جامعة الموصل
كلية العلوم – قسم الفيزياء

المستوى الاول
المقرر 103
أساسيات الكهربائية والمغناطيسية

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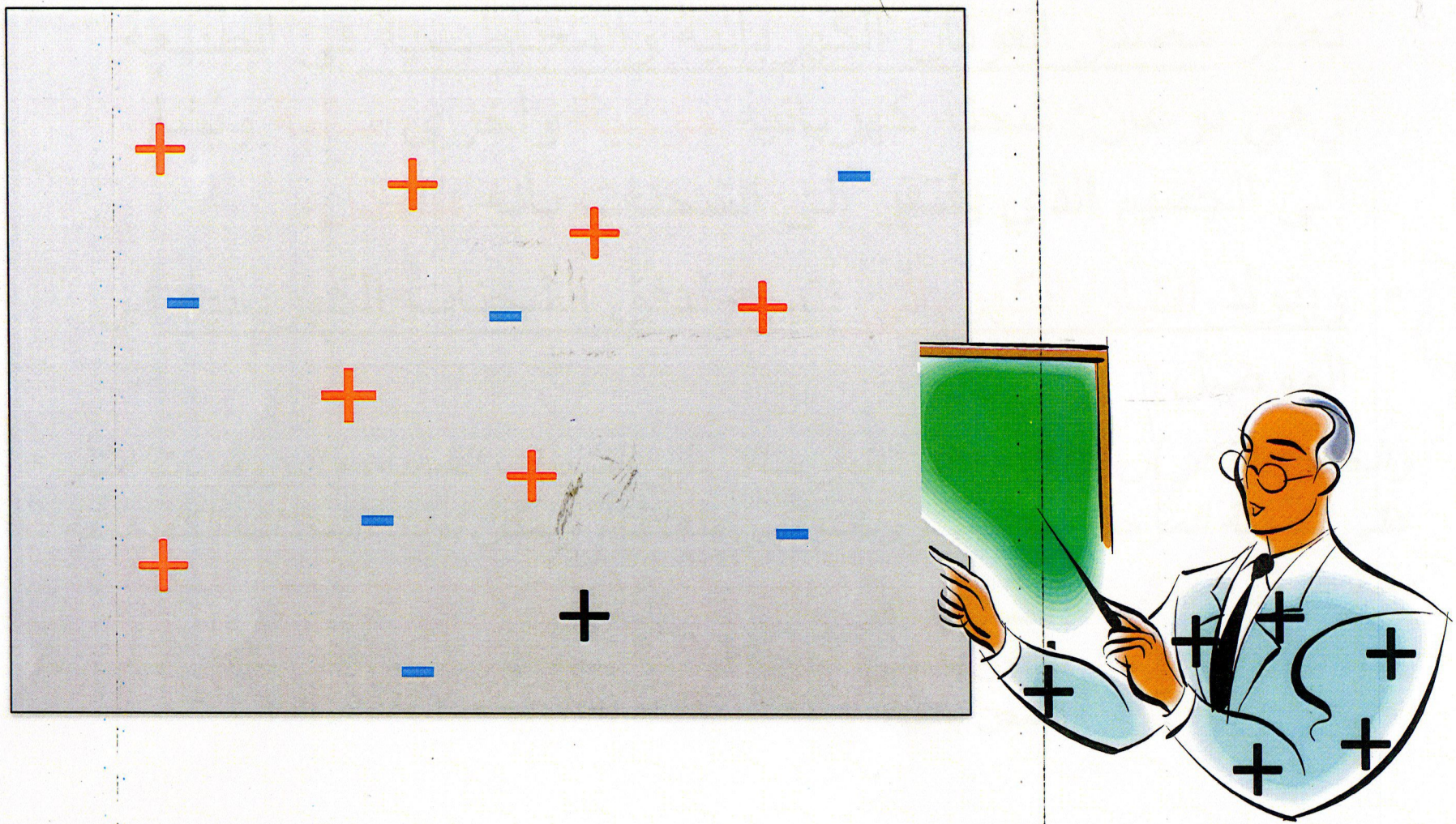
٢٠١٩-٢٠٢٠

