



3D Geometry

Question1

Let P be the plane such that it contains the straight line $\frac{x-1}{2} = \frac{y-3}{3} = \frac{z+2}{1}$ and is perpendicular to the plane $x + 2y + 3z = 4$. Let P_1 be the plane which passes through the point $(4, 2, 2)$ and is parallel to P .

Then which of the following statements is (are) TRUE?

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Options:

A.

The equation of the plane P is $7x - 5y + z = -10$

B.

The distance between the planes P and P_1 is 30

C.

The distance of the plane P from the origin is $2\sqrt{3}$

D.

The acute angle between the plane P and the plane $2x + 2y + z = 3$ is $\cos^{-1}\left(\frac{1}{3\sqrt{3}}\right)$

Answer: A

Solution:

The plane P contains the line

$$L : \frac{x-1}{2} = \frac{y-3}{3} = \frac{z+2}{1}$$

and is also perpendicular to the plane $x + 2y + 3z = 4$.

The direction ratios of line L are 2, 3, 1.

The normal vector of the given plane $x + 2y + 3z = 4$ is 1, 2, 3.

Since plane P is perpendicular to this plane, its normal vector $\vec{n}$ must be perpendicular to $(1, 2, 3)$ and also perpendicular to the line's direction $(2, 3, 1)$.

Thus, $\vec{n}$ is given by the cross product:

$$\vec{n} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 3 & 1 \\ 1 & 2 & 3 \end{vmatrix}$$

On simplifying,

$$\vec{n} = 7\hat{i} - 5\hat{j} + \hat{k}$$

The line passes through the point $(1, 3, -2)$, and since this point lies on the plane P , we use the point-normal form:

$$7(x - 1) - 5(y - 3) + (z + 2) = 0$$

On simplifying,

$$7x - 5y + z + (-7 + 15 + 2) = 0 \Rightarrow 7x - 5y + z = -10$$

Hence, equation of plane P is:

$$7x - 5y + z = -10$$

Option A is correct.

Plane P_1 is parallel to P . Hence it will have the same normal vector, so the general equation is:

$$7x - 5y + z = d$$

Since P_1 passes through the point $(4, 2, 2)$, substitute these coordinates:

$$7(4) - 5(2) + 2 = d$$

$$28 - 10 + 2 = d \Rightarrow d = 20$$

Therefore, equation of P_1 is

$$7x - 5y + z = 20$$

The distance between two parallel planes $Ax + By + Cz + D_1 = 0$ and $Ax + By + Cz + D_2 = 0$ is:

$$\frac{|D_1 - D_2|}{\sqrt{A^2 + B^2 + C^2}}$$

Here, $D_1 = -10$, $D_2 = 20$ (taking standard form). So,

$$\text{Distance} = \frac{|-10 - 20|}{\sqrt{7^2 + (-5)^2 + 1^2}} = \frac{30}{\sqrt{75}}$$

Option B is incorrect.

The formula for the perpendicular distance from point (x_1, y_1, z_1) to plane $Ax + By + Cz + D = 0$ is:

$$\frac{|Ax_1 + By_1 + Cz_1 + D|}{\sqrt{A^2 + B^2 + C^2}}$$

For origin $(0, 0, 0)$:

$$\text{Distance} = \frac{|0 + 0 + 0 - 10|}{\sqrt{75}} = \frac{10}{\sqrt{75}} = \frac{2}{\sqrt{3}} = \frac{2\sqrt{3}}{3}$$

Option C is incorrect.

Acute angle between planes P and $2x + 2y + z = 3$

Let the normal vectors be:

$$\vec{n}_1 = (7, -5, 1) \text{ and } \vec{n}_2 = (2, 2, 1).$$

The cosine of the angle between two planes is given by:

$$\cos \theta = \frac{|\vec{n}_1 \cdot \vec{n}_2|}{|\vec{n}_1| |\vec{n}_2|}$$

Substitute the values:

$$\cos \theta = \frac{|7(2) + (-5)(2) + 1(1)|}{\sqrt{75} \times 3} = \frac{1}{3\sqrt{3}}$$

Hence,

$$\theta = \cos^{-1} \left(\frac{1}{3\sqrt{3}} \right)$$

Option D is correct.

