmatrix}(2)(3)-(-1)(-1)\\(-1)(2)-(1)(3)\\(1)(-1)-(2)(2)\end{pmatrix} = \begin{pmatrix}5\\-5\\-5\end{pmatrix}$ **M1**

Simplify: $\mathbf{d} = \begin{pmatrix}1\\-1\\-1\end{pmatrix}$. Set $z = 0$: $x + 2y = 3$, $2x - y = 1$; solve: $x = 1,\ y = 1$. **A1**

$\mathbf{r} = \begin{pmatrix}1\\1\\0\end{pmatrix} + t\begin{pmatrix}1\\-1\\-1\end{pmatrix}$, i.e. through point $(1,1,0)$ with direction $(1,-1,-1)$ **A1**

(b) The three planes share a unique common point precisely when $\det(\mathbf{n}_1, \mathbf{n}_2, \mathbf{n}_3) \neq 0$. With $\mathbf{n}_3 = (1,2,k)$: **M1**

$\det(\mathbf{n}_1, \mathbf{n}_2, \mathbf{n}_3) = -5k - 5$, which vanishes at $k = -1$.

At $k = -1$, $\Pi_3 : x + 2y - z = 5$ has the same normal as Π_1 ($x + 2y - z = 3$) but a different constant, so Π_3 is parallel to but distinct from Π_1: the three planes then share **no common point** (not a common line, since Π_1 and Π_3 never meet).

$k = -1$ **A1**

Note: For every $k \neq -1$ *the three normals are linearly independent and the planes meet at a single point that depends on* k*;* $k = -1$ *is the unique value at which this fails.*

Q25 — Distance from Point to Plane; Foot of Perpendicular HARD

(a) Plane in Cartesian form: $2x - y + 2z = 6$; $\mathbf{n} = \begin{pmatrix}2\\-1\\2\end{pmatrix}$, $|\mathbf{n}| = 3$. **M1**

Distance $= \dfrac{|2(5)-1(1)+2(-2)-6|}{3} = \dfrac{|10-1-4-6|}{3} = \dfrac{|-1|}{3} = \dfrac{1}{3} = 1/3$ **M1A1 AG**

Note: Both method marks required for AG: one for formula, one for correct substitution.

(b) The perpendicular from $Q(5,1,-2)$ has parametric form: $\begin{pmatrix} 5+2s \\ 1-s \\ -2+2s \end{pmatrix}$ **M1**

Substitute into plane: $2(5+2s)-(1-s)+2(-2+2s)=6 \implies 10+4s-1+s-4+4s=6 \implies 9s=1 \implies s=\dfrac{1}{9}$

Foot: $\left(5+\dfrac{2}{9}, 1-\dfrac{1}{9}, -2+\dfrac{2}{9}\right) = \left(\dfrac{47}{9}, \dfrac{8}{9}, -\dfrac{16}{9}\right)$, i.e. $(47/9, 8/9, -16/9)$ **A1**

Q26 — Intersection Direction; Angle Between Planes; Distance HARD

(a) $\mathbf{n}_1 = \begin{pmatrix} 3 \\ -1 \\ 2 \end{pmatrix}, \mathbf{n}_2 = \begin{pmatrix} 1 \\ 2 \\ -1 \end{pmatrix}$. **M1**

$\mathbf{d} = \mathbf{n}_1 \times \mathbf{n}_2 = \begin{pmatrix} (-1)(-1)-(2)(2) \\ (2)(1)-(3)(-1) \\ (3)(2)-(-1)(1) \end{pmatrix} = \begin{pmatrix} 1-4 \\ 2+3 \\ 6+1 \end{pmatrix} = \begin{pmatrix} -3 \\ 5 \\ 7 \end{pmatrix}$ **A1 AG**

(b) $\cos\alpha = \dfrac{|\mathbf{n}_1 \cdot \mathbf{n}_2|}{|\mathbf{n}_1||\mathbf{n}_2|} = \dfrac{|3-2-2|}{\sqrt{14}\cdot\sqrt{6}} = \dfrac{1}{\sqrt{84}}$; GDC: $\alpha = \arccos\left(\dfrac{1}{\sqrt{84}}\right) \approx 83.7°$ (3 s.f.) **M1A1**

(c) Test $R(2,-1,0)$ in Π_2: $2+2(-1)-0=0$, but the plane requires 4, so $0 \neq 4$ and R does **not** lie on Π_2. **A1**

Distance $= \dfrac{|0-4|}{|\mathbf{n}_2|} = \dfrac{4}{\sqrt{1+4+1}} = \dfrac{4}{\sqrt{6}}$ (i.e. 4/sqrt(6)) ≈ 1.63 units **A1**

Note: The substitution uses $\Pi_2 : x+2y-z=4$, so R gives $2+2(-1)-0=0$, not 4 – take care with the sign of the y-term.

Q27 — Particle Line; Angle with Plane; Crossing Time HARD

(a) Direction vector from table: $\begin{pmatrix} 2 \\ -1 \\ 2 \end{pmatrix}$ (change per second).

$\mathbf{r} = \begin{pmatrix} 1 \\ 2 \\ 0 \end{pmatrix} + t\begin{pmatrix} 2 \\ -1 \\ 2 \end{pmatrix}$ **A1**

(b) $\mathbf{b} = \begin{pmatrix} 2 \\ -1 \\ 2 \end{pmatrix}$, $\mathbf{n} = \begin{pmatrix} 2 \\ 3 \\ -1 \end{pmatrix}$, $|\mathbf{b}| = 3$, $|\mathbf{n}| = \sqrt{14}$. **M1**

$\sin\theta = \dfrac{|\mathbf{b}\cdot\mathbf{n}|}{|\mathbf{b}||\mathbf{n}|} = \dfrac{|4-3-2|}{3\sqrt{14}} = \dfrac{1}{3\sqrt{14}}$; GDC: $\theta = \arcsin(0.08909\ldots) = 5.11°$ (3 s.f.) **A1**

Note: Use of cos for line-plane angle is the flagged complement error; penalise with M1 A0.

