Phys (1114)
Electricity and Magnetism

Textbook: Fundamentals of PHYSICS, 9th edition,
by HALLIDAY/ RESNICK/ WALKER

CHAPTER 1 ELECTRIC CHARGE

Physics Department

Electrostatic

21-2 Electric Charge

- **Introduction**

المقدمة

قد تستحضر كلمة **الكهرباء** إلى أذهاننا صورة تقنياتٍ حديثة معقّدة: الحواسيب، والإضاءة، والمحرّكات، والطاقة الكهربائية. لكنها تؤدي في الواقع دورًا أعمق في حياتنا اليومية؛ إذ نرى أهميتها في كل شيء—مثل الطهي والشرب—وتُعَدّ أيضًا عاملًا رئيسيًا في راحتنا.

The word *Electricity* may call to our mind an image of complex modern technology; computers , light, motors and electric power., but it plays actually an even deeper role in our daily life, which we can see its importance in every thing for example in cooking, drinking and is also considered as a main factor of our relaxation.

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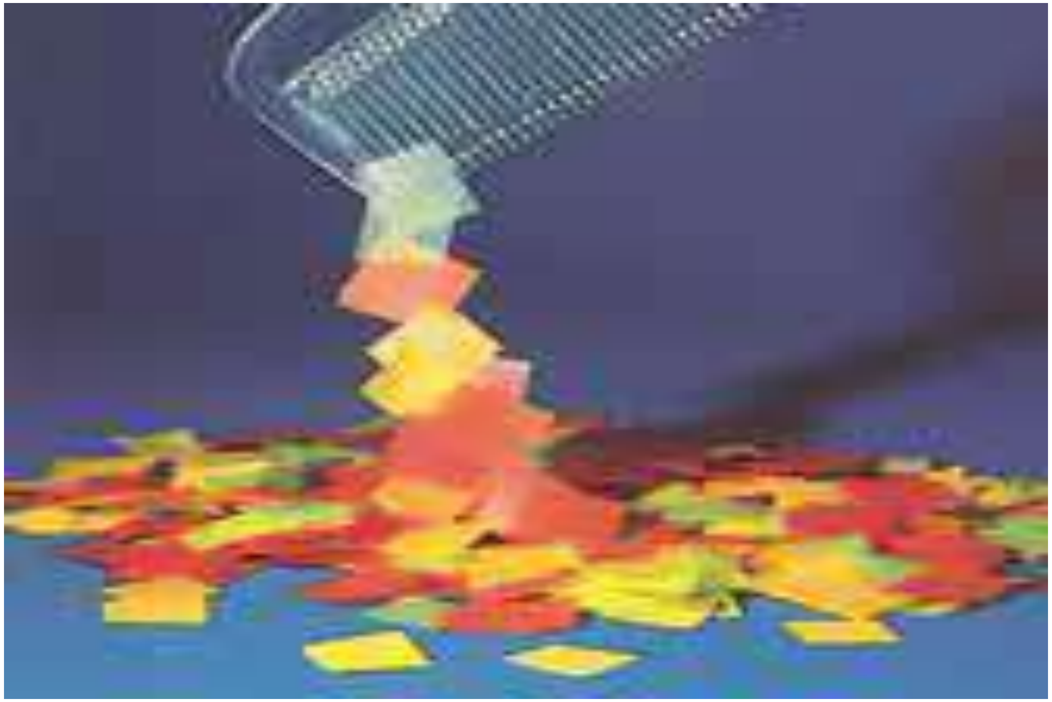
الشحنة الكهربائية



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- **Electric Charge**

Charge **is a property of matter that causes it to produce electrical and magnetic effects . The subject of the electrical effects of charges at rest is called *electrostatics*.**

الشحنة الكهربائية

الشحنة خاصية في المادة تجعلها تُحدِث تأثيراتٍ كهربائية ومغناطيسية. ويُسمّى موضوع التأثيرات الكهربائية للشحنات الساكنة **الكهروستاتيكا** (Electrostatics).

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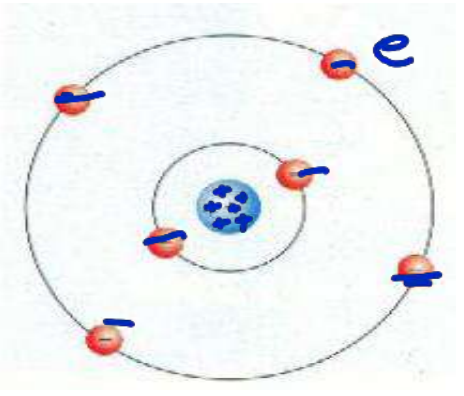
21-2 Electric Charge

- **There are two kinds of electric charges ;** ***Positive and negative*****, where like charges repel and unlike charges attract. A particle is called** ***neutral*** **if it has the same number of positive and negative charges , for example, a neutral atom (electrons (-e) = protons (+p))**



- توجد نوعان من الشحنات الكهربائية: **موجبة وسالبة**؛ حيث تتنافر الشحنات المتشابهة وتتجاذب الشحنات المختلفة. وتُسمّى الجسيمات **متعادلة** إذا كان لديها العدد نفسه من الشحنات الموجبة والسالبة؛ على سبيل المثال، الذرة المتعادلة (الإلكترونات ($e-$) = البروتونات ($p+$)).

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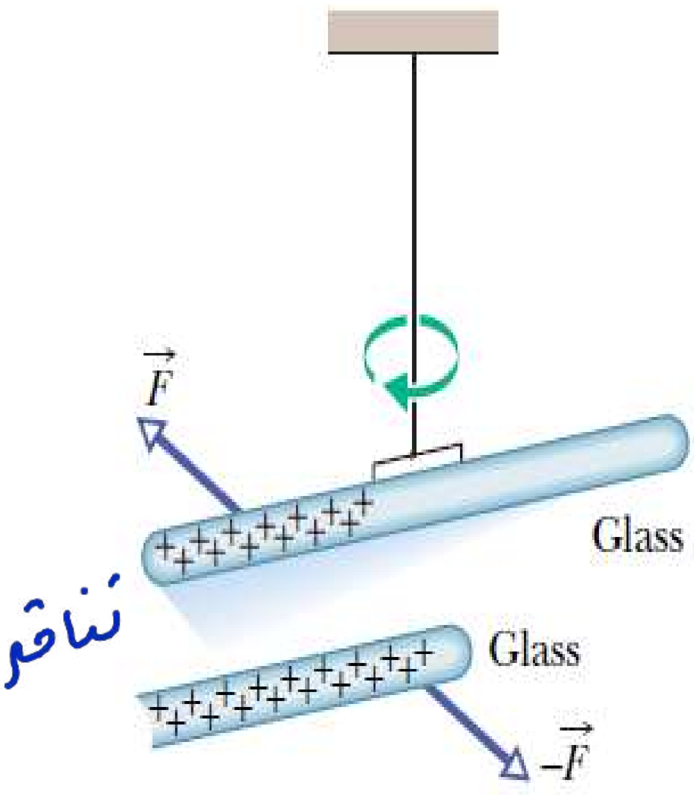
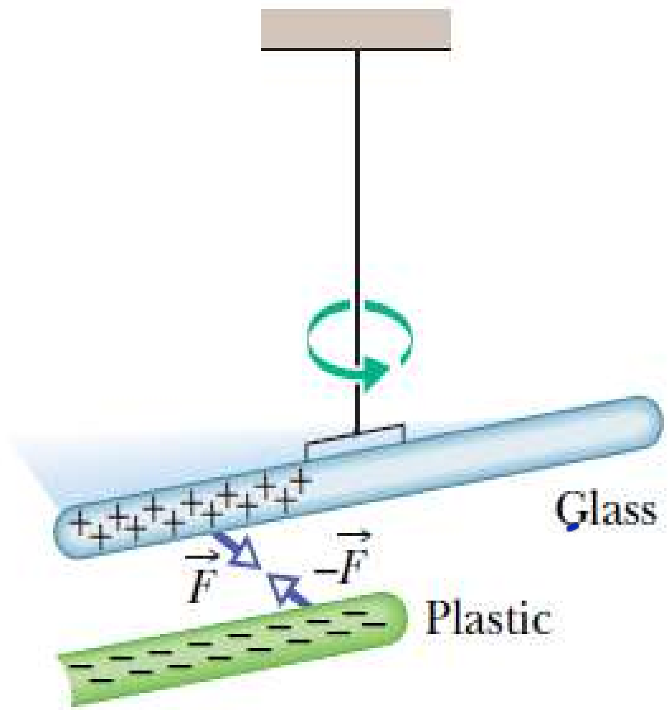
21-2 Electric Charge





Electrostatic

21-2 Electric Charge

- **The <u>SI</u> unit of charge is the *coulomb (C)*. It is defined in terms of electric current, which is the rate of flow of charge.**

$i = q/t$ ***(coulomb / sec) or Ampere*** $q = i \times t$

تعريف وحده امبير

(One coulomb is the amount of charge that is transferred through the cross section of a wire in one second when there is a current of one ampere in the wire).

