Chapter 1

Electric Fields

المجال الكهربائي

Chapter Outline

- 22.1 Properties of Electric Charges
- 22.2 Charging Objects by Induction
- 22.3 Coulomb's Law
- 22.4 Analysis Model: Particle in an Electric Field
- 22.5 Electric Field Lines
- 22.6 Motion of a Charged Particle in a Uniform Electric Field.

Introduction

- The laws of electricity and magnetism play a central role in the operation of many modern devices.

- The interatomic and intermolecular forces responsible for the formation of solids and liquids are electric in nature.

- The electromagnetic force between charged particles is one of the fundamental forces of nature.

22.1 Properties of Electric Charges

Electric Charges

- There are two kinds of electric charges: Called
+ positive and negative. −

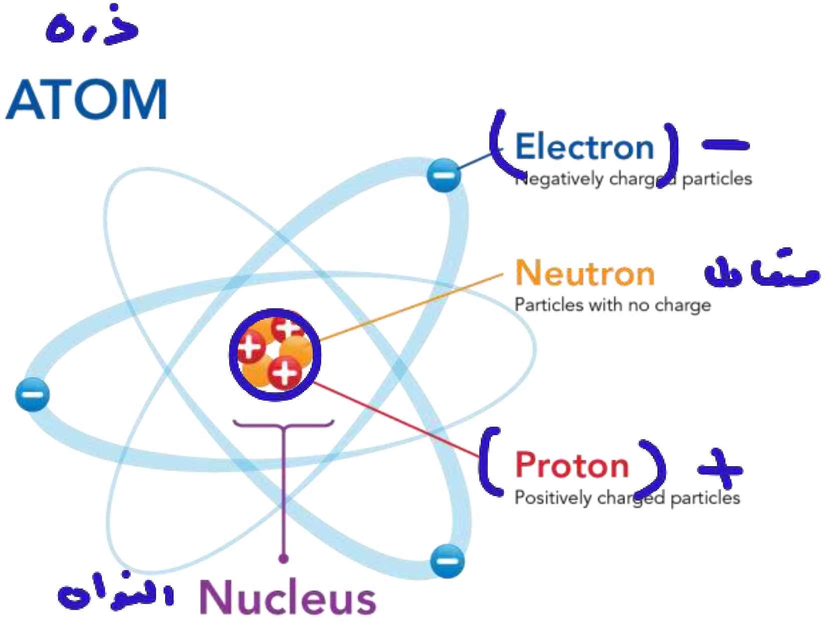
- Negative charges are the type possessed by electrons.

- Positive charges are the type possessed by protons.

نفس الشحنة تتنافر

- Charges of the same sign repel one another and charges with opposite signs attract one another.

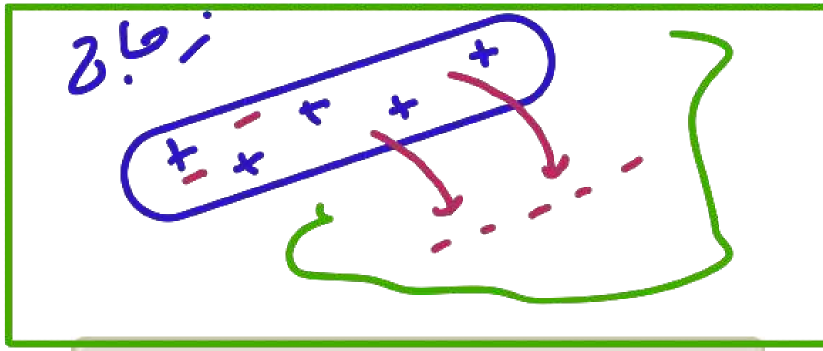
مختلف الشحنة تتجاذب



⊕ ⊕ تتنافر

⊖ ⊕ تجاذب

22.1 Properties of Electric Charges



Properties of Electric Charges

الشحنات محفوظة

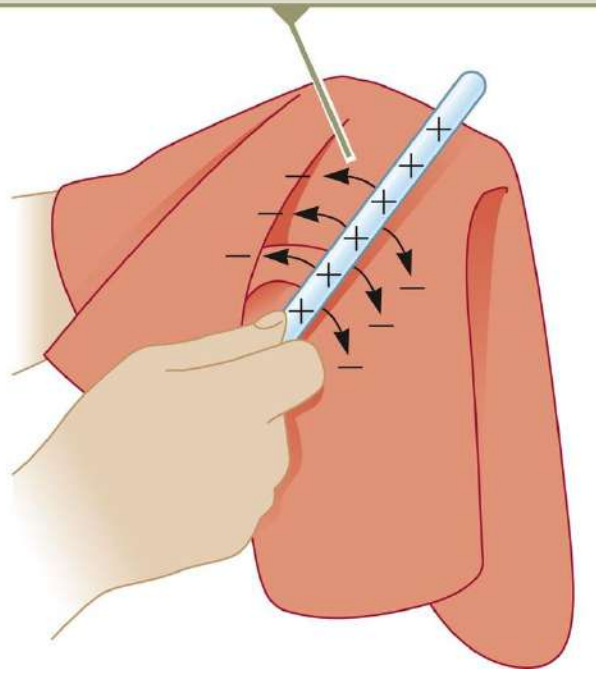
Conservation

- Electric charge is ***always conserved*** in an isolated system. الشحنات محفوظة أي لنظام معزول
- For example, charge is not created in the process of rubbing two objects together.
- The electrification is due to a ***transfer*** of charge from one object to another.

Example: A glass rod is rubbed with silk.

- Electrons are transferred from the glass to the silk.
- Each electron adds a negative charge to the silk.
- An equal positive charge is left on the rod.

Because of conservation of charge, each electron adds negative charge to the silk and an equal positive charge is left on the glass rod.



22.1 Properties of Electric Charges

Properties of Electric Charges

Quantization تكميم الشحنة

- The electric charge, q, is said to be quantized. الشحنة q مكماة
- $\boxed{q}$ is the standard symbol used for charge as a variable.
- The SI unit of charge is $\boxed{\text{Coulomb.}}$

C , μC , nC

$$q = \pm N e$$

$$N = \pm \frac{q}{e}$$

- Electric charge exists as discrete packets.

$$q = \pm Ne$$

- N is an integer
- e is the fundamental unit of charge
- $|e| = 1.6 \times 10^{-19}$ C
- Electron: $q = -e = -1.6 \times 10^{-19}$ C
- Proton: $q = +e = +1.6 \times 10^{-19}$ C

22.2 Charging Objects by Induction

يتم تصنيف المواد حسب قدرة الالكترونات على حركته

It is convenient to classify materials in terms of the ability of electrons to ***move*** through the material:

المواد الموصلة

Conductors

- Some of the electrons are free electrons not bound to the atoms which can ***move relatively freely.***
- Examples: copper, aluminum and silver.

الكترونات حرة

المواد العازلة

Insulators

- All of the electrons are ***bound*** to atoms which can not move relatively freely through the material.
- Examples: glass, rubber and wood.

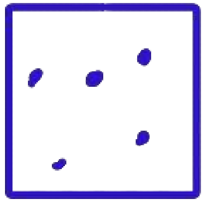
لا تتحرك بحرية

اشباه الموصلات

Semiconductors

- The electrical properties of semiconductors are somewhere ***between*** those of insulators and conductors.
- Examples: silicon and germanium (commonly used in making electronic chips).

22.2 Charging Objects by Induction

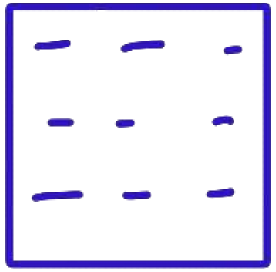


عند شحن عادم الموصل: تتوزع
الشحنات بانتظام على جميع
الماده

عند شحن ده عازله لا تستطيع
الشحنات الحركه

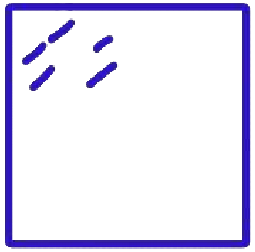
Conductors

- When a good conductor is charged in a small region, the charge readily distributes itself over the entire surface of the material.



Insulators

- When a good insulator is charged in a small region, the charge is unable to move to other regions of the material.



Semiconductors

- The electrical properties of semiconductors can be changed by the addition of controlled amounts of certain atoms to the material.

يمكن التحكم بخواص اشباه موصلات
من خلال اضافه مواد محدده اليه

.

الشحن بالحث

22.2 Charging Objects by Induction

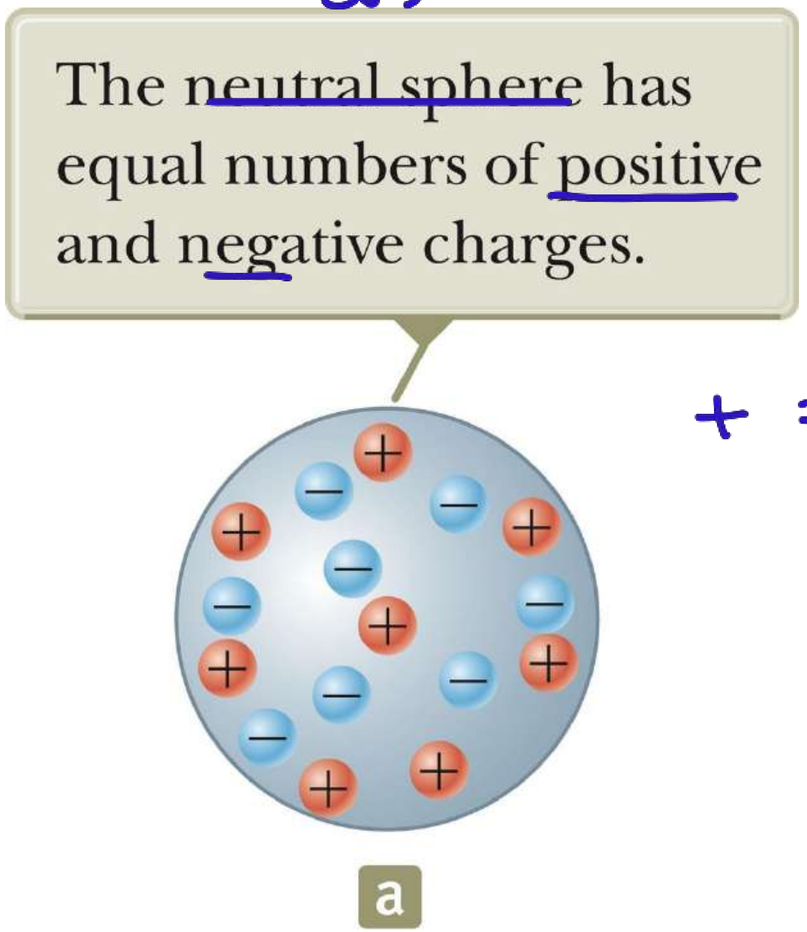
Charging by Induction (Charged Sphere)

يحدث الشحن بدون تلامس

- Charging by induction requires ***no contact*** with the object inducing the charge.

- Assume we start with a neutral metallic sphere.
  1. The sphere has the same number of positive and negative charges.

متعادلة



+ = -

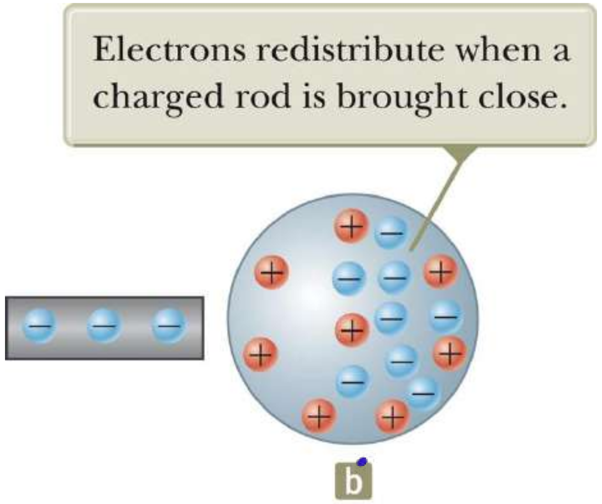
متعادل

22.2 Charging Objects by Induction

Charging by Induction (Charged Sphere)

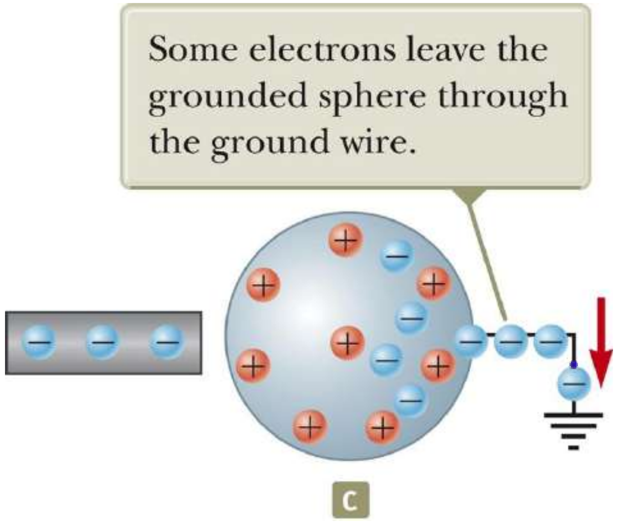
-2-

- A charged rubber rod is placed near the sphere.
  - It ***does not touch*** the sphere.
- The electrons in the neutral sphere are redistributed.



