General Physics II

Ganesh Kuwar Chhetri

Dept. of Physics,
School of Science,
Kathmandu University

Course

Course Title: General Physics II

Course Code: PHYS 102

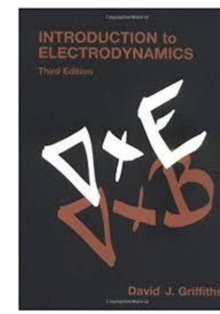
Level: B.Sc. & B.E.

Cr. Hrs.: 2 (32 Hrs.]

Year: I

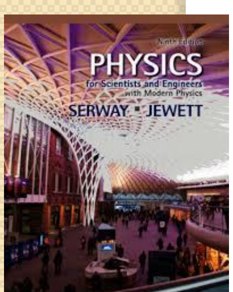
Semester: II

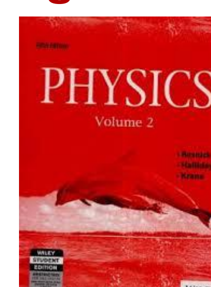
Electricity and Magnetism	– 27 Hrs
Modern Physics	– 5 Hrs



Text Books:

1. David J. Griffith, Introduction to Electrodynamics
2. R.A. Serway and J.W. Jewett, Physics for Scientist and Engineers with Modern Physics
3. D. Halliday, R. Resnick, and K. Krane, Physics Volume 2





Course Objectives

- To understand the terminology, facts, concepts and principles of electricity, magnetism and modern physics
- To demonstrate an understanding of the application of Physics in everyday life and the role of physics in other disciplines
- To recognize the importance of the work of key scientists
- To develop strong problem-solving skills
- To interpret data presented in tables, diagrams or graphs
- To develop experimental and investigative abilities
- To develop positive attitudes towards Physics
- To provide the basis for further study of the subject

Course Outline

TOPICS	LECTURE HOURS
ELECTRICTIY AND MAGNETISM	
1. Vector Analysis	3
2. Electrostatic Field	6
3. Electrostatic Field in Matter	4
4. Magnetostatics	4
5. Magnetostatic Field in Matter	4
6. Electromagnetic Induction	3
7. Electromagnetic Wave Propagation	3
MODERN PHYSICS	
1. Molecules and Solids	3
2. Nuclear Physics	2
TOTAL	**32**

Chapter - I
Vector Analysis

- **Vector Algebra**
  - Vector Operations
  - Vector Algebra: Component Form
  - Triple Products
  - Position, Displacement and Separation Vectors
- **Differential Calculus**
  - Ordinary Derivative
  - Gradient, Divergence , Curl
  - Product Rules
  - Second Derivatives
- **Integral Calculus**
  - Line, Surface, and Volume Integrals
  - The Fundamental Theorems for Gradients, Divergences and Curls
- **Spherical Polar Coordinates**

Scalars and Vectors

- Scalars have magnitude only and obey the rules of arithmetic and ordinary algebra.

  Examples: distance, mass, temperature, charge, electric potential, work, energy etc.

A **scalar quantity** is completely specified by a single value with an appropriate unit (5 m).

- Vectors have both magnitude and direction and obey the rules of vector algebra.

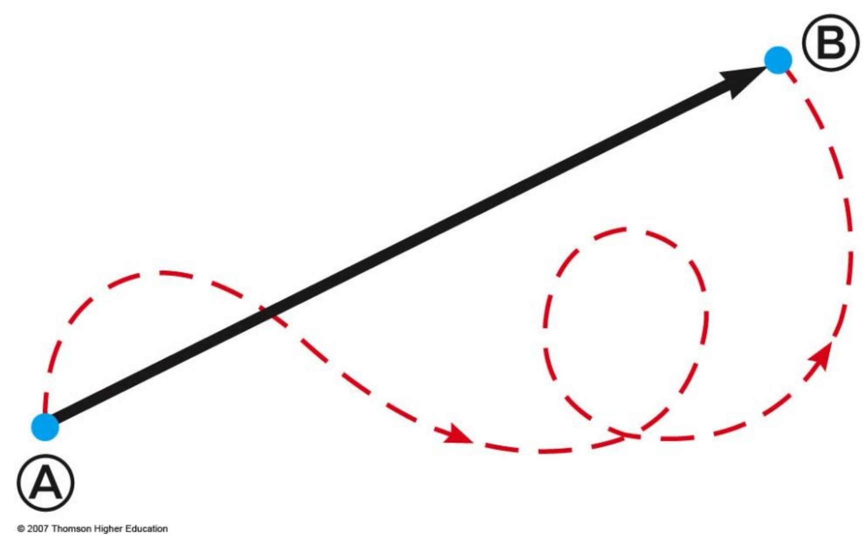
  Examples: displacement, velocity, force, momentum, torque, electric field, magnetic field etc.

