Semester II, 2017-18
Department of Physics, IIT Kanpur

PHY103A: Lecture # 1

(Text Book: Introduction to Electrodynamics by David J Griffiths)

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Course Information:

- Course Webpage: http://home.iitk.ac.in/~akjha/PHY103.htm
- Course Handout is posted on the course webpage.
- Lecture notes will be posted on the webpage after each lecture
- All the announcements will be communicated through email and/or course webpage
- Quiz # 1 (6^{th} February); Quiz # 2 (3^{rd} April)
- 1^{st} Tutorial will be on Tuesday (Jan 9^{th}); Tutorial section allotment will be sent out later
- Office hours of all the tutors will be decided in the 1^{st} tutorial
- DOAA announced Lecture tomorrow (Saturday): 11:00 – 11:50 am in L-20

Course Content (1st Part)

- Introduction to vector analysis and calculus
- Electric field
- Charge distributions
- Gauss's law
- Potentials
- Energy of charge distributions, conductors and capacitors
- Laplace equation, uniqueness theorems, method of images
- Multipole expansions
- Fields and interaction of dipoles
- Electrostatics of material media
- Linear dielectrics, force on a dielectric
- Magnetic fields, current distributions, Bio-Savart law
- Ampere's law, Magnetic vector potential
- Magnetostatics of material media.

Course Content (2nd Part)

- Electromagnetic induction
- Maxwell's equations
- Displacement current
- Energy and momentum of plane electromagnetic waves
- Poynting's theorem
- The wave equation, polarization
- Reflection and transmission coefficients for dielectric
- Brewster's angle
- Total internal reflection.

So, what do we study in electrodynamics

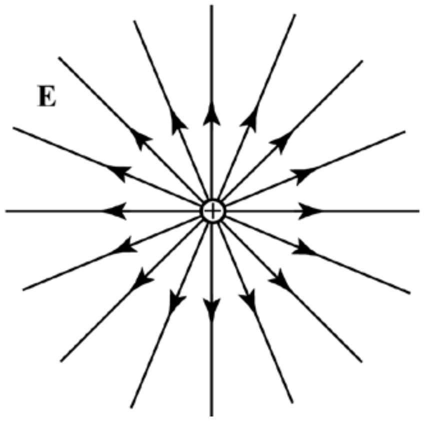
$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$ Gauss's Law $$\oint_{surf} \mathbf{E} \cdot d\mathbf{a} = \frac{Q_{\text{enc}}}{\epsilon_0}$$

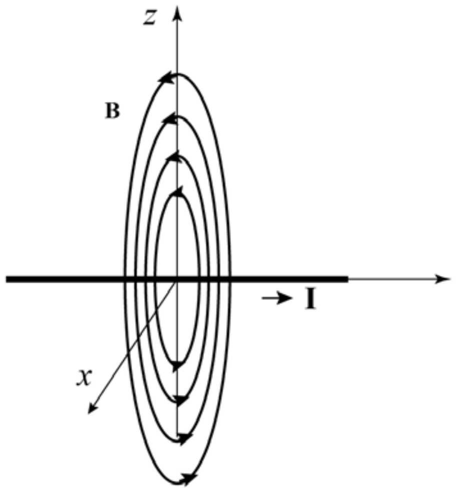
$$\nabla \times \mathbf{E} = 0$$ No Name

$$\nabla \cdot \mathbf{B} = 0$$ No Name

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J}$$ Amperes's Law $$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{enc}}$$

Maxwell's equations (Electrostatics)