(كولوم واحد هو مقدار الشحنة التي تعبر مقطع سلك خلال ثانية واحدة عندما يمر في السلك تيار شدته أمبير واحد).

If the rate of flow of charge with time is not constant, then at any instant t, current is defiend as:

$i = dq / dt$

وحده قياس الشحنه q هي كولوم (C)

وحده قياس تيار امبير = كولوم/ثانيه

$i = \frac{q}{t} = \frac{C}{S} = A$

التيار = الشحنة / الزمن

احسب التيار اذا كان
يعبر مقطعه 3μC
كل ثانيتين

$$i = \frac{q}{s} = \frac{3\times10^{-6}}{2} = 1.5\ \mu A$$

في حالة كان معدل عبور الشحنات متغير (يعتمد على الزمن) نحسب التيار من خلال المشتقة

$$i = \frac{dq}{dt}$$

التيار = مشتقة الشحنة

مثال

$$q = 3t^2 + 5t$$

ما مقدار التيار بعد 3 ثواني

$$i = \frac{dq}{dt} = 6t + 5$$

$$= 6(3) + 5 = 23\ A$$

21-3 Conductors and Insulators

- **1- Conductors** are materials through which charge can move rather freely; examples include metals (such as copper in common lamp wire), the human body, and tap water

- 2- **Nonconductors**—also called **insulators**—are materials through which charge cannot move freely; examples include rubber (such as the insulation on common lamp wire), plastic, glass, and chemically pure water

- **3- Semiconductors** are materials that are intermediate between conductors and insulators; examples include silicon and germanium in computer chips

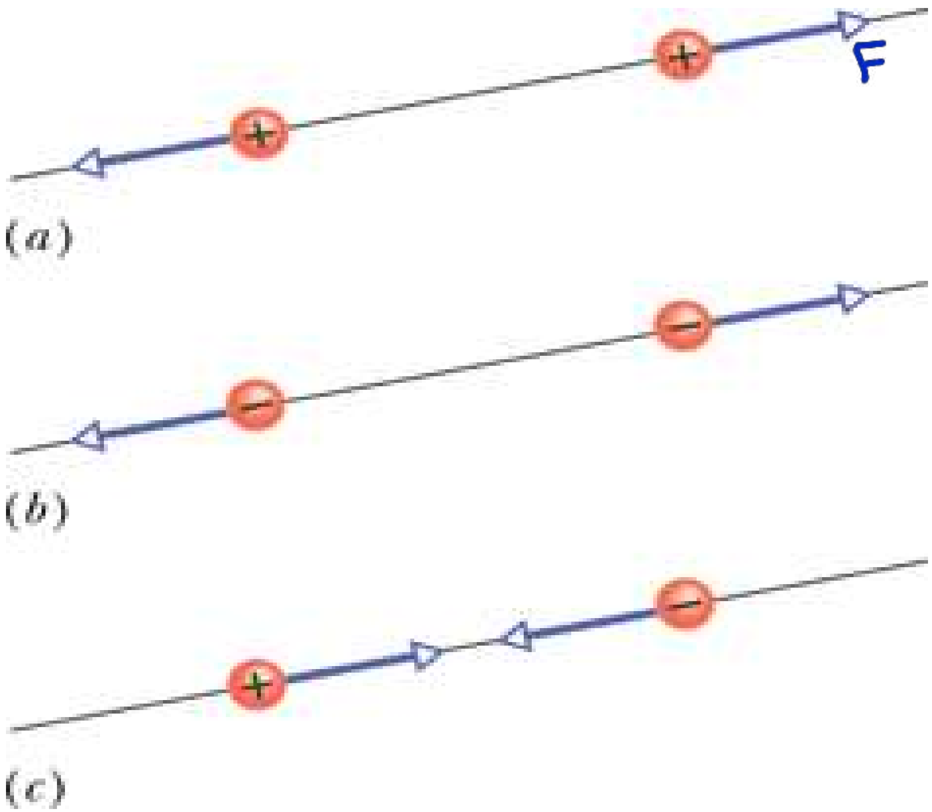
- **4- Superconductors** are materials that are *perfect* conductors

1. **الموصلات (Conductors)**: مواد تنتقل خلالها الشحنة بحرية نسبيًا؛ أمثلة: المعادن (مثل النحاس في أسلاك المصابيح الشائعة)، جسم الإنسان، وماء الصنبور.
2. **اللاموصلات / العوازل (Nonconductors/Insulators)**: مواد لا تنتقل خلالها الشحنة بحرية؛ أمثلة: المطاط (مثل عازل أسلاك المصابيح)، البلاستيك، الزجاج، والماء النقي كيميائيًا.
3. **أشباه الموصلات (Semiconductors)**: مواد تتوسط خواصها بين الموصلات والعوازل؛ أمثلة: السيليكون والجرمانيوم في الرقائق الحاسوبية.
4. **الموصلات الفائقة (Superconductors)**: مواد تكون **موصلات مثالية** (مقاومتها الكهربائية تنعدم عند شروط معينة).

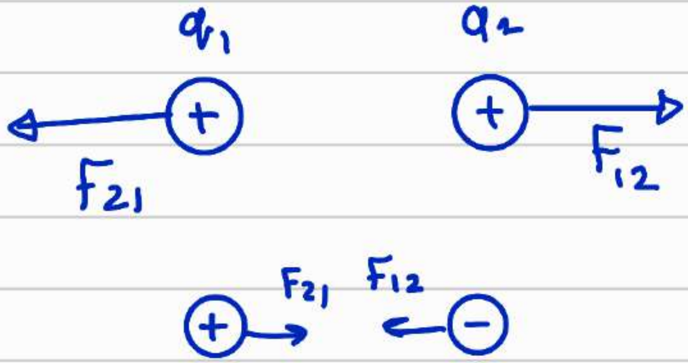
Electrostatic

21.4 Coulomb's Law

قانون كولوم



قانون كولوم :- قانون يدرس القوة الكهربائية المتبادلة بين الشحنات (نقطية)



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

$$F \propto q_1 q_2$$

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

① تكون القوة F اكبر كلما كانت الشحنات اكبر q_1, q_2

② كلما كانت المسافة اكبر قلت القوة بين الشحنات r

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

لا نعوض الشحنات السالبة في القانون

q_1 , q_2 الشحنات وتقاس بوحدة (C)

r المسافة بين الشحنتين وتقاس بـ (m)

F القوة الكهربائية (N)

$K = \frac{1}{4\pi\varepsilon}$ = ثابت كولوم $8.99 \times 10^9 \, Nm^2/c^2$

ε = السماحية الكهربائية للوسط

$\varepsilon_0 = 8.85 \times 10^{-12} \, C^2/Nm^2$

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

$$k = \frac{1}{4\pi \times 8.85 \times 10^{-12}} = 8.99 \times 10^9$$

Electrostatic

21.4 Coulomb's Law

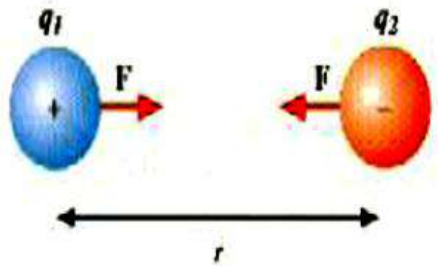
- The electrostatic force is directed along the line joining the charges, and it is attractive if the charges have unlike signs and repulsive if the charges have like signs.

- The magnitude F of the electrostatic force exerted by one point charge q_1 on another point charge q_2 is directly proportional to the magnitudes $|q_1|$ and $|q_2|$ of the charges and inversely proportional to the square of the distance r between them.