A ***vector quantity*** is completely described by a number and appropriate units plus a direction (5m, north) .

Vectors

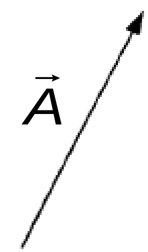
- A particle travels from A to B along the path shown by the dotted red line
  - This is the ***distance*** traveled and is a scalar

- The ***displacement*** is the solid line from A to B
  - The displacement is independent of the path taken between the two points
  - Displacement is a vector



Vector Notation

- In texts, we shall denote a vector by putting an arrow over the letter ($\vec{A}$, $\vec{B}$ and so on).
- The magnitude of a vector is written $|\vec{A}|$ or A .
- In diagrams, vector is denoted by arrow: the length of the arrow is proportional to the magnitude of the vector, and the arrowhead indicates its direction.

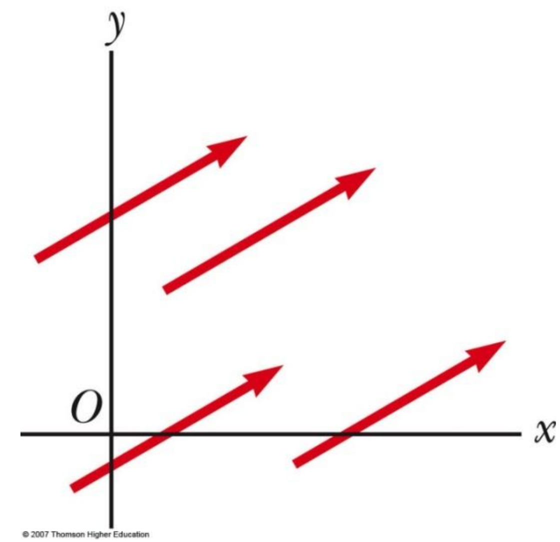


Text uses bold with arrow to denote a vector: $\vec{\mathbf{A}}$

Also used for printing is simple bold print: $\mathbf{A}$

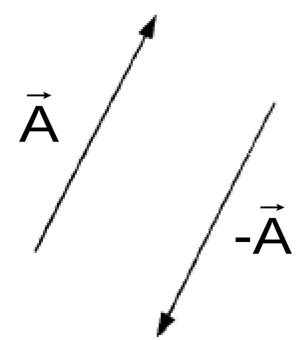
Equality of Two Vectors

- Two vectors are ***equal*** if they have the same magnitude and the same direction
- $\vec{\mathbf{A}} = \vec{\mathbf{B}}$ if $A = B$ and they point along parallel lines
- All of the vectors shown are equal



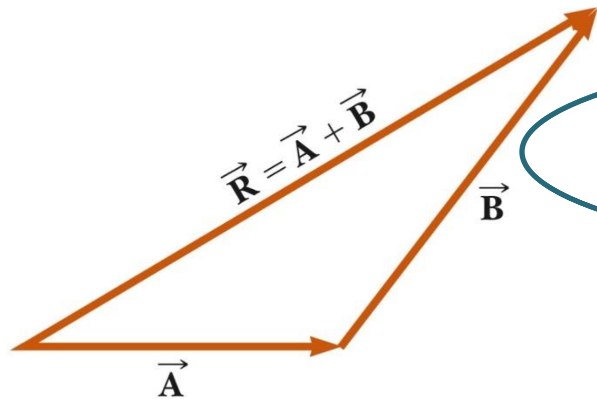
Negative of a Vector

- The negative of a vector is defined as the vector that, when added to the original vector, gives a resultant of zero
  - Represented as $-\vec{\mathbf{A}}$
  - $\vec{\mathbf{A}} + \left(-\vec{\mathbf{A}}\right) = 0$
- The negative of the vector will have the same magnitude, but point in the opposite direction