(c) Substitute into Π: $2(1+2t)+3(2-t)-(2t)=6$ **M1**

$2+4t+6-3t-2t=6 \implies -t+8=6 \implies t=2$.

Point: $(1+4,\ 2-2,\ 4) = (5,0,4)$. Time: $t=2$ s. **A1**

Note: $t=2$ lies within the stated domain $t \geq 0$, and the crossing point matches the particle's tabulated position at $t=2$.

Q28 — Reflection of a Point in a Plane HARD

(a) Substitute $S(3,-1,4)$ into LHS of Π: $3-2(-1)+2(4)=3+2+8=13\neq 5$, so $S\notin\Pi$. **A1**

(b) The line through S perpendicular to Π: $\mathbf{r} = \begin{pmatrix} 3 \\ -1 \\ 4 \end{pmatrix} + s\begin{pmatrix} 1 \\ -2 \\ 2 \end{pmatrix}$. **M1**

Foot F: substitute into Π: $(3+s)-2(-1-2s)+2(4+2s)=5$ **M1**

$3+s+2+4s+8+4s=5 \implies 9s+13=5 \implies s=-\dfrac{8}{9}$

$F = \left(3-\dfrac{8}{9},\ -1+\dfrac{16}{9},\ 4-\dfrac{16}{9}\right) = \left(\dfrac{19}{9},\dfrac{7}{9},\dfrac{20}{9}\right)$ **A1**

Reflection: $S' = 2F - S = \left(\dfrac{38}{9}-3,\ \dfrac{14}{9}+1,\ \dfrac{40}{9}-4\right) = \left(\dfrac{11}{9},\dfrac{23}{9},\dfrac{4}{9}\right)$, i.e. $(11/9, 23/9, 4/9)$ **A1**

Q29 — Perpendicular Planes; Angle Between Line of Intersection and z-axis HARD

(a) $\Pi_1 \perp \Pi_2 \iff \mathbf{n}_1\cdot\mathbf{n}_2 = 0$: $\begin{pmatrix} a \\ 2 \\ -1 \end{pmatrix}\cdot\begin{pmatrix} 2 \\ -1 \\ a \end{pmatrix} = 2a-2-a = a-2 = 0$ **M1**

$a=2$ **A1**

(b) With $a=2$: $\Pi_1 : 2x+2y-z=3$, $\Pi_2 : 2x-y+2z=5$. **M1**

Direction of intersection: $\mathbf{d} = \mathbf{n}_1\times\mathbf{n}_2 = \begin{pmatrix} 2 \\ 2 \\ -1 \end{pmatrix}\times\begin{pmatrix} 2 \\ -1 \\ 2 \end{pmatrix} = \begin{pmatrix} (2)(2)-(-1)(-1) \\ (-1)(2)-(2)(2) \\ (2)(-1)-(2)(2) \end{pmatrix} = \begin{pmatrix} 3 \\ -6 \\ -6 \end{pmatrix}$

z-axis direction: $\mathbf{k} = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$.

$\sin\phi = \dfrac{|\mathbf{d}\cdot\mathbf{k}|}{|\mathbf{d}||\mathbf{k}|} = \dfrac{6}{\sqrt{81}} = \dfrac{6}{9} = \dfrac{2}{3}$; GDC: $\phi = \arcsin\left(\dfrac{2}{3}\right) = 41.8^\circ$ (3 s.f.) **A1A1**

Note: Award first A1 for correct **d***; second A1 for final angle. Complement error penalised with A0 on final mark.*

Q30 — Line Parallel to a Plane; Distance from Point to Plane HARD

(a) Direction of ℓ: $\mathbf{b} = \begin{pmatrix} 1 \\ 1 \\ -1 \end{pmatrix}$; normal of Π: $\mathbf{n} = \begin{pmatrix} 3 \\ -1 \\ 2 \end{pmatrix}$. **M1**

$\mathbf{b}\cdot\mathbf{n} = 3 - 1 - 2 = 0$ (i.e. b . n = 0), so ℓ is parallel to Π. **A1**

Testing the point $A(2,-1,3)$ on ℓ in Π: $3(2)-(-1)+2(3) = 6+1+6 = 13 \neq 12$, so A does not lie on Π; hence ℓ does not lie in Π. **A1**

(b) Line m through $T(4,1,2)$ parallel to **n**: $\mathbf{r} = \begin{pmatrix} 4 \\ 1 \\ 2 \end{pmatrix} + s\begin{pmatrix} 3 \\ -1 \\ 2 \end{pmatrix}$. **M1**

Substitute into Π: $3(4+3s)-(1-s)+2(2+2s) = 12 \implies 12+9s-1+s+4+4s = 12 \implies 14s = -3 \implies s = -\dfrac{3}{14}$

Meeting point: $\left(4-\dfrac{9}{14}, 1+\dfrac{3}{14}, 2-\dfrac{6}{14}\right) = \left(\dfrac{47}{14}, \dfrac{17}{14}, \dfrac{11}{7}\right) = (47/14,\ 17/14,\ 11/7)$ **A1**

Distance $= |s|\cdot|\mathbf{n}| = \dfrac{3}{14}\cdot\sqrt{14} = \dfrac{3}{\sqrt{14}} = \dfrac{3\sqrt{14}}{14} \approx 0.802$ m (GDC). **A1**