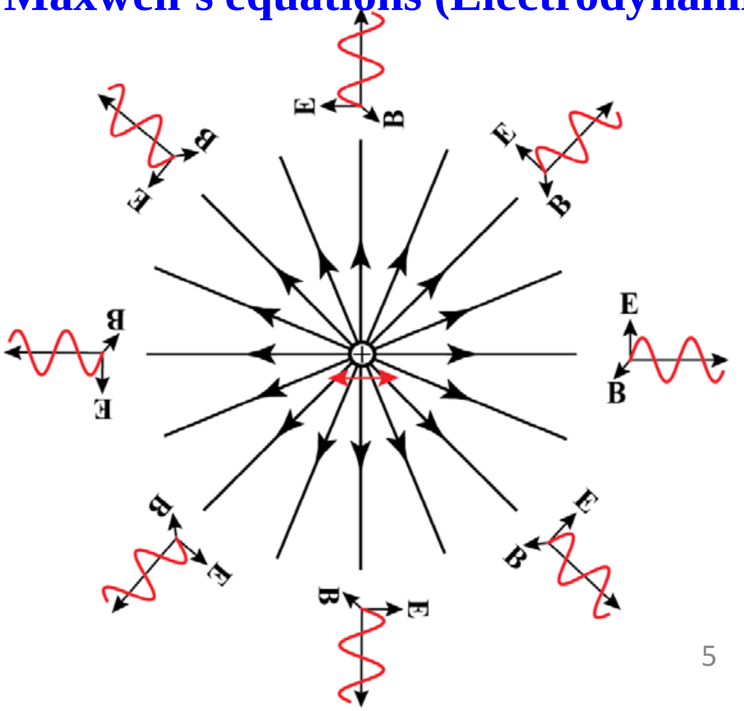
$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

Maxwell's equations (Electrodynamics)



Why Study Electrodynamics?

- 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
  - ✓ .
  - ✓ .

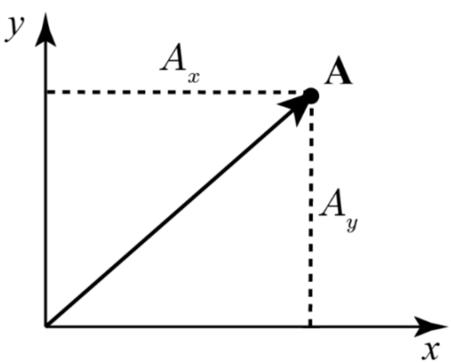
Scalars and Vectors

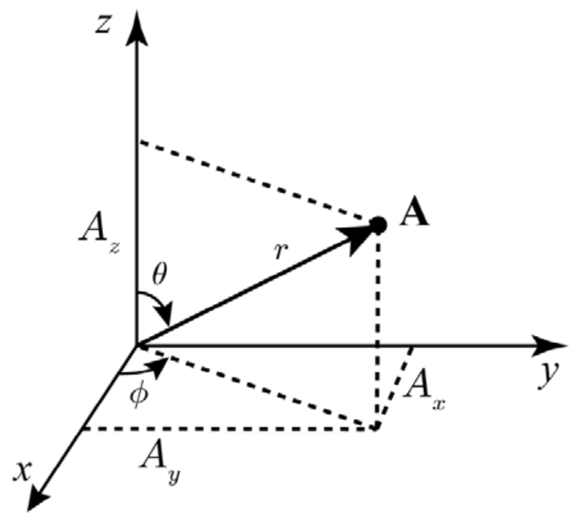
Scalars:

- Requires only one number for its description
- Example: Distance: 5 m;   Speed: 10 m/s;   Age: 14 years, etc.
- Algebra consists of addition, subtraction, multiplication, etc.

Vectors:

- Requires more than one scalars for its description.
- Example: Velocity: 5 km/s along the x-direction; $\mathbf{A} = A_x\hat{\boldsymbol{x}} + A_y\hat{\boldsymbol{y}} + A_z\,\hat{\boldsymbol{z}}$
- The corresponding algebra is called Vector Algebra