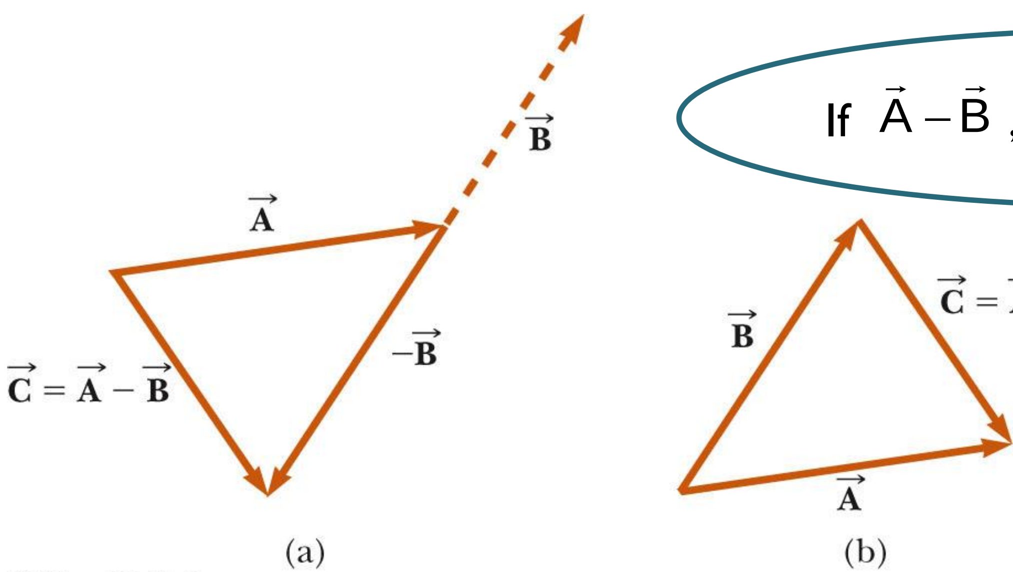
Four Vector Operations

1. Addition of Two Vectors



Place the tail of $\vec{B}$ at the head of $\vec{A}$; the sum, , $\vec{A}+\vec{B}$ is the vector from the tail of $\vec{A}$ to the head of $\vec{B}$.

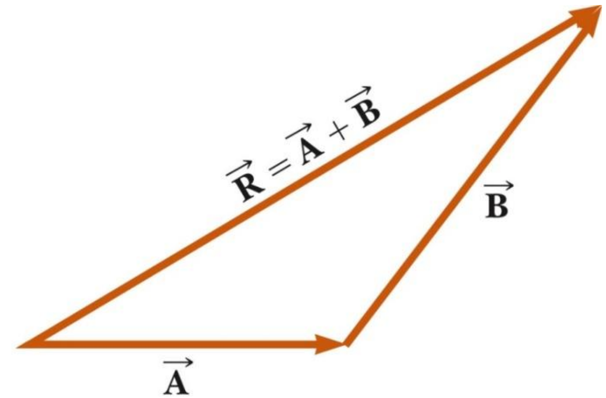
If $\vec{A}-\vec{B}$, then use $\vec{A}+(-\vec{B})$.



Addition of Vectors

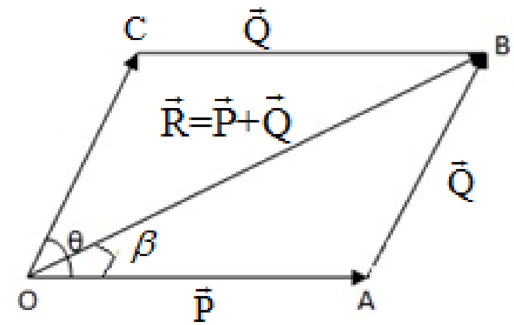
Triangle Law of Vector Addition

If two sides of a triangle taken in the same order represent the two vectors in magnitude and direction, then the third side in the opposite order represents the resultant of two vectors.



