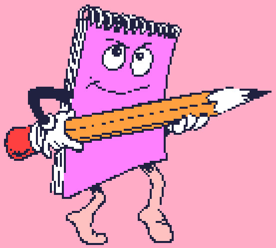
Lecture (1)

Electrostatics

Dr. Emad Sayed

Contents:

- Origin of charge
- Coulomb's law
- Electric field
- Superposition of electric field



Origin of charge

- Charges occur only in discrete amounts = "*quantized*". (*Robert Millikan*)

$$Q = N e$$

N: integer number

e: electron charge $(-1.6\times10^{-19} C)$

or proton charge $(1.6\times10^{-19} C)$

- The electric charge in an isolated system is ***conserved***, but charges may be ***re-arranged***, ***distributed*** or ***transferred***.

Charges

- **Dynamic**
  - **e.g. Electric Current**
- **Static**
  - **e.g. Photocopiers**

Static charges

Electrostatics

- Static charges are usually accumulate in insulators, either in the core or on their surfaces. Meanwhile, they populate only the surface of a conductor, where they are free to move inside the conductor.

- Grounding of machines and electric devices is necessary to avoid static charges.

- Static charges disappears with increasing of humidity

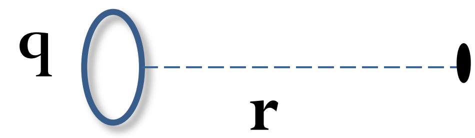
Danger of electrostatics https://www.youtube.com/watch?v=XKAhx4NdJTs

Electric field of a static point charge

The space around charge in which electric effects appear

- **Coulomb's law:**

The electric field (E) due to a point charge (q) at a point located a distance (r) from the charge is:



$$E \; \alpha \; \frac{|q|}{r^2}$$

$$\boldsymbol{E = k\,\frac{|q|}{r^2}}$$

*Where "**k**" is called "Coulomb's constant" = $9x10^9$ $N.m^2 / C^2$*

"Coulomb's constant" depends on the medium containing the charge

$$k = \frac{1}{4\pi\varepsilon_o}$$

Where ε_o is the "permittivity of air" = $8.85\text{x}10^{-12}\ C^2/N.m^2$

Permittivity:

The ability of the medium to sustain the field lines inside it.

Electric field lines

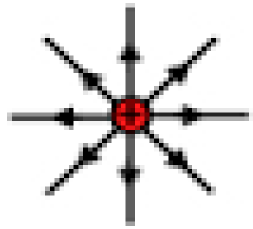
Imaginary lines flowing in the space around the charge, and they are characterized by:

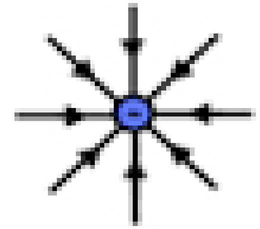
1- Lines are tangent to the direction of the field at any point.

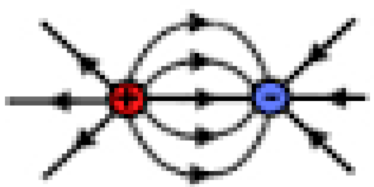
2- The number of lines per unit area is proportional to the field strength.

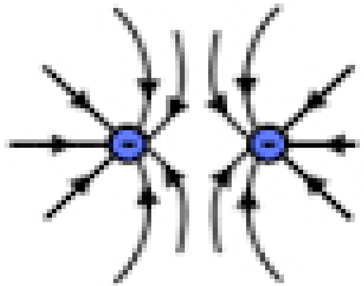
3- Field lines start from a positive charge and end at a negative charge.

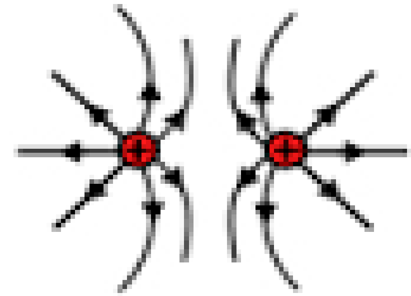
4- Lines are always perpendicular to the charge surface.