Question2

Let L be the straight line joining the points $P(1, 2, -1)$ and $Q(2, 3, 1)$. Let S be the foot of the perpendicular drawn from the point $R(4, -1, 5)$ to the line L . Another line passing through R intersects L at a point T such that the point S divides the line segment PT internally in the ratio $|PS| : |ST| = 1 : 2$, where $|PS|$ and $|ST|$ are the lengths of the line segments PS and ST , respectively.

Then which of the following statements is (are) TRUE?

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Options:

A.

The orthocentre of the triangle PRT is $\left(\frac{23}{5}, -4, \frac{31}{5}\right)$

B.

The orthocentre of the triangle PRT is $(4, 3, 5)$

C.

The area of the triangle PRT is $6\sqrt{5}$

D.

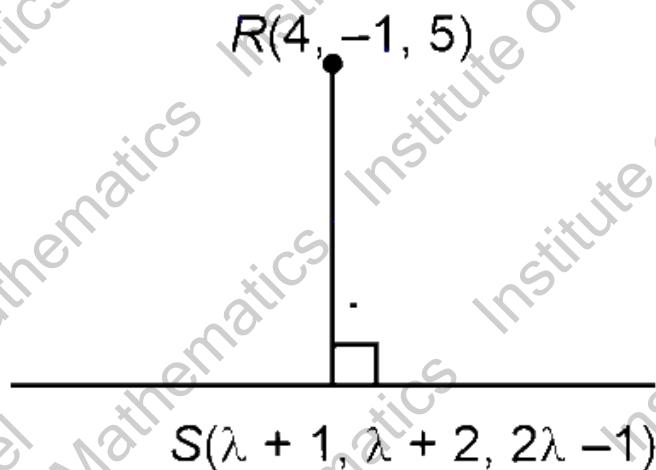
The area of the triangle PRT is $18\sqrt{5}$

Answer: A

Solution:

Equation of the line joining points $P(1, 2, -1)$ and $Q(2, 3, 1)$ is

$$\frac{x-1}{1} = \frac{y-2}{1} = \frac{z+1}{2} = \lambda$$



Let the equation of line L be as above. The point S is the foot of the perpendicular from $R(4, -1, 5)$ to line L .

The direction ratio of line L is $(1, 1, 2)$.

We use the condition for perpendicularity, which says the dot product of direction ratios of the line and of the line joining R and S is zero.

So,

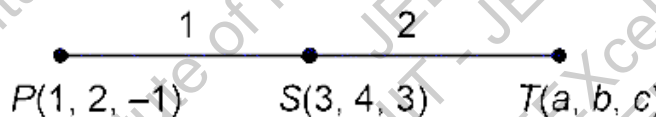
$$(\lambda - 3)(1) + (\lambda + 3)(1) + (2\lambda - 6)(2) = 0$$

Simplifying,

$$\lambda - 3 + \lambda + 3 + 4\lambda - 12 = 0$$

$$6\lambda - 12 = 0 \Rightarrow \lambda = 2$$

Therefore, coordinates of point S are $S(3, 4, 3)$.



Now, the point S divides the line segment PT internally in the ratio $1 : 2$.

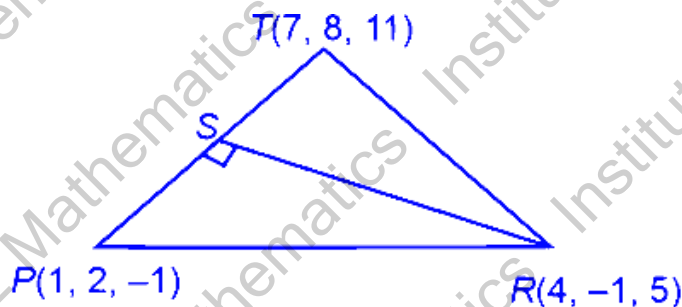
Using the section formula,

$$\frac{a+2}{3} = 3, \quad \frac{b+4}{3} = 4, \quad \frac{c-2}{3} = 3$$

Hence,

$$a = 7, \quad b = 8, \quad c = 11$$

Therefore, $T(7, 8, 11)$.



