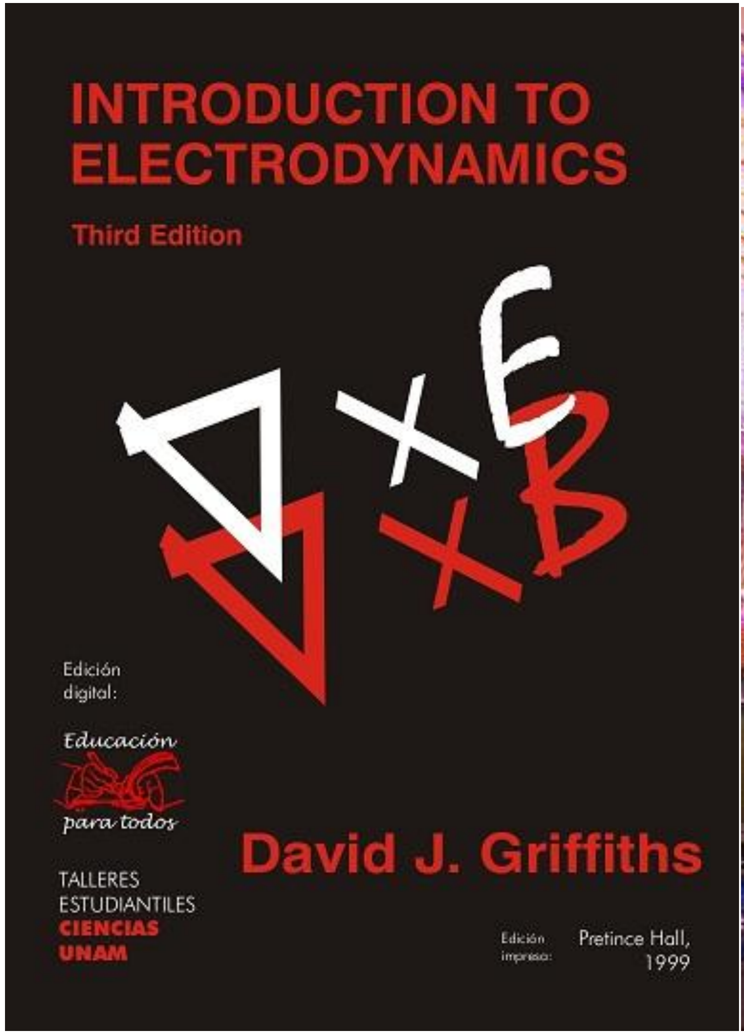
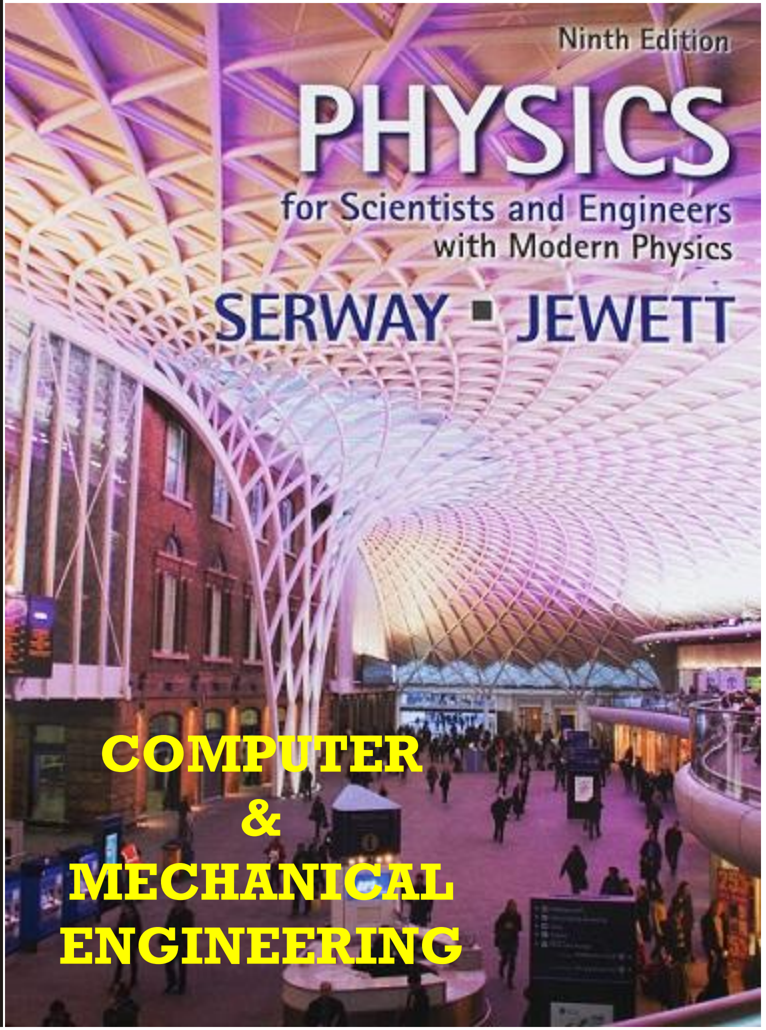
# PHYSICS

General Physics II (PHYS 102)

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# Course Outline



- Electric Charge
- Coulomb's Law
- The Electric Field
- Continuous Charge Distributions
- Problems

# Electric Charge



## Electric Charge (q):

- Charge is a fundamental and characteristics property of the elementary particles which make up matter.
- It is a scalar quantity.
- SI unit of charge is coulomb (C).
- **Kinds of Charges**
  1. Positive Charge
  2. Negative Charge

**Elementary Charge :**

The magnitude of charge on a proton or an electron.

$$e = 1.6 \times 10^{-19} C$$

**Properties of Charges:**

1. Like charges repel each other and unlike charges attract each other.
2. Electric charge is quantized. $\boxed{q = \pm ne}$
3. Electric charge is conserved.
4. The electric charge is additive in nature.
5. The charge on a body is not affected by the speed of the body.