-3-

- The sphere is grounded.
- Some electrons can leave the sphere through the ground wire.

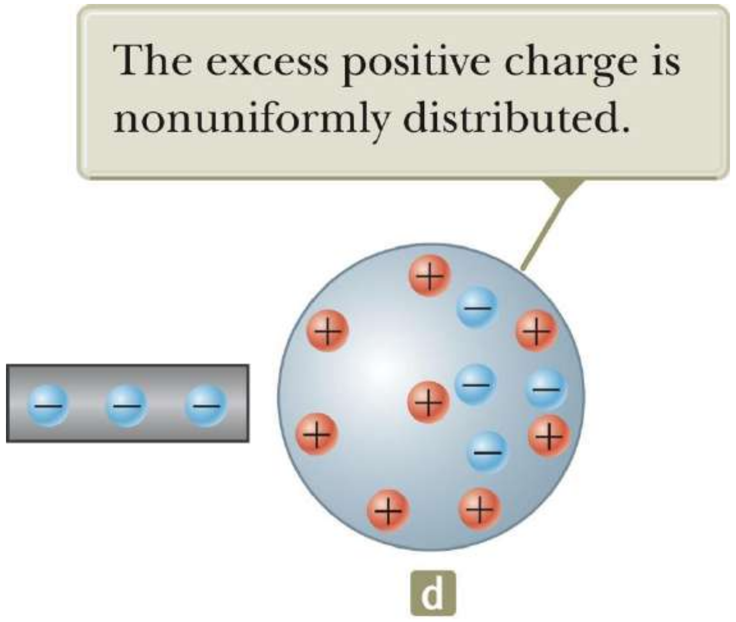


22.2 Charging Objects by Induction

Charging by Induction (Charged Sphere)

-4-

- The ground wire is removed.
- There will now be more positive charges.
- The charges are not uniformly distributed.
- The positive charge has been ***induced*** in the sphere.

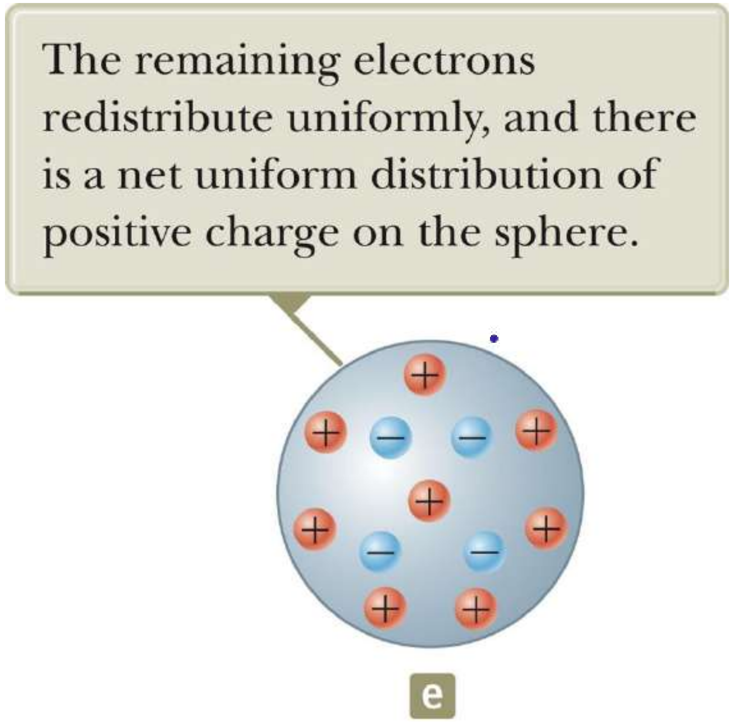


22.2 Charging Objects by Induction

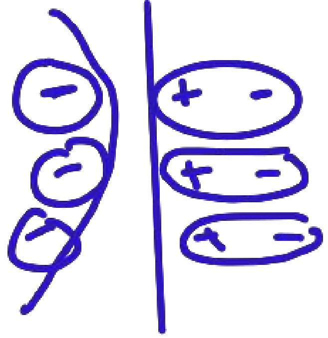
Charging by Induction (Charged Sphere)

-5-

- The rod is removed.
- The electrons remaining on the sphere redistribute themselves.
- There is still a net positive charge on the sphere.
- The charge is now uniformly distributed.
- Note the rod lost none of its negative charge during this process.



22.2 Charging Objects by Induction

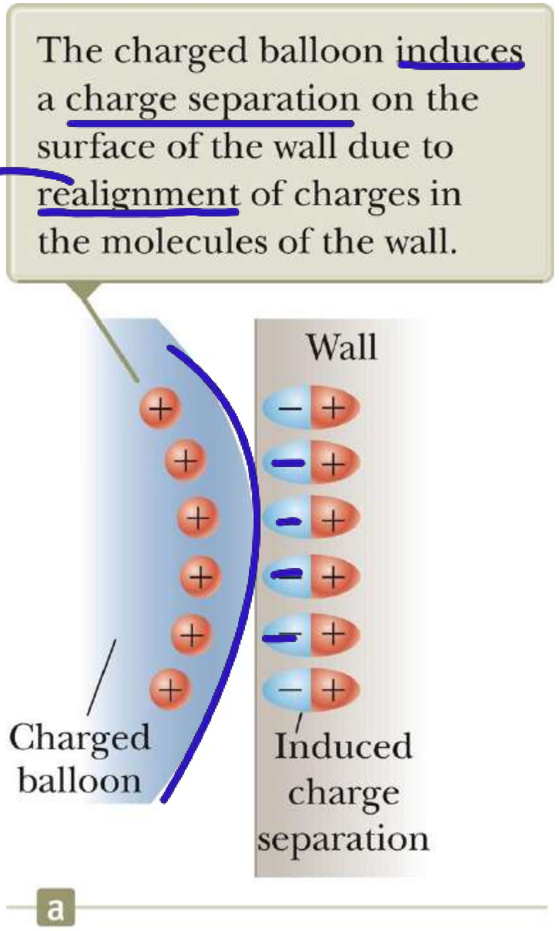


Charge Rearrangement in Insulators

- A process similar to induction can take place in insulators.
- The charges within the molecules of the material are ***rearranged***.
- The proximity of the positive charges on the surface of the object and the negative charges on the surface of the insulator results in an attractive force between the object and the insulator

جزيء

اعادة اصطفاف

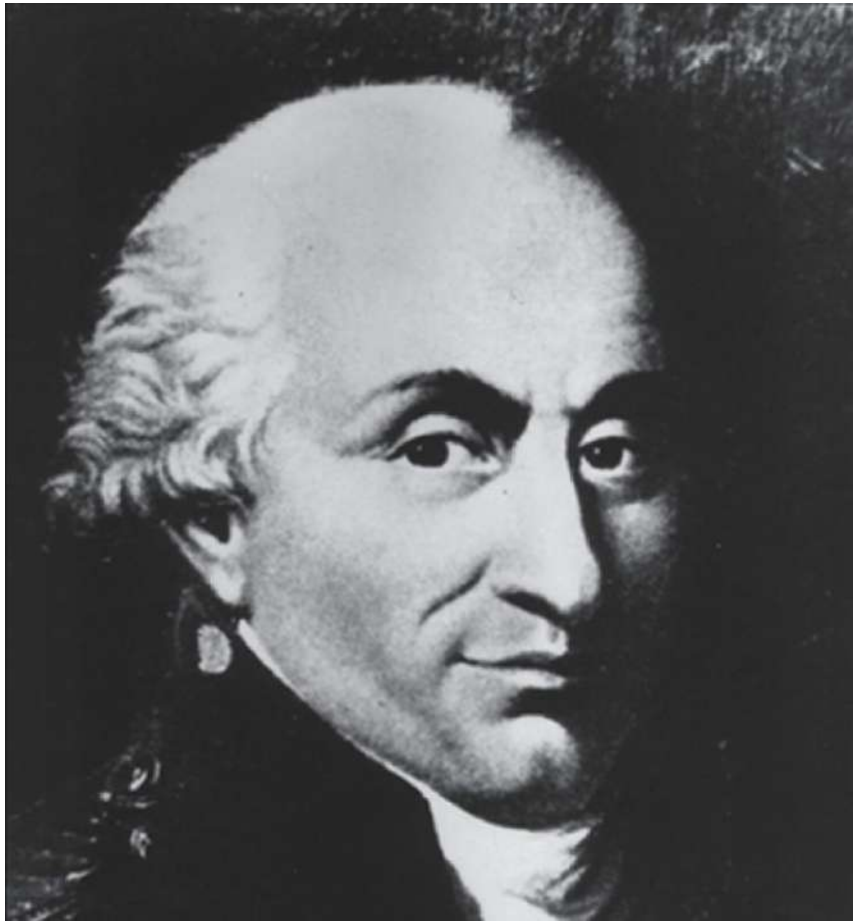


الشحنة على سطح الجسم (+) تتجاذب كهربائي
مع الأطراف السالبة للجزيئات في سطح الجسم العازل

22.3 Coulomb’s Law

Charles Coulomb

- 1736 – 1806
- French physicist
- Major contributions were in areas of electrostatics and magnetism
- Also investigated in areas of
  - Strengths of materials
  - Structural mechanics
  - Ergonomics



$\mu c = 10^{-6}$
$nc = 10^{-9}$
$mc = 10^{-3}$

22.3 Coulomb's Law

Coulomb's Law

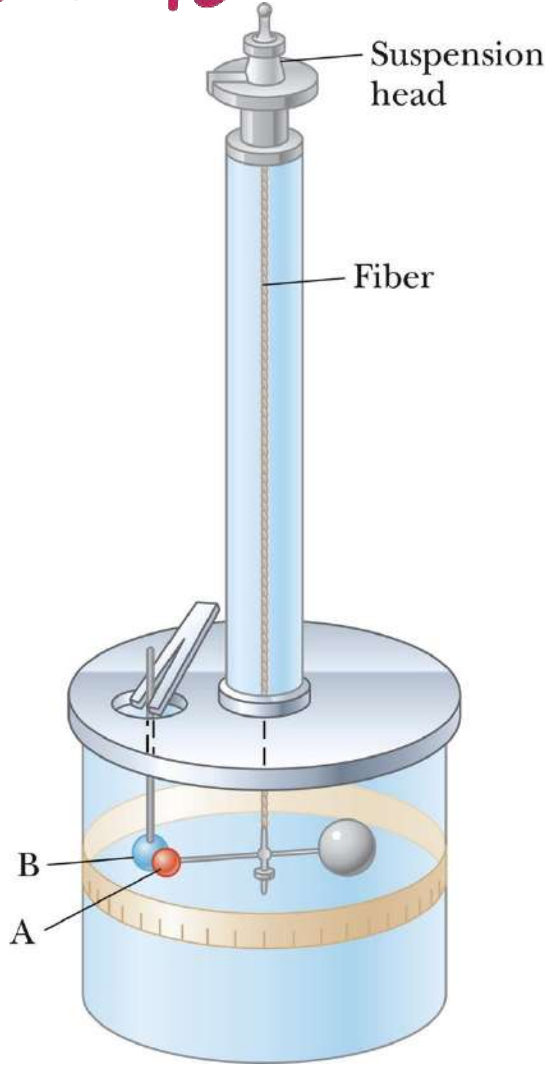
- Charles Coulomb measured the magnitudes of electric forces between two small charged spheres.

يتناسب عكسيا r^2

- The force is ***inversely*** proportional to the square of the separation *r* between the charges and directed along the line joining them.

تتناسب طرديا $q_1 q_2$

- The force is ***proportional*** to the product of the charges, q_1 and q_2 , on the two particles.
- The electrical force between two stationary point charges is given by Coulomb's Law.



22.3 Coulomb’s Law

Terminology: Point Charge

شحنة نقطية :- حجمها صفر

- The term point charge refers to a particle of ***zero size*** that carries an electric charge.

- The electrical behavior of electrons and protons is well described by modeling them as point charges.

Properties of The Electric Force

تجاذب

+ −

- The force is ***attractive*** if the charges are of ***opposite*** sign.

تنافر

+ +

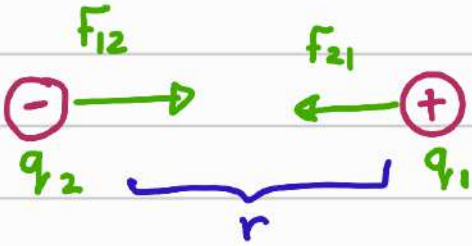
− −

- The force is ***repulsive*** if the charges are of ***like*** sign.

- The force is a conservative force. (Work is path-independent).

قوى محافظة

قانون كولوم :- يدرس القوه المتبادله بين الشحنات النقطيه



$$-F_{21} = F_{12}$$

الشحنه النقطية :- شحنه ذات ابعاد صغيره .