هاشم
رحلة الاولى G1

The world is filled with electrical charges:



مقدمة

- **الشحنة الكهربائية** هي إحدى الخواص الفيزيائية للمادة والتي تُعتبر مصدر القوتان الكهربائية والمغناطيسية في الطبيعة وهي نوعان: شحنة كهربائية موجبة وأخرى سالبة ويُشار إلى الجسيم الذي **يفتقر** إلى الشحنات بأنه متعادل،
- ويتولد **التيار الكهربائي** نتيجة تدفق الشحنات الكهربائية في الموصل.

والجدير بالذكر أن الإلكترونات تعتبر مثالاً على الشحنات السالبة، والبروتونات مثال على الشحنة الموجة، أما النيوترونات فهي متعادلة، ويمكن توليد الشحنات الكهربائية بعدة طرق منها :

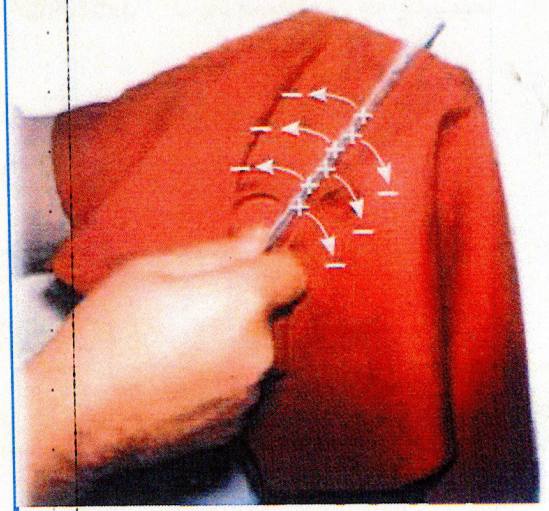
الشحن بالدلك.
الشحن باللمس
الشحن بالحث

- يحتك/يفرك

- When a glass rod is rubbed with silk حرير, electrons are transferred from the glass to the silk.

وتتم هذه العملية حسب قانون حفظ الشحنة:

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



Electric Charge

سمة ذاتية وجوهرية في جسيمات أساسية مثل:

An intrinsic characteristic of a fundamental particle, electrons & protons that accompanies it wherever they exist حيث تترافق معا اينما يكونا

Proton = positive **Electron = negative**

Each has the same value of charge

Electrically neutral – most objects have equal amounts of protons & electrons & therefore **no net charge**

وحدة الشحنة الكهربائية طبقا لنظام الوحدات الدولي SI هي الكولوم

Electrically charged objects

- an object with excess protons will have a **positive charge**
- an object with excess electrons will have a **negative charge**

فائض

$$M_{electron} = 9.11 \times 10^{-31}\ kg$$

$$M_{proton} = 1.67 \times 10^{-27}\ kg$$

Electrostatics is the study of stationary, or bound, charges.

Moving charge is known as "**current**"

- The charge builds up but **does not flow.**
- Static electricity is **potential energy**. It does **not** move. It is **stored**.

Charging a metallic object by induction بالحث:

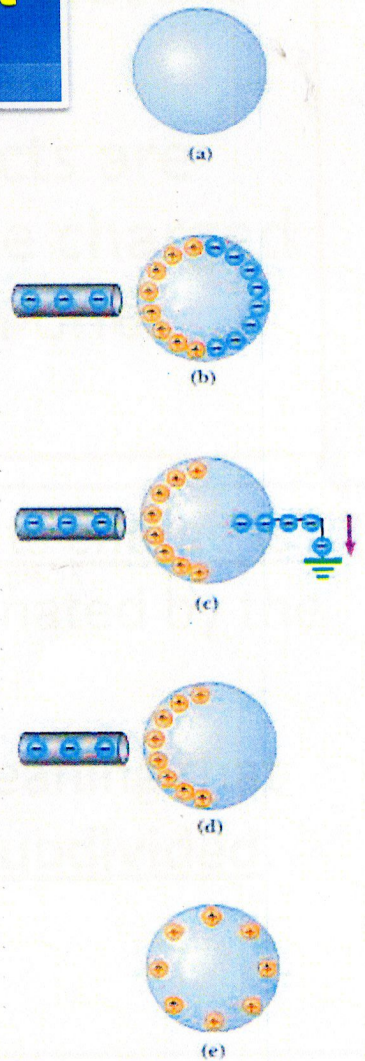
(a) A neutral متعادلmetallic sphere with equal numbers of positive and negative charges.

(b) The charge on a neutral metal sphere is redistributed اعادة توزيع when a charged rubber rod is placed توضعnear the sphere.

(c) When the sphere is grounded اي تتصل بالارض, some of the electrons leave it through the ground wire.

(d) When the ground connection is removed, the nonuniformly منتظم غير الشحن charged sphere is left with excess positive charge.

(e) When the rubber rod is moved away, the charges on the sphere redistribute themselves تعيد توزيع نفسها until حتىthe sphere's surface becomes uniformly charged منتظم الشحن.



characteristic of charge

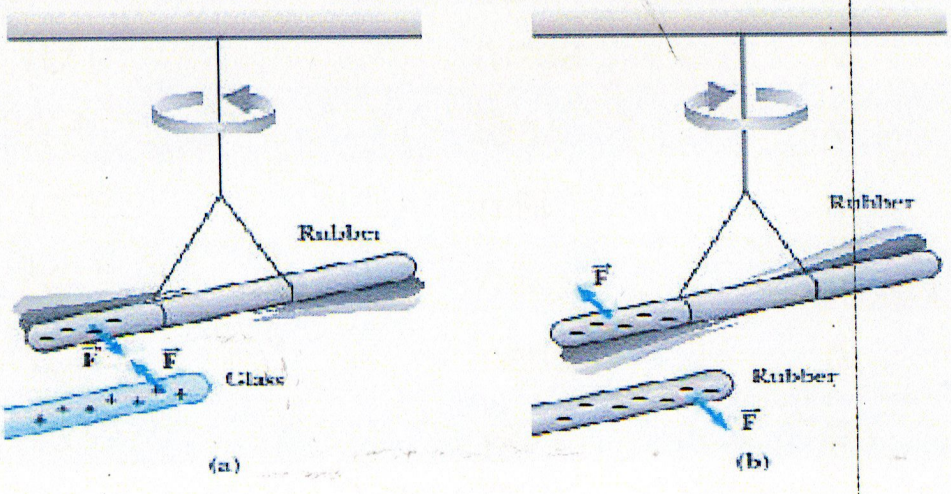
- An important characteristic of charge is that electric charge is always **conserved**.
- Charge isn't created when two neutral objects are rubbed together; rather, the objects become charged because negative charge is transferred from one object to the other.

In 1909 Millikan discovered that if an object is charged, its charge is always a multiple of a fundamental unit of charge, designated by the symbol ***e***.

In modern terms, the charge is said to be **quantized**, meaning that **charge occurs in discrete chunks that can't be further subdivided**.

An object may have a charge of ***1e, 2e, 3e***, and so on,
but **never** a fractional charge of *0.5e* or *0.22e*.

- There are two kinds of electric charge, which Benjamin Franklin (1706–1790) named **positive** and **negative**.



(a) A negatively charged rubber rod, suspended يتدلى by a thread, is attracted to a positively charged glass rod.
(b) A negatively charged rubber rod is repelled by another negatively charged rubber rod.