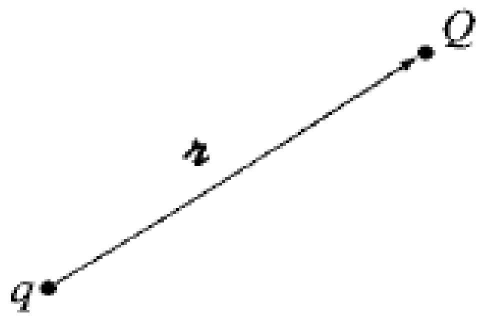
# Coulomb’s Law

ELECTROSTATIC FIELD

## Coulomb’s Law:

- The force on a test charge $Q$ due to a single point charge $q$ , which is at rest a distance $\mathscr{r}$ away is given by **Coulomb’s law**:

$$\boxed{\vec{\mathrm{F}} = \frac{1}{4\pi\varepsilon_0} \frac{qQ}{\mathscr{r}^2} \hat{\mathscr{r}}}$$




- **The magnitude of the electric force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.**

- The constant $\varepsilon_0$ is called the **permittivity of free space**.

$$\varepsilon_0 = 8.85 \times 10^{-12} \frac{\mathrm{C}^2}{\mathrm{N} \cdot \mathrm{m}^2}$$

# Electric Field

## Coulomb's Law:

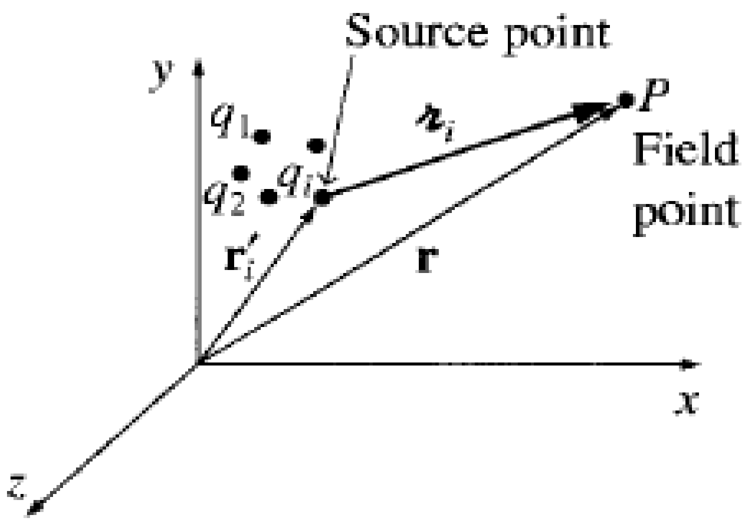
- If we have *several* point charges $q_1, q_2, \ldots, q_n$ at distances $\mathscr{r}_1, \mathscr{r}_2, \ldots, \mathscr{r}_n$ from $Q$, the total force on $Q$ is given by

$$\vec{F} = \vec{F}_1 + \vec{F}_2 + \ldots$$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 Q}{\mathscr{r}_1^{\,2}}\hat{\mathscr{r}}_1 + \frac{q_2 Q}{\mathscr{r}_2^{\,2}}\hat{\mathscr{r}}_2 + \ldots\right)$$

$$= \frac{Q}{4\pi\varepsilon_0}\left(\frac{q_1}{\mathscr{r}_1^{\,2}}\hat{\mathscr{r}}_1 + \frac{q_2}{\mathscr{r}_2^{\,2}}\hat{\mathscr{r}}_2 + \ldots\right)$$

$$\therefore \quad \boxed{\vec{F} = Q\vec{E}}$$




where $\vec{E}(\vec{r}) = \dfrac{1}{4\pi\varepsilon_0}\displaystyle\sum_{i=1}^{n}\frac{q_i}{\mathscr{r}_i^{\,2}}\hat{\mathscr{r}}_i$ $\quad\rightarrow$ electric field of the source charges

- **Principle of Superposition**: $\boxed{\vec{E} = \vec{E}_1 + \vec{E}_2 + \ldots}$

# Electric Field



## Electric Field:

- The electric field $\vec{E}$ at a point in space is defined as the electric force $\vec{F}$ acting on a positive test charge $Q$ placed at that point divided by the magnitude of the test charge:

$$\boxed{\vec{E} = \frac{\vec{F}}{Q}}$$

- The **electric field** is a vector quantity that varies from point to point and is determined by the configuration of source charges.