Parallelogram Law of Vector Addition

If two vectors are represented in magnitude and direction by the two sides of a parallelogram drawn from a point, then their resultant is given in magnitude and direction by the diagonal of the parallelogram passing through that point.



- $\boxed{R = \left|\vec{P}+\vec{Q}\right| = \sqrt{P^2+Q^2+2PQ\cos\theta}}$
- $\boxed{\tan\beta = \dfrac{Q\sin\theta}{P + Q\cos\theta}}$

Addition is commutative :

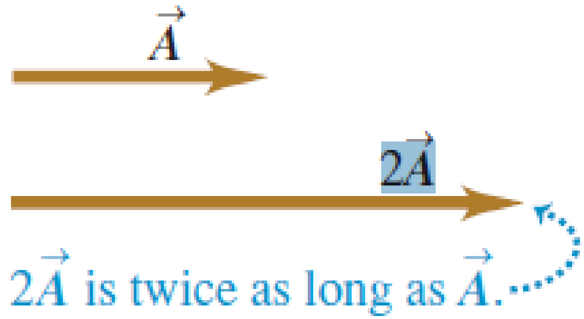
$$\vec{A}+\vec{B} = \vec{B}+\vec{A}$$

Addition is associative:

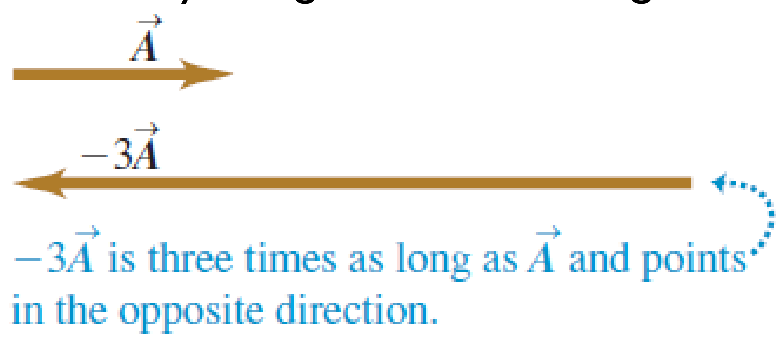
$$\left(\vec{A}+\vec{B}\right)+\vec{C} = \vec{A}+\left(\vec{B}+\vec{C}\right)$$

Multiplication by a Scalar

- Multiplying of a vector by a positive scalar multiples the magnitude but leaves the direction unchanged.



- Multiplying a vector by a negative scalar changes its magnitude and reverses its direction.



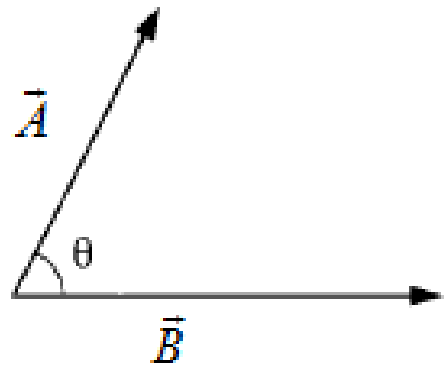
- Scalar multiplication is ***distributive:***

$$\boxed{a\left(\vec{A}+\vec{B}\right) = a\vec{A} + a\vec{B}}$$

Dot Product (Scalar Product) of Two Vectors

- The dot product of two vectors is defined by

$$\vec{A}\bullet\vec{B} \equiv AB\ \cos\theta \quad (\text{a scalar}) \qquad \left[W = \vec{F}\bullet\vec{S}\right]$$



- ➢The dot product is ***commutative:*** $\vec{A}\bullet\vec{B} = \vec{B}\bullet\vec{A}$
- ➢The dot product is ***distributive***: $\vec{A}\bullet\left(\vec{B}+\vec{C}\right) = \vec{A}\bullet\vec{B} + \vec{A}\bullet\vec{C}$
- ➢If the two vectors are parallel, then $\vec{A}\bullet\vec{B} = AB$

  If two vectors are perpendicular $\vec{A}\bullet\vec{B} = 0.$
- ➢For any vector $\vec{E}$,

$$\vec{E}\bullet\vec{E} = E^2$$

$$\Rightarrow E = \sqrt{\vec{E}\cdot\vec{E}}$$

Example 1:

- Let $\vec{C} = \vec{A} - \vec{B}$ (Figure D-1), and calculate $\vec{C} \bullet \vec{C}$.