Now, the area of triangle PRT is given by

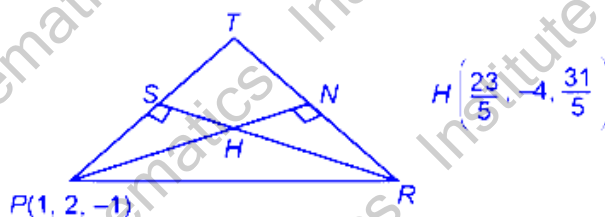
$$\text{Area} = \frac{1}{2}(PT)(RS)$$

Substituting given values,

$$\text{Area} = \frac{1}{2} \times 6\sqrt{6} \times \sqrt{30} = 18\sqrt{5}$$

Therefore, Option (D) is correct.

(A)



The equation of line RS is

$$\frac{x-4}{1} = \frac{y+1}{-5} = \frac{z-5}{2}$$

Let point H lie on line RS .

The direction ratios of PH are

$$\left(\frac{23}{5} - 1, -4 - 2, \frac{31}{5} + 1\right) = \left(\frac{18}{5}, -6, \frac{36}{5}\right)$$

The direction ratios of RT are $(-3, -9, -6)$.

The dot product of $\overrightarrow{PH}$ and $\overrightarrow{RT}$ is

$$\begin{aligned} \overrightarrow{PH} \cdot \overrightarrow{RT} &= -3\left(\frac{18}{5}\right) - 9(-6) - 6\left(\frac{36}{5}\right) \\ &= \frac{-54}{5} + 54 - \frac{216}{5} = 0 \end{aligned}$$

Since the dot product is zero, the two lines are perpendicular. Hence, point H is the orthocentre of triangle PRT .

Therefore, Option (A) is correct.

Question3

Let L_1 be the line of intersection of the planes given by the equations

$$2x + 3y + z = 4 \text{ and } x + 2y + z = 5.$$

Let L_2 be the line passing through the point $P(2, -1, 3)$ and parallel to L_1 . Let M denote the plane given by the equation

$$2x + y - 2z = 6.$$

Suppose that the line L_2 meets the plane M at the point Q . Let R be the foot of the perpendicular drawn from P to the plane M .

Then which of the following statements is (are) TRUE?

Options:

A.

The length of the line segment PQ is $9\sqrt{3}$

B.

The length of the line segment QR is 15

C.

The area of $\triangle PQR$ is $\frac{3}{2}\sqrt{234}$

D.

The acute angle between the line segments PQ and PR is $\cos^{-1}\left(\frac{1}{2\sqrt{3}}\right)$ **Answer: A****Solution:**

To find the line of intersection L_1 of the two planes given by the equations $2x + 3y + z = 4$ and $x + 2y + z = 5$, we use these equations to obtain the line in standard form:

$$L_1 : \begin{aligned} 2x + 3y + z &= 4 \\ x + 2y + z &= 5 \end{aligned}$$

Solving these equations gives us the line L_1 in standard form:

$$\frac{x+7}{1} = \frac{y-6}{-1} = \frac{z}{1}$$

For the line L_2 that passes through the point $P(2, -1, 3)$ and is parallel to L_1 , the equation is:

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

The equation of the plane M is:

$$2x + y - 2z = 6$$

To find the coordinates of the point Q where L_2 meets the plane M , assume the coordinates of Q are $(\lambda + 2, -\lambda - 1, \lambda + 3)$. Since Q lies on the plane M , substituting these into the equation of the plane gives:

$$2(\lambda + 2) + (-\lambda - 1) - 2(\lambda + 3) = 6$$

Solving, we find:

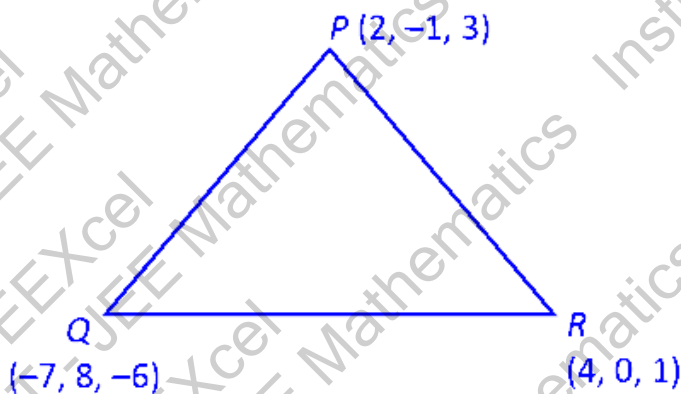
$$\lambda = -9$$

Thus, the coordinates of Q are $(-7, 8, -6)$.

For the foot of the perpendicular $R(x_1, y_1, z_1)$ from P to the plane M , using the formula for the distance from a point to a plane;

$$\frac{x_1-2}{2} = \frac{y_1+1}{1} = \frac{z_1-3}{-2} = \frac{-(4-1-6-6)}{9}$$

The solution provides the coordinates of R as $(4, 0, 1)$.



Calculating the line segments:

$$PQ = 9\sqrt{3} \text{ units}$$

$$QR = \sqrt{234} \text{ units}$$

$$PR = 3 \text{ units}$$

For the acute angle θ between PQ and PR :

$$\cos \theta = \frac{1}{3\sqrt{3}}$$

$$\sin \theta = \sqrt{\frac{26}{27}}$$

The area of triangle $\triangle PQR$ is given by:

$$\text{Area} = \frac{1}{2} \times PQ \times PR \times \sin \theta = \frac{3}{2} \sqrt{234} \text{ square units}$$

Question4

A straight line drawn from the point $P(1, 3, 2)$, parallel to the line $\frac{x-2}{1} = \frac{y-4}{2} = \frac{z-6}{1}$, intersects the plane $L_1 : x - y + 3z = 6$ at the point Q .

Another straight line which passes through Q and is perpendicular to the plane L_1 intersects the plane $L_2 : 2x - y + z = -4$ at the point R . Then which of the following statements is (are) TRUE?

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Options:

- A. The length of the line segment PQ is $\sqrt{6}$
- B. The coordinates of R are $(1, 6, 3)$
- C. The centroid of the triangle PQR is $(\frac{4}{3}, \frac{14}{3}, \frac{5}{3})$
- D. The perimeter of the triangle PQR is $\sqrt{2} + \sqrt{6} + \sqrt{11}$

Answer: A

Solution:

$$\text{line : } \frac{x-1}{1} = \frac{y-3}{2} = \frac{z-2}{1}$$

$$(x, y, z) = (\lambda + 1, 2\lambda + 3, \lambda + 2)$$

$$\text{Put in } L_1 : x - y + 3z = 6$$

$$(\lambda + 1) - (2\lambda + 3) + 3(\lambda + 2) = 6$$

$$2\lambda = 2 \Rightarrow \lambda = 1$$

$$Q = (2, 5, 3)$$

$$\text{line: } \frac{x-2}{1} = \frac{y-5}{-1} = \frac{z-3}{3}$$

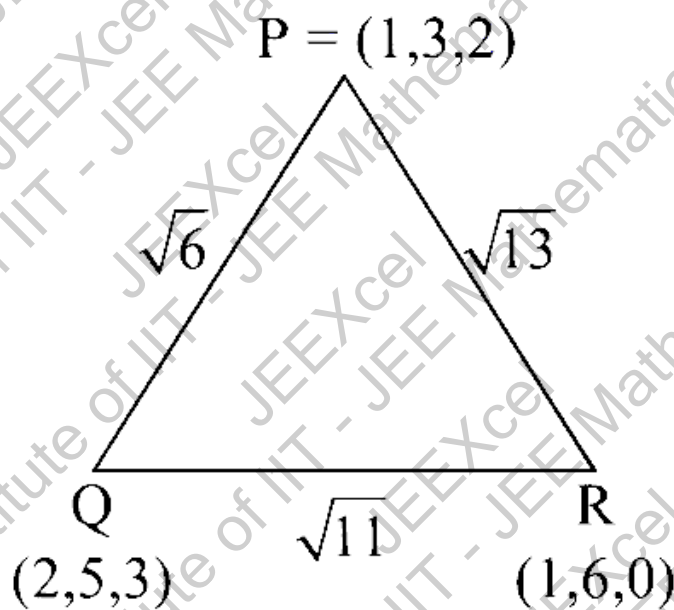
$$(x, y, z) = (t + 2, 5 - t, 3t + 3)$$

$$\text{Put in } L_2 : 2x - y + z = -4$$

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

$$6t = -6 \Rightarrow t = -1$$

$$R = (1, 6, 0)$$



$$\text{Perimeter} = \sqrt{6} + \sqrt{13} + \sqrt{11}$$

$$\text{Centroid} = \left(\frac{4}{3}, \frac{14}{3}, \frac{5}{3} \right)$$

Question 5

Let $\mathbb{R}^3$ denote the three-dimensional space. Take two points $P = (1, 2, 3)$ and $Q = (4, 2, 7)$. Let $\text{dist}(X, Y)$ denote the distance between two points X and Y in $\mathbb{R}^3$. Let

$$S = \{X \in \mathbb{R}^3 : (\text{dist}(X, P))^2 - (\text{dist}(X, Q))^2 = 50\} \text{ and}$$

$$T = \{Y \in \mathbb{R}^3 : (\text{dist}(Y, Q))^2 - (\text{dist}(Y, P))^2 = 50\}.$$

Then which of the following statements is (are) TRUE?

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Options:

- A. There is a triangle whose area is 1 and all of whose vertices are from S .
- B. There are two distinct points L and M in T such that each point on the line segment LM is also in T .
- C. There are infinitely many rectangles of perimeter 48, two of whose vertices are from S and the other two vertices are from T .
- D. There is a square of perimeter 48, two of whose vertices are from S and the other two vertices are from T .

Answer: A

Solution:

$$S = \{X : (XP)^2 - (XQ)^2 = 50\}$$

$$T = \{Y : (YQ)^2 - (YP)^2 = 50\}$$

for finding $S \equiv X(x, y, z)$ and for $T \equiv Y(x, y, z)$

$$((x-1)^2 + (y-1)^2 + (z-1)^2) - ((x-4)^2 + (y-2)^2 + (z-7)^2) = 50$$

$$\Rightarrow S = \{(x, y, z) : 6x + 8z = 105\}$$

$$T = \{(x, y, z) : 6x + 8z = 5\}$$

Since S and T both are plane;

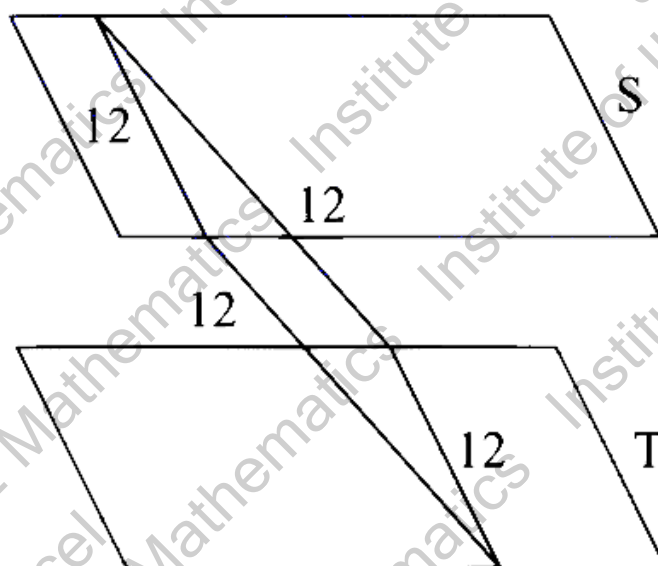
(A) There exist a triangle in plane S whose area = 1 (always)

(B) L & M lies on plane T , hence line segment joining L & M will lie on plane T .