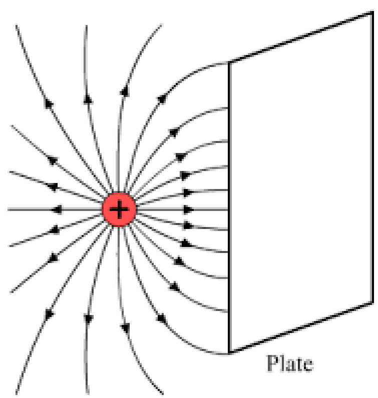

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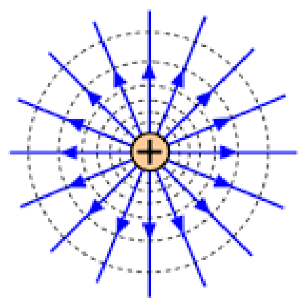
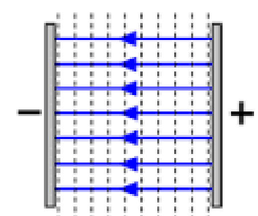
Plate

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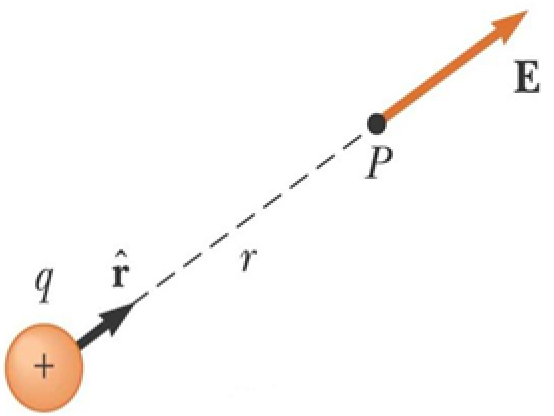
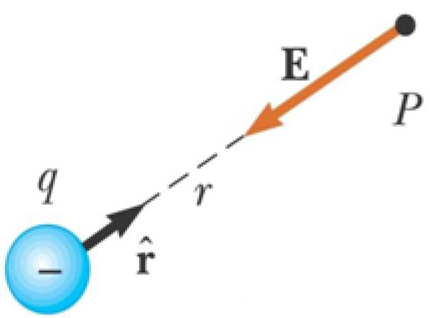
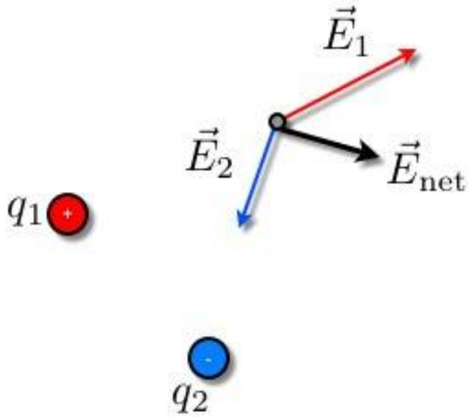
How to determine the field direction

The sign of the charge affects the field direction:

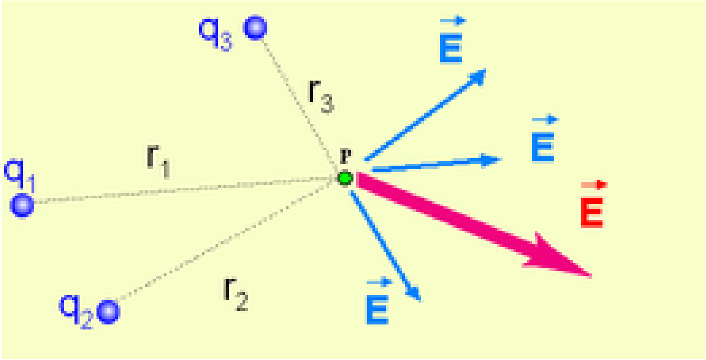






Superposition of electric fields

The ***resultant electric field*** *at a given point due to a number of charges is the* ***vector*** *sum of electric field of the individual charges at this point:*



$$\vec{E}_{tot} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \ldots\ldots \vec{E}_N$$