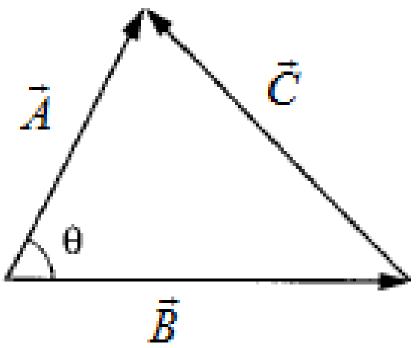


Figure D-1

Solution: $\vec{C} \bullet \vec{C} = \left(\vec{A} - \vec{B}\right) \bullet \left(\vec{A} - \vec{B}\right)$

$$= \vec{A} \bullet \vec{A} - \vec{A} \bullet \vec{B} - \vec{B} \bullet \vec{A} + \vec{B} \bullet \vec{B}$$

$$\therefore \quad \boxed{C^2 = A^2 + B^2 - 2AB\cos\theta}$$

This is the ***law of cosines.***

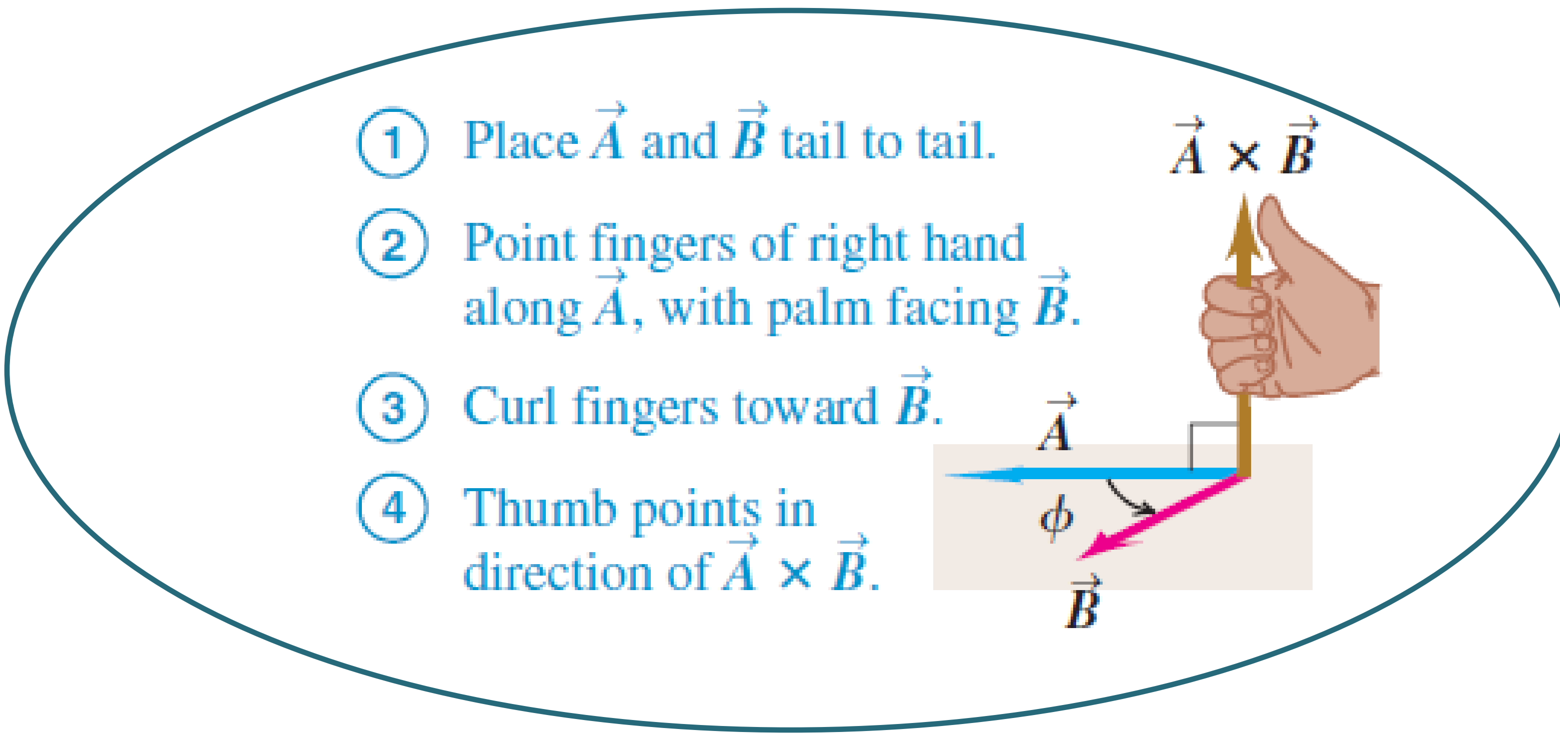
Cross Product (Vector Product) of Two Vectors

