BROAD ROOT SCHOLARS ACADEMY

Formulae On Vector Algebra

Position Vector and Magnitude

- If $P(x, y, z)$ is any point in 3D, then the line joining the point to the origin gives its position vector and is denoted by $\overrightarrow{OP} = \vec{r} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$

- If $\vec{a} = a\hat{\imath} + b\hat{\jmath} + c\hat{k}$, then magnitude of the vector is given by $|\vec{a}| = \sqrt{a^2 + b^2 + c^2}$

Direction Cosines & Direction Ratios

- If $P(x, y, z)$ having position vector $\vec{r}$ makes angle α, β, γ with X, Y & $Z - axis$ respectively, then the **direction cosines** are given by: $l = \cos\alpha, m = \cos\beta$ and $n = \cos\gamma$
  - ✓ $\cos\alpha = \frac{x}{|\vec{r}|}, \cos\beta = \frac{y}{|\vec{r}|}\ and\ \cos\gamma = \frac{z}{|\vec{r}|}$

- If α, β, γ are the direction angles of vector $\vec{r} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$ then its **direction cosines** are also given by $\cos\alpha = \frac{x}{|\vec{r}|}$, $\cos\beta = \frac{y}{|\vec{r}|}$ and $\cos\gamma = \frac{z}{|\vec{r}|}$
  - ✓ $x = |\vec{r}|\cos\alpha = |\vec{r}|l, \quad y = |\vec{r}|\cos\beta = |\vec{r}|m, \quad z = |\vec{r}|\cos\gamma = |\vec{r}|n$

- $(|\vec{r}|l,\ |\vec{r}|m,\ |\vec{r}|n)$ are the **direction ratios** denoted by a, b & c respectively of the given vector.
  - ✓ $a = |\vec{r}|l, \quad b = |\vec{r}|m, \quad c = |\vec{r}|n$

- If l, m & n are the **direction cosines** of a vector then $l^2 + m^2 + n^2 = 1$

- The **direction ratios** of the line joining $P(x_1, y_1, z_1)$ and $Q(x_2, y_2, z_2)$ are given by:

  $a = x_2 - x_1, \quad b = y_2 - y_1, \quad c = z_2 - z_1$

- The **direction cosines** of the line joining $P(x_1, y_1, z_1)$ and $Q(x_2, y_2, z_2)$ are given by:

  $l = \frac{x_2 - x_1}{|PQ|}, \quad m = \frac{y_2 - y_1}{|PQ|}, \quad m = \frac{z_2 - z_1}{|PQ|}$

- ✓ If $\vec{a} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$, then x, y, z are direction ratios of $\vec{a}$.
- ✓ If $\vec{a} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$, then $l\hat{\imath} + m\hat{\jmath} + n\hat{k}$ or $\cos\alpha\,\hat{\imath} + \cos\beta\,\hat{\jmath} + \cos\gamma\,\hat{k}$ gives $\hat{a}$

Vector Algebra

- If $\vec{a} = a_1\hat{\imath} + b_1\hat{\jmath} + c_1\hat{k}$ and $\vec{b} = a_2\hat{\imath} + b_2\hat{\jmath} + c_2\hat{k}$ then:
  - ✓ $\vec{a} + \vec{b} = (a_1 + a_2)\hat{\imath} + (b_1 + b_2)\hat{\jmath} + (c_1 + c_2)\hat{k}$
  - ✓ $\vec{a} - \vec{b} = (a_1 - a_2)\hat{\imath} + (b_1 - b_2)\hat{\jmath} + (c_1 - c_2)\hat{k}$
  - ✓ $\vec{a}.\vec{b} = a_1a_2 + b_1b_2 + c_1c_2 = |\vec{a}||\vec{b}|\cos\theta$
  - ✓ $\vec{a} \times \vec{b} = \begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \end{vmatrix} = |\vec{a}||\vec{b}|\sin\theta\,\hat{n}$
- Angle between the vectors, $\theta = cos^{-1}\left(\frac{\vec{a}.\vec{b}}{|\vec{a}||\vec{b}|}\right)$ or $\theta = sin^{-1}\left(\frac{\vec{a}\times\vec{b}}{|\vec{a}||\vec{b}|}\right)$
- Projection of a vector $\vec{a}$ on the vector $\vec{b}$ is given by $\frac{1}{|\vec{b}|}(\vec{a}.\vec{b})$