This means:

$$E_x = E_{1x} + E_{2x} + E_{3x} + \ldots\ldots E_{Nx}$$

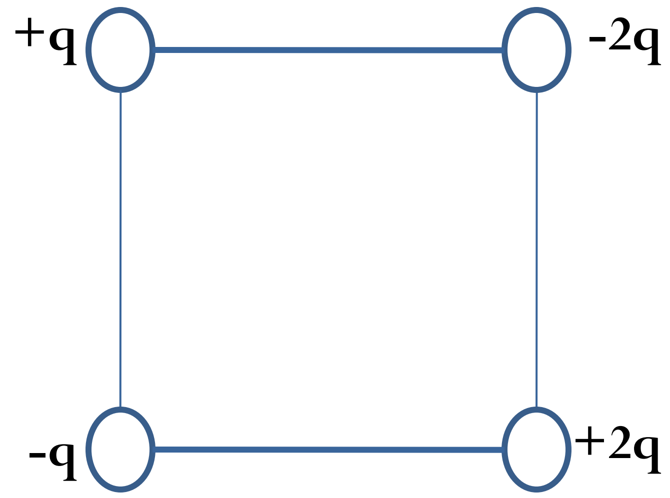
$$E_y = E_{1y} + E_{2y} + E_{3y} + \ldots\ldots E_{Ny}$$

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

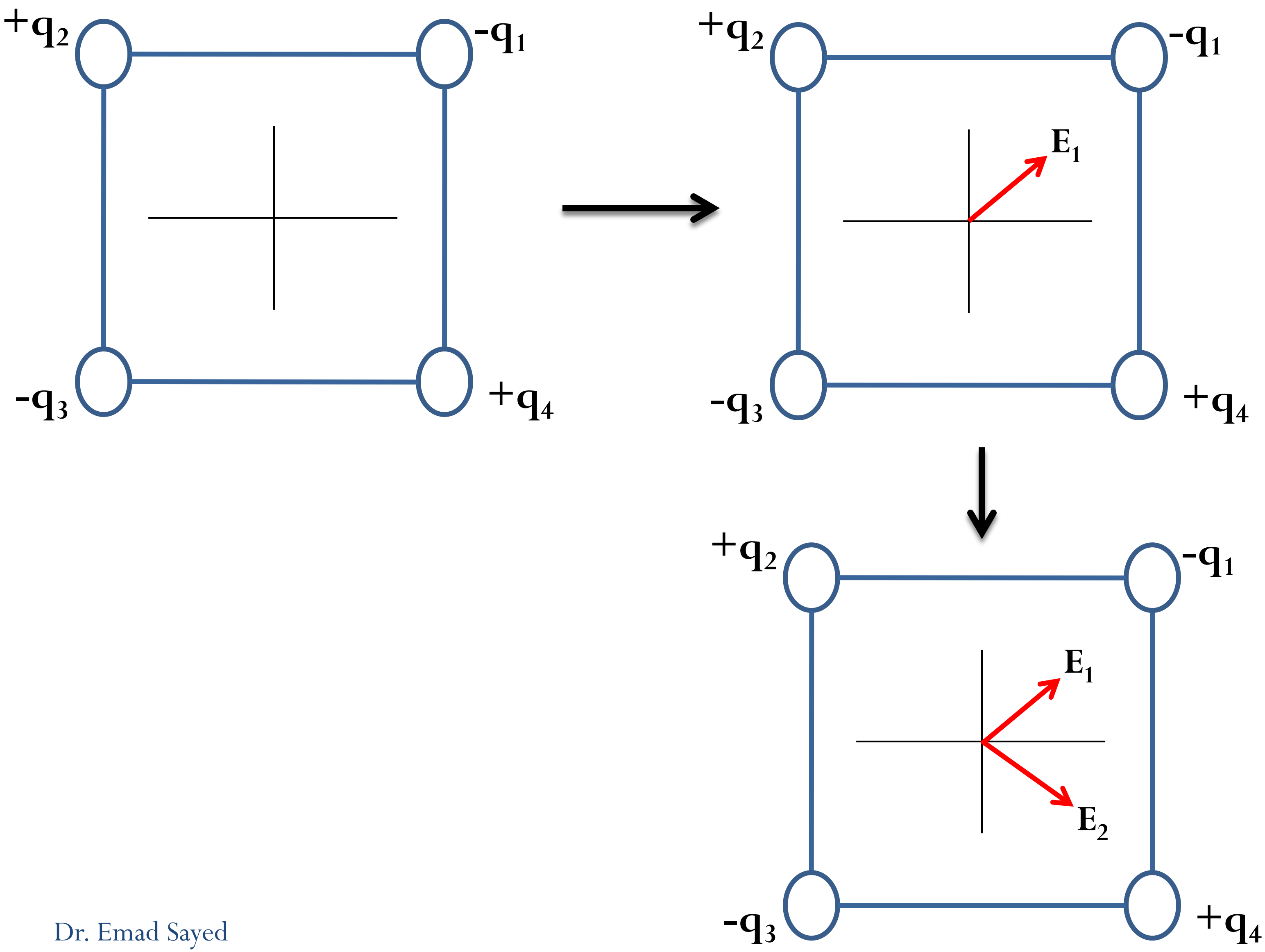
$$\theta = tan^{-1}\frac{E_y}{E_x} \qquad direction$$

Example

What are the magnitude and direction of the electric field at the center of the square of length side 5cm , and $q= 1x10^{-8}$ C, at its corners?