- **يتجه** القوة الكهروستاتيكية على امتداد الخط الواصل بين الشحنتين، وتكون **جاذبة** إذا كانت الشحنتان **مختلفتي الإشارة**، و**تنافرية** إذا كانتا **متشابهتي الإشارة**.
- **مقدار** القوة الكهروستاتيكية F التي تؤثر بها شحنة نقطية q_1 في شحنة نقطية أخرى q_2 يتناسب طرديًا مع مقداري الشحنتين $|q_1|$ و$|q_2|$، ويتناسب عكسيًا مع **مربع** المسافة r بينهما.

$$F \propto q_1 q_2$$

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



$$F \propto \frac{q_1 q_2}{r^2}$$

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

$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1||q_2|}{r^2} \qquad \text{(Coulomb's law).}$$

$$\vec{F} = k\frac{q_1 q_2}{r^2}\,\hat{\mathrm{r}} \qquad \text{(Coulomb's law),}$$

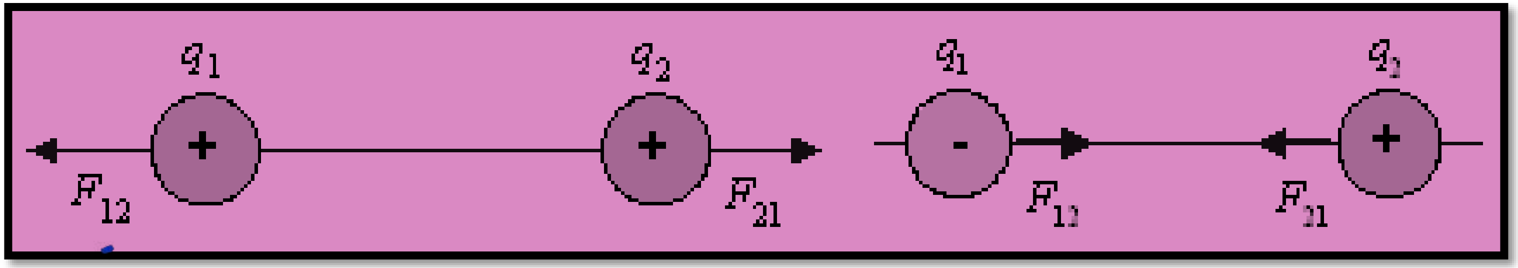
in which $\hat{\mathrm{r}}$ is a unit vector along an axis extending through the two particles, r is the distance between them, and k is a constant.

$$k = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9\,\mathrm{N\cdot m^2/C^2}.$$

ثابت السماحية

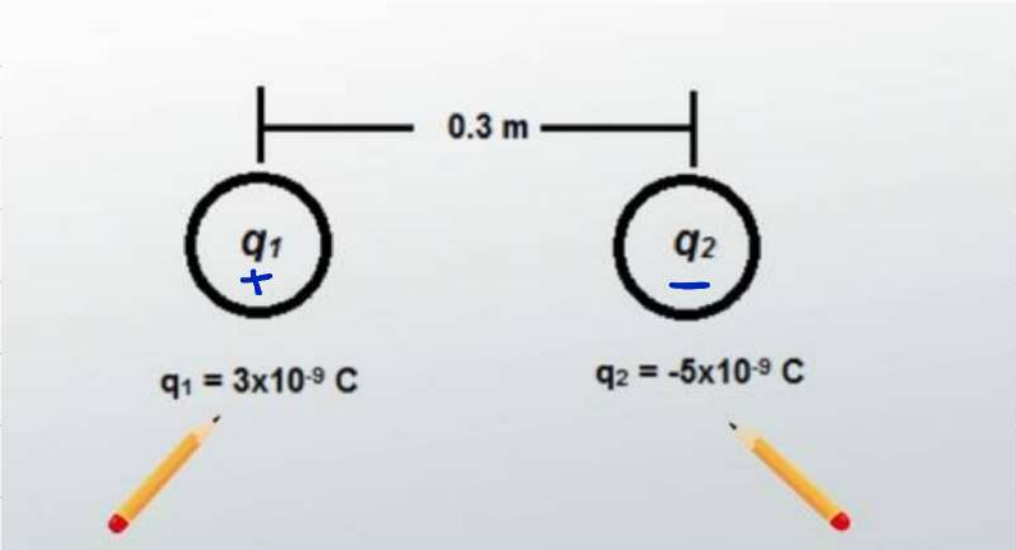
The quantity ε_0, called the **permittivity constant**, sometimes appears separately in equations and is

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



$$F_{12} = K\frac{q_1 q_2}{r^2} = F_{21}$$

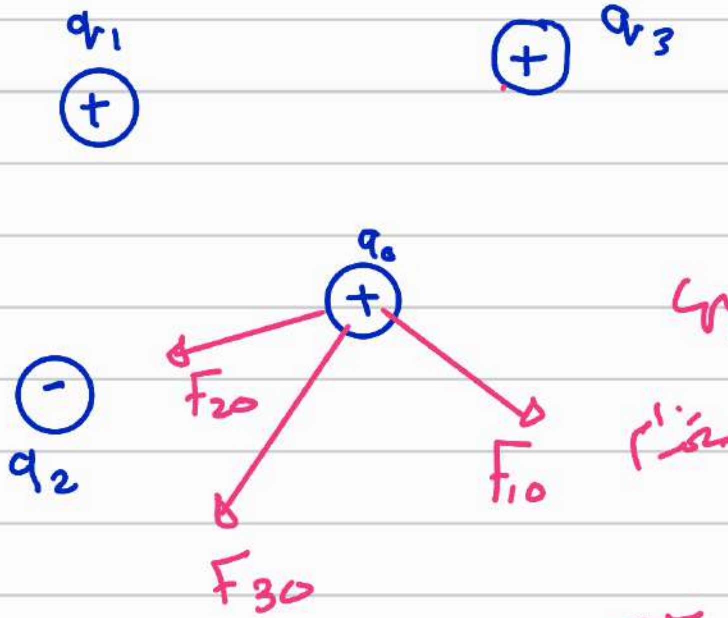
$$\bar{F}_{12} = -\bar{F}_{21}$$



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

$$= \frac{8.99\times10^{9} \times 3\times10^{-9} \times 5\times10^{-9}}{(0.3)^2}$$