On the basis of observations such as these, we conclude that <u>like charges repel one another and unlike charges attract one another</u>

هذه الظاهرة تدل على ان هناك قوة تصاحب وجود الشحنة .
وتأثير هذه القوة باتجاه يتبع قوة الشحنة وبنوع الشحنة اي انها متجهة .

Multiplying factor	Prefix name	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Q Write the following quantities in a concise form using (a) standard form, and (b) scientific notation
(i) 0.000 018 A (ii) 15 000 V (iii) 250 000 000 W

A

(a) (i) $0.000\,018\,A = 1.8 \times 10^{-5}\,A$
(ii) $15\,000\,V = 1.5 \times 10^{4}\,V$
(iii) $250\,000\,000\,W = 2.5 \times 10^{8}\,W$

(b) (i) $0.000\,018\,A = 18\,\mu A$
(ii) $15\,000\,V = 15\,kV$
(iii) $250\,000\,000\,W = 250\,MW$ **Ans**

المواد الموصلة – المواد العازلة – والمواد الشبة موصلة

- **المواد الموصلة conductors**

وهي المواد التي تنقل خلالها الشحنة الكهربائية في الحال وهي المعادن ..حيث يكون ارتباط الالكترونات الخارجية بالذرة يكون ضعيفا فهي حرة في التنقل داخل التركيب البلوري لمعدن وتسمى free electrons

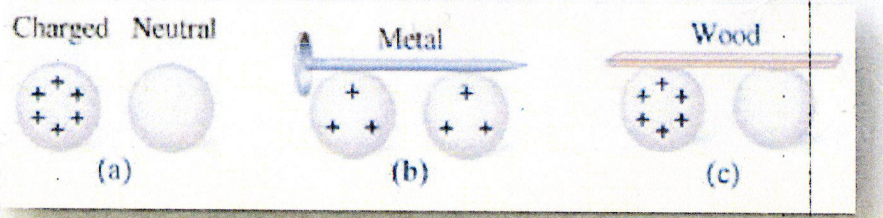
- **المواد العازلة insulators**

وهي المواد التي لا تنتقل خلالها الشحنات الكهربائية في الحال لعدم احتوائها على الكترونات طليقة. اذ ان جميع الكترونات الدار الخارجي للذرة مرتبطة بالشبيكة البلورية او التركيب الجزيئي للمادة. كالمايكا والزجاج والبلاستك.

- **المواد شبه الموصلة semiconductors**

وهي المواد التي لها خواص وسطية بين الموصلات والعوازل من حيث قابليتا في التوصيل الكهربائي ومن اشهرها الجرمانيوم والسيلكون. ولكن يمكن زيادة قابلية هذه المواد للتوصيل الكهربائي بإضافة كميات صغيرة من الشوائب impurities اي التطعيم..

In **conductors**, electric charges move freely. All other materials are called **insulators**.



واجب: اكتب تقريرا مفصلة يوضح كل نوع من هذه المواد في تركيبها وكيف يتم سلوكها كهربائيا

Coulomb's law

In 1785 Charles Coulomb (1736–1806) experimentally established the fundamental law of **Electric Force** between two stationary charged particles.

An **Electric Force** has the following properties:

- **1.** It is attractive if the charges are of opposite sign and repulsive if the charges have the same sign.

- **2.** It is proportional to the product of the magnitudes of the charges, $q1$ and $q2$, of the two particles.

- **3.** It is inversely proportional to the square of the separation distance r, between them.

وهذه النتائج تعد صحيحة بالنسبة للشحنات النقطية point charge وهي التي تكون ذات ابعاد صغيرة بالنسبة للمسافة الفاصلة بينهما .

من خلال مشاهدات كولوم التجريبية هذه استطاع ان يصيغ علاقة رياضية تجمعها.