- The cross product of two vectors is defined by

$$\vec{A}\times\vec{B} \equiv AB\sin\theta\,\hat{n} \qquad (\text{a vector}) \qquad \left[\vec{\tau} = \vec{r}\times\vec{F}\right]$$

where $\hat{n}$ is the unit vector perpendicular to the plane $\vec{A}$ and $\vec{B}$.

- The direction of is determined by using **right-hand rule.**



Cross Product of Two Vectors

- The cross product is **not commutative**: $\vec{A}\times\vec{B}\neq\vec{B}\times\vec{A}$
- The cross product is ***distributive***: $\vec{A}\times\left(\vec{B}+\vec{C}\right)=\vec{A}\times\vec{B}+\vec{A}\times\vec{C}$

- If the two vectors are parallel, then $\vec{A}\times\vec{B}=0$
- If two vectors are perpendicular, then $\left|\vec{A}\times\vec{B}\right|=AB$

Geometrically,

$\left|\vec{A}\times\vec{B}\right|$ gives the area of the parallelogram generated by $\vec{A}$ and $\vec{\mathrm{B}}$ (Figure D-2).

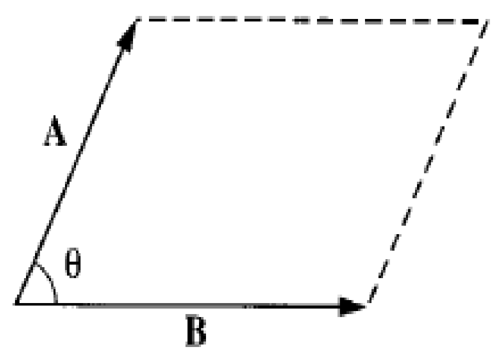
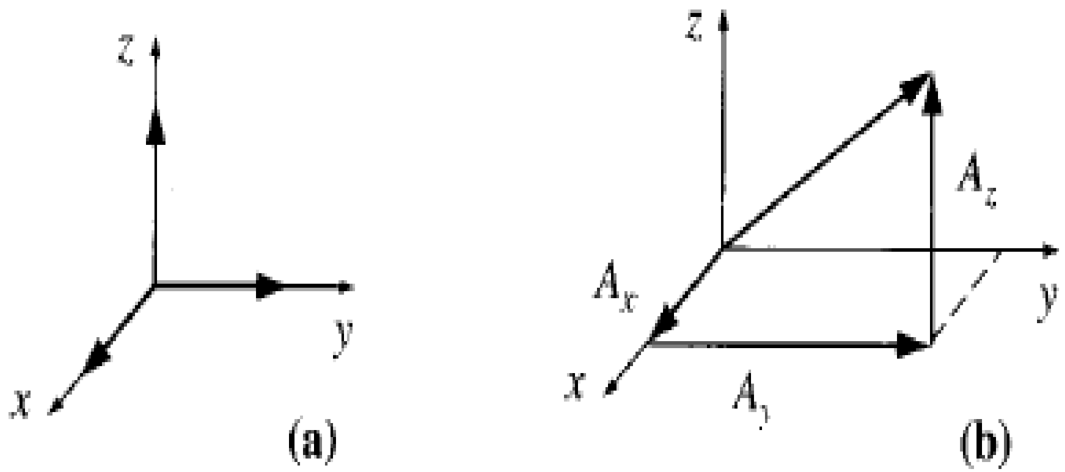


