# Applied Physics for Engineers (PHY121)

# Electrostatics

LECTURE # 2

Instructor

**Muhammad Kaleem Ullah**

*Lecturer*

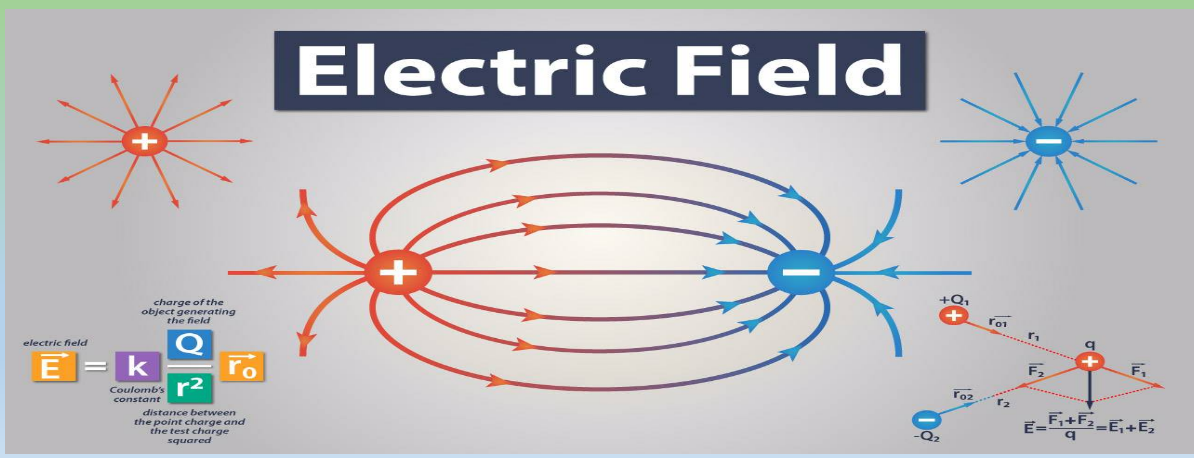
*Department of Physics*

*CUI, Lahore Campus.*

1

## Outlines

1. Electric Field
2. Electric Field Lines
3. Electric field due to a Point Charge



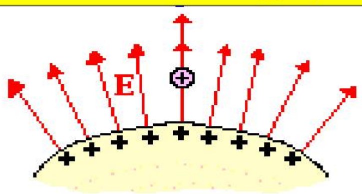

2

## 1.2 Electric Field

An electric field is a region in which an electric force will act on a charge that is placed in the region.

$$\vec{E} = \frac{\vec{F}}{q_o}$$

**Electric Field Strength, $\vec{E}$**




**Definition** : The electric force, F acting on a test charge that is placed in the electric field region divided by the magnitude charge of the test charge, $q_0$.

E is a vector quantity. SI unit for E is N $C^{-1}$.

Electric field patterns can be represented by electric field lines which is drawn pointing in the direction of the E vector at any point.

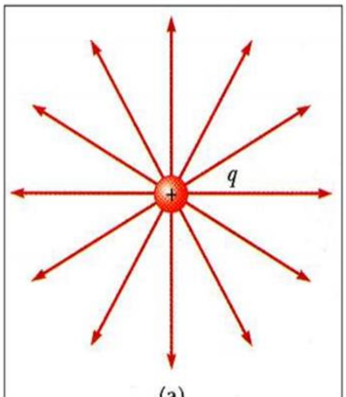
3

(1) These electric filed lines never cross each other and the number of lines determine the strength of the electric field.

(2) E is large when the field lines are close together and small when they are far apart.

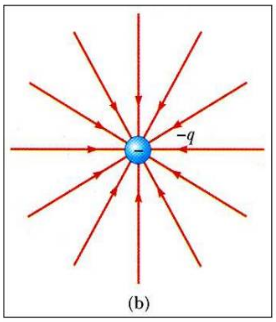
(3) A positive and a negative charge can produce electric field.

(4) The direction of E for a positive point charge is outward from the charge in all direction (3 dimension).




(a)

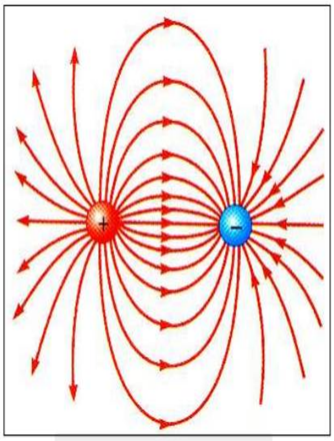
4




(5) The direction of E for a negative point charge is toward the charge in all direction (3 dimension)

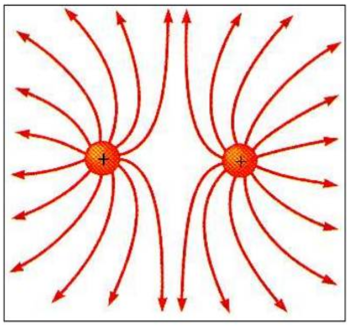
(6) The number of electric field lines entering or leaving a charge is proportional to the magnitude of the charge.