* كلما كان مقدار الشحنين q_1 و q_2 اكبر كلما كانت القوه اكبر (طردي)

* كلما كانت المسافه اصغر كانت القوه اكبر (عكسي)

$$\boxed{F = k \frac{|q_1|\,|q_2|}{r^2}}$$

لانعوض اشاره الشحنات

q_1 و q_2 مقدار الشحنات — كولوم (C)

r المسافه بين الشحنين — r (m)

K ثابت كولوم — Nm^2/C^2

$\boxed{8.99 \times 10^9}$ Nm^2/C^2

F القوه المتبادله بين الشحنين — (N)

ثابت كولوم K_e

$$K_e = \frac{1}{4\pi \epsilon_0}$$

ϵ_0 السماحيه الكهربائيه للفراغ

Permitivity of free space

$$\epsilon_0 = 8.85 \times 10^{-12} \ C^2/N m^2$$

مثال اضافي

Two-point charges, $q_1 = +9\ \mu C$ and $q_2 = 4\ \mu C$, are separated by a distance $r = 12$ cm. What is the magnitude of the electric force?

$q_1 = 9 \times 10^{-6} C$ $q_2 = 4 \times 10^{-6} C$ $r = 12$ cm

$r = 0.12 m$

$$F = \frac{K |q_1||q_2|}{r^2}$$

$$= \frac{8.99 \times 10^{9} \times 9 \times 10^{-6} \times 4 \times 10^{-6}}{(0.12)^2} = 22.5 N$$

22.3 Coulomb's Law

Coulomb's Law, Equation

- Remember that force is a ***vector*** quantity.

- Mathematically the magnitude of the electric force is given by,

$$\boxed{F_e = k_e \frac{|q_1||q_2|}{r^2}}$$

- k_e is called Coulomb constant which has the value

$$\boxed{k_e = 8.9876 \times 10^9 \ \mathrm{N.m^2/C^2}}$$

- k_e is related to a constant called the permittivity of free space ϵ_0 as:

ثابت كولوم مرتبط ب ϵ_0 (السماحيه الكهربائيه للفراغ)

$$k_e = \frac{1}{4\pi\epsilon_0}$$

- Thus,

$$\epsilon_0 = 8.8542 \times 10^{-12} \mathrm{C^2/N.m^2}$$

كتله البروتون تقريبا تساوي كتله النيوترون وكتله الالكترون صغيره جدا

البروتون والالكترون لهما نفس الشحنة $\left.\begin{matrix} e^- \\ p^+ \end{matrix}\right]$

22.3 Coulomb’s Law

Notes About Charges and Particles

- Remember the charges need to be in coulombs.
- e is the smallest unit of charge (except quarks!)
- $e = 1.6 \times 10^{-19}$ C So 1 C needs 6.24×10^{18} electrons or protons
- Typical charges can be in the μC range.

TABLE 23.1 *Charge and Mass of the Electron, Proton, and Neutron*

شحنه كتله

Particle	Charge (C)	Mass (kg)
Electron (e)	$-1.602\,176\,5 \times 10^{-19}$	$9.109\,4 \times 10^{-31}$
Proton (p)	$+1.602\,176\,5 \times 10^{-19}$	$1.672\,62 \times 10^{-27}$
Neutron (n)	0	$1.674\,93 \times 10^{-27}$

- e is the smallest unit of charge The electron and proton are identical in the magnitude of their charge, but very different in mass.
- The proton and the neutron are similar in mass, but very different in charge.

كم عدد الالكترونات في شحنه مقدارها 1C

$$q = Ne$$

$$N = \frac{q}{e} = \frac{1}{1.6 \times 10^{-19}}$$

$$N = 6.25 \times 10^{18} \text{ electron}$$

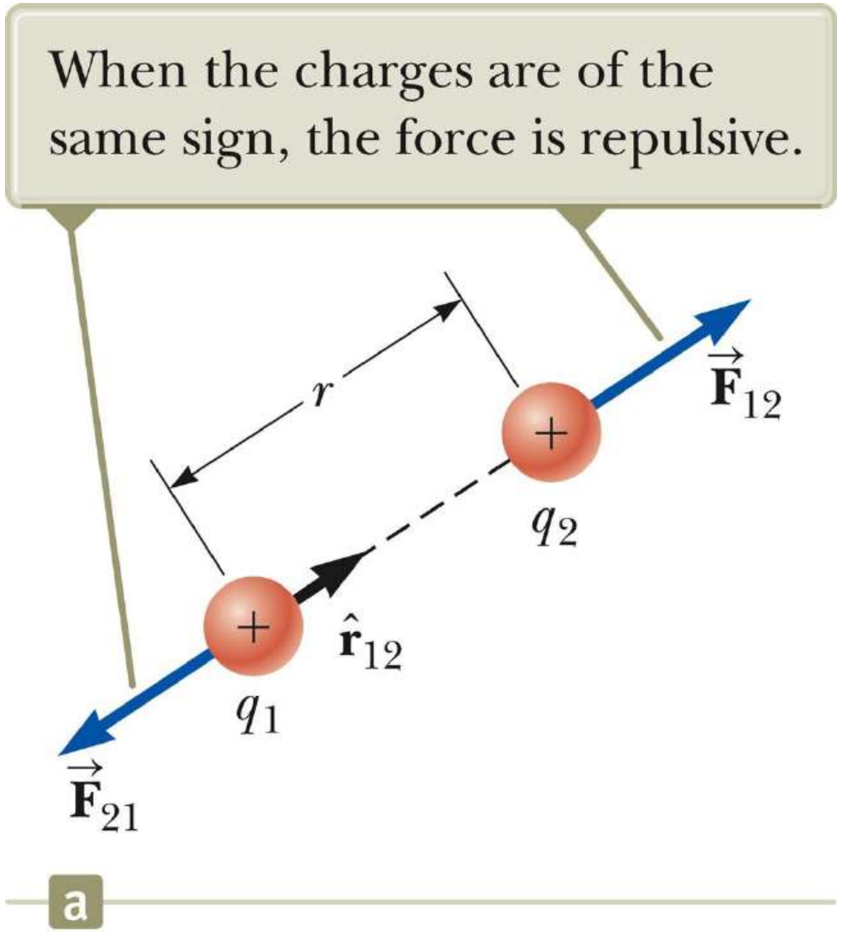
22.3 Coulomb's Law

Vector Nature of Electric Forces

- In vector form,

$$\vec{\mathbf{F}}_{12} = k_e \frac{q_1 q_2}{r^2} \hat{\mathbf{r}}_{12}$$

- $\hat{\mathbf{r}}_{12}$ is the unit vector directed from q_1 to q_2.
- $\vec{\mathbf{F}}_{12}$ is the force by q_1 on q_2.
- The like charges produce a repulsive force between them.



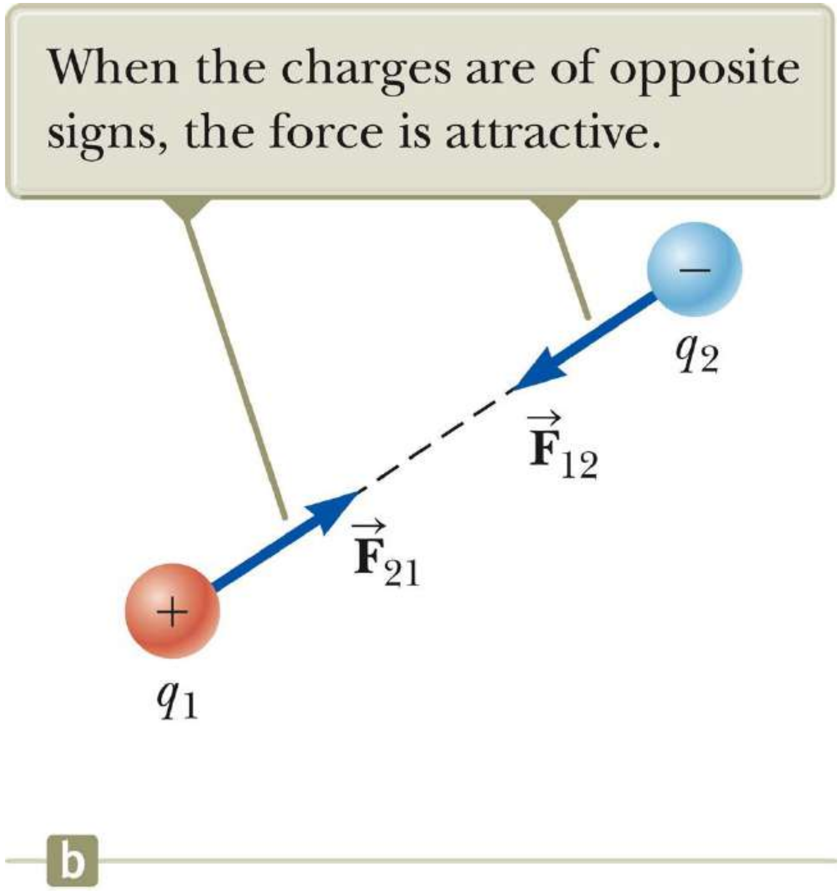
22.3 Coulomb's Law

Vector Nature of Electric Forces

- Electrical forces obey Newton's Third Law.

$$\vec{\mathbf{F}}_{12} = -\vec{\mathbf{F}}_{21}$$

- The force on q_1 is equal in magnitude and opposite in direction to the force on q_2
- With like signs for the charges, the product q_1 q_2 is positive and the force is repulsive.
- With unlike signs for the charges, the product q_1 q_2 is negative and the force is attractive.



القوة الكاملة :- مجموع متجهات القوة
المؤثرة في شحنة معينة

22.3 Coulomb's Law

A Final Note about Directions

- The sign of the product of $q_1\ q_2$ gives the ***relative*** direction of the force between q_1 and q_2.

- The absolute direction is determined by the actual location of the charges.

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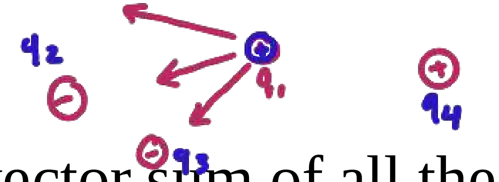
Multiple Charges

- The ***resultant*** force on any one charge equals the vector sum of the forces exerted by the other individual charges that are present.

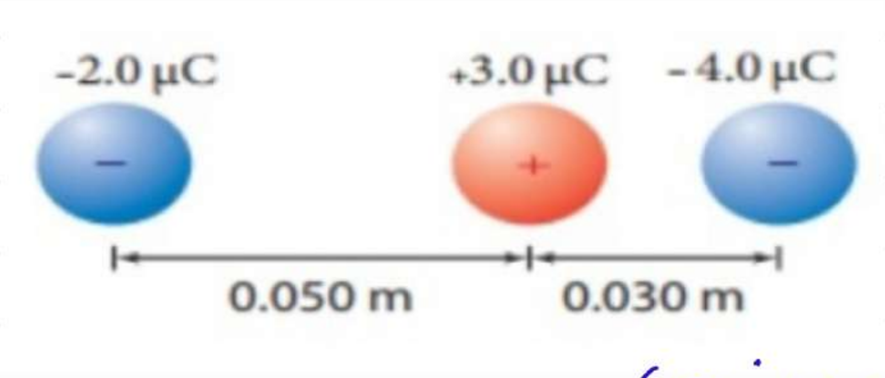


- The resultant force on q_1 is the vector sum of all the forces exerted on it by other charges.