$$= 1.49\times10^{-6}\,N$$



احسب القوة المؤثرة في الشحنة q_0

① نحدد اتجاهات القوى ونرسمها

② نحسب كل قوة لوحدها باستخدام قانون كولوم

③ نجمع المتجهات

$\sum F_x$ $\sum F_y$

$$F_{12} = K\frac{q_1 q_2}{r^2}$$

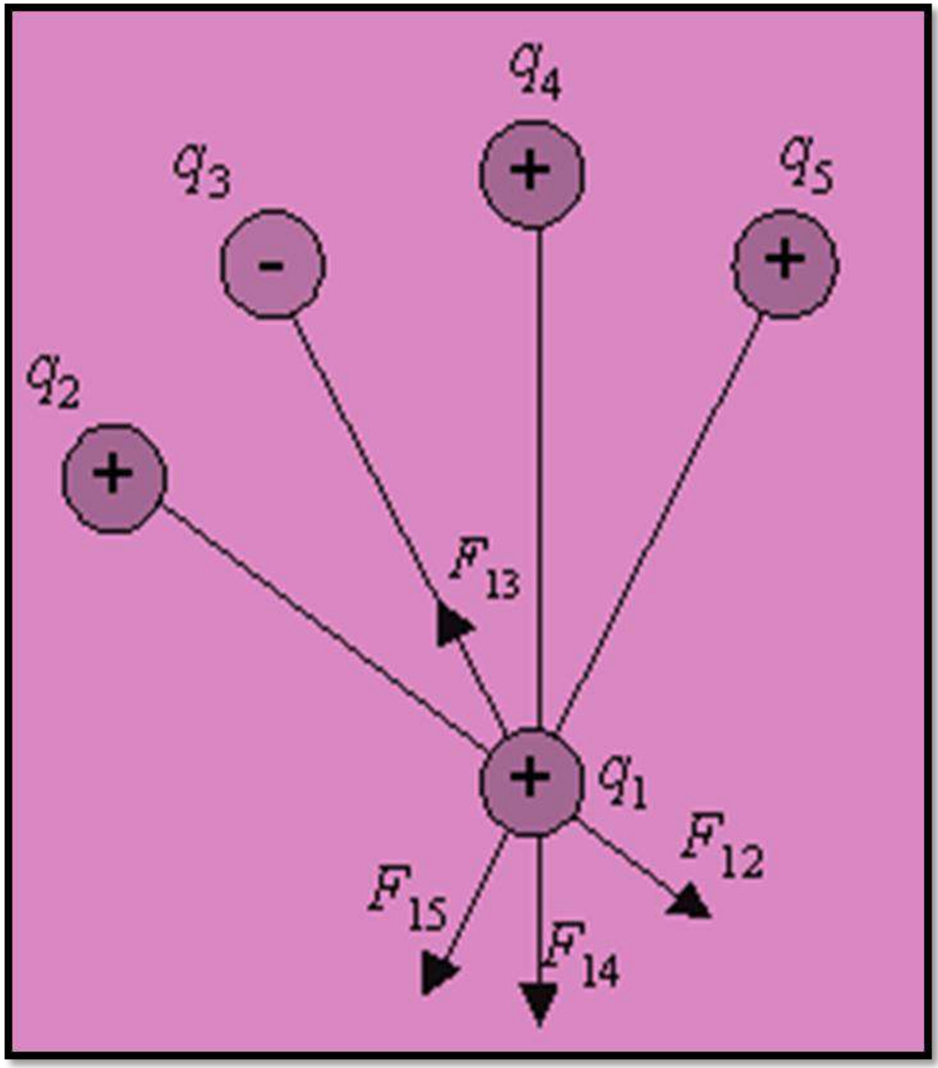
$$F_{13} = K\frac{q_1 q_3}{r^2}$$

$$F_{14} = K\frac{q_1 q_4}{r^2}$$

$$\bar{F}_1 = \bar{F}_{12} + \bar{F}_{13} + \bar{F}_{14} + \bar{F}_{15}$$

$$F_{1x} = F_{12x} + F_{13x} + F_{14x}$$

$$F_{1y} = F_{12y} + F_{13y} + F_{14y}$$



$$F_1 = \sqrt{(F_x)^2 + (F_y)^2}$$

$$\theta = \tan^{-1} \frac{F_y}{F_x}$$

$F_1 = 3i + 4j$

$F_1 = \sqrt{3^2 + 4^2} = 5N$

$\theta = \tan^{-1} \frac{4}{3}$

$\theta = 53^\circ$

Electrostatic

21. 5 Charge Quantisation

- Any charge (q) is *an integer multiplied by the charge* on the electron. Thus the charge exist in discrete packet rather than in continuous amounts and hence is said to be *quantised.*

The quantum of charge has magnitude **e** where

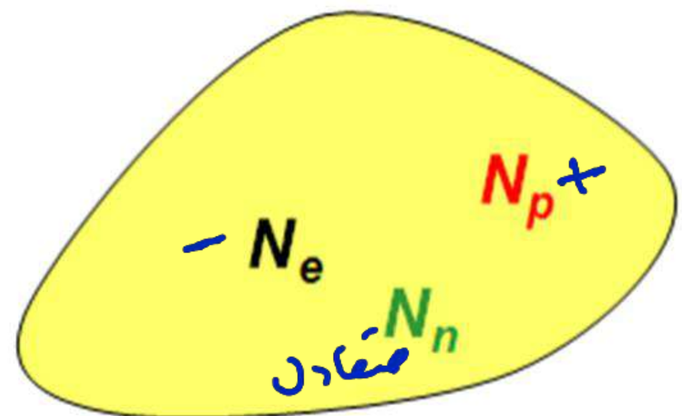
$$e = 1.602 \times 10^{-19}\ \text{C}.$$

$$q = ne, \qquad n = \pm 1, \pm 2, \pm 3, \ldots,$$

$$Q_{net} = -e\times N_e + e\times N_p + 0\times N_n = e\left(N_p - N_e\right)$$

e: 1.6×10^{-19} ; N_p: عدد p ; N_e: عدد الالكترونات

4e⁻, 5P, 10n



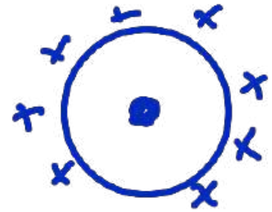
$$Q = -4(1.6\times10^{-19}) + 5(1.6\times10^{-10}) + 10(0)$$

- Total number of charges, $n = \left(N_p - N_e\right)$ is an integer.

$$Q = 2\times1.6\times10^{-19}$$

6p, 4e → 2

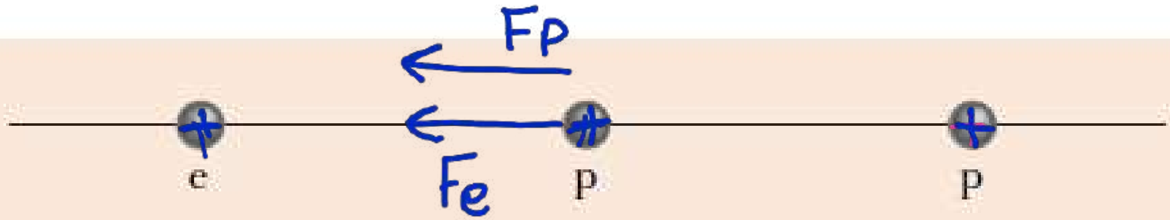
shell theorem



- A shell of uniform charge attracts or repels a charged particle that is outside the shell as if all the shell's charge were concentrated at its center.
- If a charged particle is located inside a shell of uniform charge, there is no net electrostatic force on the particle from the shell.

- الغلاف الكروي ذو الشحنة المنتظمة **يجذب أو يصدّ** جسيمًا مشحونًا موجودًا **خارج** الغلاف كما لو أن **كل شحنة الغلاف مركّزة في مركزه.**
- إذا كان الجسيم المشحون **داخل** الغلاف الكروي ذي الشحنة المنتظمة، فلا **توجد قوة كهربائية محصّلة** من الغلاف على هذا الجسيم.

CHECKPOINT 2



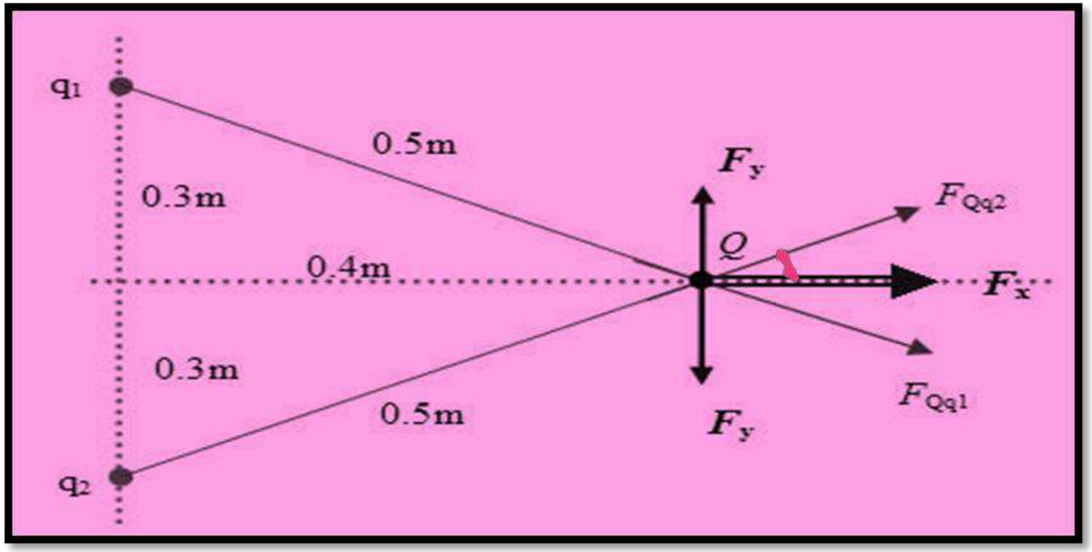
The figure shows two protons (symbol p) and one electron (symbol e) on an axis. What is the direction of (a) the electrostatic force on the central proton due to the electron, (b) the electrostatic force on the central proton due to the other proton, and (c) the net electrostatic force on the central proton?