**Electric field lines (patterns) for two equal and opposite point charges.**

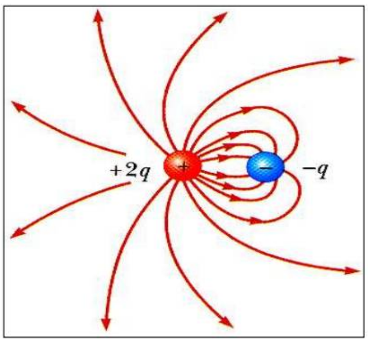


5

**Electric field lines (patterns) for two equal positive point charges.**

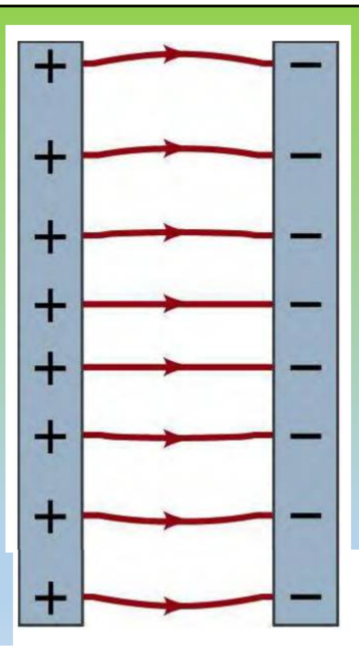


**Electric field lines (patterns) for a point charge +2q and a second point charge –q.**




6

**Electric field lines (patterns) for two opposite charged parallel metal plates**



The electric field lines are perpendicular to the surface of the metal plates.

The lines go directly from positive plate to the negative plate.

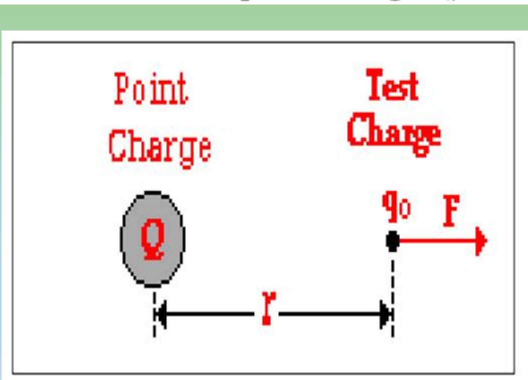
The field lines are parallel and equally spaced in the central region far from the edges but fringe outward near the edges.

In the central region, the electric field has the same magnitude at all points.

7

## Electric field strength, E for a point charge.

Consider a test charge, $q_0$ located at a distance r from a point charge Q,




According to Coulomb's Law ;

$$\vec{F} = k\frac{Qq_o}{r^2} \quad \cdots(1)$$

From definition :

$$\vec{E} = \frac{\vec{F}}{q_o} \quad \cdots(2)$$

By substituting (1) into (2), we get :

$$\boxed{\vec{E} = k\frac{Q}{r^2}}$$

8

where

k – Comloub constant ( $9.0 \times 10^9$ N m$^2$ C$^{-2}$ )

Q – point charge that produce electric field

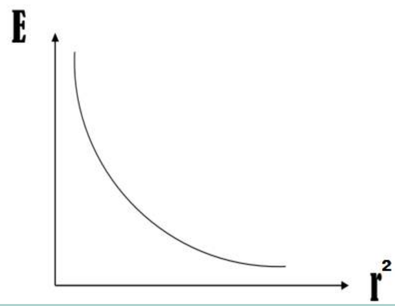
r – distance a point from the point charge

Notice that E is inversely proportional to r$^2$

$$E \propto \frac{1}{r^2}$$

The strength of E will decrease when the distance from the charge increase.

The relationship between E and r$^2$ can be shown in the graph below.




**Note:**

The direction of the electric field strength, ***E depends on*** **the sign of the point charge only**.

9

How we draw the electric field line, E that exist at point P ?