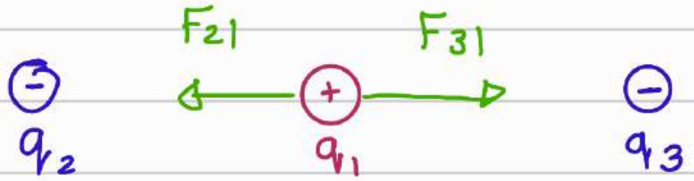
- For example, if four charges are present, the resultant force on one of these equals the vector sum of the forces exerted on it by each of the other charges.

$$\boxed{\vec{\mathbf{F}}_1 = \vec{\mathbf{F}}_{21} + \vec{\mathbf{F}}_{31} + \vec{\mathbf{F}}_{41}}$$

Find the resultant force acting on the positive charge



① نحدد اتجاهات القوى و نرسمها



② نحسب كل قوى لوحدها باستخدام قانون كولوم

$$F_{21} = \frac{k\, q_1 q_2}{r_{12}^2} = \frac{8.99\times10^{9}\times 3\times10^{-6}\times 2\times10^{-6}}{(0.05)^2} = 22\,N$$

$$F_{31} = \frac{k\, q_1\, q_3}{r_{13}^2} = \frac{8.99\times10^{9}\times3\times10^{-6}\times 4\times10^{-6}}{0.03^2} = 120\,N$$

③ كتابة القوى على شكل متجهات

$F_{21} = -22\,i$ $\qquad$ $F_{31} = +120\,i$

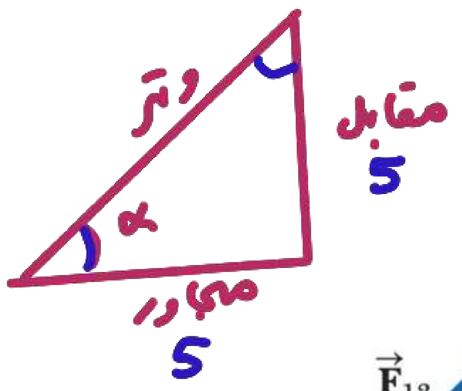
④ جمع المتجهات لحساب المحصلة:

$$F_1 = F_{21} + F_{31} = -22i + 120i = (98i)\,N$$

22.3 Coulomb's Law

$\sin\alpha = \frac{\text{مقابل}}{\text{وتر}}$

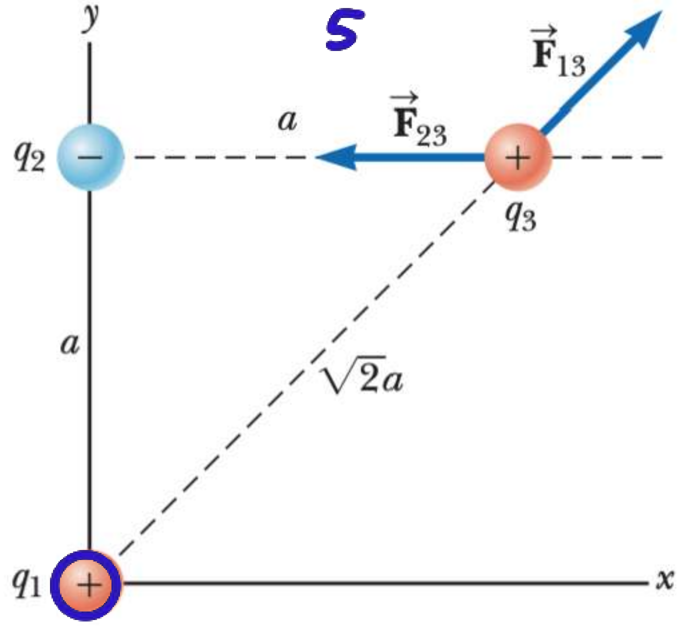
$\cos\alpha =$ مجاور



Example 1:

Consider three point charges located at the corners of a right triangle as shown in Figure 22.8, where $q_1 = q_3 = 5.00\ \mu C$, $q_2 = -2.00\ \mu C$, and $a = 0.100$ m. Find the resultant force exerted on q_3.

حساب القوة المحصلة المؤثرة في q_3



Solution

1. The direction of forces at q_3:

a) Set q_3 as the origin

b) Draw a dotted line between q_3 and q_1 .

c) Since q_3 has the same charge as q_1, the force points away from q_1 along the line.

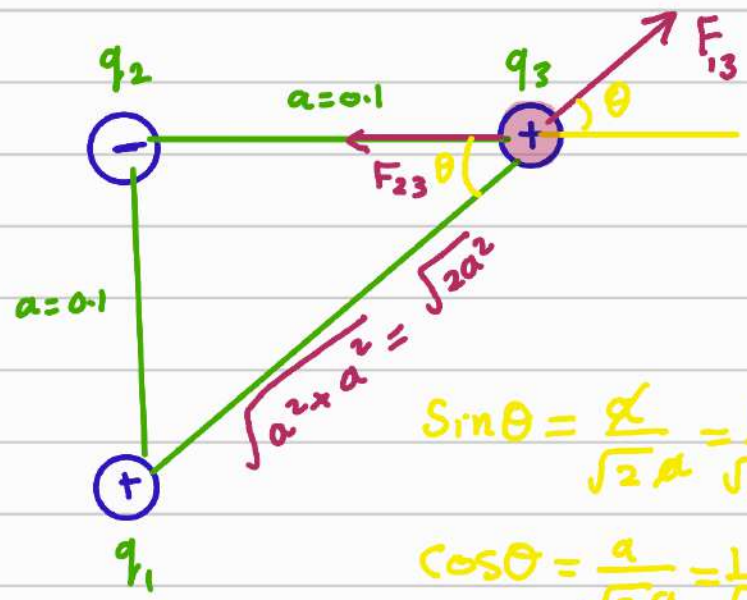
Repeat steps b) and c) for q_2, noting that the force points towards q_2 since they differ in signs.

There are two forces their sum produces the resultant force.

$$\vec{F}_3 = \vec{F}_{13} + \vec{F}_{23}$$

$q_1 = 5\times10^{-6}$
$q_3 = 5\times10^{-6}$
$q_2 = -2\times10^{-6}$

$r_{13}^2 = \left(\sqrt{2a^2}\right)^2 = 2a^2$
$= 2(0.1)^2$



$\sin\theta = \frac{\cancel{a}}{\sqrt{2}\cancel{a}} = \frac{1}{\sqrt{2}}$

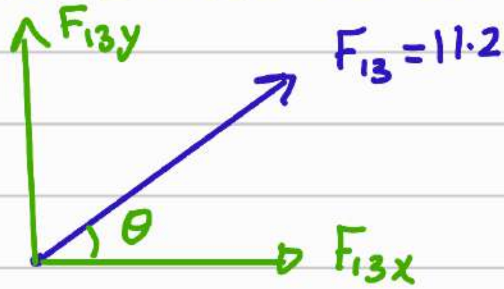
$\cos\theta = \frac{a}{\sqrt{2}a} = \frac{1}{\sqrt{2}}$

$$F_{13} = \frac{k q_1 q_3}{r_{13}^2} = \frac{8.99\times10^{9}\times5\times10^{-6}\times5\times10^{-6}}{2(0.1)^2} = 11.2\,N$$

$$F_{23} = \frac{k q_2 q_3}{r_{23}^2} = \frac{8.99\times10^{9}\times2\times10^{-6}\times5\times10^{-6}}{(0.1)^2} = 8.99\,N$$

$F_{23} = 8.99\,N$

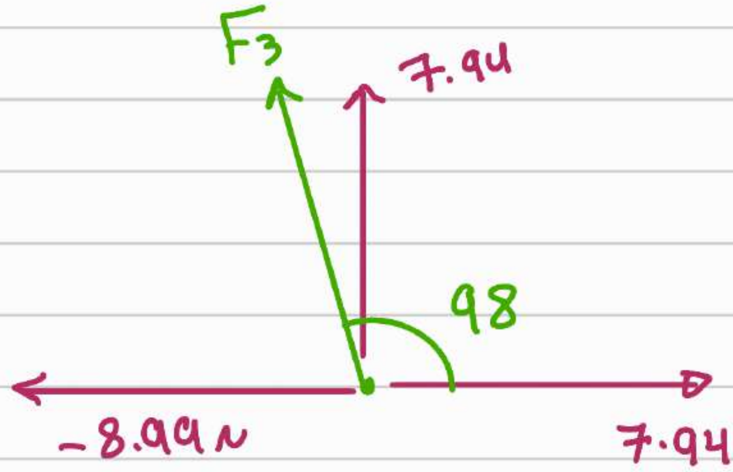
$\boxed{F_{23} = -8.99\,i\ N}$



$F_{13} = F_{13}\cos\theta\, i + F_{13}\sin\theta\, j$

$F_{13} = 11.2\left(\frac{1}{\sqrt{2}}\right) i + 11.2\left(\frac{1}{\sqrt{2}}\right) j$

$\boxed{F_{12} = 7.94i + 7.94j}$



حـاب اكحلة

$$F = F_{13} + F_{23}$$

$$= 7.94i + 7.94j - 8.99i$$

$$\boxed{F_3 = -1.05\,i + 7.94j}$$

$$|F_3| = \sqrt{(1.05)^2 + (7.94)^2} = 8N$$

$$\theta = \tan^{-1}\left(\frac{7.94}{-1.04}\right) = -82.5$$

x,y + مركابه

x - 180 نجمع

y - 360 نجمع

$$= -82.5 + 180$$

$$= 98$$

22.3 Coulomb's Law

Example 1: Solution

2. The separation distance between each charge and q_3:

Given

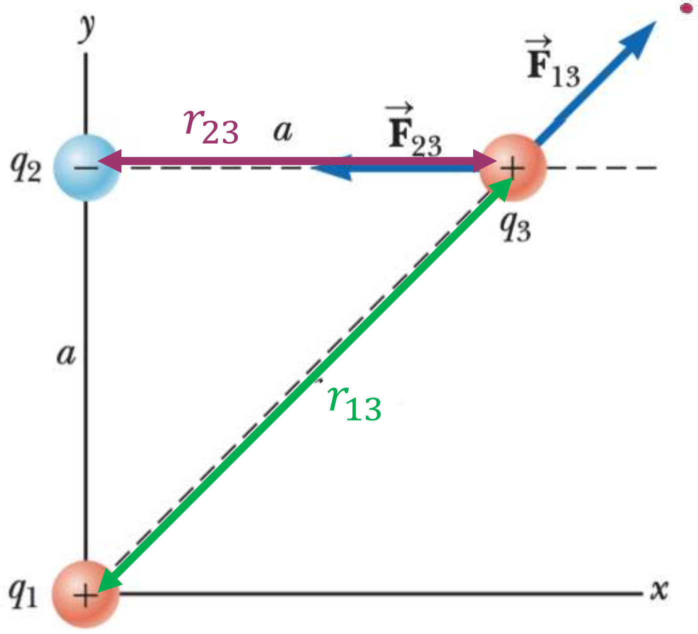
$$r_{23} = a$$

From the right tringle,

$$r_{13}^2 = a^2 + a^2$$

$$\Rightarrow r_{13}^2 = 2a^2$$

$$\Rightarrow r_{13} = \sqrt{2}a$$



3. The magnitude of each force:

$$F_{23} = k_e \frac{|q_2||q_3|}{r_{23}^2}$$

$$= (8.99 \times 10^9)\frac{(5.00 \times 10^{-6})(2.00 \times 10^{-6})}{(0.100)^2}$$

$$= 8.99\text{N}$$

$$F_{13} = k_e \frac{|q_1||q_3|}{r_{13}^2}$$

$$= (8.99 \times 10^9)\frac{(5.00 \times 10^{-6})(5.00 \times 10^{-6})}{\left(\sqrt{2}\, 0.100\right)^2}$$

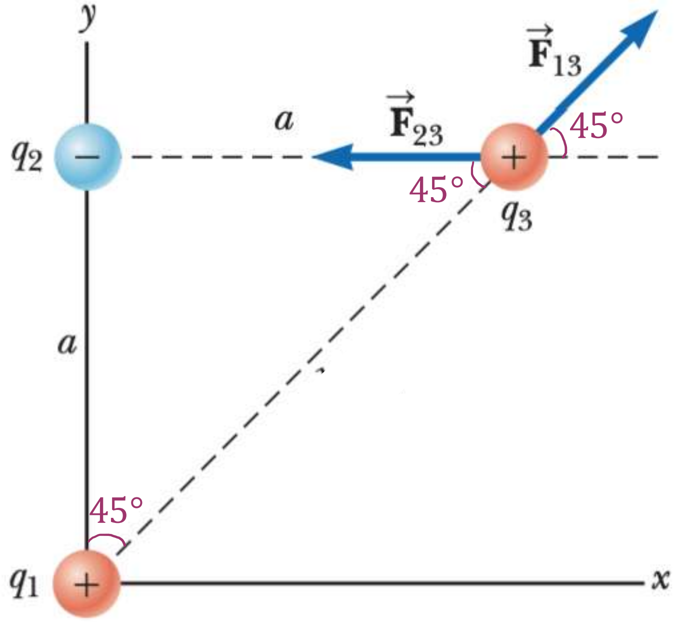
$$= 11.23\text{N}$$

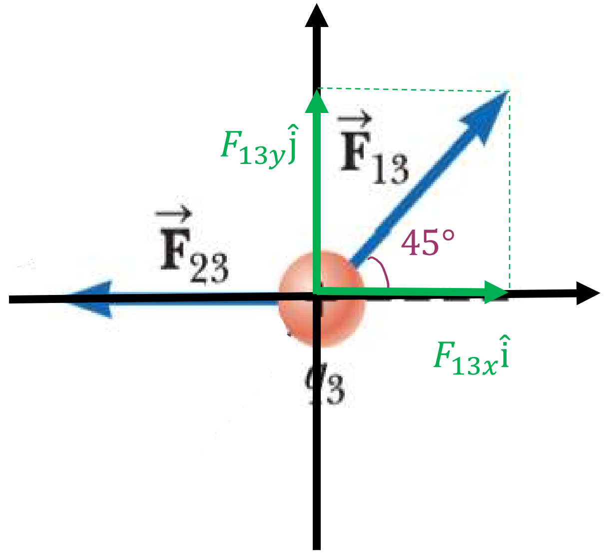
22.3 Coulomb's Law

Example 1: Solution

4. Resolving the forces into components:

First, we note from the right triangle that the angles are 45°. Since opposite angles are equal, the angle that F_{13} makes with the horizontal is 45°.