Answer: (a) left towards the electron
(b) left away from the other proton
(c) left

$F = F_p + F_e$

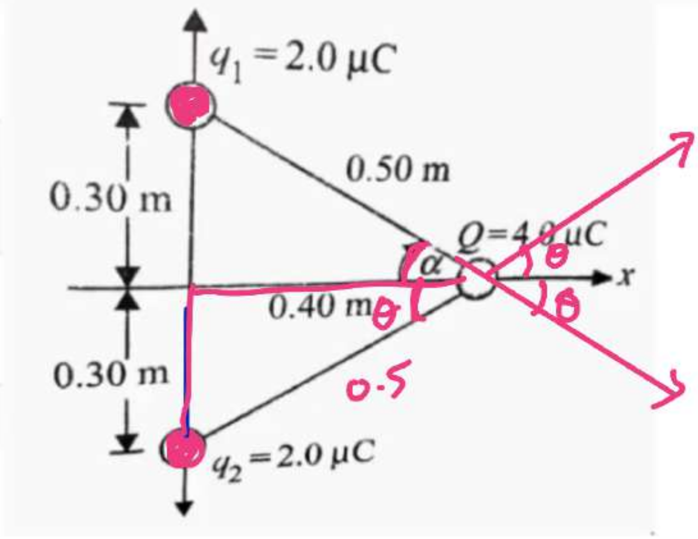
1- *In the Fig. if* $q_1 = q_2 = 2x10^{-6}C$ and $Q = 4x10^{-6}C$

What the net force on Q from q_1 and q_2?



$$F_{Qq1} = K\frac{qQ}{r^2} = 9\times10^9\frac{(4\times10^{-6})(2\times10^{-6})}{(0.5)^2} = 0.29\,N = F_{Qq2}$$

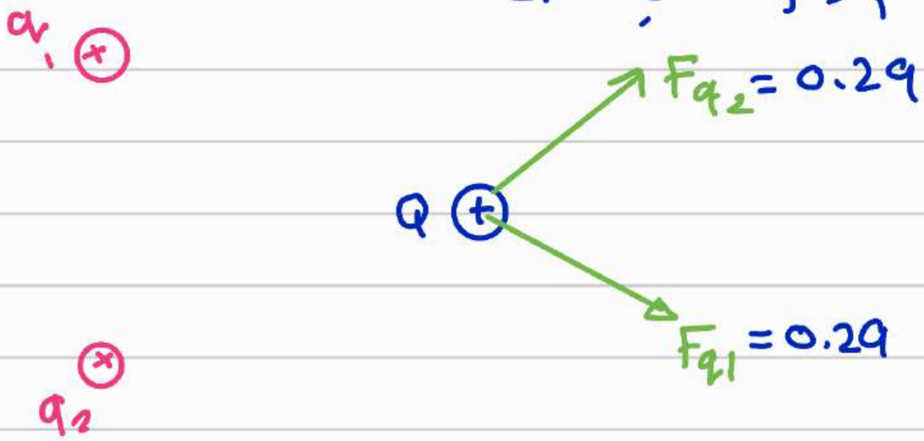
In fig two equal positive point charge $q_1 = q_2 = 2.0\mu C$. Interact with a third point charge $Q = 4.0\mu C$. The magnitude as well as direction of the net force on Q is



$\sin\theta = \frac{0.3}{0.5} = \frac{\text{المقابل}}{\text{الوتر}}$

$\cos\theta = \frac{0.4}{0.5} = \frac{\text{المجاور}}{\text{الوتر}}$

① تحديد اتجاهات القوة المؤثرة في Q

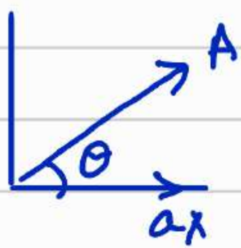


② نحسب كل قوة لوحدها

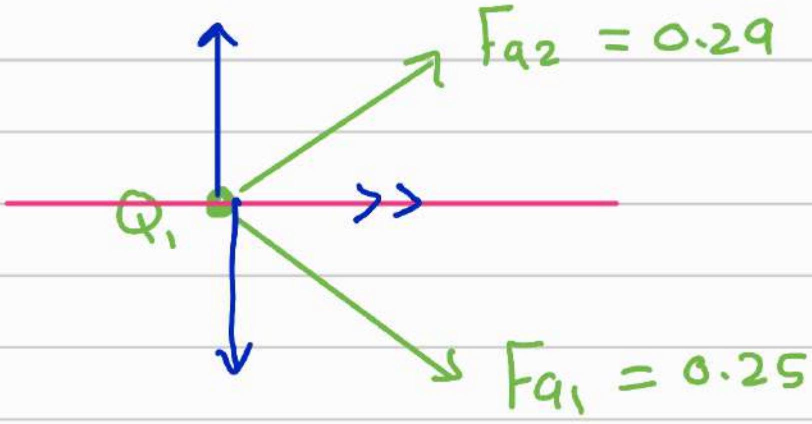
$$F_{q_1} = \frac{k\, q_1 Q}{r^2} = \frac{9\times10^{9} \times 2\times10^{-6} \times 4\times10^{-6}}{(0.5)^2} = 0.29\,N$$

$$F_{q_2} = \frac{k\, q_2 Q}{r^2} = \frac{9\times10^{9} \times 2\times10^{-6} \times 4\times10^{-6}}{(0.5)^2} = 0.29\,N$$

③ نكتب كل قوة على شكل متجه i j
(تحليل اتجاهات)



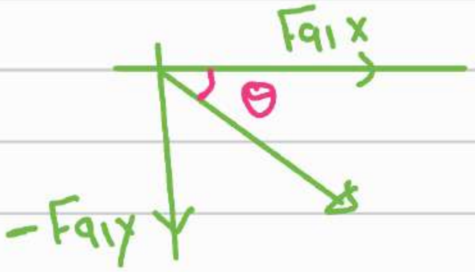
$A = a_x i + a_y j$ → $a_x = A\cos\theta$, $a_y = A\sin\theta$



$$F_{q_2} = F_{q_2}\cos\theta\, i + F_{q_2}\sin\theta\, j$$

$$= 0.29\left(\frac{0.4}{0.5}\right) i + 0.29\left(\frac{0.3}{0.5}\right) j$$

$$\boxed{F_{q_2} = 0.232 i + 0.174 j}$$



$$F_{q_1} = F_{q_1}\cos\theta\, i - F_{q_1}\sin\theta\, j$$

$$= 0.29\left(\frac{0.4}{0.5}\right) i - 0.29\left(\frac{0.3}{0.5}\right) j$$

$$\boxed{F_{q_1} = 0.232 i - 0.174 j}$$

④ نجمع المتجهات جميعها لحساب المحصلة

$$F_Q = F_{q_1} + q_{q_2}$$

$$F_Q = 0.46 i \Rightarrow \longrightarrow$$

$$F_x = F\cos\theta = 0.29\left(\frac{0.4}{0.5}\right) = 0.23\,N$$

$$F_y = -F\sin\theta = -0.29\left(\frac{0.3}{0.5}\right) = -0.17\,N$$

$$\sum F_x = 2\times 0.23 = 0.46\,N$$
$$\sum F_y = 0$$

$F = 0.46\ i$

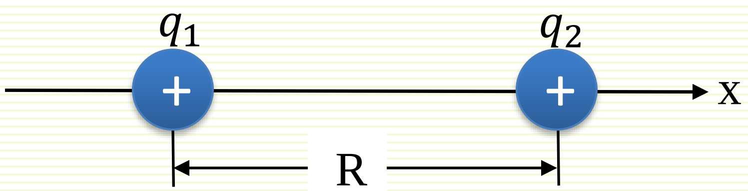
The net force is 0.46 N on the x axis .

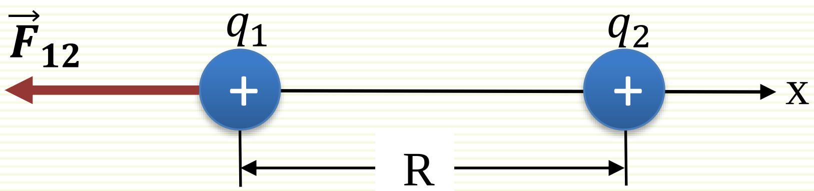
Sample Problem 21.01

Finding the net force due to two other particles

- (a) Two positively charged particles fixed in place on an x −axis. The charges are $q_1 = 1.60 \times 10^{-19} C$ and $q_2 = 3.2 \times 10^{-19} C$, and the particle separation is $R = 0.0200\, m$. What are the magnitude and direction of the electrostatic force $\vec{F}_{12}$ on particle 1 from particle 2?

