

Scalar product

The scalar product is used to find the angle between two vectors (or between two lines).

The formula for scalar product is

$$\mathbf{a} \cdot \mathbf{b} = ab \cos \theta \text{ (LEARN THIS!!)}$$

where a is the magnitude of \mathbf{a} , b is the magnitude of \mathbf{b} , and θ is the angle between vectors \mathbf{a} and \mathbf{b} .

Note: The angle between two lines is the angle between their direction vectors.

Example:

Find the angle between the vectors

$$3\mathbf{i} + 2\mathbf{j} - 2\mathbf{k} \text{ and } -4\mathbf{i} - \mathbf{j} + 3\mathbf{k}.$$

Solution:

Step 1: Find the scalar product:

$$\begin{pmatrix} 3 \\ 2 \\ -2 \end{pmatrix} \cdot \begin{pmatrix} -4 \\ -1 \\ 3 \end{pmatrix} = -12 - 2 - 6 = -20$$

Step 2: Find the magnitude of each vector:

$$\begin{vmatrix} 3 \\ 2 \\ -2 \end{vmatrix} = \sqrt{9+4+4} = \sqrt{17}, \quad \begin{vmatrix} -4 \\ -1 \\ 3 \end{vmatrix} = \sqrt{16+1+9} = \sqrt{26}$$

Step 3: Use the formula for the scalar product:

$$\mathbf{a} \cdot \mathbf{b} = ab \cos \theta$$

$$-20 = \sqrt{17} \times \sqrt{26} \times \cos \theta$$

$$\cos \theta = \frac{-20}{\sqrt{17} \times \sqrt{26}} = -0.9513$$

So, $\theta = 162^\circ$

There is also an acute angle between the lines. This is $180 - 162 = 18^\circ$.

VECTORS

The magnitude of a vector is its length. The

magnitude of the vector $\begin{pmatrix} a \\ b \\ c \end{pmatrix}$ is $\sqrt{a^2 + b^2 + c^2}$.

The distance between 2 points A and B is $|\overrightarrow{AB}|$.

Example: a) Find the vector equation of line l_1 passing through the points A(1, -2, 6) and B(7, 1, -3).

b) A second line l_2 has equation

$$\mathbf{r} = (1 + 2\mathbf{j} + 3\mathbf{k}) + s(4\mathbf{i} - 6\mathbf{j} + 2\mathbf{k}).$$

Show that line l_1 and l_2 are skew and find the angle between the lines.

Solution:

a) The direction of the line is

$$\overrightarrow{AB} = \mathbf{b} - \mathbf{a} = \begin{pmatrix} 7 \\ 1 \\ -2 \end{pmatrix} - \begin{pmatrix} 1 \\ -2 \\ 6 \end{pmatrix} = \begin{pmatrix} 6 \\ 3 \\ -8 \end{pmatrix}$$

The line passes through (1, -2, 6), so the equation is

$$\mathbf{r} = \begin{pmatrix} 1 \\ -2 \\ 6 \end{pmatrix} + t \begin{pmatrix} 6 \\ 3 \\ -8 \end{pmatrix}$$

b) To show lines are skew we show they can't intersect. We do this by writing the two vector equations equal to each other and attempting to solve the equations:

$$\begin{pmatrix} 1 \\ -2 \\ 6 \end{pmatrix} + t \begin{pmatrix} 6 \\ 3 \\ -8 \end{pmatrix} = \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix} + s \begin{pmatrix} 4 \\ -6 \\ 2 \end{pmatrix}$$

NOTE: It is ESSENTIAL that the lines are written with different parameters.

The vector equation of the line passing through the point (a, b, c) in the direction of the vector

$$l\mathbf{i} + m\mathbf{j} + n\mathbf{k} \text{ is: } \mathbf{r} = \begin{pmatrix} a \\ b \\ c \end{pmatrix} + t \begin{pmatrix} l \\ m \\ n \end{pmatrix}$$

Note: t is a parameter and \mathbf{r} is the position vector of a general point (x, y, z) on the line.

Lines are called skew if they do not intersect and if they are not parallel. So to prove that two lines are skew you prove they don't intersect.

We can form equations:

$$1 + 6t = 1 + 4s \rightarrow 6t - 4s = 0 \quad (1)$$

$$-2 + 3t = 2 - 6s \rightarrow 3t + 6s = 4 \quad (2)$$

$$6 - 8t = 3 + 2s \rightarrow 8t + 2s = 3 \quad (3)$$

Solving equations (1) and (2):

$$6t - 4s = 0 \quad (1)$$

$$6t + 12s = 8 \quad (2) \times 2$$

Subtract equations to remove t : $16s = 8$

$$\text{So } s = 0.5.$$

From equation (1), we then get $t = 1/3$.

To show they are skew lines, we must check that these values do not work in the 3rd equation:

$$8t + 2s = 8 \times \frac{1}{3} + 2 \times 0.5 \neq 3$$

Therefore the lines are skew.

We find the angle between the direction vectors:

$$\begin{pmatrix} 6 \\ 3 \\ -8 \end{pmatrix} \cdot \begin{pmatrix} 4 \\ -6 \\ 2 \end{pmatrix} = 24 - 18 - 16 = -10$$

$$\begin{vmatrix} 6 \\ 3 \\ -8 \end{vmatrix} = \sqrt{36+9+64} = \sqrt{109} \quad \text{and} \quad \begin{vmatrix} 4 \\ -6 \\ 2 \end{vmatrix} = \sqrt{56}$$

$$\text{So } -10 = \sqrt{109} \times \sqrt{56} \times \cos \theta$$

$$\text{Therefore } \cos \theta = -0.12799 \Rightarrow \theta = 97.4^\circ$$

So the acute angle is 82.6° .

Calculus And Vectors Formula Sheet

Michael Sullivan



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