(C) Distance between S & T

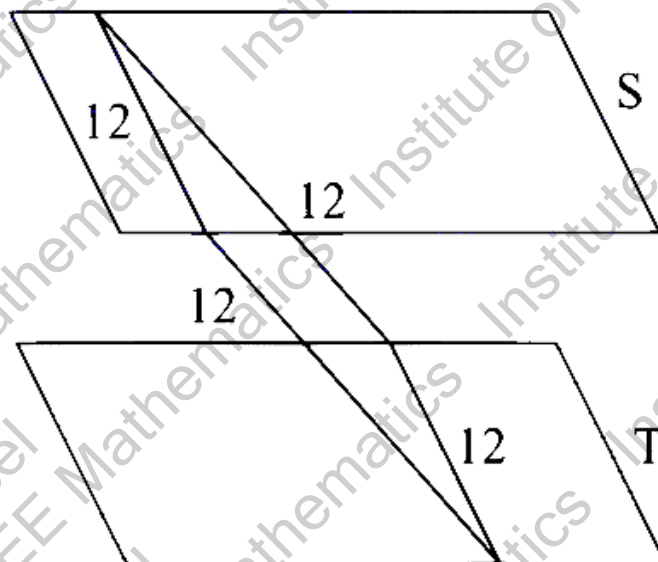
$$d = \left| \frac{105-5}{10} \right| = 10$$

Hence for rectangle of perimeter 48 can exist.



There will be infinite such rectangle possible.

(D) For square



Hence Answers A, B, C, D are correct.

Question6

Let P_1 and P_2 be two planes given by

$$P_1 : 10x + 15y + 12z - 60 = 0$$

$$P_2 : -2x + 5y + 4z - 20 = 0$$

Which of the following straight lines can be an edge of some tetrahedron whose two faces lie on P_1 and P_2 ?

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Options:

A. $\frac{x-1}{0} = \frac{y-1}{0} = \frac{z-1}{5}$

B. $\frac{x-6}{-5} = \frac{y}{2} = \frac{z}{3}$

C. $\frac{x}{-2} = \frac{y-4}{5} = \frac{z}{4}$

D. $\frac{x}{1} = \frac{y-4}{-2} = \frac{z}{3}$

Answer: A

Solution:

P_1 and P_2 be two planes given by

$$P_1 : 10x + 15y + 12z - 60 = 0$$

$$P_2 : -2x + 5y + 4z - 20 = 0$$

Now finding line of intersection of both the planes,

Let $z = \lambda$, then

$$10x + 15y = 60 - 12\lambda \dots\dots\dots (1)$$

$$-2x + 5y = 20 - 4\lambda \dots\dots\dots (2)$$

Now solving the eq. (1) and (2) we get,

$$\frac{x}{0} = \frac{y-4}{-4} = \frac{z}{5} \quad (\because \lambda = z)$$

Now any skew line with the line of intersection of given plane can be edge of tetrahedron.

Now using above concept we will solve all options.

For option (A)

$$\frac{x-1}{0} = \frac{y-1}{0} = \frac{z-1}{5}$$

Point is $(1, 1, 5\lambda + 1)$

Now satisfying this point in given plane we have,

$$10 \times 1 + 15 \times 1 + 12 \times (5\lambda + 1) - 60 = 0$$

$$\Rightarrow 60\lambda = 23$$

$$\Rightarrow \lambda = \frac{23}{60}$$

Now we can see line is intersecting the plane P_1 , at some point.

Now checking for plane (P_2)

$$-2 \times 1 + 5 \times 1 + 4(5\lambda + 1) = 20$$

$$\Rightarrow 20\lambda = 13$$

$$\Rightarrow \lambda = \frac{13}{20}$$

Also intersecting plane (P_2)

Hence, it can be the edge of tetrahedron.