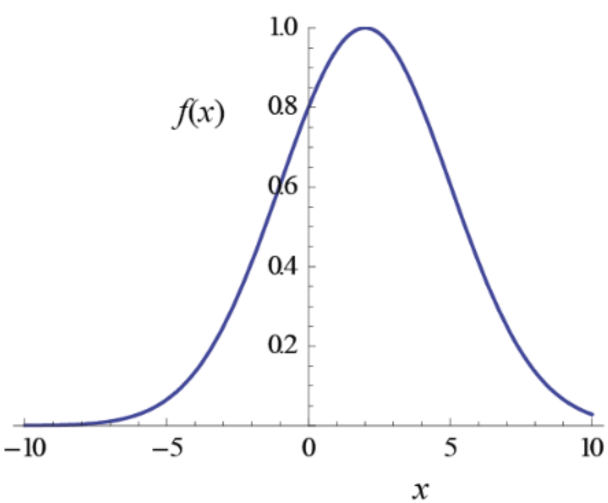


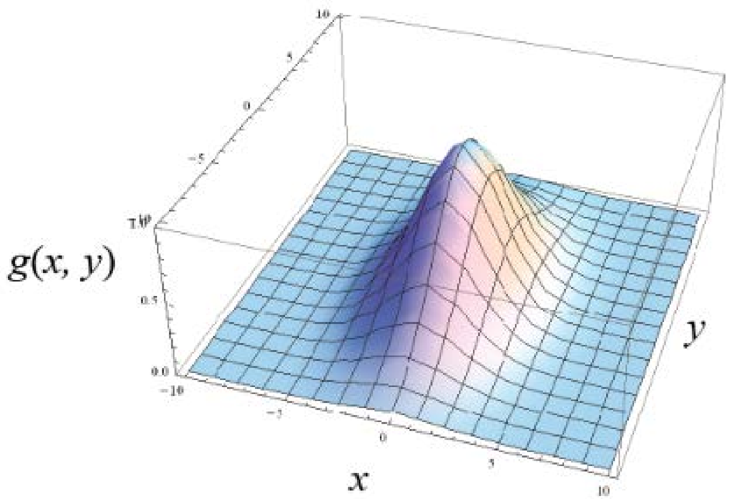


Scalar and Vector functions/fields

Scalar functions:

- Requires only one function for its description
- Example: $f(x),\ g(x,y),\ t\,(x,y,z)$
- Algebra consists of addition, subtraction, multiplication, etc.
- Calculus consists of differentiation, integration, etc.



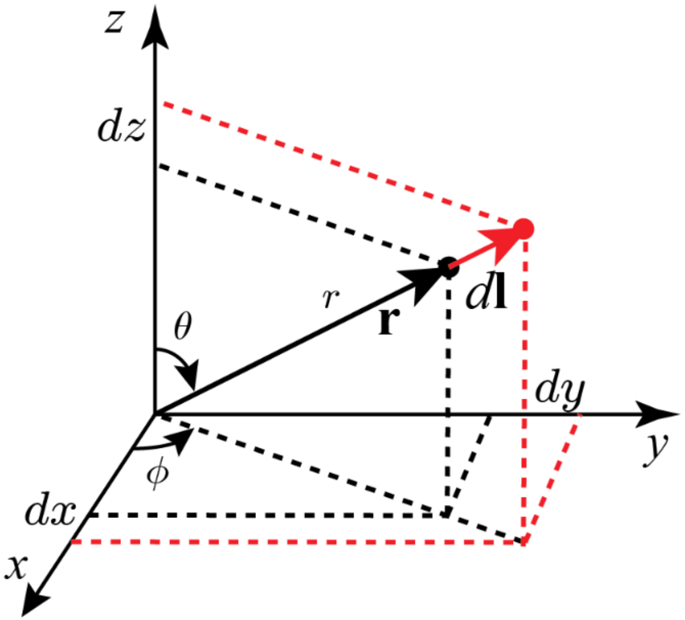


Vector functions:

- Requires more than one scalar functions for its description.
- Example: $\mathbf{A}(x,y,z) = A_x(x,y,z)\hat{\boldsymbol{x}} + A_y(x,y,z)\hat{\boldsymbol{y}} + A_z\,(x,y,z)\hat{\boldsymbol{z}}$
- The corresponding algebra is called Vector Algebra
- The corresponding calculus is called Vector calculus