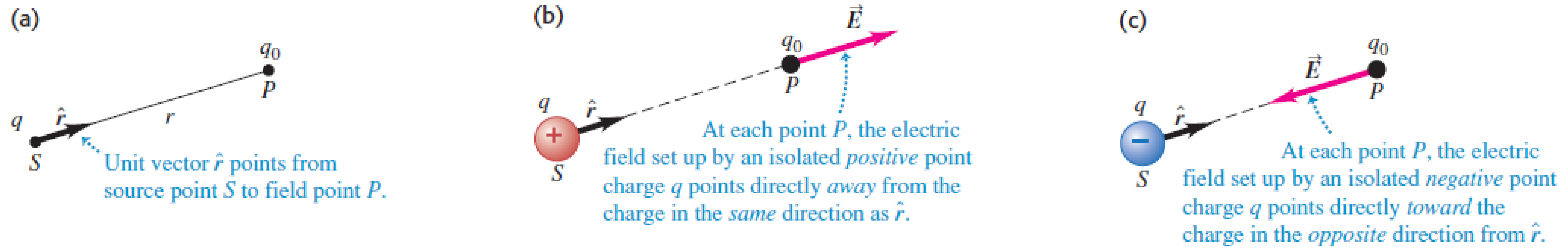
- The SI unit of **electric field** $\vec{E}$ is newton per coulomb $\left(\mathrm{N\,C^{-1}}\right)$.

# Electric Field

## Electric Field of a Point Charge:

- The electric field $\vec{E}$ produced at point *P* by an isolated point charge q at the origin *S* is given by

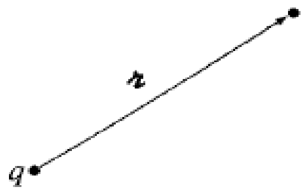
$$\boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^3}\vec{r}}$$




$$\boxed{\vec{E} \text{ is produced by } q \text{ but acts } q_0 \text{ on the charge at point } P.}$$

- The electric field $\vec{E}$ produced at field point *P* by an isolated point charge q at the source point *S* is given by

$$\boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{\mathscr{r}^2}\hat{\mathscr{r}} = \frac{1}{4\pi\varepsilon_0}\frac{q}{\mathscr{r}^3}\vec{\mathscr{r}}}$$



# Line Integral of Electric Field

ELECTROSTATIC FIELD

## Electric Field:

- The electric field at a point $\vec{r}$ due to a point charge q located at the origin is given by

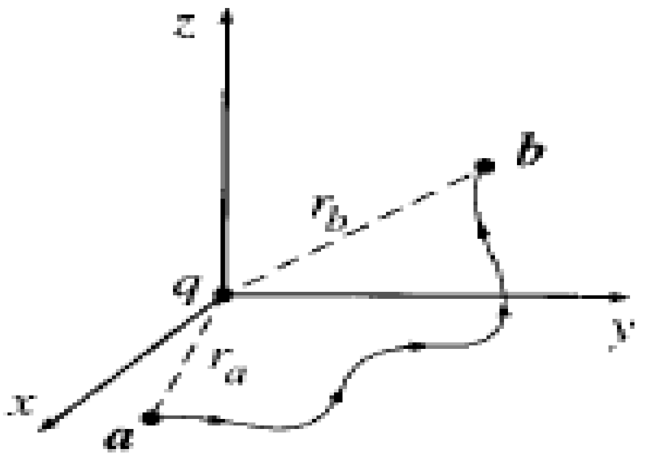
$$\vec{E}(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

- The line integral of electric field:

$$\int_a^b \vec{E}\cdot d\vec{l} = \int_a^b \left(\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}\right)\cdot\left(dr\,\hat{r} + r\,d\theta\,\hat{\theta} + r\sin\theta\,d\phi\,\hat{\phi}\right)$$

$$= \frac{q}{4\pi\varepsilon_0}\int_a^b \frac{1}{r^2}dr = \frac{q}{4\pi\varepsilon_0}\left[-\frac{1}{r}\right]_{r_a}^{r_b}$$

$$\boxed{= \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_a}-\frac{1}{r_b}\right]}$$




- The electric field due to stationary charges is conservative field

The amount of work done by the electric field $\vec{E}$ when a unit positive charge moves from point $a$ to point $b$

$$\boxed{W_E = \int_a^b \vec{E}\cdot d\vec{l} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_a}-\frac{1}{r_b}\right]}$$

# The curl of Electric Field

## The curl of Electric Field:

- The line integral of electric field around a closed path is zero.

$$\text{i.e.} \quad \oint_c \vec{E}\cdot d\vec{l} = 0$$

$$\text{or} \int_s (\nabla\times\vec{E})\cdot d\vec{a} = 0 \qquad [\text{ Using Stoke's Theorem }]$$

$$\therefore \quad \boxed{\nabla\times\vec{E} = 0}$$

$$\nabla\times\vec{E} = 0$$

The electric field at point $\vec{r}$ due to a point charge $q$ located at the origin is

$$\vec{E}(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^3}\vec{r}$$

$$\text{So,} \quad \nabla\times\vec{E} = \nabla\times\left[\frac{1}{4\pi\varepsilon_0}\frac{q}{r^3}\vec{r}\right] = \frac{q}{4\pi\varepsilon_0}\left[\nabla\times\left(\frac{\vec{r}}{r^3}\right)\right] = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r^3}(\nabla\times\vec{r}) + \nabla\left(\frac{1}{r^3}\right)\times\vec{r}\right]$$

$$= \frac{q}{4\pi\varepsilon_0}\left[0 + (-3r^{-3-2})\vec{r}\times\vec{r}\right]$$

