ARMS

ACADEMY

GENERAL PHYSICS

Chapter 23

Our Groups

قناة الاكاديمية

Telegram

Chapter -21-Electric Charge and Electric Field

Atoms: A neutral atom has the same number of protons as electrons.

الذرات: تحتوي الذرة المتعادلة على نفس عدد البروتونات مثل الإلكترونات

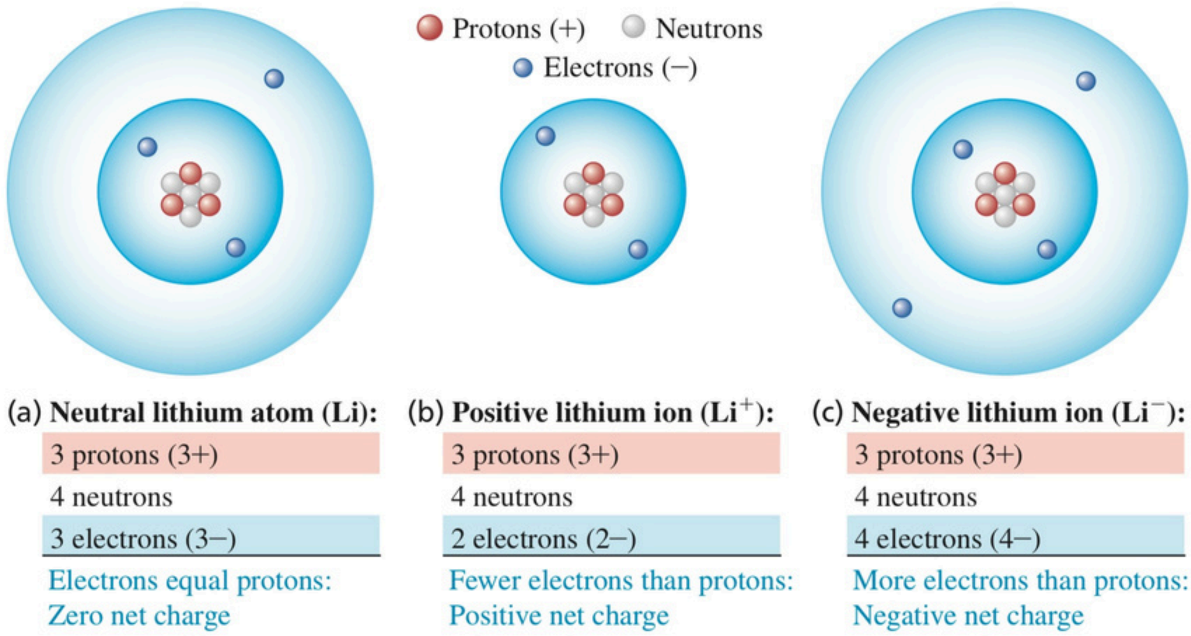
ions:

A positive ion is an atom with one or more electrons removed.
A negative ion has gained one or more electrons.

الأيونات:

الأيون الموجب هو ذرة تمت ازالة إلكترون واحد أو اكثر منها.

الايون السالب اكتسب إلكترونًا واحداً أو اكثر.



21.1 Electric Charge

They rubbed amber with wool, the amber could attract other objects, we say that the amber has acquired a net electric charge, or has become charged.

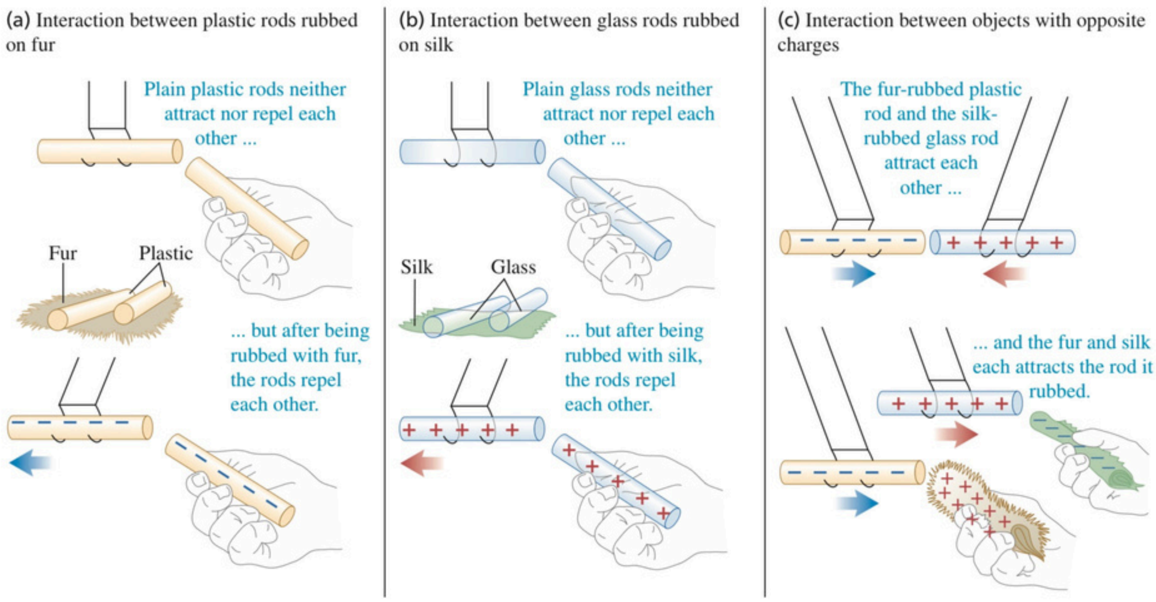
لقد قاموا بفرك الكهرمان بالصوف، فكان الكهرمان قادراً على جذب أشياء أخرى، فنقول ان كان الكهرمان اكتسب شحنة كهربائية صافية، أو أصبح مشحوناً.