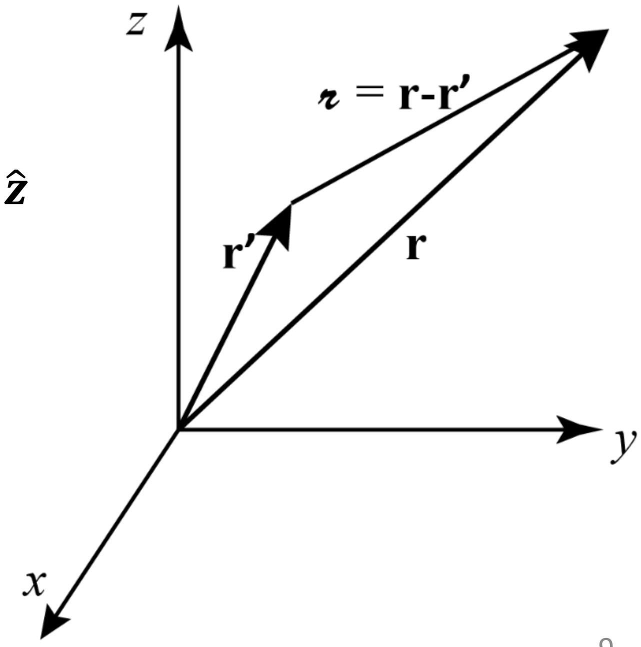
Examples of vector functions/fields:

- Position vector: $\mathbf{r} = x\,\hat{\boldsymbol{x}} + y\,\hat{\boldsymbol{y}} + z\,\hat{\mathbf{z}}$



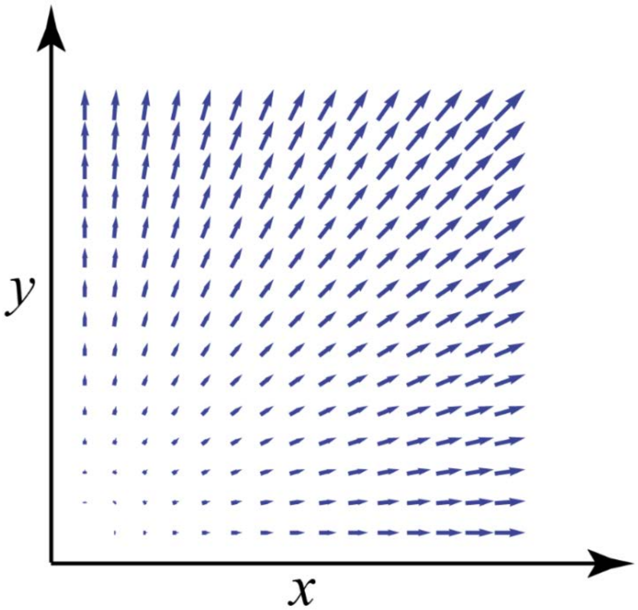
- Displacement vector: $d\mathbf{l} = x\,\hat{\boldsymbol{x}} + y\,\hat{\boldsymbol{y}} + z\,\hat{\mathbf{z}}$

- Separation vector:
  $\hat{\boldsymbol{\mathscr{r}}} = \mathbf{r} - \mathbf{r}' = (x - x')\,\hat{\boldsymbol{x}} + (y - y')\,\hat{\boldsymbol{y}} + (z - z')\,\hat{\mathbf{z}}$