"الخطوة الأولى"



"الخطوة الثانية"

$(r_1)^2 = (2.5)^2 + (2.5)^2$

$r_1 = 3.5 \text{ cm} = 3.5x10^{-2} \text{ m}$

$r_1 = r_2 = r_3 = r_4$

$q_1 = -2x10^{-8}$ C

$q_2 = +1x10^{-8}$ C

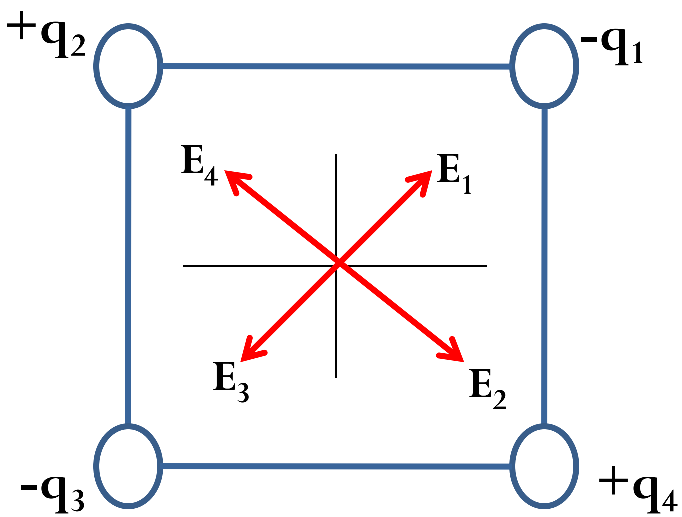
$q_3 = -1x10^{-8}$ C

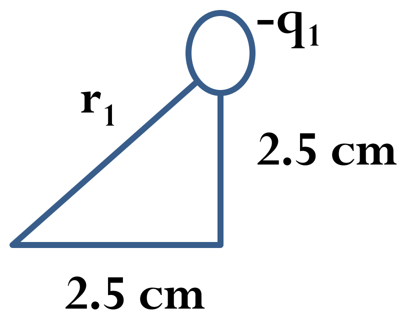
$q_4 = +2x10^{-8}$ C

$$E = k\frac{|q|}{r^2}$$

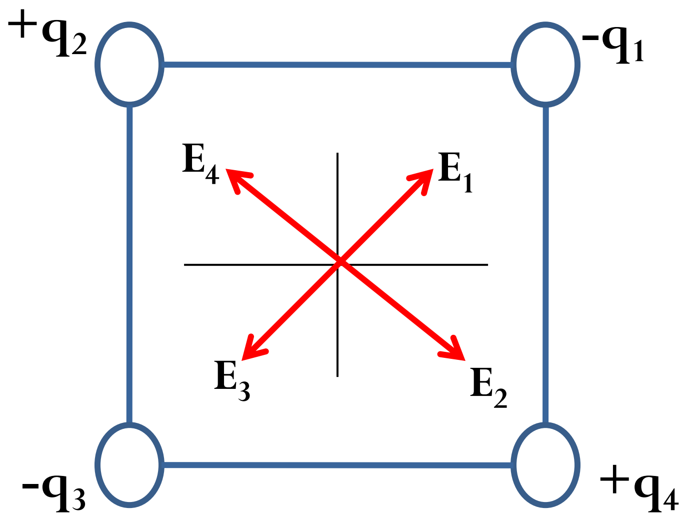
$E_1 = 144x10^3$ N/C , $E_2 = 72x10^3$ N/C

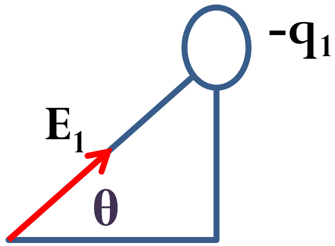
$E_3 = 72x10^3$ N/C , $E_4 = 144x10^3$ N/C