مقدار الاتجاه





$r = 0.02\ m$

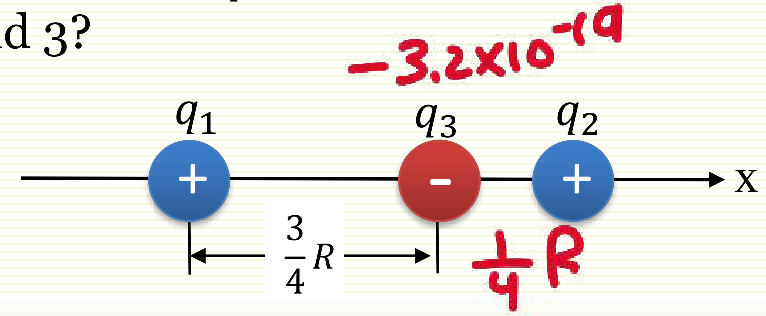
$$F = k\frac{q_1 q_2}{r^2} = \frac{8.99\times10^{9} \times 1.6\times10^{-19} \times 3.2\times10^{-19}}{(0.02)^2} = 1.15\times10^{-24}\ N$$

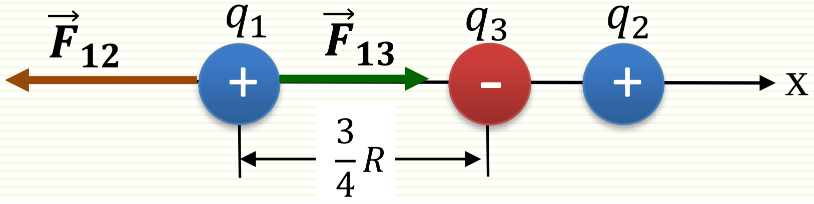
$$F_{12} = -1.15\times10^{-24}\,\hat{i}\ N$$

Sample Problem 21.01

Finding the net force due to two other particles

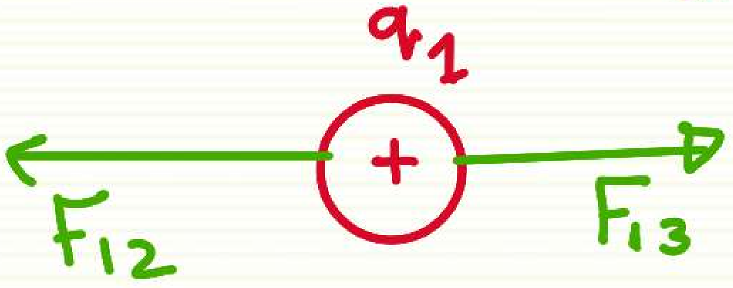
- (b) The particle 3 now lies on the x −axis between particles 1 and 2. Particle 3 has charge $q_3 = -3.20 \times 10^{-19} C$ and is at a distance $\frac{3}{4}R$ from particle 1. what is the net electrostatic force $\vec{F}_{1,net}$ on particle 1 due to particles 2 and 3?





(F_1 net) q_1 مامقدار القوه الكهربائيه المحصله المؤثره على الشحنه

والناتجه من الشحنه الثانيه والثالثه



$$\vec{F}_{12} = \frac{k\, q_1 q_2}{r^2} = \frac{8.99\times10^{9} \times 1.6\times10^{-19} \times 3.2\times10^{-19}}{(0.02)^2}$$

$$F_{12} = -1.15\times10^{-24}\,\hat{i} \quad N$$

$$F_{13} = \frac{k\, q_1\, q_3}{r^2} = \frac{8.99\times10^{9} \times 1.6\times10^{-19} \times 3.2\times10^{-19}}{\left(\frac{3}{4}\times 0.02\right)^2}$$

$$F_{13} = +2.05\times10^{-24}\,\hat{i} \quad N$$

$$\bar{F}_{net} = F_{13} + F_{12}$$

$$= (-1.15\times10^{-24} + 2.05\times10^{-24})\,\hat{i}$$

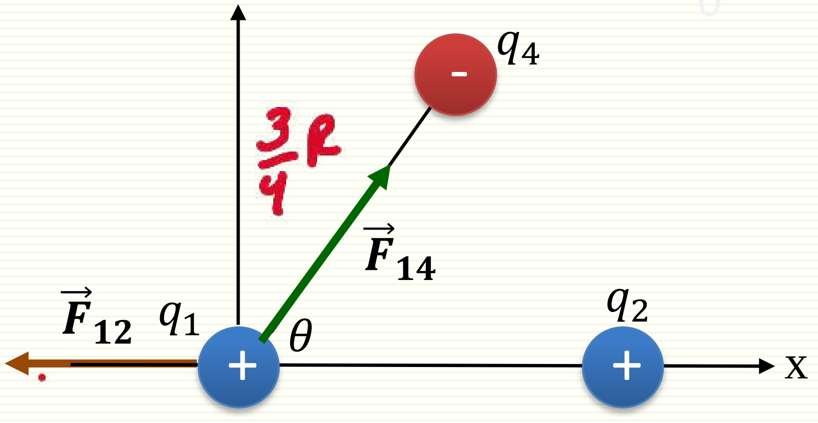
$$= 0.9\times10^{-24}\,\hat{i}$$

$$= 9\times10^{-25}\,\hat{i} \quad N$$

Sample Problem 21.01

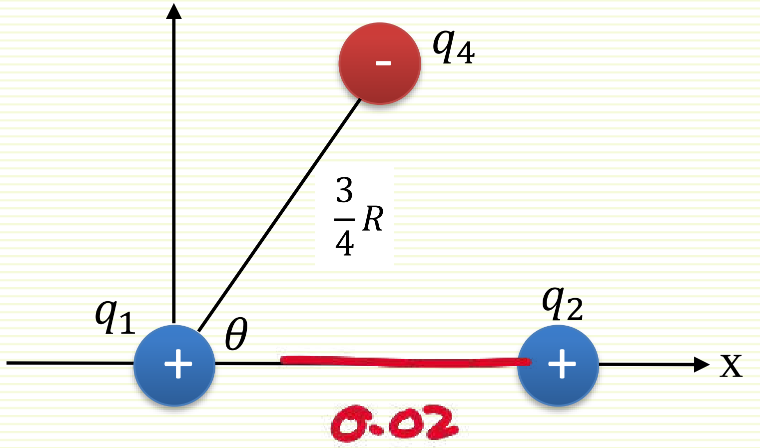
Finding the net force due to two other particles

- (c) The particle 4 is now included, it has charge $q_4 = -3.20 \times 10^{-19} C$, is at a distance $\frac{3}{4}R$ from particle 1, and lies on a line that makes an angle $\theta = 60^o$ with the $x-$axis. What is the net electrostatic force $\vec{F}_{1,net}$ on particle 1 due to particles 2 and 4?



Solution:

- The net force $\vec{F}_{1,net}$ is the vector sum of $\vec{F}_{12}$ and a new force $\vec{F}_{14}$ acting on particle 1 due to particle 4. Because particles 1 and 4 have charge of opposite signs, particle 1 is attracted to particle 4. so, force $\vec{F}_{14}$ on particle 1 is directed toward particle 4, at angle $\theta = 60^o$.
- $F_{14} = \frac{1}{4\pi\varepsilon_o}\frac{|q_1||q_2|}{\left(\frac{3}{4}R\right)^2} = \left(8.99 \times 10^9 N.\frac{m^2}{C^2}\right) \times \frac{(1.60\times10^{-19}C)(3.20\times10^{-19}C)}{\left(\frac{3}{4}\right)^2 (0.0200\, m)^2}$
- $F_{14} = 2.05 \times 10^{-24} N$
- The net force $\vec{F}_{1,net}$ on particle 1 is
- $\vec{F}_{1,net} = \vec{F}_{12} + \vec{F}_{14}$