$$F_{13x} = F_{13}\cos\theta = (11.23)\cos 45° = 7.94\text{N}$$

$$F_{13y} = F_{13}\sin\theta = (11.23)\sin 45° = 7.94\text{N}$$

22.3 Coulomb's Law

Example 1: ***Solution***

5. Resultant force:

Method 1

F_{23}

$$F_{3x} = 7.94 - \boxed{8.99} = -1.05\text{N}$$
$$F_{3y} = 7.94\text{N}$$

$$\Rightarrow \vec{\mathbf{F}}_3 = F_{3x}\hat{\mathbf{i}} + F_{3y}\hat{\mathbf{j}} = \boxed{-1.05\hat{\mathbf{i}} + 7.94\hat{\mathbf{j}}}$$

Method 2

$$\vec{\mathbf{F}}_{13} = -8.99\hat{\mathbf{i}}$$

$$\vec{\mathbf{F}}_{23} = 7.94\hat{\mathbf{i}} + 7.94\,\hat{\mathbf{j}}$$

$$\Rightarrow \vec{\mathbf{F}}_3 = \vec{\mathbf{F}}_{13} + \vec{\mathbf{F}}_{23} = -8.99\hat{\mathbf{i}} + 7.94\hat{\mathbf{i}} + 7.94\,\hat{\mathbf{j}} = \boxed{-1.05\hat{\mathbf{i}} + 7.94\hat{\mathbf{j}}}$$

$$F_3 = \sqrt{F_{3x}^2 + F_{3y}^2} = \sqrt{(-1.05)^2 + (7.94)^2} = 8.01\ \text{N}$$

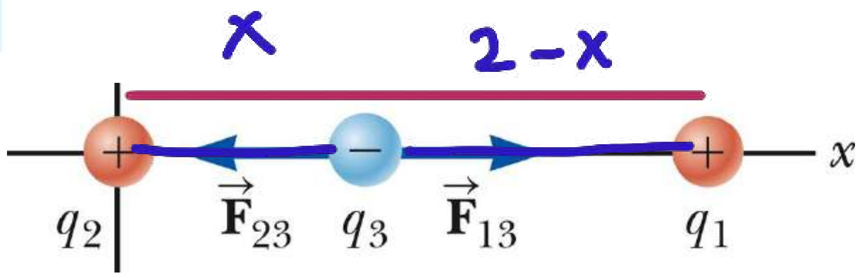
$$\theta = \tan^{-1}\left(\frac{F_{3y}}{F_{3x}}\right) = \tan^{-1}\left(\frac{7.49}{-1.05}\right) = -82.0 + 180 = 98.0°$$

22.3 Coulomb’s Law

Example 2:

Three point charges lie along the x axis as shown in Figure 22.9. The positive charge $q_1 = 15.0\ \mu C$ is at $x = 2.00$ m, the positive charge $q_2 = 6.00\ \mu C$ is at the origin, and the net force acting on q_3 is zero. What is the x coordinate of q_3?

Solution



1. The direction of forces at q_3:

(same steps from example 1, but both forces are attractive).

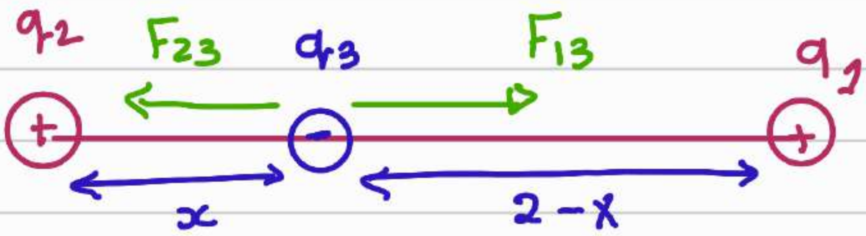
There are two forces their sum produces the resultant force.

$$\vec{\mathbf{F}}_3 = \vec{\mathbf{F}}_{13} + \vec{\mathbf{F}}_{23}$$

Since the net force on q_3 is zero

$$0 = \vec{\mathbf{F}}_{13} + \vec{\mathbf{F}}_{23}$$

$$-F_{23} = F_{13}$$



$$F_{23} = F_{13}$$

$$\frac{\cancel{K}\, q_2 \cancel{q_3}}{x^2} = \frac{\cancel{K}\, q_1 \cancel{q_3}}{(2-x)^2}$$

$$\frac{6 \times \cancel{10^{-6}}}{x^2} = \frac{15 \times \cancel{10^{-6}}}{(2-x)^2}$$

$$\frac{6}{x^2} = \frac{15}{(2-x)^2}$$

$$\sqrt{\frac{(2-x)^2}{x^2}} = \sqrt{\frac{15}{6}}$$

$$\frac{2-x}{x} = 1.581 \qquad 2 - x = 1.581x$$

$$2 = 1.581x + 1x \qquad 2 = 2.581x$$

$$x = \frac{2}{2.581} \qquad x = 0.774 \text{ m}$$

22.3 Coulomb's Law

Example 2:Solution

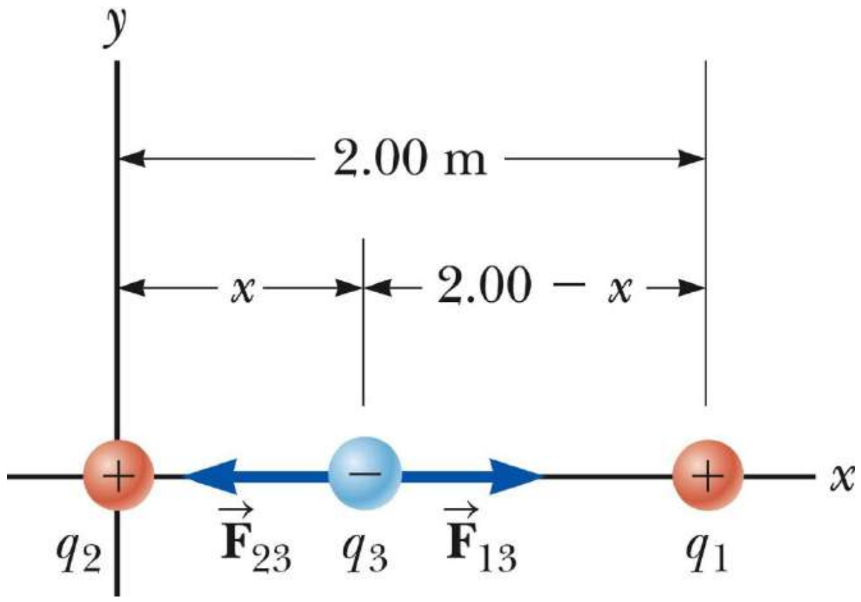
$$\Rightarrow \vec{\mathbf{F}}_{13} = -\vec{\mathbf{F}}_{23}$$

- The forces have the same magnitude but opposite direction,

$$\Rightarrow F_{13} = F_{23}$$

$$\Rightarrow k_e \frac{|q_1||q_3|}{r_{13}^2} = k_e \frac{|q_2||q_3|}{r_{23}^2}$$

$$\Rightarrow \frac{|q_1|}{r_{13}^2} = \frac{|q_2|}{r_{23}^2}$$



2. The separation distance between each charge and q_3:

$$r_{23} = x$$
$$r_{13} = 2.00 - x$$

22.3 Coulomb's Law

Example 2:Solution

$$\Rightarrow \frac{|q_1|}{r_{13}^2} = \frac{|q_2|}{r_{23}^2}$$

$$\Rightarrow \frac{q_1}{(2.00 - x)^2} = \frac{q_2}{x^2}$$

$$\Rightarrow (2.00 - x)^2 q_2 = x^2\, q_1$$

$$\Rightarrow (2.00 - x)\sqrt{q_2} = \pm x\,\sqrt{q_1}$$

$$\Rightarrow 2.00\sqrt{q_2} - x\sqrt{q_2} = \pm x\,\sqrt{q_1}$$

$$\Rightarrow -x\sqrt{q_2} \mp x\,\sqrt{q_1} = -2.00\sqrt{q_2}$$

$$\Rightarrow x(\sqrt{q_2} \pm \sqrt{q_1}) = 2.00\sqrt{q_2}$$

$$\Rightarrow x = \frac{2.00\sqrt{q_2}}{\sqrt{q_2} \pm \sqrt{q_1}}$$

$$\Rightarrow x_+ = \frac{2.00\sqrt{(6.00 \times 10^{-6})}}{\sqrt{6.00 \times 10^{-6}} + \sqrt{15.0 \times 10^{-6}}} = \boxed{0.775\text{m}}$$

$$\Rightarrow x_- = \frac{2.00\sqrt{(6.00 \times 10^{-6})}}{\sqrt{6.00 \times 10^{-6}} - \sqrt{15.0 \times 10^{-6}}}$$

$$= -3.44\text{m}$$

The negative root gives a second location, but it does not corresponds to the problem given.

المجال الكهربائي

22.4 Analysis Model: Particle in an Electric Field

E N/C

Electric Field – Introduction

F قوة مجال

- The electric force is a field force.
- Field forces can act through space.
- The effect is produced even with ***no physical contact*** between objects.

قوى مجال تؤثر دون تلامس

- Faraday developed the concept of a field in terms of electric fields.

Electric Field – Definition

- An electric field is said to exist in the region of space around a charged object.

+

- This charged object is the ***source charge.***
- When another charged object, the ***test charge,*** enters this electric field, an electric force acts on it.

22.4 Analysis Model: Particle in an Electric Field

Electric Field – Mathematical Expression

- The electric field is defined as the electric force on the test charge per unit charge. القوه المؤثره على شحنة اختبار

- The electric field vector, $\vec{\mathbf{E}}$, at a point in space is defined as the electric force $\vec{\mathbf{F}}_e$ acting on a positive test charge, q_0, placed at that point divided by the test charge:

$$\boxed{\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}_e}{q_0}}$$

→ شحنة الاختبار

Notes

- $\vec{\mathbf{E}}$ is the field produced by some charge or charge distribution, separate from the test charge.

- The existence of an electric field is a property of the source charge.
  - The presence of the test charge is not necessary for the field to exist.

شحنة الاختبار هي فقط لفحص المجال

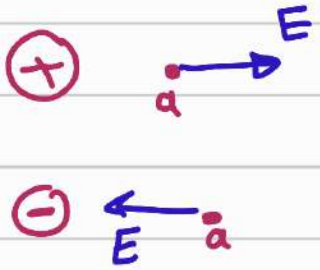
- The test charge serves as a detector of the field.

$\vec{E}$ المجال الكهربائي :. القوة الكهربائية المؤثرة في شحنة اختبار

$$\boxed{\vec{E} = \frac{F}{q_0}} = \frac{\text{القوة}}{\text{الشحنة}} = \frac{N}{C}$$

دائماً اتجاه المجال يكون بنفس اتجاه القوة المؤثرة على الشحنة الاختبار الموجبة

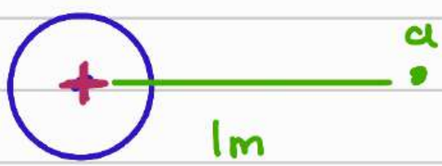
$$E = \frac{F}{q_0} = \frac{\frac{k q \cancel{q_0}}{r^2}}{\cancel{q_0}} = \frac{kq}{r^2}$$



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

اذا كانت الشحنة المؤثرة موجبة المجال خارج الشحنة
اذا كانت الشحنة المؤثرة سالبة المجال داخل للشحنة

$q = 5\mu C$



$$\bar{E} = \frac{8.99\times10^{9} \times 5\times10^{-6}}{1^2}$$

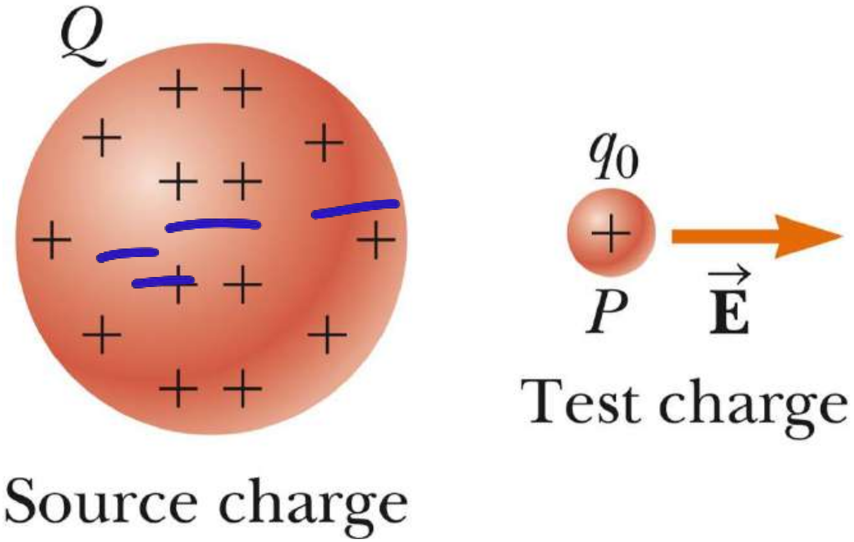
$$\bar{E} = 45000 \ N/C$$

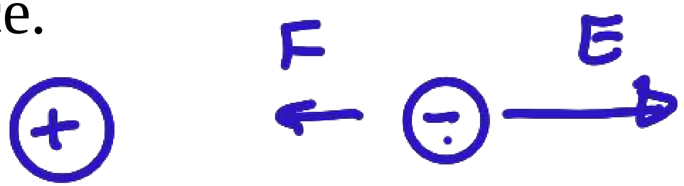
22.4 Analysis Model: Particle in an Electric Field

Electric Field – Notes, cont.

