Course Title: Electromagnetics

Course Code: EPHY105L

Total Credit: 3 (2-0-2)

- ✓ Vector operators and coordinate systems
- ✓ Gauss' law and its applications
- ✓ Electric fields in matter and Electric polarization
- ✓ Biot-Savart law
- ✓ Ampere's law and applications
- ✓ Magnetic fields in matter, Magnetization
- ✓ Faraday's law of electromagnetic induction
- ✓ Displacement current and the generalized Ampere's law
- ✓ Maxwell's equations
- ✓ Electromagnetic waves

Mid-term: 15%
End-term: 35%
Quiz: 30%

Quiz will be held at each lecture from next week

Text Book: Introduction to Electrodynamics by David. J. Griffiths

Reference Book: Fundamentals of Physics by D. Halliday, R. Resnick, & J. Walker

Why Study Electromagnetics?

Must for Scientist and Engineers working in ANY field.

Most everyday equipment involve electrodynamics

- Mobile
- Computers
- Radio
- Satellite communications
- Lasers
- Projectors
- Light bulbs

Most everyday forces that we feel are of electromagnetic type:

- Normal Force from the floor or chair
- Chemical forces binding a molecule together
- Impact force between two colliding objects

Vector Operator

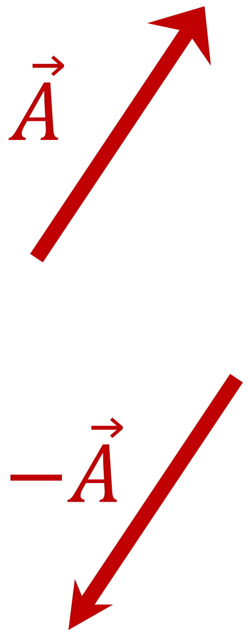
Scalars: Quantities have magnitude but no direction.

Vectors: Quantities have both magnitude and direction.

In diagrams, vectors are denoted by arrows:

✓ The length of the arrow is proportional to the magnitude of the vector

✓ The arrowhead indicates its direction.



Magnitude of $\vec{A} = |A|$

$-\vec{A}$ is a vector with the same magnitude but of opposite direction.

Magnitude of $-\vec{A} = |A|$

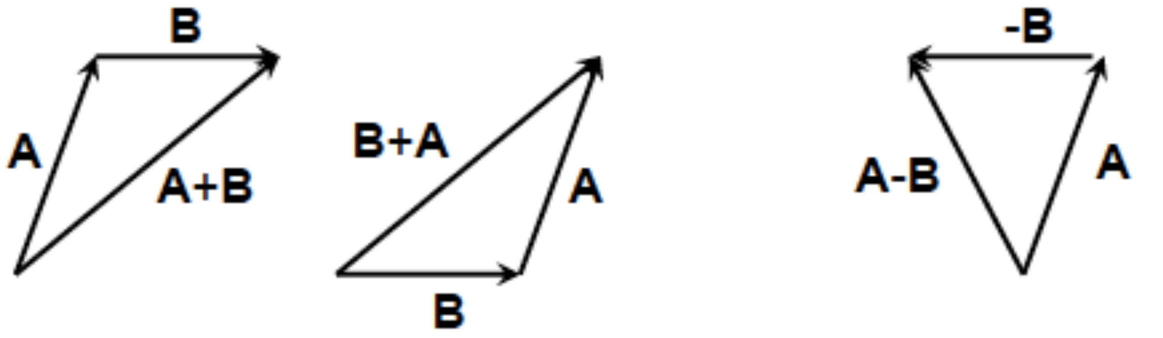
For our convenience, we will sometime denote the vector by boldface

Vector Operations

Addition of two vectors:

✓ Commutative: $\mathbf{A} + \mathbf{B} = \mathbf{B} + \mathbf{A}$

✓ Associative: $(\mathbf{A} + \mathbf{B}) + \mathbf{C} = \mathbf{A} + (\mathbf{B} + \mathbf{C})$