Two positive or two negative charges repel each other.

تتنافر شحنتان موجبتان أو شحنتان سالبتان.

A positive charge and a negative charge attract each other.

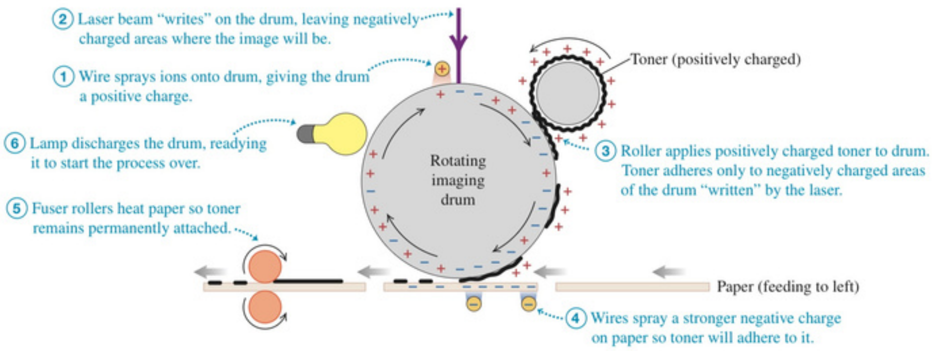
الشحنة الموجبة والشحنة السالبة تتجاذبان مع بعضهما البعض.



The printer is example of conductor and insulator in the same time

الطابعة هي مثال للموصل والعازل في نفس الوقت

Figure 21.2 Schematic diagram of the operation of a laser printer.



The proton and electron have the same magnitude charge.

البروتون والالكترون لهما نفس المقدار من الشحنة.

The magnitude of charge of the electron or proton is a natural unit of charge. All observable charge is quantized in this unit

مقدار شحنة الالكترون أو البروتون هو وحدة طبيعية للشحنة. يتم تحديد كل شحنة يمكن ملاحظتها في هذه الوحدة

The universal principle of charge conservation states that the algebraic sum of all the electric charges in any closed system is constant.

تنص القاعدة العالمية لحفظ الشحنة على ان المجموع الجبري لجميع الشحنات الكهربائية في أي نظام مغلق يكون ثابتًا.

When a glass rod is rubbed with silk, electrons are transferred from the glass to the silk. Because of conservation of charge, each electron adds negative charge to the silk, and an equal positive charge is left behind on the rod

عند دلك قضيب زجاجي بالحرير تنتقل الإلكترونات من الزجاج إلى الحرير.
وبسبب مبدأ حفظ الشحنة يضيف كل إلكترون شحنة سالبة إلى الحرير وتبقى شحنة موجبة مساوية لها على القضيب

21.2 Conductors, Insulators, and Induced Changes

A *conductor* permits the easy movement of charge through it (such as copper and aluminum). An *insulator* does not.