"الخطوة الثالثة"





$\theta_1 = \theta_2 = \theta_3 = \theta_4 = 45^o$

$E_{1x} = E_1 \cos 45 = 102 \times 10^3$ N/C

$E_{2x} = E_2 \cos 45 = 51 \times 10^3$ N/C

$E_{3x} = -E_3 \cos 45 = -51 \times 10^3$ N/C

$E_{4x} = -E_4 \cos 45 = -102 \times 10^3$ N/C

$E_x = 0$

$E_{1y} = E_1 \sin 45 = 102 \times 10^3$ N/C

$E_{2y} = -E_2 \sin 45 = -51 \times 10^3$ N/C

$E_{3y} = -E_3 \sin 45 = -51 \times 10^3$ N/C

$E_{4y} = E_4 \sin 45 = 102 \times 10^3$ N/C

$E_y = 102 \times 10^3$ N/C

$E = 102 \times 10^3$ N/C in the +ve y-direction

Note

The resultant field of two charges equals zero only if:

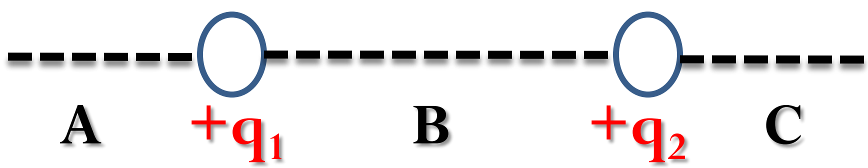
1- $r = \infty$

2- The two fields are equal in magnitude and opposite in direction.

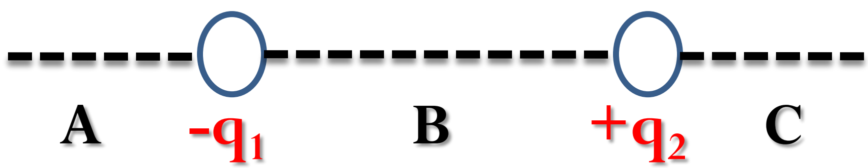
Example

Determine the zone at which the electric field may equal to zero in the following cases:

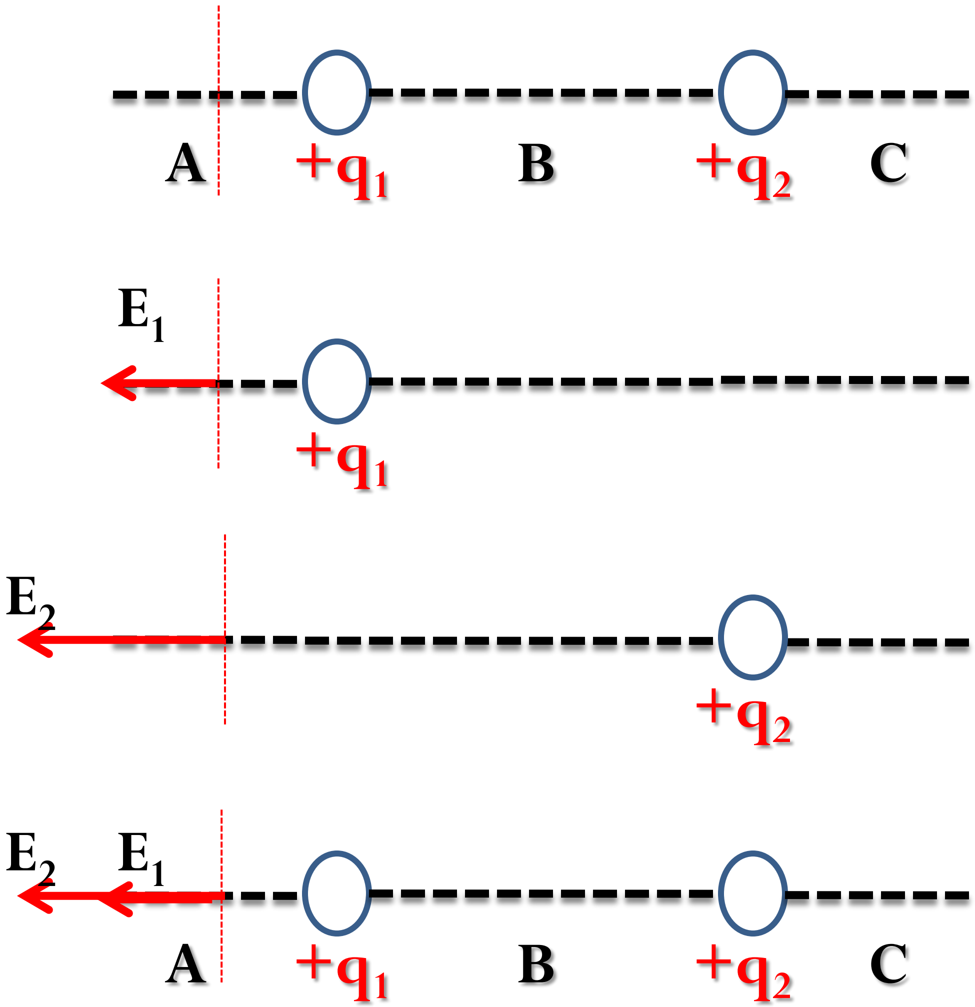
a.