For option (B)

$$\frac{x-6}{-5} = \frac{y}{2} = \frac{z}{3} \text{ point is } (-5\lambda + 6, 2\lambda, 3\lambda)$$

this point is satisfying plane P_1

$$10(-5\lambda + 6) + 15 \times 2\lambda + 12 \times 3\lambda = 60$$

$$\Rightarrow -50\lambda + 60 + 30\lambda + 36\lambda = 60$$

$$\Rightarrow 16\lambda = 0$$

$$\Rightarrow \lambda = 0$$

Now checking for plane P_2

$$-2(-5\lambda + 6) + 5 \times 2\lambda + 4 \times 3\lambda = 20$$

$$\Rightarrow +10\lambda - 12 + 10\lambda + 12\lambda = 20$$

$$\Rightarrow 32\lambda = 32$$

$$\Rightarrow \lambda = 1$$

Hence, it can be the edge of tetrahedron.

For option (C)

$$\frac{x}{-2} = \frac{y-4}{5} = \frac{z}{4}$$

point is $(-2\lambda, 5\lambda + 4, 4\lambda)$

Similarly checking in plane P_1 we get.

$$\lambda \text{ for } P_1 = 0$$

$$\lambda \text{ for } P_2 = 0$$

Hence, it can not be the edge of tetrahedron

For option (D),

$$\frac{x}{1} = \frac{y-4}{-2} = \frac{z}{3}$$

point $(\lambda, -2\lambda + 4, 3\lambda)$ and for $\lambda = 0$ point will be $(0, -4, 0)$ which is lying on line of intersection and DR of plane P_2 is $(-2, 5, 4)$ and DR of line is $(1, -2, 3)$

Now line is lying completely on P_2

Hence, it can be the edge of tetrahedron.

Question 7

Let S be the reflection of a point Q with respect to the plane given by

$$\vec{r} = -(t+p)\hat{i} + t\hat{j} + (1+p)\hat{k}$$

where t, p are real parameters and $\hat{i}, \hat{j}, \hat{k}$ are the unit vectors along the three positive coordinate axes. If the position vectors of Q and S are $10\hat{i} + 15\hat{j} + 20\hat{k}$ and $\alpha\hat{i} + \beta\hat{j} + \gamma\hat{k}$ respectively, then which of the following is/are TRUE ?

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Options:

A. $3(\alpha + \beta) = -101$

B. $3(\beta + \gamma) = -71$

C. $3(\gamma + \alpha) = -86$

D. $3(\alpha + \beta + \gamma) = -121$

Answer: A

Solution:

Given : equation of plane

$$\vec{r} = -(t + p)\hat{i} + t\hat{j} + (1 + p)\hat{k}$$

on rearranging we get,

$$\vec{r} = \hat{k} + t + (-\hat{i} + \hat{j}) + p(-\hat{i} + \hat{k})$$

So, equation of plane in standard form is given by

$$[\vec{r} - \hat{k} \quad -\hat{i} + \hat{j} \quad -\hat{i} + \hat{k}] = 0$$

$$\Rightarrow \begin{bmatrix} x & y & z - 1 \\ -1 & 1 & 0 \\ -1 & 0 & 1 \end{bmatrix} = 0$$

$$\Rightarrow x + y + z = 1 \dots \dots \dots (1)$$

Now given co-ordinate of $Q = (10, 15, 20)$

And Co-ordinates of $S = (\alpha, \beta, \gamma)$

Now using the image formula of point and plane we get,

$$\frac{\alpha - 10}{1} = \frac{\beta - 15}{1} = \frac{\gamma - 20}{1} = \frac{-2(10 + 15 + 20 - 1)}{3}$$

$$\Rightarrow \alpha - 10 = \beta - 15 = \gamma - 20 = \frac{-88}{3}$$

$$\Rightarrow \alpha = \frac{-58}{3}, \beta = \frac{-43}{3}, \gamma = \frac{-28}{3}$$

Now solving all options.

$$3(\alpha + \beta) = -101$$

$$3(\beta + \gamma) = -71$$

$$3(\gamma + \alpha) = -86$$

$$3(\alpha + \beta + \gamma) = -129$$

Question 8

Let $\alpha^2 + \beta^2 + \gamma^2 \neq 0$ and $\alpha + \gamma = 1$. Suppose the point $(3, 2, -1)$ is the mirror image of the point $(1, 0, -1)$ with respect to the plane $\alpha x + \beta y + \gamma z = \delta$. Then which of the following statements is/are TRUE?