المطلوب حساب القوه الكهروستكونيه المحصله المؤثره في الجسم

(q_1) والناتجه q_2 و q_4

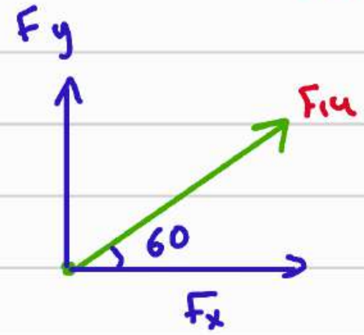
رسم القوى

حساب كل قوه

$$\vec{F}_{12} = \frac{K q_1 q_2}{r^2} = \frac{8.99\times10^{9}\times1.6\times10^{-19}\times3.2\times10^{-19}}{(0.02)^2}$$

$$F_{12} = -1.15\times10^{-24}\,\hat{i}$$

$$F_{14} = \frac{K q_1 q_4}{(\frac{3}{4}R)^2} = \frac{8.99\times10^{9}\times1.6\times10^{-19}\times3.2\times10^{-19}}{(\frac{3}{4}\times0.02)^2}$$



$$F_{14} = 2.05\times10^{-24}\ N$$

$F_x = F\cos\theta$

$F_y = F\sin\theta$

$$F_x = F_{14}\cos60 = 2.05\times10^{-24}\times\cos60 = 1.025\times10^{-24}\,\hat{i}$$

$$F_y = F_{14}\sin60 = 2.05\times10^{-24}\times\sin60 = 1.775\times10^{-24}\,\hat{j}$$

$$F_{14} = 1.025\times10^{-24}\,\hat{i} + 1.775\times10^{-24}\,\hat{j}$$

القوه المحصلة = مجموع كل القوى

$$F_{1net} = F_{12} + F_{14} = -1.15\times10^{-24}\,\hat{i} + 1.025\times10^{-24}\,\hat{i} + 1.775\times10^{-24}\,\hat{j}$$

$$F_{1\,net} = -0.125\times10^{-24}\,\hat{i} + 1.78\times10^{-24}\,\hat{j}\ N$$

Sample Problem 21.01

Finding the net force due to two other particles

- Because the forces $\vec{F}_{12}$ and $\vec{F}_{14}$ are not directed along the same axis, we cannot sum simply by combining their magnitudes. We use the summing in unit-vector notation

$$\vec{F}_{14} = (F_{14}\cos\theta)\hat{\imath} + (F_{14}\sin\theta)\hat{\jmath} = \left(2.05\times10^{-24}\cos 60^{o}\right)\hat{\imath} + \left(2.05\times10^{-24}\sin 60^{o}\right)\hat{\jmath}$$
$$= \left(1.025\times10^{-24}\ N\right)\hat{\imath} + \left(1.775\times10^{-24}\ N\right)\hat{\jmath}$$

- Then we sum:

$$\vec{F}_{1,net} = \vec{F}_{12} + \vec{F}_{14} = \left(-1.15\times10^{-24}N\right)\hat{\imath} + \left(1.025\times10^{-24}\ N\right)\hat{\imath} + \left(1.775\times10^{-24}\ N\right)\hat{\jmath}$$
$$= \left(-1.25\times10^{-25}N\right)\hat{\imath} + (1.78\times10^{-24}N)\hat{\jmath}$$

Sample Problem 21.02

Equilibrium of two forces on a particle

- Two particles fixed in place: a particle of charge $q_1 = +8q$ at the origin and a particle of charge $q_2 = -2q$ at $x = L$. At what point (other than infinitely far away) can a proton be placed so that it is in equilibrium (the net force on it is zero)? Is that equilibrium stable or unstable? (That is, if the proton is displaced, do the forces drive it back to the point of equilibrium or drive it farther away?

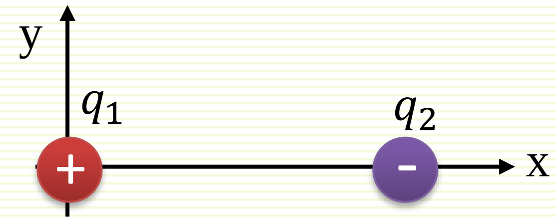


Fig. (a)

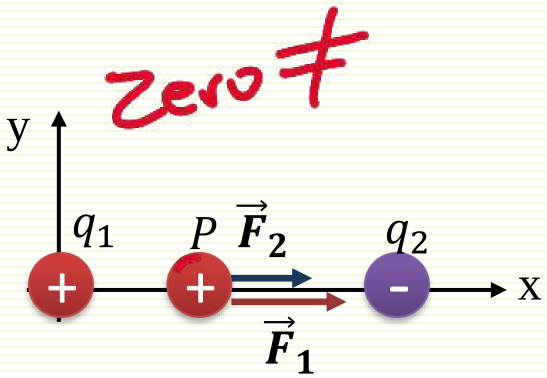


Fig. (b)

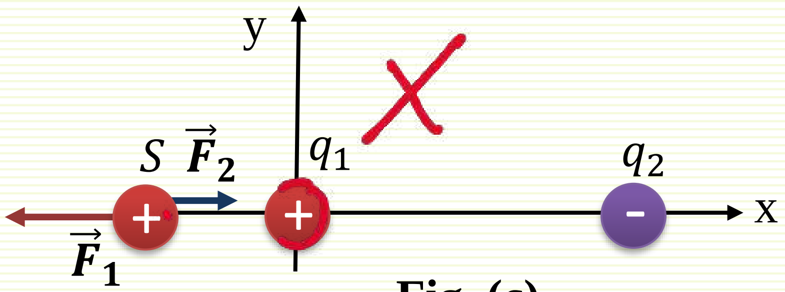


Fig. (c)

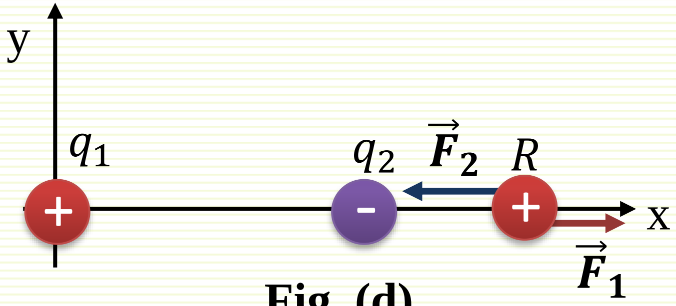
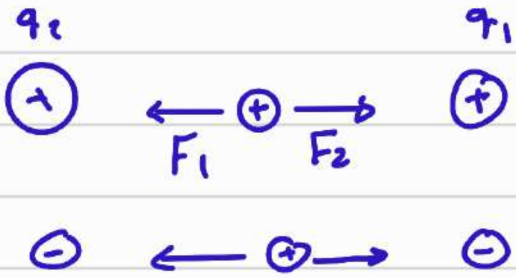
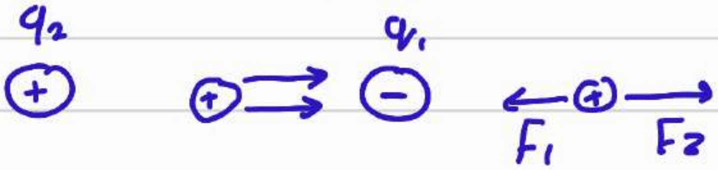


Fig. (d)

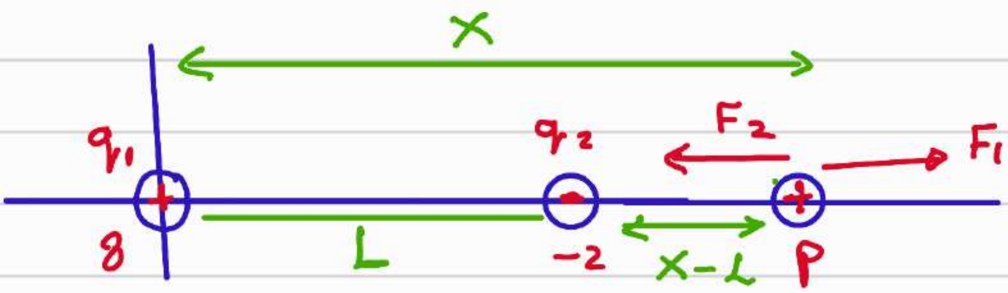
نقطة التعادل



اذا كانت الشحنتين لهما نفس الاشاره فان نقطة التعادل تقع بينهما و أقرب الى الشحنه الاصغر



اذا كانت الشحنات متعاكسة بالاشارة فان نقطة التعادل تقع خارجهما و أقرب الى الشحنه الاصغر



$$F_1 = F_2$$

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

$$\frac{k\,(8q)\,q_p}{x^2} = \frac{k\,(2q)\,q_p}{(x-L)^2}$$

$$\frac{8}{x} = \frac{2}{(x-L)^2}$$

$$\frac{8}{2} = \frac{(x)^2}{(x-L)}$$

$$\sqrt{4} = \sqrt{\frac{x^2}{(x-L)^2}}$$

$$2 = \frac{x}{x-L}$$

$$x = 2x - 2L$$

$$x - 2x = -2L$$

$$\boxed{x = 2L}$$

Sample Problem 21.02

Equilibrium of two forces on a particle

- If $\vec{F}_1$ is the force on the proton due to charge q_1 and $\vec{F}_2$ is the force on the proton due to charge q_2, then the point we seek is where

$$\vec{F}_1 + \vec{F}_2 = 0$$

- Thus,

$$\vec{F}_1 = -\vec{F}_2$$

- This tells us that at the point we seek, the forces acting on the proton due to the other two particles must be of equal magnitudes, $F_1 = F_2$, and that the forces must have opposite directions.