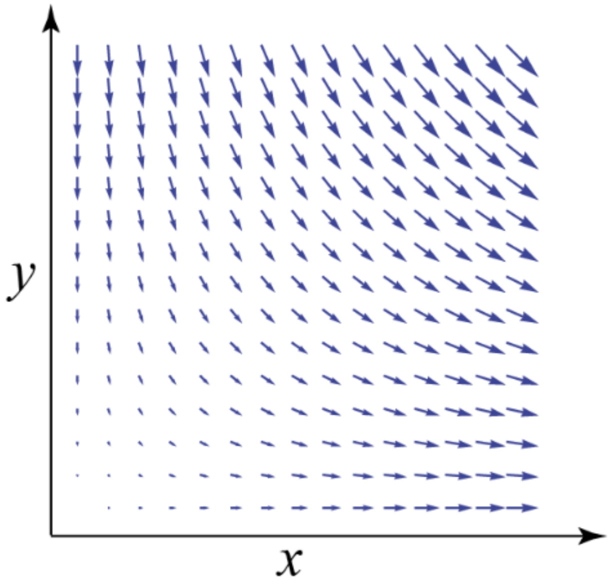


Realization of vector functions/fields:

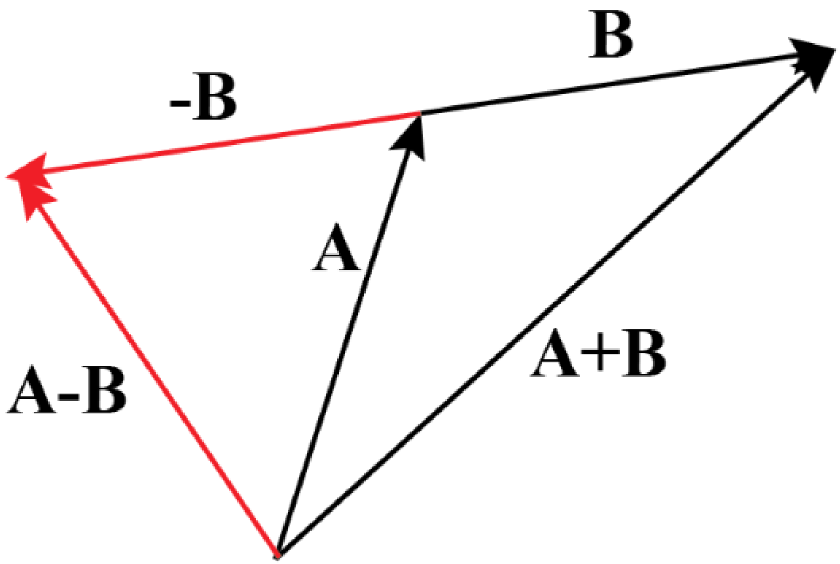
- Example # 1: $\mathbf{g}(x, y) = \boldsymbol{x}\,\widehat{\boldsymbol{x}} + \boldsymbol{y}\,\widehat{\boldsymbol{y}}$



- Example # 2: $\mathbf{g}(x, y) = \boldsymbol{x}\,\widehat{\boldsymbol{x}} - \boldsymbol{y}\,\widehat{\boldsymbol{y}}$



Vector Algebra



Addition:

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

Subtraction:

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

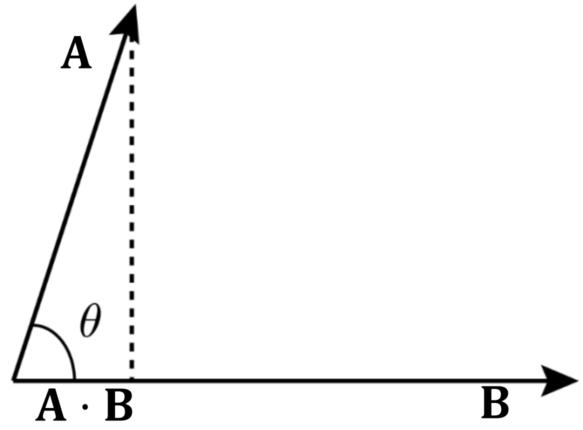
Multiplication:

(1) Scalar product (dot product):

$$\mathbf{A} \cdot \mathbf{B} = |\mathbf{A}||\mathbf{B}|\cos\theta$$

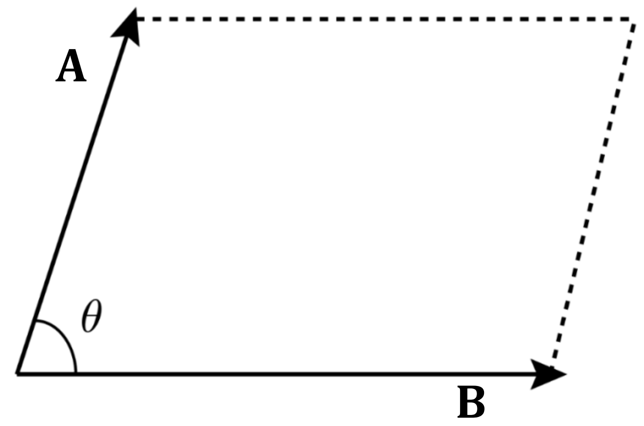
$$= \left(A_x\hat{\boldsymbol{x}} + A_y\hat{\boldsymbol{y}} + A_z\hat{\boldsymbol{z}}\right) \cdot \left(B_x\hat{\boldsymbol{x}} + B_y\hat{\boldsymbol{y}} + B_z\hat{\boldsymbol{z}}\right)$$

$$= A_xB_x + A_yB_y + A_zB_z$$



Scalar product is a scalar quantity

Vector Algebra



(2) Vector product (cross product):

$$\mathbf{A}\cdot\mathbf{B} = |\mathbf{A}||\mathbf{B}|\sin\theta\ \hat{n}$$

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

vector product is a vector quantity

(3) Triple product (Scalar): $\mathbf{A}\cdot(\mathbf{B}\times\mathbf{C}) = \mathbf{B}\cdot(\mathbf{C}\times\mathbf{A}) = \mathbf{C}\cdot(\mathbf{A}\times\mathbf{B})$

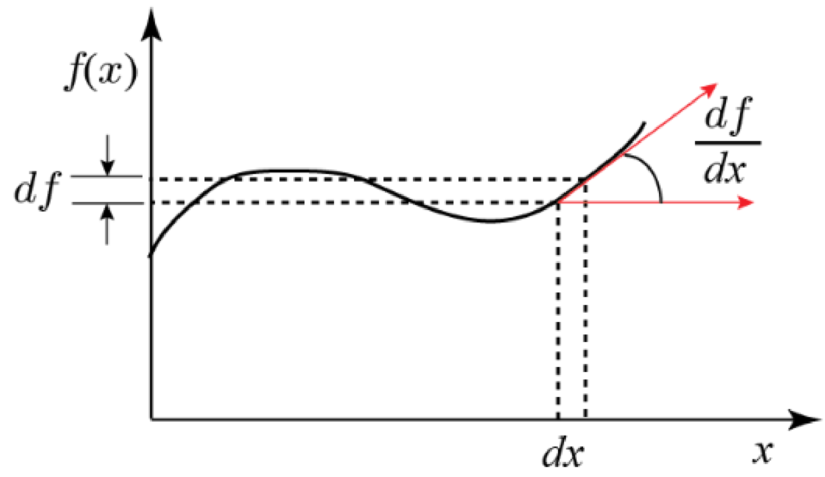
(4) Triple product (vector): $\mathbf{A}\times(\mathbf{B}\times\mathbf{C}) = \mathbf{B}(\mathbf{A}\cdot\mathbf{C}) - \mathbf{C}(\mathbf{A}\cdot\mathbf{B})$

Vector Calculus

When working with functions one also has to study calculus in addition to studying algebra. The calculus dealing with vector function is referred to as the vector calculus. Calculus mainly involves differentiation and integration

Differential Calculus

$$df = \left(\frac{df}{dx}\right) dx$$



Integral Calculus

$$I = \int_a^b f(x)dx$$