اتجاه المجال هو نفسه اتجاه القوة المؤثرة على q_0

- The direction of $\vec{\mathbf{E}}$ is that of the force on a positive test charge.
- The SI units of $\vec{\mathbf{E}}$ are $\boxed{\text{N/C}}$.
- We can also say that an electric field exists at a point if a test charge at that point experiences an electric force.





22.4 Analysis Model: Particle in an Electric Field

Relationship Between Force and Field.

$E = \dfrac{F}{q_0}$ $\quad\quad$ $F = E q_0$

- From the definition of electric field,

$$\vec{\mathbf{F}}_e = q\vec{\mathbf{E}}$$

  - This expression is valid for a point charge only.
  - One of zero size
  - For larger objects, the field may vary over the size of the object.

لا يستخدم هذا القانون لتوزيعات الشحنات

- If q is positive, the force and the field are in the same direction.

اذا كانت الشحنة المتأثرة موجبة

$\longrightarrow F$

$\longrightarrow E$

- If q is negative, the force and the field are in opposite directions.

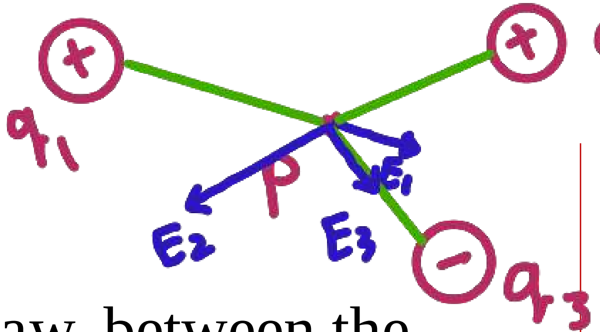
اذا كانت الشحنة المتأثرة سالبة

$\longrightarrow F$

$E \longleftarrow$

22.4 Analysis Model: Particle in an Electric Field

Electric Field, Vector Form.



- Remember Coulomb’s law, between the source and test charges, can be expressed as

$$\vec{\mathbf{F}}_e = k_e \frac{q q_0}{r^2} \hat{\mathbf{r}}$$

- Then, the electric field will be

$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}_e}{q_0} = k_e \frac{q}{r^2} \hat{\mathbf{r}}$$

$$\boxed{\Rightarrow \vec{\mathbf{E}} = k_e \frac{q}{r^2} \hat{\mathbf{r}}}$$

تمثل الاتجاه.

- At any point P, the total electric field due to a group of source charges equals the vector sum of the electric fields of all the charges.

المجال الكلي = جمع متجهات جميع المجالات

$$\vec{\mathbf{E}} = k_e \sum_i \frac{q_i}{r_i^2} \hat{\mathbf{r}}_i$$

جمع اتجاهي

22.4 Analysis Model: Particle in an Electric Field

Electric Field, Direction.

- a) q is positive, the force is directed away from q.

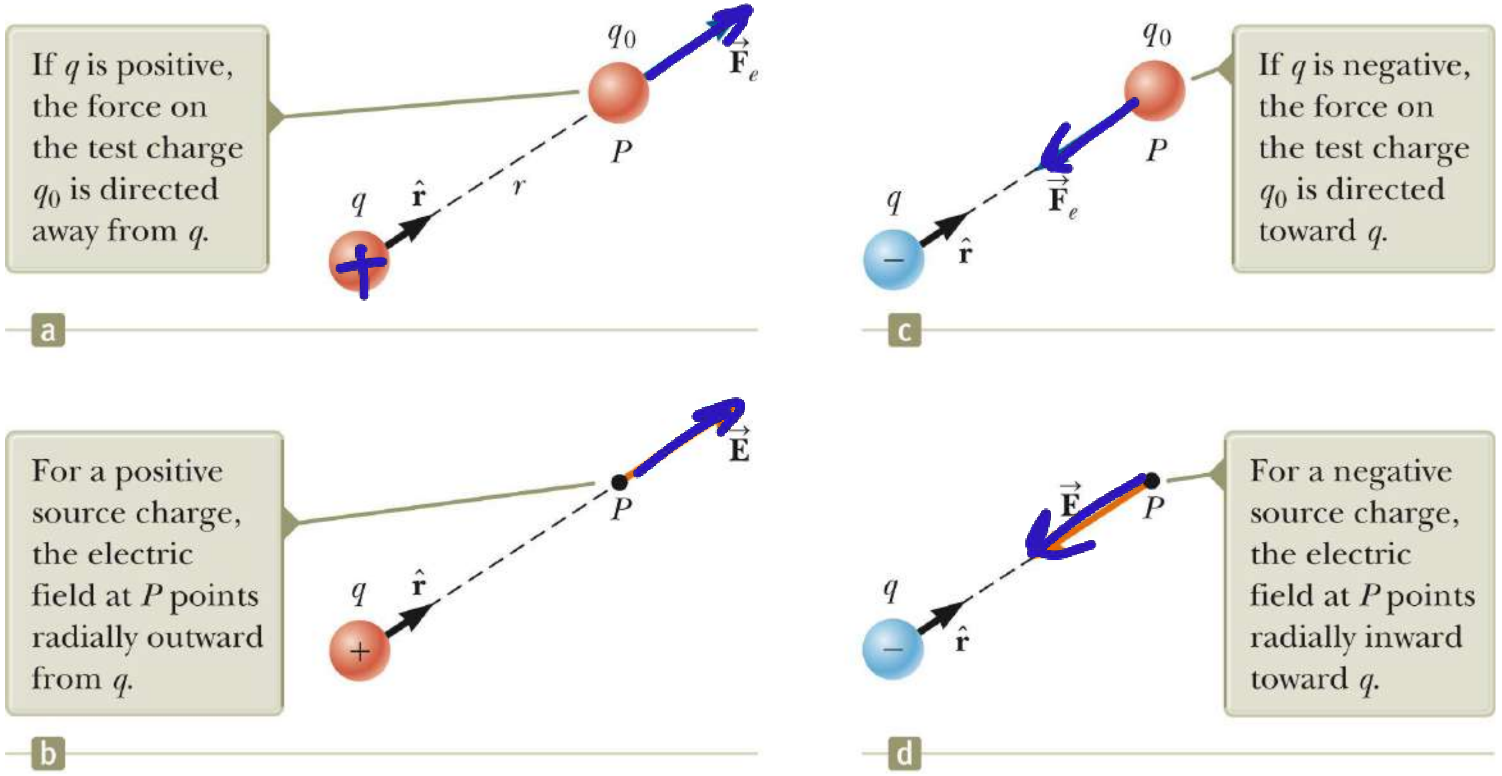
  نحو الخارج

- b) The direction of the field is also away from the positive source charge.

- c) q is negative, the force is directed toward q.

  نحو الشحنه

- d) The field is also toward the negative source charge



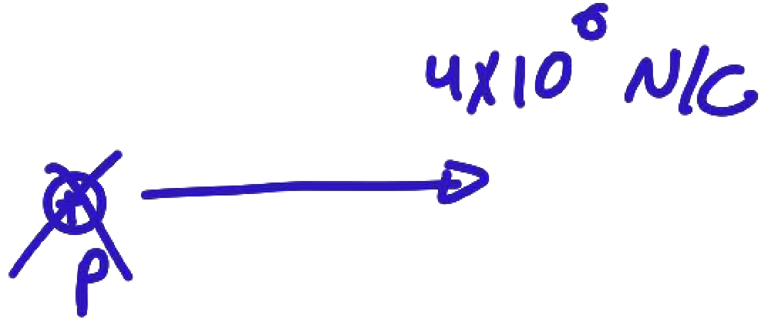
22.4 Analysis Model: Particle in an Electric Field

Quick Quiz

UICK QUIZ 22.4 A test charge of +3 μC is at a point *P* where an external electric field is directed to the right and has a magnitude of 4×10^6 N/C. If the test charge is replaced with another test charge of -3 μC, what happens to the external electric field at *P*? **(a)** It is unaffected. **(b)** It reverses direction. **(c)** It changes in a way that cannot be determined.

لا يتأثر مقدار، اتجاه

بمقدار، شحنة الاختبار

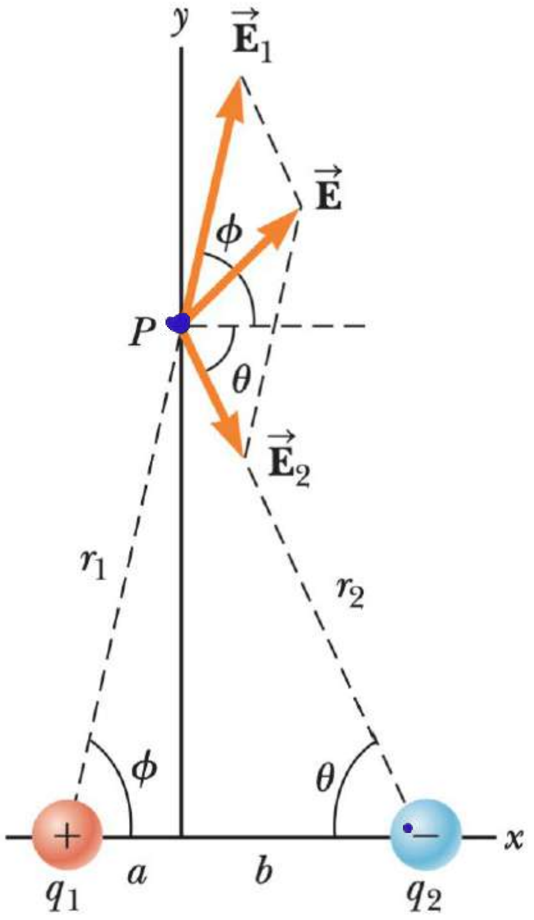


22.4 Analysis Model: Particle in an Electric Field

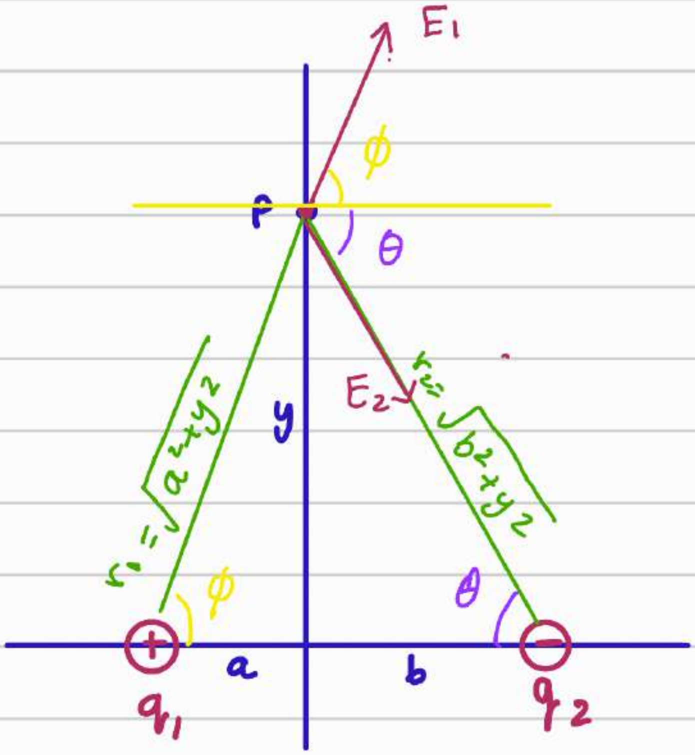
Example 3

Charges q_1 and q_2 are located on the x axis, at distances a and b, respectively, from the origin as shown in Figure 22.13.

(A) Find the components of the net electric field at the point P, which is at position $(0, y)$.