Vector Components

- If $\vec{a} = a_1\hat{\imath} + b_1\hat{\jmath} + c_1\hat{k}$ then unit vector in the direction of $\vec{a}$ is given by $\hat{a} = \frac{1}{|\vec{a}|}.\vec{a}$
- If $P(x_1, y_1, z_1)$ and $Q(x_2, y_2, z_2)$ are two given points then the vector equation of the line $\overrightarrow{PQ} = (x_2 - x_1)\hat{\imath} + (y_2 - y_1)\hat{\jmath} + (z_2 - z_1)\hat{k}$

Section Formula

- If the point R divides the line joining the position vector of P and Q in the ratio $m{:}n$, then the position vector of R is given by:
  - ✓ Internally, $\vec{r} = \frac{m\vec{b}+n\vec{a}}{m+n}$
  - ✓ Externally, $\vec{r} = \frac{m\vec{b}-n\vec{a}}{m-n}$

Area

- If $\vec{a}$ and $\vec{b}$ are the adjacent sides of a triangle then its area is given by $\frac{1}{2}\left|\vec{a} \times \vec{b}\right|$
- If $\vec{a}$ and $\vec{b}$ are the adjacent sides of a parallelogram then its area is given by $\left|\vec{a} \times \vec{b}\right|$

Vector Properties

- If $\vec{a} = a_1\hat{\imath} + b_1\hat{\jmath} + c_1\hat{k}$ and $\vec{b} = a_2\hat{\imath} + b_2\hat{\jmath} + c_2\hat{k}$, they are collinear if $\frac{a_1}{a_2} = \frac{b_1}{b_2} = \frac{c_1}{c_2}$
- Dot Product:
  - If $\vec{a} \perp \vec{b}$ then $\theta = \frac{\pi}{2}$ hence $\vec{a}.\vec{b} = 0$
  - If $\vec{a} \parallel \vec{b}$ then $\theta = 0$ hence $\vec{a}.\vec{b} = |\vec{a}||\vec{b}|$
  - If $\theta = \pi$ then $\vec{a}.\vec{b} = -|\vec{a}||\vec{b}|$
  - Cauchy-Schwartz inequality: $|\vec{a}.\vec{b}| \leq |\vec{a}||\vec{b}|$
  - Triangle inequality: $\left|\vec{a} + \vec{b}\right| \leq |\vec{a}| + \left|\vec{b}\right|$
  - $\hat{\imath}.\hat{\imath} = \hat{\jmath}.\hat{\jmath} = \hat{k}.\hat{k} = 1$ and $\hat{\imath}.\hat{\jmath} = \hat{\jmath}.\hat{k} = \hat{k}.\hat{\imath} = 0$
- Cross Product:
  - $\vec{a} \parallel \vec{b}$ then $\theta = 0$ hence $\vec{a} \times \vec{b} = 0$
  - If $\vec{a} \perp \vec{b}$ then $\theta = \frac{\pi}{2}$ hence $\vec{a} \times \vec{b} = |\vec{a}||\vec{b}|$
  - $\hat{\imath} \times \hat{\imath} = \hat{\jmath} \times \hat{\jmath} = \hat{k} \times \hat{k} = 0$ and $\hat{\imath} \times \hat{\jmath} = \hat{k},\ \hat{\jmath} \times \hat{k} = \hat{\imath}$ & $\hat{k} \times \hat{\imath} = \hat{\jmath}$

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- CONCEPT **CLARITY** FIRST
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RESULTS ARE A BY-PRODUCT OF THE PROCESS

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