Figure D-2

Vector Algebra: Component Form

- Let $\hat{i}$, $\hat{j}$, and $\hat{k}$ be unit vectors parallel to axes respectively (Figure V-1).



$$\vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k} \quad \text{and} \quad \vec{B} = B_x\hat{i} + B_y\hat{j} + B_z\hat{k}$$

- **Addition of Two Vectors**

$$\vec{A} + \vec{B} = (A_x + B_x)\hat{i} + (A_y + B_y)\hat{j} + (A_z + B_z)\hat{k}$$

- **Multiplication by a Scalar**

$$a\vec{A} = (aA_x)\hat{i} + (aA_y)\hat{j} + (aA_z)\hat{k}$$

Vector Algebra: Component Form

Dot Product of Two Vectors

$$\vec{A}\bullet\vec{B} = A_x B_x + A_y B_y + A_z B_z$$

$$\left[\ \hat{i}\bullet\hat{i} = \hat{j}\bullet\hat{j} = \hat{k}\bullet\hat{k} = 1\ ; \quad \hat{i}\bullet\hat{j} = \hat{j}\bullet\hat{k} = \hat{k}\bullet\hat{i} = 0\ \right]$$

For any vector $\vec{A}$ **,** $A = \sqrt{A_x{}^2 + A_y{}^2 + A_z{}^2}$

Cross Product of Two Vectors

$$\vec{\mathbf{A}}\times\vec{\mathbf{B}} = (A_x\hat{i} + A_y\hat{j} + A_z\hat{k})\times(B_x\hat{i} + B_y\hat{j} + B_z\hat{k})$$

$$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

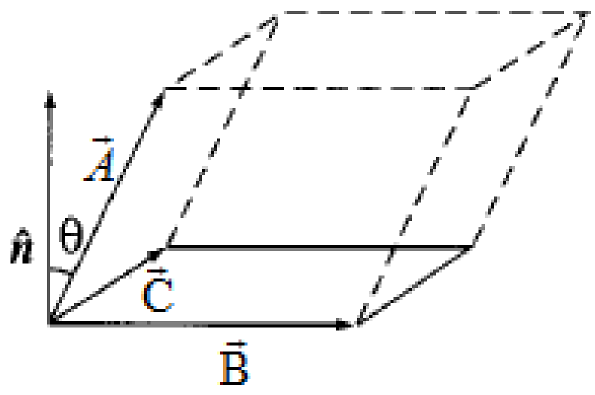
$$= (A_y B_z - A_z B_y)\hat{i} + (A_z B_x - A_x B_z)\hat{j} + (A_x B_y - A_y B_x)\hat{k}$$

$$\boxed{\because\ \left[\hat{i}\times\hat{i} = 0; \quad \hat{i}\times\hat{j} = \hat{k}, \qquad \hat{j}\times\hat{i} = -\hat{k}\right]}$$

Triple Product

Scalar triple product: $\vec{A}\bullet(\vec{B}\times\vec{C})$

For a parallelepiped generated by $\vec{A}, \vec{B}$ and $\vec{C}$.



$$\vec{A}\bullet(\vec{B}\times\vec{C}) = \left|\vec{B}\times\vec{C}\right|\left(A\cos\theta\right)$$

$$= \text{Area of the base of parallelepiped} \times \text{Altitude of the parallelepiped}$$

$$= \text{Volume of the parallelepiped generated by } \vec{A}, \vec{B} \text{ and } \vec{C}$$

$$* \quad \vec{A}\bullet(\vec{B}\times\vec{C}) = \vec{B}\bullet(\vec{C}\times\vec{A}) = \vec{C}\bullet(\vec{A}\times\vec{B})$$

$$* \quad \vec{A}\bullet(\vec{B}\times\vec{C}) = \begin{vmatrix} A_x & A_y & A_z \\ B_x & B_y & B_z \\ C_x & C_y & C_z \end{vmatrix}$$

$$* \quad \vec{A}\bullet(\vec{B}\times\vec{C}) = (\vec{A}\times\vec{B})\bullet\vec{C}$$