$$= 0$$

# Continuous Charge Distribution



## Linear Charge Density

$$\lambda = \frac{dq}{dl'}$$

$\downarrow$

charge-per-unit-length

$\left[ dl' \rightarrow \text{an element of length along the line} \right]$

## Surface Charge Density

$$\sigma = \frac{dq}{da'}$$

$\downarrow$

charge-per-unit-area

$\left[ da' \rightarrow \text{an element of area on the surface} \right]$

## Volume Charge Density

$$\rho = \frac{dq}{d\tau'}$$

$\downarrow$

charge-per-unit-volume

$\left[ d\tau' \rightarrow \text{an element of volume} \right]$

**Small Charge Distribution**

$$dq \rightarrow \lambda dl' \sim \sigma da' \sim \rho d\tau'$$

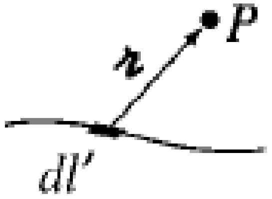
# Electric Field due to Continuous Charge Distribution

## Electric Field Due to a Continuous Charge Distribution:

$$\vec{E}(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\int \frac{dq}{\mathcal{R}^2}\,\hat{\mathcal{R}}$$


### The electric field of a line charge

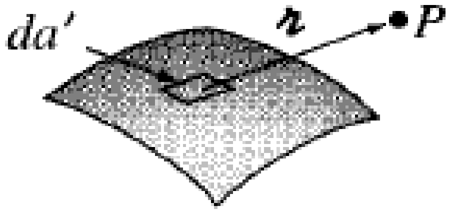
$$\vec{E}(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\int \frac{\lambda(r')\,dl'}{\mathcal{R}^2}\,\hat{\mathcal{R}}$$




Line charge, λ

### The electric field for a surface charge

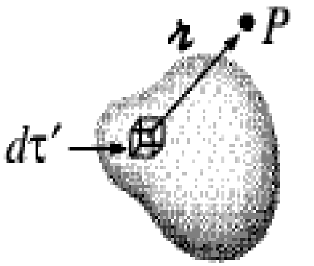
$$\vec{E}(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\int \frac{\sigma(r')\,da'}{\mathcal{R}^2}\,\hat{\mathcal{R}}$$




Surface charge, σ

### The electric field for a volume charge

$$\vec{E}(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\int \frac{\rho(r')\,d\tau'}{\mathcal{R}^2}\,\hat{\mathcal{R}}$$




Volume charge, ρ

# Problem

**1. Electric Field** a distance $z$ above the midpoint between two equal charges, $q$, a distance $d$ apart

ELECTROSTATIC FIELD

From Figure

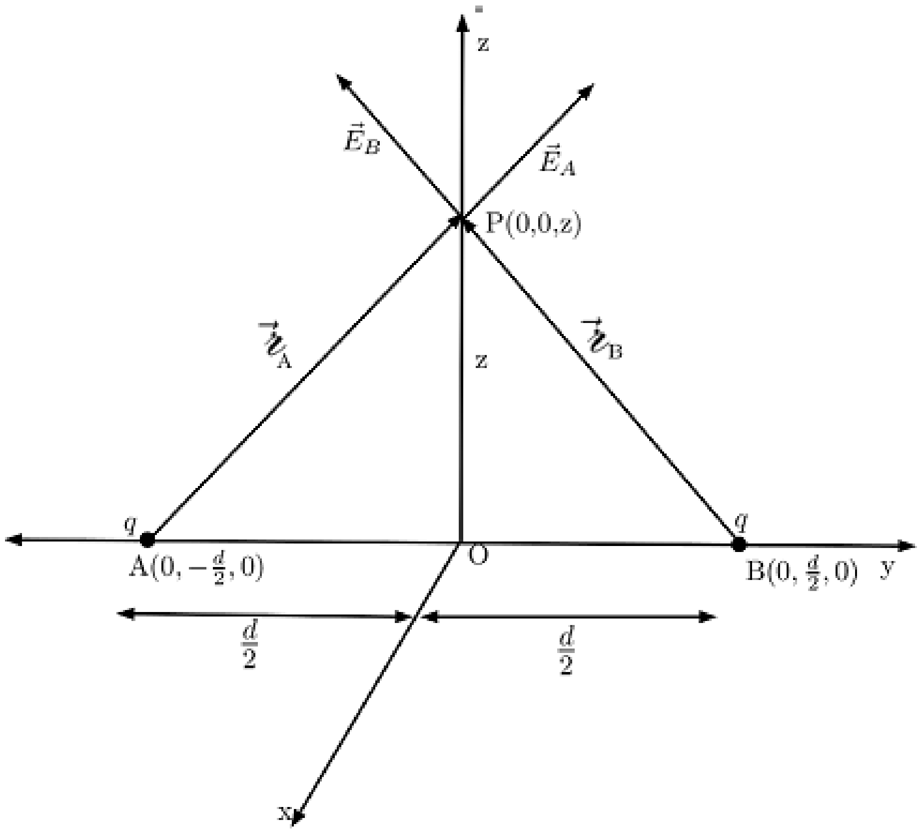
$$\vec{r}_A = (0-0)\hat{i} + \left(0+\frac{d}{2}\right)\hat{j} + (z-0)\hat{k} = \frac{d}{2}\hat{j} + z\hat{k}$$