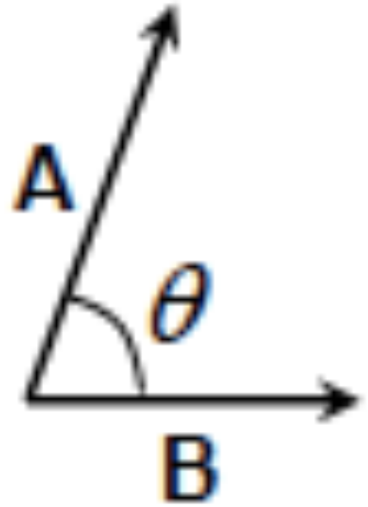
Multiplication by scalars:

Multiplies the magnitude but leaves the direction unchanged

Distributive: $a(\mathbf{A} + \mathbf{B}) = a\mathbf{A} + a\mathbf{B}$

Product of two vectors:

1. ***Dot Product (scalar product):*** $\mathbf{A}\cdot\mathbf{B} = AB\cos\theta$,
where θ is the angle between these two vectors.



2. ***Cross product (vector product):*** $\mathbf{A} \times \mathbf{B} \equiv AB\sin\theta\, \hat{n}$,
where $\hat{n}$ is a unit vector pointing perpendicular to the plane of **A** and **B** vectors
(direction is determined by the right-hand rule)

Properties of Dot and Cross Products

1. Dot Product:

✓ Commutative: $\mathbf{A}\cdot\mathbf{B} = \mathbf{B}\cdot\mathbf{A}$

✓ Distributive: $\mathbf{A}\cdot(\mathbf{B} + \mathbf{C}) = \mathbf{A}\cdot\mathbf{B} + \mathbf{A}\cdot\mathbf{C}$

2. Cross Product:

✓ Distributive: $A \times (B + C) = A\times B + A\times C$

✓ Not commutative: $A\times B = -B\times A$

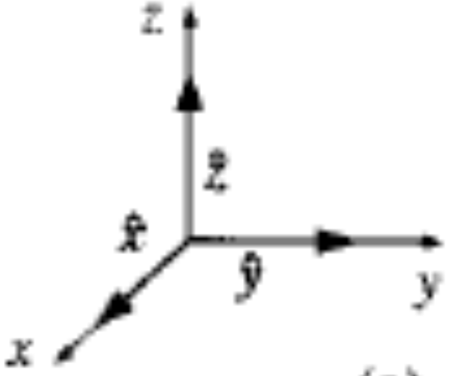
Vector Algebra

Let $\hat{\mathbf{x}}, \hat{\mathbf{y}}$ and $\hat{\mathbf{z}}$ be unit vectors parallel to the x, y, and z axes, respectively. An arbitrary vector **A** can be expressed in terms of these basis vectors.

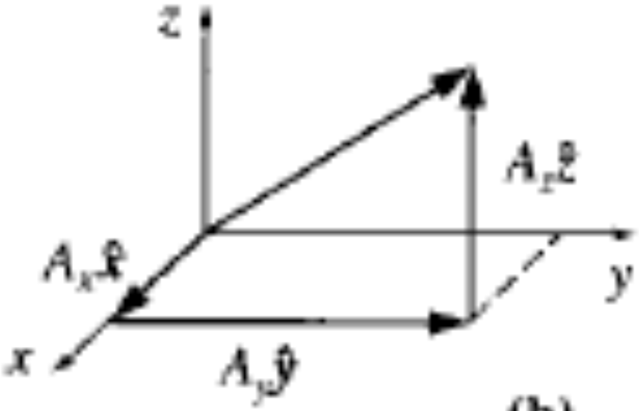
$$\vec{A} = A_x\,\hat{i} + A_y\,\hat{j} + A_z\,\hat{k}$$

$$\mathbf{A} = A_x\hat{\mathbf{x}} + A_y\hat{\mathbf{y}} + A_z\hat{\mathbf{z}}$$

The numbers A_x, A_y, and A_z are called components.