Sample Problem 21.02

Equilibrium of two forces on a particle

- Because a proton has a positive charge, the proton and the particle of charge q_1 are of the same sign, and force $\vec{F}_1$ on the proton must point away from q_1.
- Also, the proton and the particle of charge q_2 are of opposite signs, so force $\vec{F}_2$ on the proton must point toward q_2. "away from q_1 and toward q_2" can be in opposite directions only if the proton is located on the x −axis.
- If the proton is on the x −axis at any point between q_1 and q_2, (Point P in Figure b), then $\vec{F}_1$ and $\vec{F}_2$ are in the same direction and not in opposite directions.

Sample Problem 21.02
Equilibrium of two forces on a particle

- If the proton is at any point on the x –axis to the left of q_1, (Point S in Figure c), then $\vec{F}_1$ and $\vec{F}_2$ are in opposite directions. But $\vec{F}_1$ and $\vec{F}_2$ cannot have equal magnitudes there: $\vec{F}_1$ must be greater than $\vec{F}_2$, because $\vec{F}_1$ is produced by a closer charge (with lesser r) of greater magnitude ($8q$ versus $2q$).

- Finally, if the proton is at any point on the x –axis to the right of q_2, (Point R in Figure d), then $\vec{F}_1$ and $\vec{F}_2$ are again opposite directions. However, because now the charge of greater magnitude (q_1) is farther away from the proton than the charge of lesser magnitude, there is a point at which $\vec{F}_1$ is equal to $\vec{F}_2$.

Sample Problem 21.02

Equilibrium of two forces on a particle

- Let x be the coordinate of this point, and let q_p be the charge of the proton. So

$$F_1 = F_2$$

$$\frac{1}{4\pi\varepsilon_o}\frac{(8q)(q_p)}{x^2} = \frac{1}{4\pi\varepsilon_o}\frac{(2q)(q_p)}{(x-L)^2}$$

$$\therefore \left(\frac{x}{x-L}\right)^2 = 4$$

- Taking the square roots of both sides, so

$$\left(\frac{x}{x-L}\right) = 2 \quad \Rightarrow \quad x = 2(x-L)$$

$$x = 2x - 2L \quad \Rightarrow \quad 2x - x = 2L$$

$$\therefore x = 2L$$

Sample Problem 21.02

Equilibrium of two forces on a particle

اتزان غير ثابت

- The equilibrium at $x = 2L$ is unstable; that is, if the proton is displaced leftward from the point R, then F_1 and F_2 both increase but F_2 increase more (because q_2 is closer than q_1), and a net force will drive the proton farther leftward.
- If the proton is displaced rightward, both F_1 and F_2 decrease but F_2 decrease more, and a net force will then drive the proton farther rightward.
- In a stable equilibrium, if the proton is displaced slightly, it returns to the equilibrium position.

يعتبر الاتزان غير مستقر لانه عند سحب الشحنه الى اليسار قليلاً تصبح قوة F_2 اكبر لتغير ويسحب البروتون نحو اليسار

Mutual electric repulsion in a nucleus

The nucleus in an iron atom has a radius of about 4.0×10^{-15} m and contains 26 protons.

(a) What is the magnitude of the repulsive electrostatic force between two of the protons that are separated by 4.0×10^{-15} m?

KEY IDEA

The protons can be treated as charged particles, so the magnitude of the electrostatic force on one from the other is given by Coulomb's law.

Calculation: Table 21-1 tells us that the charge of a proton is $+e$. Thus, Eq. 21-4 gives us

$$F = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

$$= \frac{(8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(1.602 \times 10^{-19}\ \text{C})^2}{(4.0 \times 10^{-15}\ \text{m})^2}$$

$$= 14\ \text{N}. \qquad \text{(Answer)}$$

No explosion: This is a small force to be acting on a macroscopic object like a cantaloupe, but an enormous force to be acting on a proton. Such forces should explode the nucleus of any element but hydrogen (which has only one proton in its nucleus). However, they don't, not even in nuclei with a great many protons. Therefore, there must be some enormous attractive force to counter this enormous repulsive electrostatic force.

(b) What is the magnitude of the gravitational force between those same two protons?

KEY IDEA

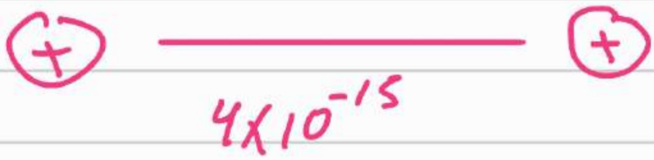
Because the protons are particles, the magnitude of the gravitational force on one from the other is given by Newton's equation for the gravitational force (Eq. 21-2).

Calculation: With m_p ($= 1.67 \times 10^{-27}$ kg) representing the mass of a proton, Eq. 21-2 gives us

$$F = G\frac{m_p^2}{r^2}$$

$$= \frac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(1.67 \times 10^{-27}\ \text{kg})^2}{(4.0 \times 10^{-15}\ \text{m})^2}$$

$$= 1.2 \times 10^{-35}\ \text{N}. \qquad \text{(Answer)}$$

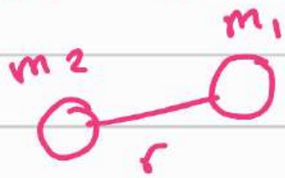


$q = 1.6 \times 10^{-19}\, C$

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{r^2} = \frac{8.99 \times 10^{9} \times (1.6 \times 10^{-19})^2}{(4 \times 10^{-15})^2}$$

$$= 14.3\, N$$

قوه الجاذبيه (القانون العام للجذب



$$F = G \frac{m_1 m_2}{r^2}$$

$$F = G \frac{(m_p)^2}{r^2}$$

$$F = \frac{6.67 \times 10^{-11} \times (1.67 \times 10^{-27})}{(4 \times 10^{-15})^2}$$

$$= 1.2 \times 10^{-35}\, N$$

(1) Calculate the number of electrons that are found in a 1 C charge.

Ans $q = ne$ → $n = q/e = 1/1.6 \times 10^{-19}$

$= 6.25 \times 10^{18}$ electrons

(2) How many electrons do pass through a wire has 1 mA current in 20 second?

Ans

$i = q/t$ → $q = it$ → $ne = it$

$n = it/e = 1 \times 10^{-3} \times 20 / 1.6 \times 10{-}19$

(3) If the charge that excess through a wire in an interval of time is given by

$q = q_0 \sin(60t)$, where $q_0 = 3\ \mu C$ and t is measured by second. Find the current flows in the wire in the fifth second.

Ans

$i = dq/dt$

i (in the fifth second) = i (t=5) – i(t=4)

$i = q_0 (60) \cos(60t) = 60 \times 3\times10^{-6} \cos(60(5-4))$

$i = 90\times10^{-6}$ A

$= 90\ \mu A$

Homework

Chapter 21: Electric Charge

3-7-24

Pages 575-576

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Further Ref.

1/ كتاب الكهربية والمغناطيسية لـ د محمود الكوفحي و د عبد السلام غيث

2/ Study Guide for Electricity & Magnetism, Dr Farage S. Al Hazmi & Dr Ali Z. Al Zahrani