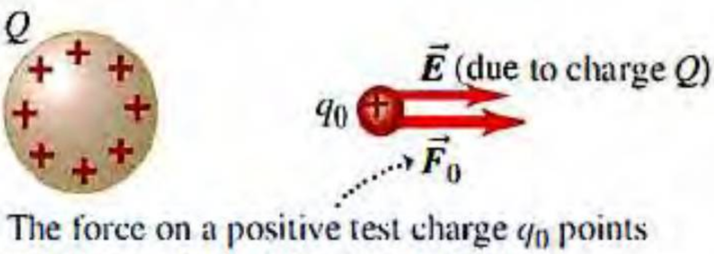
**Use this concept :**

E is outward for + charge

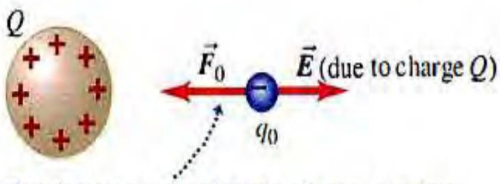
E is inward for − charge

Vector E is draw along the line that joining point P and the charge.

The force $\vec{F}_0 = q_0 \vec{E}$ exerted on a point charge $q_0$ placed in an electric field $\vec{E}$.




The force on a positive test charge $q_0$ points in the direction of the electric field.




The force on a negative test charge $q_0$ points opposite to the electric field.

10

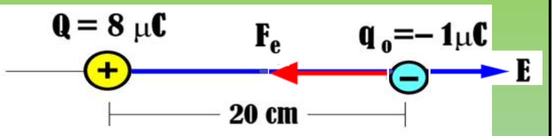
## Example 4

Determine

(a) the electric field strength at a point X at a distance of 20 cm from a point charge Q = +8 μC.

(b) the electric force that acts on a point charge q = –1 μC placed at point X.

**Solution:**




(a) From $\vec{E} = k\dfrac{Q}{r^2}$

$$= (9\times10^{9})\frac{(8\times10^{-6})}{0.2^{2}}$$

$\boxed{E = 1.8 \times 10^{6}\ \text{N C}^{-1}}$

(b) Knowing that

$$\vec{E} = \frac{\vec{F}}{q_o}$$

$\vec{F} = q_o\vec{E}$

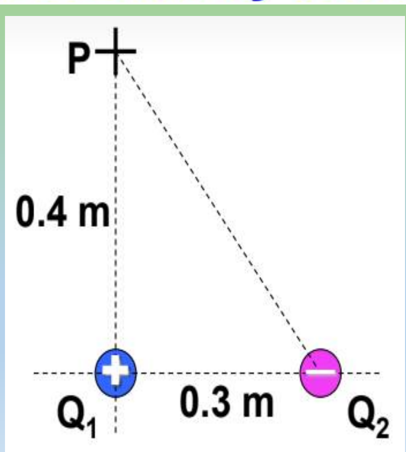
$= (1 \times 10^{-6})(1.8 \times 10^{6})$

$\boxed{F = 1.8 \text{ N towards Q}}$



## Example 5

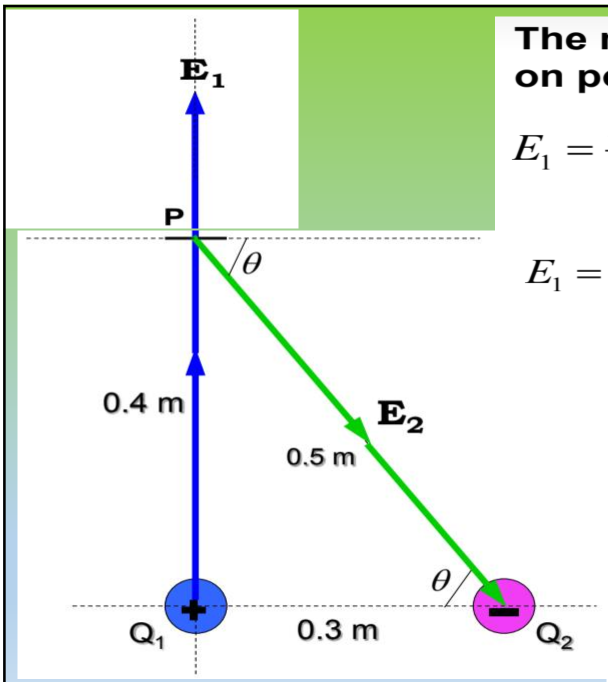
Two point charges, $Q_1$ = +7 μC and $Q_2$ = -5 μC are separated by a distance of 0.3 m between each other as in figure below. Determine the resultant E produced by these two charges at point P.




**Solution :**

First, we have to draw the vector diagram for E produced by $Q_1$ and $Q_2$ at point P.

$E_1$ is produced by $Q_1$ and $E_2$ is produced by $Q_2$.