(a)



(b)

Vector Algebra

(i) To add vectors, add like components.

$$\mathbf{A}+\mathbf{B}=(A_x\hat{\mathbf{x}}+A_y\hat{\mathbf{y}}+A_z\hat{\mathbf{z}})+(B_x\hat{\mathbf{x}}+B_y\hat{\mathbf{y}}+B_z\hat{\mathbf{z}})$$

$$=(A_x+B_x)\hat{\mathbf{x}}+(A_y+B_y)\hat{\mathbf{y}}+(A_z+B_z)\hat{\mathbf{z}}$$

(ii) To multiply by a scalar, multiply each component.

$$a\mathbf{A}=a(A_x\hat{\mathbf{x}}+A_y\hat{\mathbf{y}}+A_z\hat{\mathbf{z}})$$

$$=aA_x\hat{\mathbf{x}}+aA_y\hat{\mathbf{y}}+aA_z\hat{\mathbf{z}}$$

(iii) To calculate the dot product, multiply like components, and add.

$$\mathbf{A}\cdot\mathbf{B} = (A_x\hat{\mathbf{x}} + A_y\hat{\mathbf{y}} + A_z\hat{\mathbf{z}})\cdot(B_x\hat{\mathbf{x}} + B_y\hat{\mathbf{y}} + B_z\hat{\mathbf{z}})$$
$$= A_xB_x + A_yB_y + A_zB_z$$

(iv) To calculate the cross product, form the determinant whose first row is $\hat{\mathbf{x}}, \hat{\mathbf{y}}$ and $\hat{\mathbf{z}}$, whose second row is A (in component form), and whose third row is B.

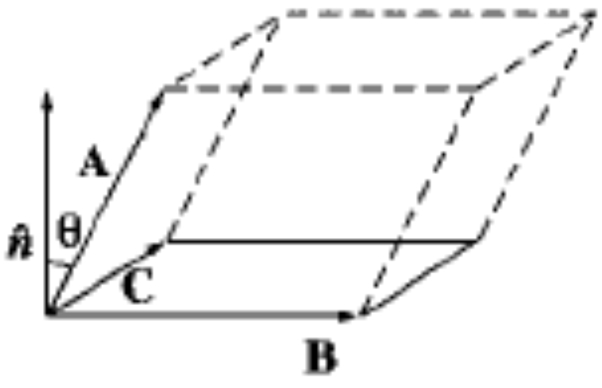
$$\mathbf{A}\times\mathbf{B} = \begin{vmatrix} \hat{\mathbf{x}} & \hat{\mathbf{y}} & \hat{\mathbf{z}} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix} = \begin{matrix} (A_yB_z - A_zB_y)\hat{\mathbf{x}} \\ +(A_zB_x - A_xB_z)\hat{\mathbf{y}} \\ +(A_xB_y - A_yB_x)\hat{\mathbf{z}} \end{matrix}$$

Triple Product

Since the cross product of two vectors is itself a vector, it can be dotted or crossed with a third vector to form a triple product.

(i) **Scalar triple product: A·(B×C)**. Geometrically, |**A**·(**B**×**C**)| is the volume of a parallelepiped generated by these three vectors as shown below.

$$\mathbf{A}\cdot(\mathbf{B}\times\mathbf{C})=\mathbf{B}\cdot(\mathbf{C}\times\mathbf{A})=\mathbf{C}\cdot(\mathbf{A}\times\mathbf{B})$$



In component form

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

Vector Operator

(ii) **Vector triple product: A×(B×C)**. The vector triple product can be simplified by the so-called **BAC-CAB** rule.

$$\mathbf{A}\times(\mathbf{B}\times\mathbf{C}) = \mathbf{B}(\mathbf{A}\cdot\mathbf{C}) - \mathbf{C}(\mathbf{A}\cdot\mathbf{B})$$

Notice that $(\mathbf{A}\times\mathbf{B})\times\mathbf{C} \neq \mathbf{A}\times(\mathbf{B}\times\mathbf{C})$

$$(\mathbf{A}\times\mathbf{B})\times\mathbf{C} = -\mathbf{C}\times(\mathbf{A}\times\mathbf{B}) = -\mathbf{A}(\mathbf{B}\cdot\mathbf{C}) + \mathbf{B}(\mathbf{A}\cdot\mathbf{C})$$

Question: Under which condition $(\mathbf{A}\times\mathbf{B})\times\mathbf{C} = \mathbf{A}\times(\mathbf{B}\times\mathbf{C})$?

Answer: **B** is perpendicular to **A** and **C**