$$\Rightarrow r_A = \left(\frac{d^2}{4} + z^2\right)^{\frac{1}{2}}$$

and

$$\vec{r}_B = (0-0)\hat{i} + \left(0-\frac{d}{2}\right)\hat{j} + (z-0)\hat{k} = -\frac{d}{2}\hat{j} + z\hat{k}$$

$$\Rightarrow r_B = \left(\frac{d^2}{4} + z^2\right)^{\frac{1}{2}}$$



# Problem

ELECTROSTATIC FIELD

**1. Electric Field** a distance $z$ above the midpoint between two equal charges, $q$, a distance $d$ apart

- **Electric Field** at *P* due to the charge at A is

$$\vec{E}_A = \frac{1}{4\pi\varepsilon_0}\frac{q}{\mathscr{r}_A^3}\vec{\mathscr{r}}_A = \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(\frac{d^2}{4}+z^2\right)^{\frac{3}{2}}}\left(\frac{d}{2}\hat{j}+z\hat{k}\right) \quad \text{................(1)}$$

- **Electric Field** at *P* due to the charge at B is

$$\vec{E}_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{\mathscr{r}_B^3}\vec{\mathscr{r}}_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(\frac{d^2}{4}+z^2\right)^{\frac{3}{2}}}\left(-\frac{d}{2}\hat{j}+z\hat{k}\right) \quad \text{................(2)}$$

- Therefore, **the total electric field at *P*:**

$$\vec{E} = \vec{E}_A + \vec{E}_B$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(\frac{d^2}{4}+z^2\right)^{\frac{3}{2}}}\left(\frac{d}{2}\hat{j}+z\hat{k}\right) + \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(\frac{d^2}{4}+z^2\right)^{\frac{3}{2}}}\left(-\frac{d}{2}\hat{j}+z\hat{k}\right)$$

$$\therefore \boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0}q\frac{2z}{\left(\frac{d^2}{4}+z^2\right)^{\frac{3}{2}}}\hat{k}}$$

when $z \gg d$

Electric field, $\vec{E} = \frac{1}{4\pi\varepsilon_0}q\frac{2z}{\left(z^2\right)^{\frac{3}{2}}}\hat{k}$

$$\therefore \boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2q}{z^2}\hat{k}}$$

# Problem

**2. Electric Field** a distance $z$ above the midpoint of a straight line segment of length 2L, which carries a uniform charge $\lambda$

From Figure

$$\vec{\mathscr{r}} = (0-0)\hat{i} + (0-y')\hat{j} + (z-0)\hat{k} = -y'\hat{j} + z\hat{k}$$

$$\Rightarrow \mathscr{r} = \left(y'^2 + z^2\right)^{\frac{1}{2}}$$

The charge on an element of length dy′ at C along the line is

$$\boxed{dq = \lambda dy'}$$

The electric field at $P$ due to the charge $dq\,(=\lambda dy')$ is given by

$$d\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{dq}{\mathscr{r}^3}\vec{\mathscr{r}} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda dy'}{\left(y'^2+z^2\right)^{\frac{3}{2}}}\left(-y'\hat{j} + z\hat{k}\right)$$

................(1)

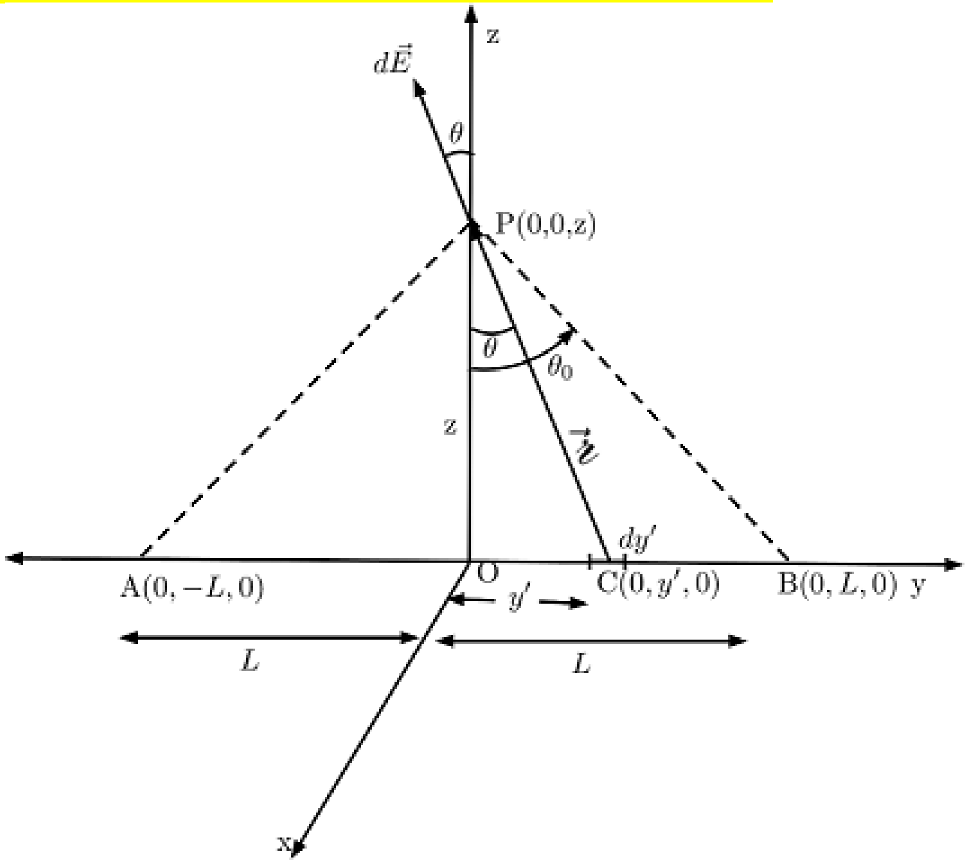



**Figure E-2 illustrates the geometry and the coordinates to be used**

# Problem

**2. Electric Field** a distance $z$ above the midpoint of a straight line segment of length 2L, which carries a uniform charge $\lambda$