Triple product

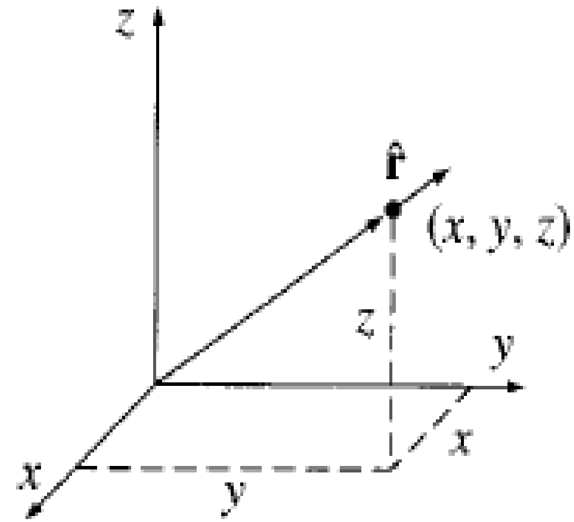
Vector triple product: $\vec{A}\times(\vec{B}\times\vec{C})$

The vector triple product can be simplified by the **BAC-CAB** rule:

$$\boxed{\vec{A}\times(\vec{B}\times\vec{C})=\vec{B}(\vec{A}\bullet\vec{C})-\vec{C}(\vec{A}\bullet\vec{B})}$$

Position and Displacement Vector

Position Vector:



$$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$$

* $$r = \sqrt{x^2 + y^2 + z^2} = \left(x^2 + y^2 + z^2\right)^{\frac{1}{2}}$$

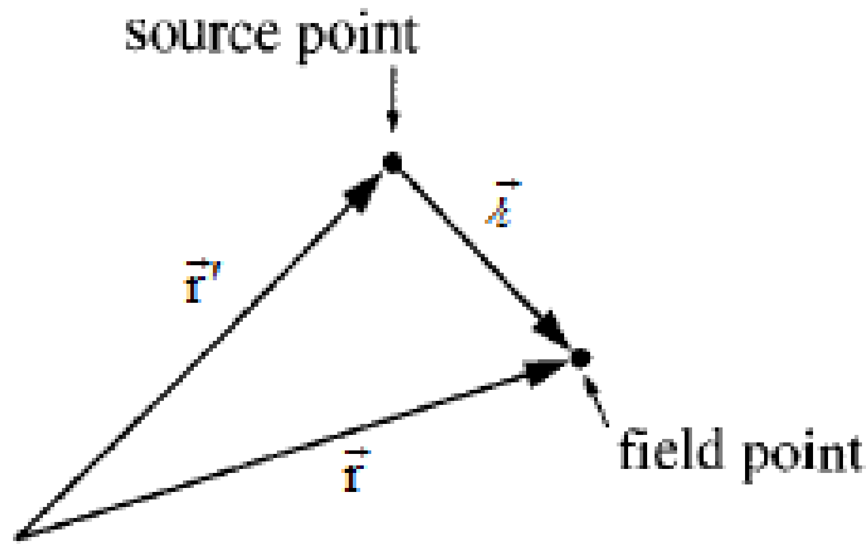
* $$\hat{r} = \frac{\vec{r}}{r} = \frac{x\hat{i} + y\hat{j} + z\hat{k}}{\sqrt{x^2 + y^2 + z^2}}$$

Infinitesimal Displacement Vector:

$$\boxed{d\vec{l} = dx\hat{i} + dy\hat{j} + dz\hat{k}}$$

Separation Vector

Separation Vector



The **separation vector** from the source point to the field point is

$$\vec{\mathscr{r}} = (\vec{r}-\vec{r}')$$

$$= (x - x')\hat{i} + (y - y')\hat{j} + (z - z')\hat{k}$$

Text Books & References

1. **David J. Griffith**, Introduction to Electrodynamics
2. **R. A. Serway and J.W. Jewett**, Physics for Scientist and Engineers with Modern Physics
3. **Halliday and Resnick**, Fundamental of Physics


Thank you