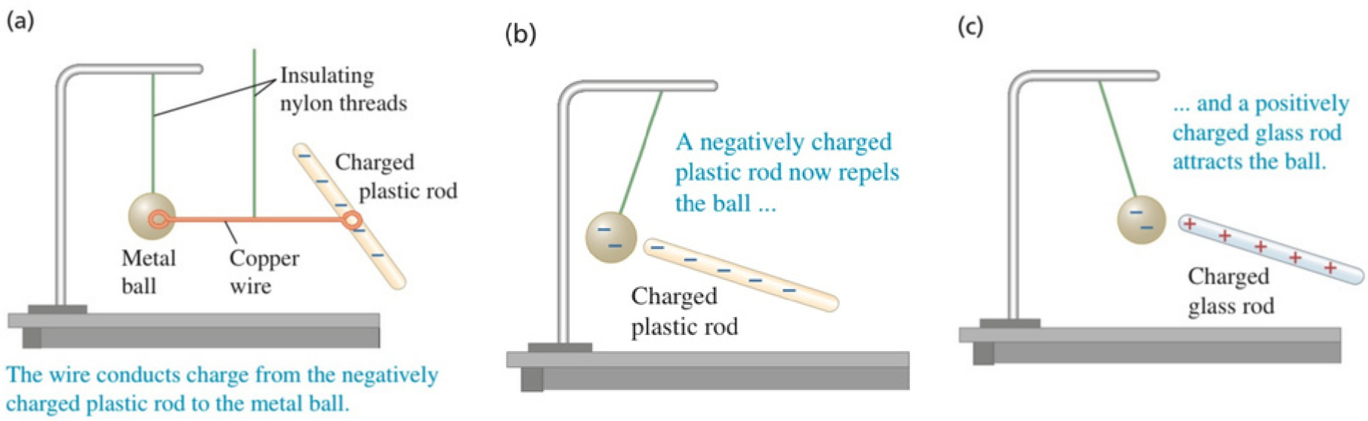
يسمح الموصل بمرور الشحنات الكهربائية بسهولة عبره (مثل النحاس والألمنيوم)، بينما لا يسمح العازل بذلك.

Most metals are good conductors, while most nonmetals are insulators.

معظم المعادن موصلات جيدة، في حين ان معظم اللافلزات عازلة.

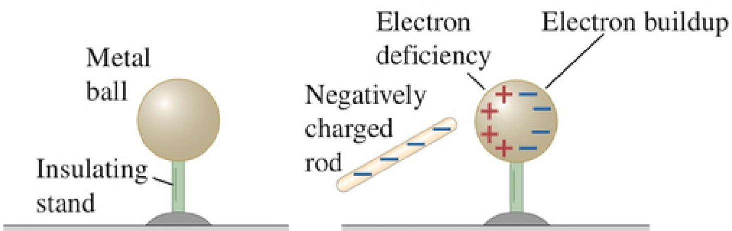
Semiconductors are intermediate in their properties between good conductors and good insulators

اشباه الموصلات متوسطة في خصائصها بين الموصلات الجيدة والعوازل الجيدة



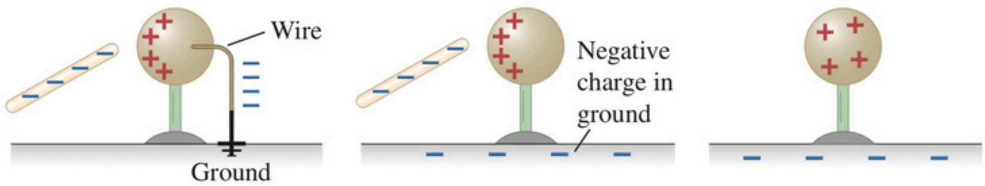
Charging by induction

Figure 21.7 Charging a metal ball by induction.



(a) Uncharged metal ball

(b) Negative charge on rod repels electrons, creating zones of negative and positive **induced charge**.



(c) Wire lets electron buildup (induced negative charge) flow into ground.

(d) Wire removed; ball now has only an electron-deficient region of positive charge.

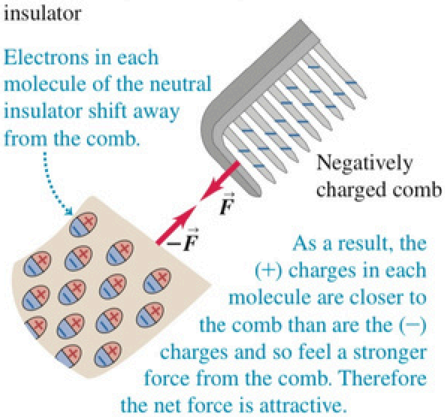
(e) Rod removed; electrons rearrange themselves, ball has overall electron deficiency (net positive charge).

Electric forces on uncharged objects

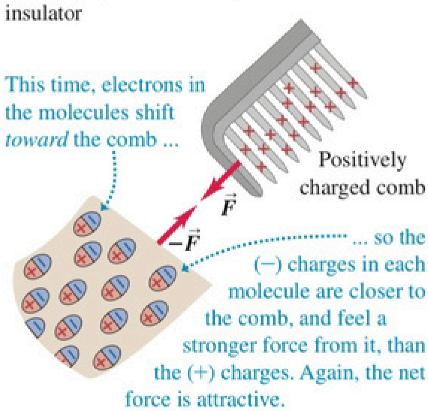
Figure 21.8 The charges within the molecules of an insulating material can shift slightly. As a result, a comb with either sign of charge attracts a neutral insulator. By Newton's third law the neutral insulator exerts an equal-magnitude attractive force on the comb.