ELECTROSTATIC FIELD

- Total Electric field at *P* due to the charge on whole line segment AB:

$$\vec{E}=\int_{-L}^{+L} d\vec{E}=\frac{1}{4\pi\varepsilon_0}\lambda\left[\int_{-L}^{L}\frac{\left(-y'\,\hat{j}+z\,\hat{k}\right)dy'}{\left(y'^2+z^2\right)^{\frac{3}{2}}}\right]=\frac{1}{4\pi\varepsilon_0}\lambda\left[\int_{-L}^{L}\frac{-y'\,\hat{j}\,dy'}{\left(y'^2+z^2\right)^{\frac{3}{2}}}+\int_{-L}^{L}\frac{z\,\hat{k}\,dy'}{\left(y'^2+z^2\right)^{\frac{3}{2}}}\right]=\frac{1}{4\pi\varepsilon_0}\lambda\left[2\int_{0}^{L}\frac{zdy'}{\left(y'^2+z^2\right)^{\frac{3}{2}}}\right]\hat{k} \qquad \text{...............(2)}$$

$$\because \int_{-\alpha}^{\alpha} f(x)dx = 2\int_{0}^{\alpha} f(x)dx \quad ;\text{ for even function } f(x)$$

$$= 0 \qquad ;\text{ for odd function } f(x)$$

put $\quad y' = z\tan\theta$

$$\Rightarrow dy' = z\sec^2\theta\, d\theta$$

when $y' = 0$, then $\theta = 0$

when $y' = L$, then $\theta = \tan^{-1}\left(\frac{L}{z}\right) = \theta_0$ (say)

# Problem

**2. Electric Field** a distance $z$ above the midpoint of a straight line segment of length 2L, which carries a uniform charge $\lambda$

$$\therefore \quad \vec{E} = \frac{1}{4\pi\varepsilon_0}\lambda\left[2z\int_0^{\theta_0}\frac{z\sec^2\theta d\theta}{z^3\sec^3\theta}\right]\hat{k}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{2\lambda}{z}\left[\int_0^{\theta_0}\cos\theta\, d\theta\right]\hat{k}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{2\lambda}{z}[\sin\theta_0]\hat{k}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{2\lambda}{z}\left[\frac{L}{\sqrt{z^2+L^2}}\right]\hat{k}$$

$$\therefore \quad \boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda(2L)}{z\sqrt{z^2+L^2}}\hat{k}}$$

................(3)

For points far from the line $(z \gg L)$:

$$\vec{E} \cong \frac{1}{4\pi\varepsilon_0}\frac{\lambda(2L)}{z^2}\hat{k}$$

$$\therefore \boxed{\vec{E} \cong \frac{1}{4\pi\varepsilon_0}\frac{q}{z^2}\hat{k}}$$ ................(4)

For far away the line "looks" like a point charge q $=\lambda(2L)$.

As $L \to \infty$:

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda(2L)}{z\sqrt{z^2+L^2}}\hat{k} = \frac{1}{4\pi\varepsilon_0}\frac{2\lambda}{z\sqrt{\frac{z^2}{L^2}+1}}\hat{k}$$

$$\therefore \boxed{\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\lambda}{z}\hat{k}}$$ [Field of an infinite straight wire]

................(5)

# Problem

ELECTROSTATIC FIELD

**3. Electric Field** a distance $z$ above the centre of a circular loop of radius $r$, which carries a uniform line charge $\lambda$.