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Options:

A. $\alpha + \beta = 2$

B. $\delta - \gamma = 3$

C. $\delta + \beta = 4$

D. $\alpha + \beta + \gamma = \delta$

Answer: A

Solution:

Since, the point $A(3, 2, -1)$ is the mirror image of the point $B(1, 0, -1)$ with respect to the plane $\alpha x + \beta y + \gamma z = \delta$, then

$$\frac{\alpha}{3-1} = \frac{\beta}{2-0} = \frac{\gamma}{(-1)-(-1)}$$

$$\Rightarrow \frac{\alpha}{1} = \frac{\beta}{1} = \frac{\gamma}{0} \Rightarrow \gamma = 0$$

it is given that $\alpha + \gamma = 1 \Rightarrow \alpha = 1$, so $\beta = 1$.

And, the mid-point of AB, $M(2, 1, -1)$ lies on the given plane, so

$$2\alpha + \beta - \gamma = \delta$$

$$\Rightarrow 2(1) + (1) - 0 = \delta \Rightarrow \delta = 3$$

$$\therefore \alpha + \beta = 2, \delta - \gamma = 0, \delta + \beta = 4.$$

Question9

Let L_1 and L_2 be the following straight lines.

$$L_1 : \frac{x-1}{1} = \frac{y}{-1} = \frac{z-1}{3} \text{ and } L_2 : \frac{x-1}{-3} = \frac{y}{-1} = \frac{z-1}{1}.$$

Suppose the straight line

$$L : \frac{x-\alpha}{l} = \frac{y-1}{m} = \frac{z-\gamma}{-2}$$

lies in the plane containing L_1 and L_2 and passes through the point of intersection of L_1 and L_2 . If the line L bisects the acute angle between the lines L_1 and L_2 , then which of the following statements is/are TRUE?

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Options:

A. $\alpha - \gamma = 3$

B. $l + m = 2$

C. $\alpha - \gamma = 1$

D. $l + m = 0$

Answer: A

Solution:

Equation of given straight lines

$$L_1 : \frac{x-1}{1} = \frac{y}{-1} = \frac{z-1}{3}$$

$$\text{and } L_2 : \frac{x-1}{-3} = \frac{y}{-1} = \frac{z-1}{1}$$

having vector form respectively, are

$$\text{and } \mathbf{r} = (\hat{i} + \hat{k}) + \lambda(\hat{i} - \hat{j} + 3\hat{k})$$

$$\mathbf{r} = (\hat{i} + \hat{k}) + \mu(-3\hat{i} - \hat{j} + \hat{k})$$

$$\therefore (\hat{i} - \hat{j} + 3\hat{k}) \cdot (-3\hat{i} - \hat{j} + \hat{k})$$

$$= -3 + 1 + 3 = 1 \text{ is positive,}$$

$\therefore$ Angle between supporting line vectors of lines L_1 and L_2 is acute, and point of intersection of given lines L_1 and L_2 is $(1, 0, 1)$

Now, vector along the acute angle bisector of vectors $(\hat{i} - \hat{j} + 3\hat{k})$ and $(-3\hat{i} - \hat{j} + \hat{k})$ is $(\hat{i} - \hat{j} + 2\hat{k})$ or $(\hat{i} + \hat{j} - 2\hat{k})$

It is given that line

$L : \frac{x-\alpha}{l} = \frac{y-\beta}{m} = \frac{z-\gamma}{n}$ is the bisector of the acute angle between the lines L_1 and L_2 , so

$$l = 1 \text{ and } m = 1$$

$$\text{and } \frac{l-\alpha}{1} = \frac{0-1}{1} = \frac{1-\gamma}{-2}$$

$$\Rightarrow \alpha = 2, \gamma = -1$$

$$\therefore \alpha - \gamma = 3, l + m = 2$$