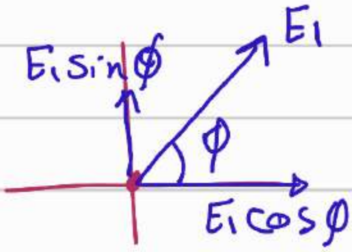


$$E = \frac{kq}{r^2}$$



$$E_1 = k\frac{q_1}{r_1^2} = \frac{kq_1}{a^2+y^2}$$

$$E_2 = \frac{kq_2}{r_2^2} = \frac{kq_2}{b^2+y^2}$$

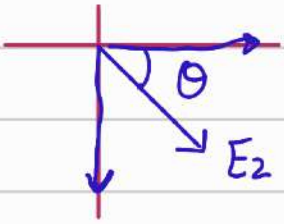


$$E_1 = E_1\cos\phi\, i + E_1 \sin\phi\, j$$

$$E_1 = \frac{kq_1}{a^2+y^2}\cos\phi\, i + \frac{kq_1}{a^2+y^2}\sin\phi\, j$$

$$\cos\phi = \frac{a}{\sqrt{a^2+y^2}} \qquad \sin\phi = \frac{y}{\sqrt{a^2+y^2}}$$

$$\boxed{E_1 = \frac{kq_1 a}{(a^2+y^2)^{3/2}}\, i + \frac{kq_1 y}{(a^2+y^2)^{3/2}}\, j}$$



$$E_2 = E_2\cos\theta\, i - E_2 \sin\theta\, j$$

$$\cos\theta = \frac{b}{\sqrt{b^2+y^2}} \qquad \sin\theta = \frac{y}{\sqrt{b^2+y^2}}$$

$$\boxed{E_2 = \frac{kq_2 b}{(b^2+y^2)^{3/2}}\, i - \frac{kq_2 y}{(b^2+y^2)^{3/2}}\, j}$$

$$E = E_1 + E_2$$

$$E = \underbrace{\left[\frac{kq_1 a}{(a^2+y^2)^{3/2}} + \frac{kq_2 b}{(b^2+y^2)^{3/2}}\right]}_{E_x} i + \underbrace{\left[\frac{kq_1 y}{(a^2+y^2)^{3/2}} - \frac{kq_2 y}{(b^2+y^2)^{3/2}}\right]}_{E_y} j$$

حالة خاصة افترض ان $a = b$ ثم

تكون مقدار المجال عند النقطة P $\quad q_1 = q_2$

$$a = b \Rightarrow a$$

$$E = \left[\frac{kqa}{(a^2+y^2)^{3/2}} + \frac{kq \cdot a}{(b^2+y^2)^{3/2}}\right] i + 0\, j$$

$$E = \frac{2kqa}{(a^2+y^2)^{3/2}}\, i$$

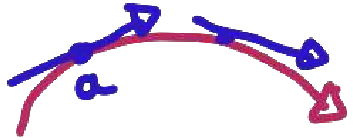
خطوط المجال

22.5 Electric Field Lines

Definition

طريقة لتمثيل المجال الكهربائي بصرياً

- Field lines give us a means of representing the electric field pictorially.

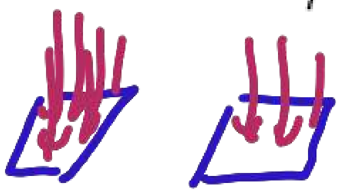


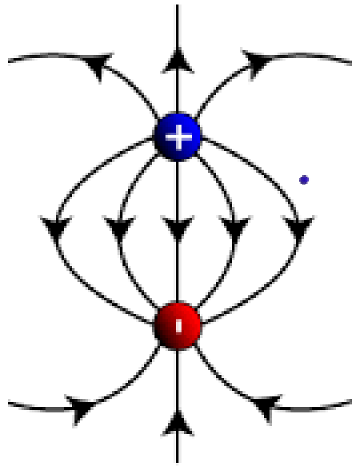
مماس

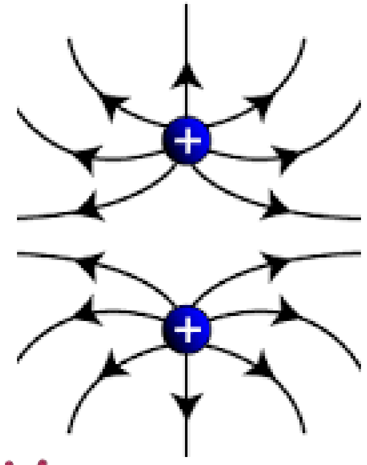
- The electric field vector is ***tangent*** to the electric field line at each point. يتحدد اتجاه المجال باتجاه المماس لخط المجال

- The line has a direction that is the same as that of the electric field vector. عدد خطوط المجال التي تقطع مساحة عمودياً عليها تتناسب طردياً مع مقدار المجال

- The number of lines per unit area through a surface perpendicular to the lines is proportional to the magnitude of the electric field in that region.



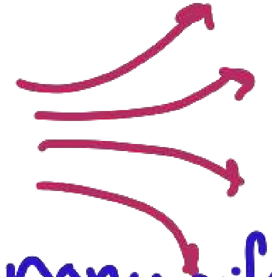




22.5 Electric Field Lines

نفس الاتجاه ونفس المقدار

uniform

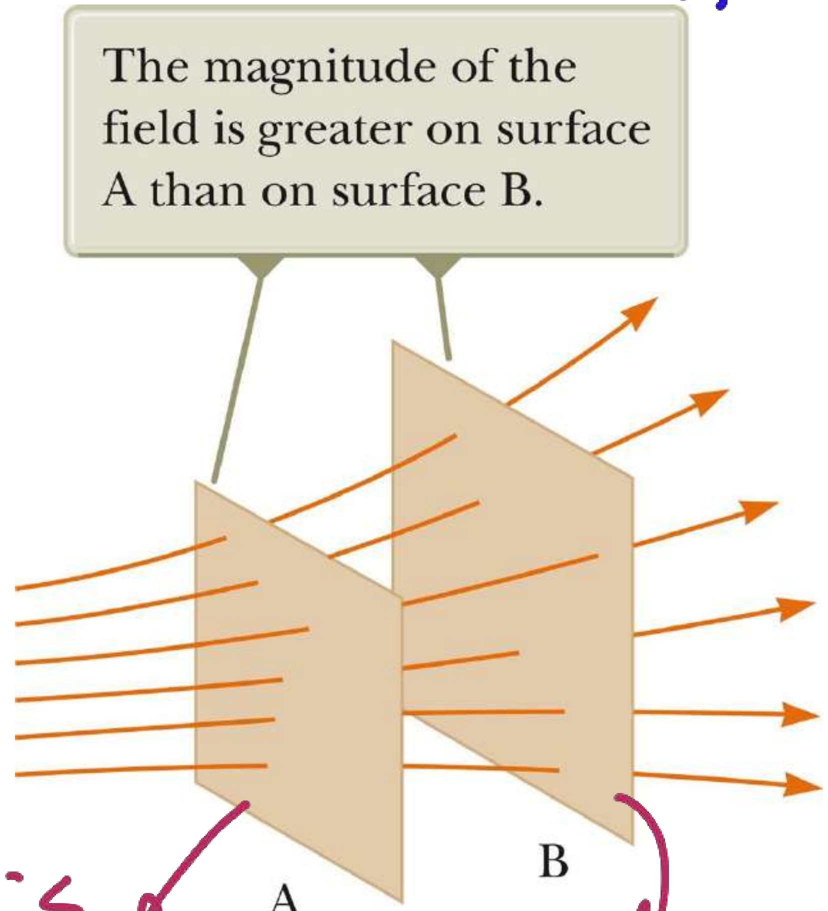


nonuniform

Example

- The density of lines through surface A is greater than through surface B.
- Thus, the magnitude of the electric field is greater on surface A than B.
- The lines at different locations point in different directions. This indicates the field is nonuniform.

غير منتظم



كثافة اكبر

كثافة اقل

22.5 Electric Field Lines

الشحنه الموجبه

Positive Point Charge

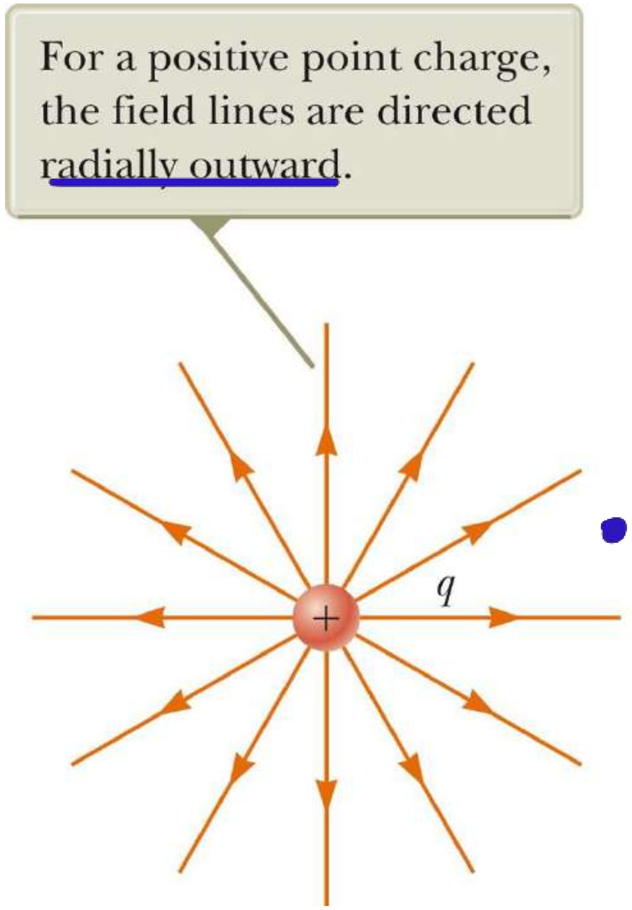
- The field lines radiate outward in all directions. تكون خارجة في جميع الاتجاهات

- In three dimensions, the distribution is spherical. تنتشر في ثلاث ابعاد (كروية)

- The lines are directed ***away*** from the source charge. تكون خارجه من الشحنه

- A positive test charge would be repelled away from the positive source charge.

شحنة الاختبار تتنافر مع الشحنة



22.5 Electric Field Lines

الشحنة السالبة

Negative Point Charge

تتجه نحو الداخل

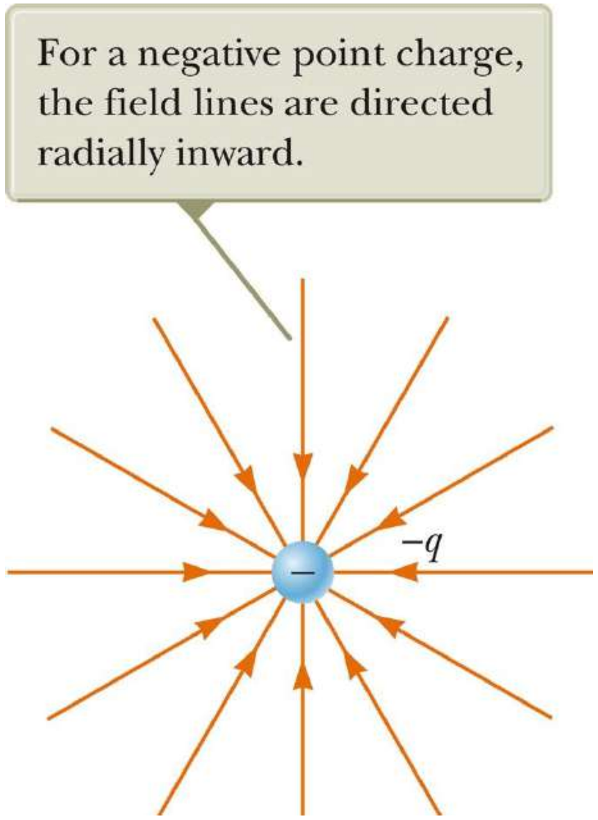
- The field lines radiate ***inward*** in all directions.

- The lines are directed toward the source charge.

تتجه نحو الشحنة

- A positive test charge would be attracted toward the negative source charge.

شحنة الاختبار تنجذب للشحنة السالبة



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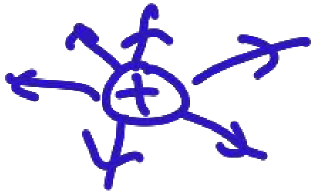
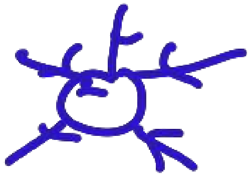




22.5 Electric Field Lines

قواعد رسم خطوط المجال

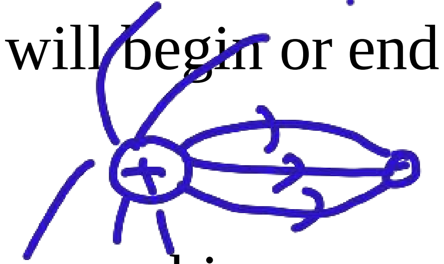
Rules for Drawing

خطوط المجال يتجه من الشحنة الموجبة باتجاه السالبة

- The lines must ***begin*** on a positive charge and ***terminate*** on a negative charge.

في حال وجود فائض من نوع شحنة ستبدأ الخطوط وتنتهي في اللانهاية

- In the case of an excess of one type of charge, some lines will begin or end infinitely far away.



- The ***number of lines*** drawn leaving a positive charge or approaching a negative charge is ***proportional to the magnitude*** of the charge.

عدد الخطوط المرسومة تتناسب طردياً مع مقدار الشحنة

- No two field lines can cross.

لا يمكن أن يتقاطع خطين

- Remember field lines are ***not*** material objects, they are a pictorial representation used to qualitatively describe the electric field.