**The magnitude of the electric fields on point P,**

$$E_1 = \frac{kQ_1}{r_1^{\,2}}$$

$$E_1 = \frac{(9\times10^9)(7\times10^{-6})}{(0.4)^2} = 3.93\times10^5\ N\ C^{-1}$$

**and**

$$E_2 = \frac{kQ_2}{r_2^{\,2}}$$

$$E_2 = \frac{(9\times10^9)(5\times10^{-6})}{(0.5)^2}$$

$$= 1.80\times10^5\ N\ C^{-1}$$



**Since E is a vector quantity, so we have to resolve $E_1$ and $E_2$ into x and y component and find the summation of each of the component.**

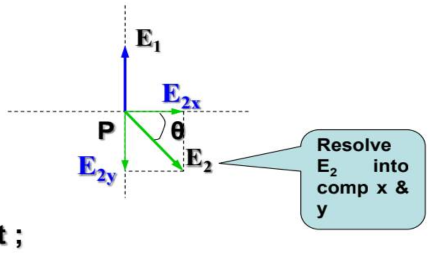
| Vector | x-comp.($N\ C^{-1}$) | y-comp.($N\ C^{-1}$) |
|---|---|---|
| $\vec{E}_1$ | $0$ | $3.93\times10^5$ |
| $\vec{E}_2$ | $1.80\times10^5\cos 53.13$ $=1.08\times10^5$ | $1.80\times10^5\sin 53.13$ $=-1.44\times10^5$ |

$$E = 2.714\times10^5\ N\ C^{-1}$$

**Direction of the resultant E is given by ;**

$$\tan\ \theta = \frac{E_y}{E_x} = \left(\frac{2.49\times10^5}{1.08\times10^5}\right)$$

$\theta = 66.64^o$ **above the positive x-axis**




**Given that ;**

**tan θ = 0.4 / 0.3**

**θ = 53.13°**

$$\sum E_x = 1.08\times10^5\ N\ C^{-1}$$

$$\sum E_y = 2.49\times10^5\ N\ C^{-1}$$

**Therefore, the magnitude of the resultant E is ;**

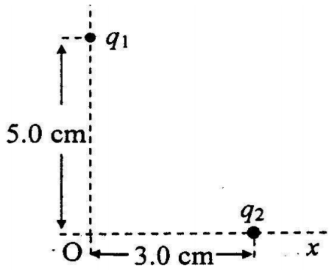
$$E = \sqrt{\sum E_x^{\ 2} + \sum E_y^{\ 2}}$$

$$E = \sqrt{(1.08\times10^5)^2 + (2.49\times10^5)^2}$$

## FOLLOW UP EXERCISE

(1) a) Define electric field.

b)



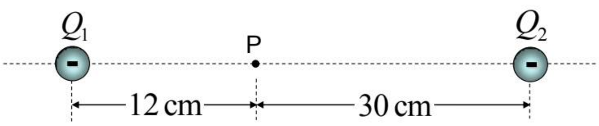

Two point charges, $q_1$=-12 $\mu C$ and $q_2$=+8 $\mu C$ are arranged as shown in FIGURE above.

(i) Copy FIGURE and draw the direction of the electric field $E_1$ and $E_2$ at the origin produced by charge $q_1$ and $q_2$ respectively.

(ii) Calculate the magnitude of the resultant electric field at the origin.

Answer : $Eo = 9.09 \times 10^7\ \mathrm{N\,C^{-1}}$

(2) Two point charges, $Q_1$= –3.0 μC and $Q_2$= –5.0 μC, are placed 12 cm and 30 cm from the point P respectively as shown in Figure below.




Determine

a) the magnitude and direction of the electric field intensity at P,

b) the nett electric force exerted on $q_0$= +1 μC if it is placed at P,

c) the distance of a point from $Q_1$ where the electric field intensity is zero.

15

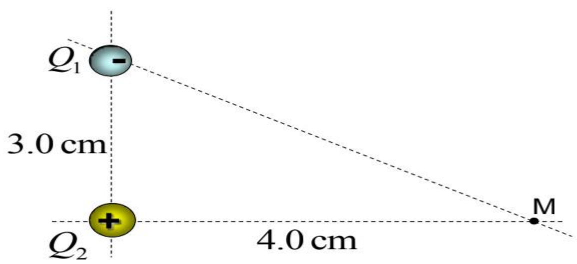
**Answer :**

(a) $E_P = -1.38 \times 10^6\ \mathrm{N\,C^{-1}}$ Towards $Q_1$

(b) 1.38 N Towards $Q_1$

(c) 0.183 m

(3) Two point charges, $Q_1$= –2.0 nC and $Q_2$= +3.2 nC, are placed 3.0 cm apart as shown in Figure below.




Determine the magnitude and direction of the resultant electric field intensity at point M.

Answer :

$E_M = 1.30 \times 10^4\ \mathrm{N\,C^{-1}}$ at $\theta$=19.3° above +$x$ axis

16

**END OF LECTURE**

17