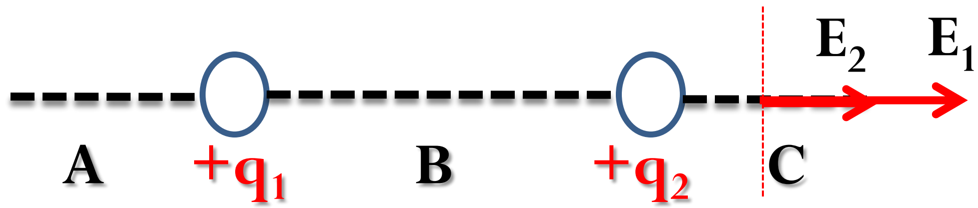
b.



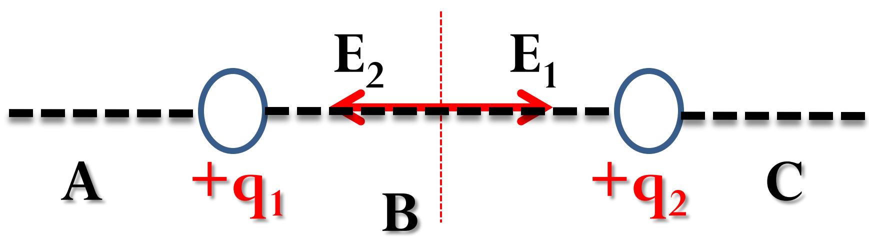
a.



(E) never equals zero in zone **A**

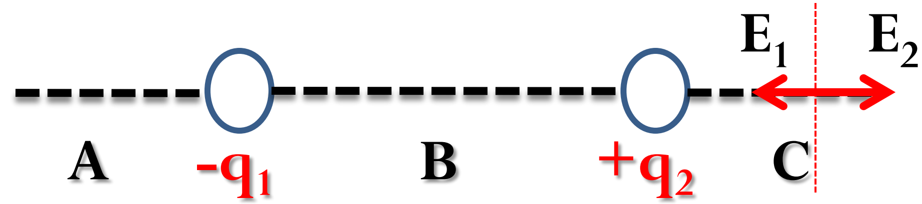


(E) never equals zero in zone **C**

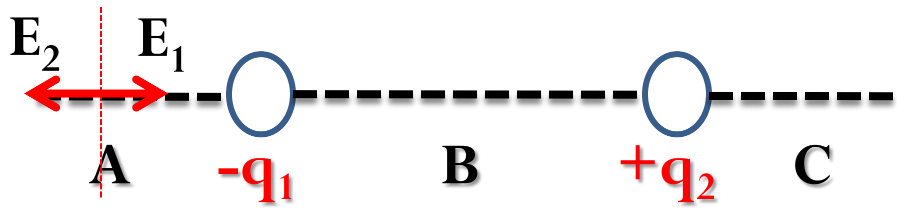


(E) may equal to zero in zone **B**

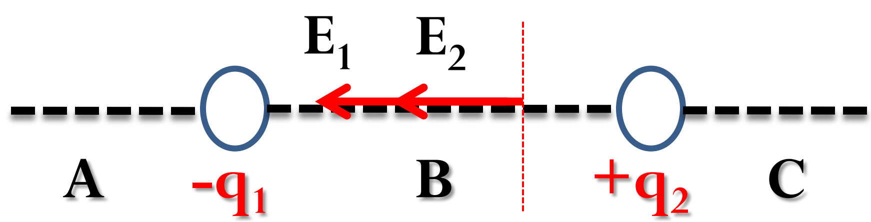
b.