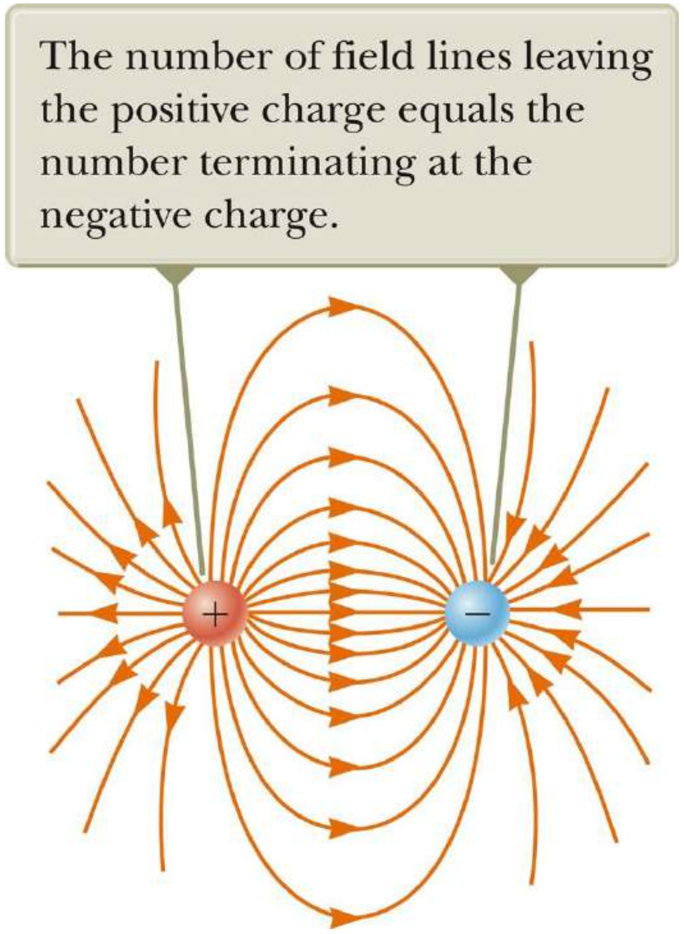
22.5 Electric Field Lines

ثنائي القطب

Dipole شحنتين نفس المقدار لكن متعاكسة

- The charges are ***equal*** and ***opposite***.

- The number of field lines leaving the positive charge equals the number of lines terminating on the negative charge.



q ⊕ q ⊕ 2q

E

22.5 Electric Field Lines

Like Charges شحنتين متشابهتين

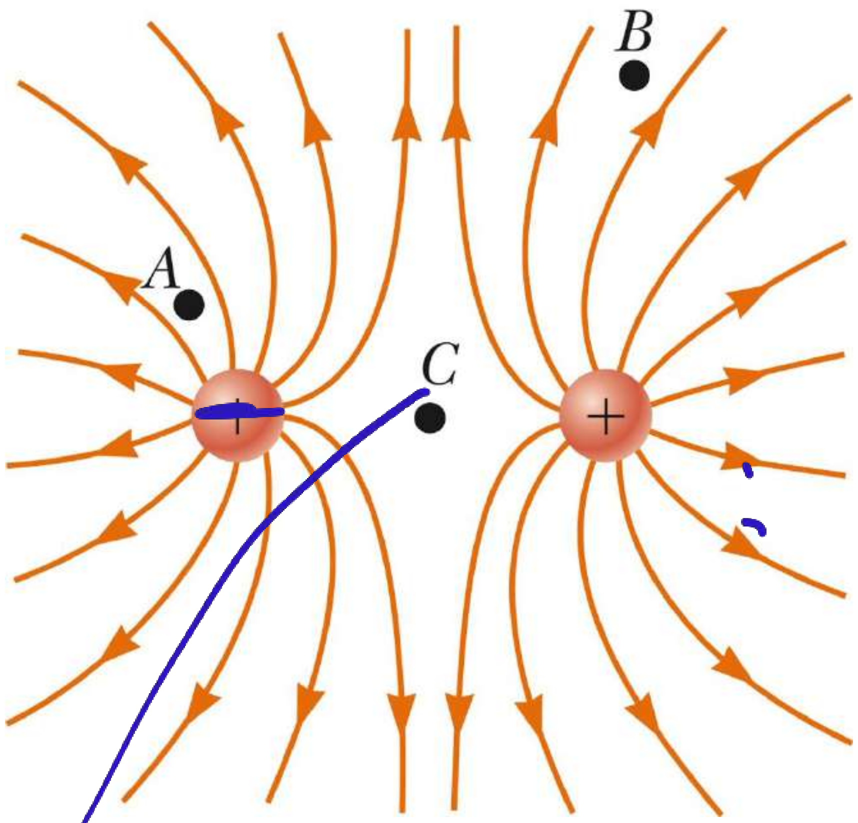
- The charges are ***equal*** and ***positive***.

- The same number of lines leave each charge since they are equal in magnitude.

عندما مسافة كبيرة تقريبا، المجال يساوي المجال الناتج عن 2q

- At a great distance, the field is approximately equal to that of a single charge of $2q$.

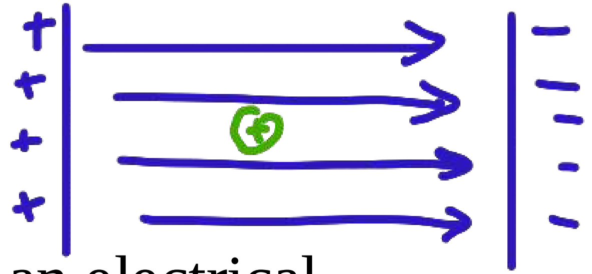
- Since there are no negative charges available, the field lines end infinitely far away.



انعدام المجال $E = 0$

حركه الشحنات الكهربائي في مجال كهربائي منتظم

22.6 Motion of a Charged Particle in a Uniform Electric Field.



$\vec{E}$

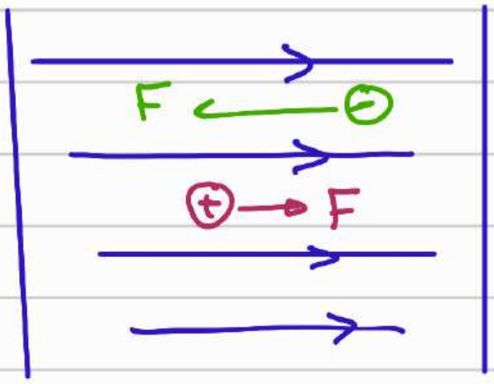
$\vec{F}$

- When a charged particle is placed in an electric field, it experiences an electrical force.
- If this is the only force on the particle, it must be the net force.

تسارع

- The net force will cause the particle to accelerate according to Newton's second law.

$$\vec{\mathbf{F}}_e = q\vec{\mathbf{E}} = m\vec{\mathbf{a}}$$



Uniform

$E \Rightarrow$ مقدار ثابت

$$F = qE$$

عند وضع شحنة موجبة في مجال منتظم فإنها تتأثر بقوة

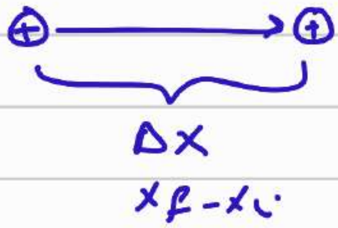
مع اتجاه المجال وتكتسب تسارع

عند وضع شحنة سالبة في مجال كهربائي منتظم فإنها

تتأثر بقوة عكس اتجاه المجال

$$F = ma = Eq$$

$$\boxed{a = \frac{Eq}{m}}$$



$$v_f = v_i + at$$

$$\Delta x = v_i t + \frac{1}{2} a t^2$$

$$v_f^2 = v_i^2 + 2a\Delta x$$

22.6 Motion of a Charged Particle in a Uniform Electric Field.

- If the field is ***uniform***, then the acceleration is ***constant***.
- The particle under constant acceleration model can be applied to the motion of the particle.

$$v_{xf} = v_{xi} + a_x t$$
$$x_f - x_i = \bar{v}_x t = \tfrac{1}{2}(v_{xi} + v_{xf})\, t$$
$$x_f - x_i = v_{xi} t + \tfrac{1}{2} a_x t^2$$
$$v_{xf}^{\,2} = v_{xi}^{\,2} + 2a_x(x_f - x_i)$$

- The electric force causes a particle to move according to the models of forces and motion.
- If the particle has a ***positive*** charge, its acceleration is in the ***direction*** of the field.
- If the particle has a ***negative*** charge, its acceleration is in the direction ***opposite*** the electric field.

22.6 Motion of a Charged Particle in a Uniform Electric Field.

Example 4:

An electron enters the region of a uniform electric field as shown in Figure 22.21, with $v_i = 3.00 \times 10^6$ m/s and $E = 200$ N/C. The horizontal length of the plates is $\ell = 0.100$ m.

(A) Find the acceleration of the electron while it is in the electric field.

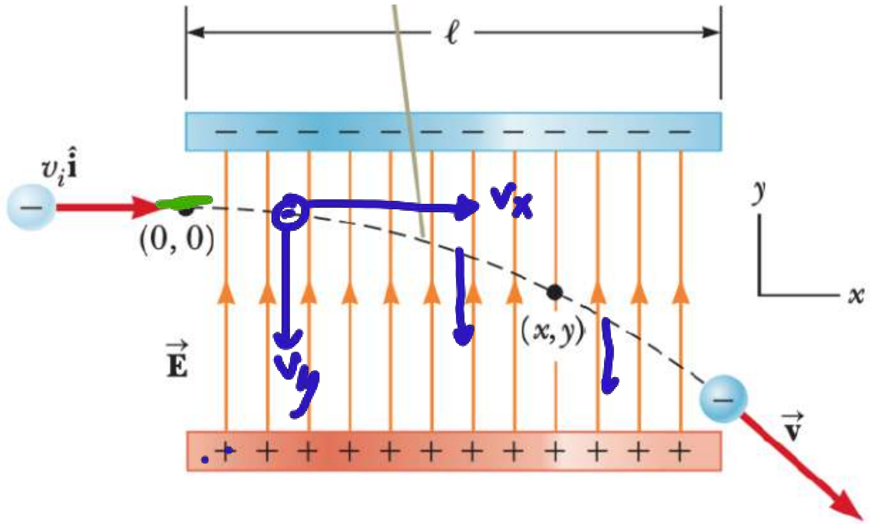
(B) Assuming the electron enters the field at time $t = 0$, find the time at which it leaves the field.

(C) Assuming the vertical position of the electron as it enters the field is $y_i = 0$, what is its vertical position when it leaves the field?

y

$a_x = 0$ السرعه الافقيه V_x ثابته

a_y السرعه العموديه متغيره



$q = -1.6\times10^{-19}$ $\qquad$ $m = 9.11\times10^{-31}$ kg

a)

الت، ع

$$a = \frac{qE}{m} = \frac{1.6\times10^{-19}\times 200}{9.11\times10^{-31}} = 3.5\times10^{13}\ m/s^2$$

نحو الاسفل

$-3.5\times10^{13}\,\hat{j}\ m/s^2$

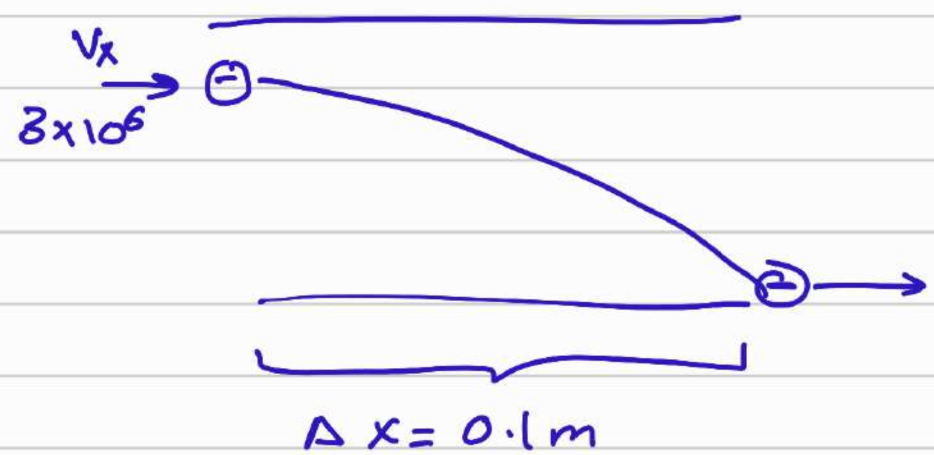
b)

$y_i = 0$

$V_{yi} = 0$

$a = 3.5\times10^{13}$ m/s

$t = 3.33\times10^{-8}$



b)

$$\Delta x = U_{ix}\,t + \cancel{\tfrac{1}{2}a_x t^2} \quad \text{zero}$$

$0.1 = 3\times10^6\ t$ $\qquad$ $t = \frac{0.1}{3\times10^6} = 3.33\times10^{-8}$ s

c)

$$\Delta y = \cancel{U_{iy}}\,t + \tfrac{1}{2}a_y t^2 \quad \text{zer}$$

$$y_f - y_i = -\tfrac{1}{2}\times3.5\times10^{13}\times(3.33\times10^{-8})^2$$

$$y_f = -1.95\times10^{-2}\ m$$