The magnitude of the electric force F between charges q_1 and q_2 separated by a distance r is given by

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

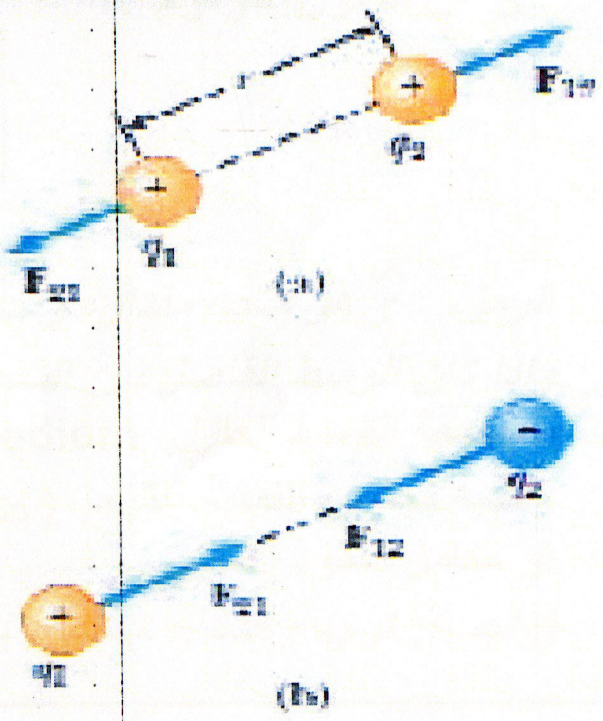
Coulomb's law

where k is a constant called the *Coulomb constant*. $k \approx 9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2}$.

This applies exactly only to point charges and to spherical distributions of charges.

F_{12} = force on 1 due to 2 $\qquad$ F_{21} = force on 2 due to 1

(a) When the charges are of the same sign, the force is repulsive.
(b) When the charges are of opposite sign, the force is attractive



ان وحدة الشحنة لا تعرف طبقا لقانون كولوم بل بوحدة التيار الكهربائي وتسمى (الكولوم C)

- وفي اغلب الاحيان يستبدل k بثابت اخر يدعى **سماحية الفراغ** **permittivity of vacuum** ((ε_o)) وقيمته واحد وفق العلاقة التالية:

$$\varepsilon_0 = \frac{1}{4\pi k}$$

- اي ان قانون كولوم :

$$\vec{F} = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2}\hat{r}$$

- الرمز $\hat{r}$ هو متجه مقداره واحد واتجاهه من q1 الى q2 ويسمى وحدة المتجه *unite vector*
- واذا كان الوسط الفاصل بين الشحنتين **عازلا** فيستبدل بثابت يسمى *سماحية الوسط العازل* permittivity of medium ((ε)) وله نفس الوحدة.
- وعليه نجد ان النسبة بينهما ($K = \varepsilon / \varepsilon_o$) ويسمى ثابت العزل dielectric constant او معامل النفوذ النسبي .
- *(واجب): اوجد وحدة* ε *مستعينا بقانون كولوم .*

EXAMPLES

Example 1: *Forces in a Hydrogen Atom*

The electron and proton of a hydrogen atom are separated by a distance of about 5.3×10^{-11} m. . Find the magnitudes of the electric force **Fe** and the gravitational force **Fg** that each particle exerts on the other, and the ratio of the: **Fe / Fg** . (اعتبر الشحنتين متساويتين في القيمة)

Solution

Substitute $|q_1| = |q_2| = e$ and the distance into Coulomb's law to find the electric force:

$$F_e = k_e \frac{|e|^2}{r^2} = \left(8.99 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right) \frac{(1.6 \times 10^{-19}\,\text{C})^2}{(5.3 \times 10^{-11}\,\text{m})^2}$$

$$= 8.2 \times 10^{-8}\,\text{N}$$

Substitute the masses and distance into Newton's law of gravity to find the gravitational force:

$$F_g = G \frac{m_e m_p}{r^2}$$

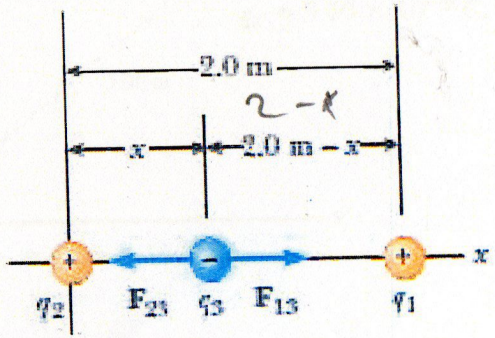
$$= \left(6.67 \times 10^{-11} \frac{\text{N} \cdot \text{m}^2}{\text{kg}^2}\right) \frac{(9.11 \times 10^{-31}\,\text{kg})(1.67 \times 10^{-27}\,\text{kg})}{(5.3 \times 10^{-11}\,\text{m})^2}$$

$$= 3.6 \times 10^{-47}\,\text{N}$$

Find the ratio of the two forces:

$$\frac{F_e}{F_g} = 2.27 \times 10^{39}$$

Example 2: Three charges lie along the *x* -axis as in Figure . The positive charge $q1$ =15 μC is at x =2.0 m, and the positive charge $q2$ = 6.0 μC is at the origin. Where must a *negative* charge $q3$ be placed on the *x*-axis so that the resultant electric force on it is zero?



Solution

Write the x-component of $\vec{F}_{13}$:

$$F_{13x} = +k_e \frac{(15 \times 10^{-6}\ \text{C})|q_3|}{(2.0\ \text{m} - x)^2}$$

Write the x-component of $\vec{F}_{23}$:

$$F_{23x} = -k_e \frac{(6.0 \times 10^{-6}\ \text{C})|q_3|}{x^2}$$

Set the sum equal to zero:

$$k_e \frac{(15 \times 10^{-6}\ \text{C})|q_3|}{(2.0\ \text{m} - x)^2} - k_e \frac{(6.0 \times 10^{-6}\ \text{C})|q_3|}{x^2} = 0$$

Cancel k_e, 10^{-6} and q_3 from the equation, and rearrange terms (explicit significant figures and units are temporarily suspended for clarity):

$$6(2 - x)^2 = 15x^2$$

Put this equation into standard quadratic form, $ax^2 + bx + c = 0$:

$$6(4 - 4x + x^2) = 15x^2 \rightarrow 2(4 - 4x + x^2) = 5x^2$$
$$3x^2 + 8x - 8 = 0$$

Apply the quadratic formula:

$$x = \frac{-8 \pm \sqrt{64 - (4)(3)(-8)}}{2 \cdot 3} = \frac{-4 \pm 2\sqrt{10}}{3}$$

Only the positive root makes sense:

$$x = 0.77\ \text{m}$$

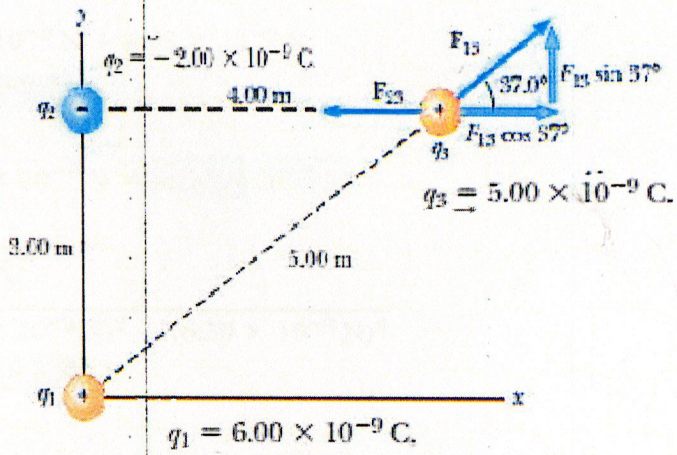
Note: If q3 is to the right or left of the other two charges, then the net force on q3 can't be zero, because then F13 and F23 act in the same direction.