(E) may equal to zero in zone **C**



(E) may equal to zero in zone **A**

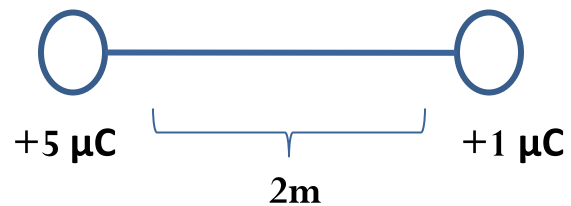


(E) never equals zero in zone **B**

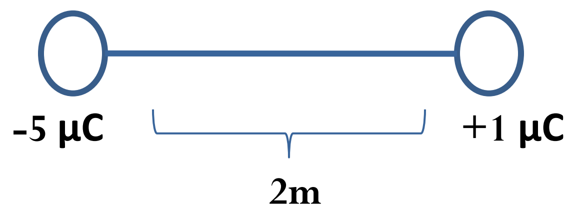
Example

Locate the points at which the electric field equals zero in the following cases:

a.



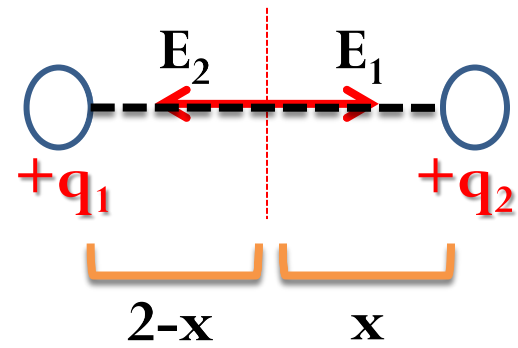
b.



a.

$q_1 = 5x10^{-6}$ C

$q_2 = 1x10^{-6}$ C



$E_1 = E_2$

$$k\frac{|q_1|}{r_1^2} = k\frac{|q_2|}{r_2^2}$$

$$\frac{5x10^{-6}}{(2-x)^2} = \frac{1x10^{-6}}{x^2}$$

$5x^2 = (2\text{-}x)^2$

$x = 0.6$ m

and

$X = \infty$

b.

$q_1 = -5x10^{-6}$ C
$q_2 = 1x10^{-6}$ C

$E_1 = E_2$

$$k\frac{|q_1|}{r_1^2} = k\frac{|q_2|}{r_2^2}$$

$$\frac{5x10^{-6}}{(2+x)^2} = \frac{1x10^{-6}}{x^2}$$

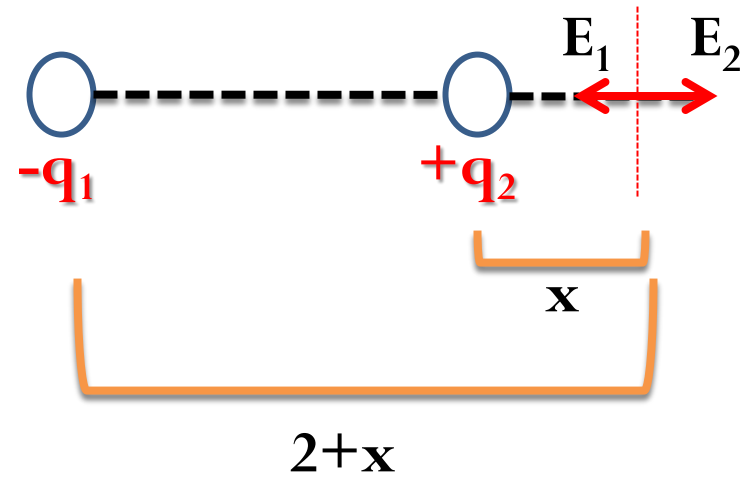
$5x^2 = (2+x)^2$

x = 1.6 m

and

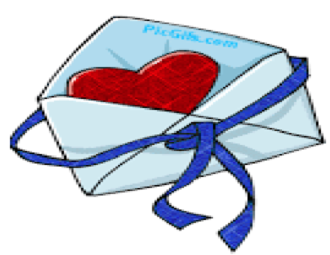
X = ∞

The point is chosen nearer to smaller charge value



To Remember

- Origin of charge
- Coulomb's law
- Electric field
- Superposition of electric field



Best wishes for you