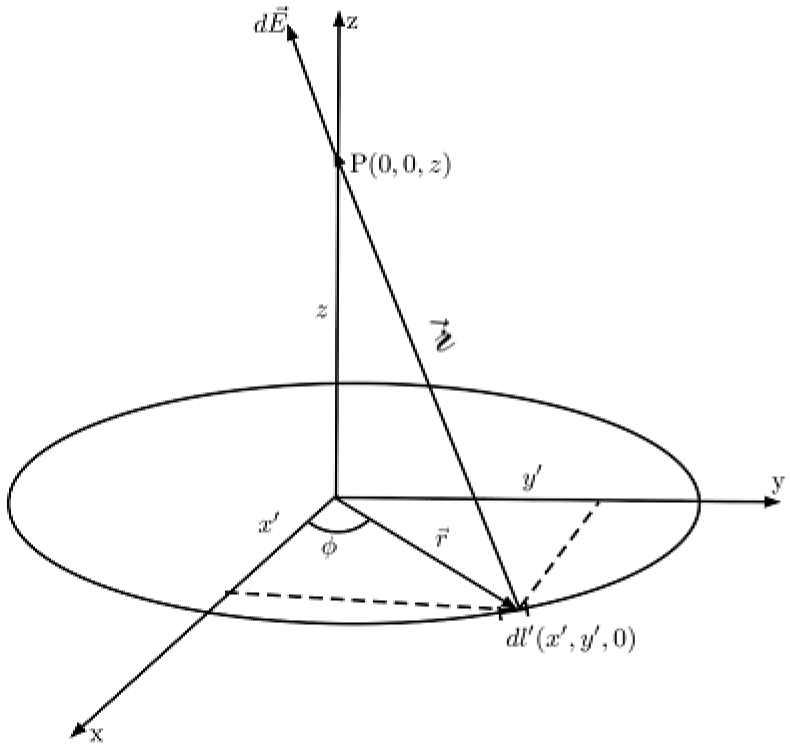
From Figure

$$\vec{\mathscr{r}} = -x'\,\hat{i} - y'\,\hat{j} + z\,\hat{k} = -r\cos\phi\,\hat{i} - r\sin\phi\,\hat{j} + z\,\hat{k}$$

and $\mathscr{r} = \left(r^2 + z^2\right)^{\frac{1}{2}}$

The charge on an element of length $dl'$ along a cirular loop is

$$\boxed{dq = \lambda dl' = \lambda\left(r d\phi\right)}$$




**An elemental length $dl'$ on the ring with coordinates $(x', y', 0)$ subtends an elemental angle $d\phi$ at the centre.**

**Figure E-3 illustrates the geometry and the coordinates to be used**

# Problem

ELECTROSTATIC FIELD

**3. Electric Field** a distance $z$ above the centre of a circular loop of radius $r$, which carries a uniform line charge $\lambda$.

The electric field at $P$

due to the charge $dq\left(=\lambda dl'\right)$ is given by

$$d\vec{E}=\frac{1}{4\pi\varepsilon_0}\frac{dq}{\mathscr{r}^3}\vec{\mathscr{r}}$$

$$=\frac{1}{4\pi\varepsilon_0}\frac{\lambda dl'}{\left(r^2+z^2\right)^{\frac{3}{2}}}\left(-r\cos\phi\,\hat{i}-r\sin\phi\,\hat{j}+z\,\hat{k}\right)$$

$$\therefore\quad \boxed{d\vec{E}=\frac{1}{4\pi\varepsilon_0}\frac{\lambda\left(rd\phi\right)}{\left(r^2+z^2\right)^{\frac{3}{2}}}\left(-r\cos\phi\,\hat{i}-r\sin\phi\,\hat{j}+z\,\hat{k}\right)}$$

...............(1)

$\therefore$ The net electric field at $P$ due to the charge on whole circular loop is

$$\vec{E}=\int d\vec{E}$$

$$=\frac{1}{4\pi\varepsilon_0}\frac{r\lambda}{\left(r^2+z^2\right)^{\frac{3}{2}}}\left[-\left(r\int_0^{2\pi}\cos\phi\,d\phi\right)\hat{i}-\left(r\int_0^{2\pi}\sin\phi\,d\phi\right)\hat{j}+z\left(\int_0^{2\pi}d\phi\right)\hat{k}\right]$$

$$=\frac{1}{4\pi\varepsilon_0}\frac{r\lambda}{\left(r^2+z^2\right)^{\frac{3}{2}}}\left[0-0+z\left(2\pi\right)\hat{k}\right]$$

$$=\frac{1}{4\pi\varepsilon_0}\lambda\left(2\pi r\right)\frac{z}{\left(r^2+z^2\right)^{\frac{3}{2}}}\hat{k}$$

$$\therefore\quad \boxed{\vec{E}=\frac{1}{4\pi\varepsilon_0}q\frac{z}{\left(r^2+z^2\right)^{\frac{3}{2}}}\hat{k}}\qquad ...............(2)$$

where q $=\lambda\left[2\pi r\right]$ is the total charge on the circular loop.

# Problem



**4. Electric Field** a distance $z$ above the centre of a flat circular disc of radius $R$, which carries a uniform surface charge $\sigma$.

- The disk can be considered as the combination of an infinite number of infinitesimally thin rings.

Consider a ring of radius $r$ and thickness $dr$ of this disk.

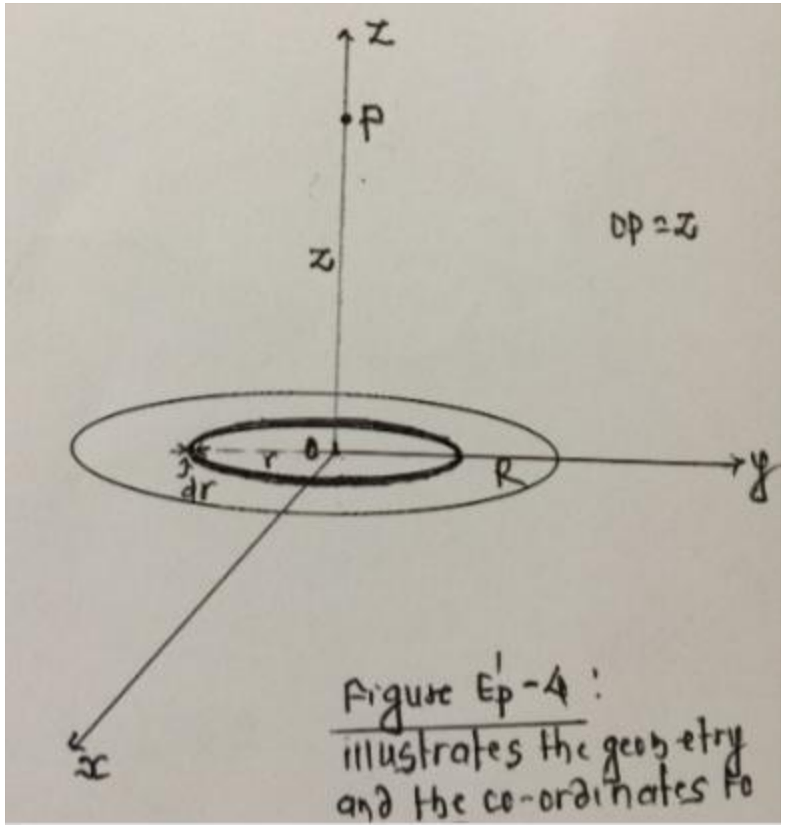
The charge on this ring is $\mathrm{d}q = \sigma\left(2\pi r\ dr\right)$ ................ (1)