Example: A Charge Triangle: Consider three point charges at the corners of a triangle, as shown in Figure,

(a) Find the components of the force exerted by q2 on q3.

(b) Find the components of the force exerted by q1 on q3.

(c) Find the resultant force on q3, in terms of components and als in terms of magnitude and direction.



Solution

(a) Find the components of the force exerted by q_2 on q_3.

Find the magnitude of $\vec{F}_{23}$ with Coulomb's law:

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

$$= (8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2) \frac{(2.00 \times 10^{-9}\ \text{C})(5.00 \times 10^{-9}\ \text{C})}{(4.00\ \text{m})^2}$$

$$F_{23} = 5.62 \times 10^{-9}\ \text{N}$$

Because $\vec{F}_{23}$ is horizontal and points in the negative x-direction, the negative of the magnitude gives the x-component, and the y-component is zero:

$$F_{23x} = -5.62 \times 10^{-9}\ \text{N}$$

$$F_{23y} = 0$$

(b) Find the components of the force exerted by q_1 on q_3.

Find the magnitude of $\vec{F}_{13}$:

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

$$= (8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2) \frac{(6.00 \times 10^{-9}\ \text{C})(5.00 \times 10^{-9}\ \text{C})}{(5.00\ \text{m})^2}$$

$$F_{13} = 1.08 \times 10^{-8}\ \text{N}$$

Use the given triangle to find the components:

$$F_{13x} = F_{13}\cos\theta = (1.08 \times 10^{-8}\ \text{N})\cos(37°)$$

$$= 8.63 \times 10^{-9}\ \text{N}$$

$$F_{13y} = F_{13}\sin\theta = (1.08 \times 10^{-8}\ \text{N})\sin(37°)$$

$$= 6.50 \times 10^{-9}\ \text{N}$$

(c) Find the components of the resultant vector.

Sum the x-components to find the resultant F_x:

$$F_x = -5.62 \times 10^{-9}\,\text{N} + 8.63 \times 10^{-9}\,\text{N}$$
$$= 3.01 \times 10^{-9}\,\text{N}$$

Sum the y-components to find the resultant F_y:

$$F_y = 0 + 6.50 \times 10^{-9}\,\text{N} = 6.50 \times 10^{-9}\,\text{N}$$

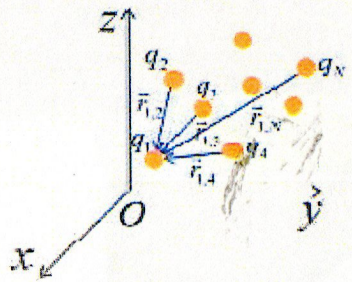
Find the magnitude of the resultant force on the charge q_3, using the Pythagorean theorem:

$$|\vec{\mathbf{F}}| = \sqrt{F_x^2 + F_y^2}$$
$$= \sqrt{(3.01 \times 10^{-9}\,\text{N})^2 + (6.50 \times 10^{-9}\,\text{N})^2}$$
$$= 7.16 \times 10^{-9}\,\text{N}$$

Find the angle the force vector makes with respect to the positive x-axis:

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = \tan^{-1}\left(\frac{6.50 \times 10^{-9}\,\text{N}}{3.01 \times 10^{-9}\,\text{N}}\right) = 65.2°$$

SYSTEM WITH MANY CHARGES:



The total force experienced by charge q_1 is the *vector sum* of the forces on q_1 exerted by other charges.

$$\vec{F}_1 = \text{Force experienced by } q_1$$
$$= \vec{F}_{1,2} + \vec{F}_{1,3} + \vec{F}_{1,4} + \cdots + \vec{F}_{1,N}$$

PRINCIPLE OF SUPERPOSITION:

$$\vec{F}_1 = \sum_{j=2}^{N} \vec{F}_{1,j}$$