The electric field at $P$ due to the charge $dq\left(=\sigma\ 2\pi r\ dr\right)$ on the ring is given by

$$d\vec{E} = \frac{1}{4\pi\varepsilon_0} dq \frac{z}{\left(r^2+z^2\right)^{\frac{3}{2}}}\hat{k}$$

$$= \frac{1}{4\pi\varepsilon_0}\left(\sigma\ 2\pi r\ dr\right)\frac{z}{\left(r^2+z^2\right)^{\frac{3}{2}}}\hat{k} \qquad \text{using Eq.(1)}$$

$$\therefore \boxed{d\vec{E} = \frac{\sigma z}{2\varepsilon_0}\frac{r\ dr}{\left(r^2+z^2\right)^{\frac{3}{2}}}\hat{k}} \qquad ............... \qquad (2)$$



# Problem

ELECTROSTATIC FIELD

**4. Electric Field** a distance $z$ above the centre of a flat circular disc of radius $R$, which carries a uniform surface charge $\sigma$.

- Hence the electric field at *P* due to the charge on the whole flat circular disk is given by

$$\vec{E}_{disk} = \int d\vec{E} = \frac{\sigma z}{2\varepsilon_0}\left[\int_0^R \frac{r\,dr}{\left(r^2+z^2\right)^{\frac{3}{2}}}\right]\hat{k} \qquad \ldots\ldots\ldots\ldots\ldots \qquad (3)$$

put $r^2 + z^2 = t^2$

$\Rightarrow r\,dr = t\,dt$

when $r = 0$, then $t = z$

when $r = R$, then $t = \sqrt{R^2+z^2}$

$$\because \quad \vec{E} = \frac{\sigma z}{2\varepsilon_0}\left[\int_z^{\sqrt{R^2+z^2}} \frac{t\,dt}{t^3}\right]\hat{k} = \frac{\sigma z}{2\varepsilon_0}\left[\int_z^{\sqrt{R^2+z^2}} \frac{1}{t^2}dt\right]\hat{k}$$

$$= \frac{\sigma z}{2\varepsilon_0}\left[-\frac{1}{t}\right]_z^{\sqrt{R^2+z^2}}\hat{k} = \frac{\sigma z}{2\varepsilon_0}\left[\left(-\frac{1}{\sqrt{R^2+z^2}}\right)-\left(-\frac{1}{z}\right)\right]\hat{k}$$

$$\therefore \quad \boxed{\vec{E} = \frac{\sigma}{2\varepsilon_0}\left[1-\frac{z}{\sqrt{R^2+z^2}}\right]\hat{k}}$$

# Problem

ELECTROSTATIC FIELD

**4. Electric Field** a distance $z$ above the centre of a flat circular disc of radius $R$, which carries a uniform surface charge $\sigma$.

As $R \to \infty$:

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}[1-0]\hat{k} = \frac{\sigma}{2\varepsilon_0}\hat{k}$$

$\uparrow$

Electrcic field due to infinite sheet of charge

For points far from the disk $(z \gg R)$:

$$\vec{E} = \frac{\sigma}{2\varepsilon_0}\left[1-\frac{z}{\sqrt{R^2+z^2}}\right]\hat{k} = \frac{\sigma}{2\varepsilon_0}\left[1-\frac{1}{\left(\frac{R^2+z^2}{z^2}\right)^{\frac{1}{2}}}\right]\hat{k} = \frac{\sigma}{2\varepsilon_0}\left[1-\left(1+\frac{R^2}{z^2}\right)^{-\frac{1}{2}}\right]\hat{k}$$

$$\cong \frac{\sigma}{2\varepsilon_0}\left[1-\left\{1-\frac{1}{2}\frac{R^2}{z^2}+\ldots\right\}\right]\hat{k}$$ using binomial expansion

$$\cong \frac{\sigma}{2\varepsilon_0}\frac{1}{2}\frac{R^2}{z^2}\hat{k} = \frac{1}{4\pi\varepsilon_0}\frac{\sigma\left(\pi R^2\right)}{z^2}\hat{k}$$

$$\therefore \boxed{\vec{E} \cong \frac{1}{4\pi\varepsilon_0}\frac{q}{z^2}\hat{k}}$$ where q $=\sigma\left(\pi R^2\right)$ is the total charge on the disk

For far away the disk "looks" like a point charge q $=\sigma\left(4\pi R^2\right)$.

# Text Books & References



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Thank you