(a) A charged comb picking up uncharged pieces of plastic

(b) How a negatively charged comb attracts an insulator



(c) How a positively charged comb attracts an insulator



21.3 Coulomb's Law

The magnitude of the electric force between two point charges is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.

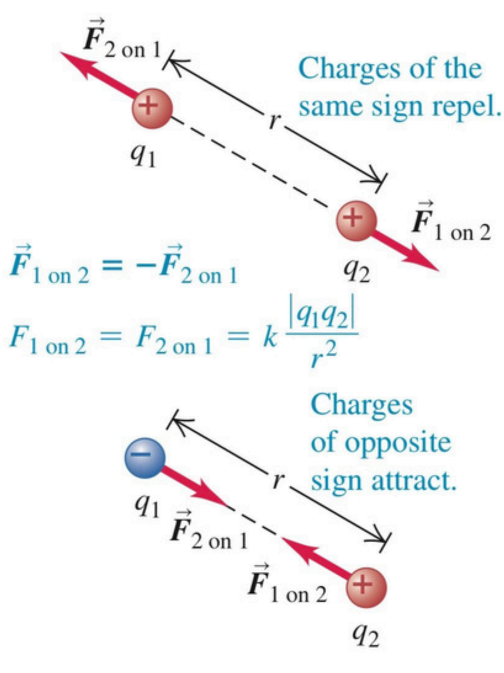
يتناسب مقدار القوة الكهربائية بين شحنتين نقطيتين طرديا مع حاصل ضرب شحنتيهما، ويتناسب عكسيا مع مربع المسافة بينهما

$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_1q_2|}{r^2}$$

$$\varepsilon_0 = 8.854 \times 10^{-12}\ C^2/N \bullet m^2$$

$$\frac{1}{4\pi\varepsilon_0} = k = 8.988 \times 10^9\ N \bullet m^2/C^2$$

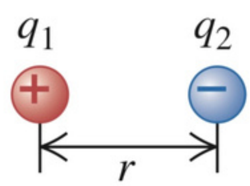
Interactions between point charges



Example 21.2 Force between two point charges

Two point charges, $q_1 = +25$ nC and $q_2 = -75$ nC, are separated by a distance r = 3.0 cm (**Fig. 21.12a**). Find the magnitude and direction of the electric force (a) that q_1 exerts on q_2 and (b) that q_2 exerts on q_1.

(a) The two charges



$$F_{1\text{ on }2} = \frac{1}{4\pi\varepsilon_0}\frac{|q_1q_2|}{r^2}$$

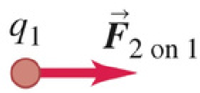
$$= (9.0 \times 10^9\ \text{N} \bullet \text{m}^2/\text{C}^2)\frac{|(+25 \times 10^{-9}\ \text{C})(-75 \times 10^{-9}\ \text{C})|}{(0.030\ \text{m})^2}$$

$$= 0.019\ \text{N}$$

(b) Free-body diagram for charge q_2

$$F_{2\text{ on }1} = \frac{1}{4\pi\varepsilon_0}\frac{|q_1q_2|}{r^2} = F_{1\text{ on }2} = 0.019\ \text{N}$$

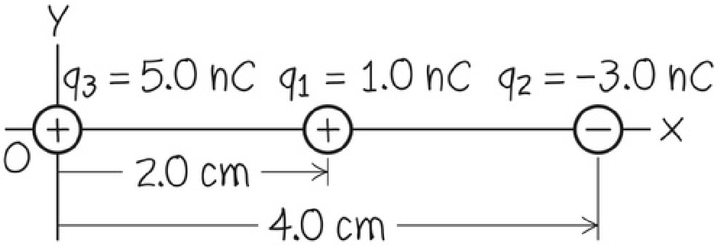
(c) Free-body diagram for charge q_1



Example 21.3 Vector addition of electric forces on a line

Two point charges are located on the *x*-axis of a coordinate system: $q_1 = 1.0$ nC is at x = +2.0 cm, and $q_2 = -3.0$ nC is at $x = +4.0$ cm. What is the total electric force exerted by q_1 and q_2 on a charge $q_3 = 5.0$ nC at $x = 0$?

$$F_{1\text{ on }3} = \frac{1}{4\pi\varepsilon_0}\frac{|q_1 q_3|}{r_{13}^{\,2}}$$



$$= (9.0 \times 10^9\ \text{N} \bullet \text{m}^2/\text{C}^2)\frac{(1.0 \times 10^{-9}\ \text{C})(5.0 \times 10^{-9}\ \text{C})}{(0.020\ \text{m})^2}$$

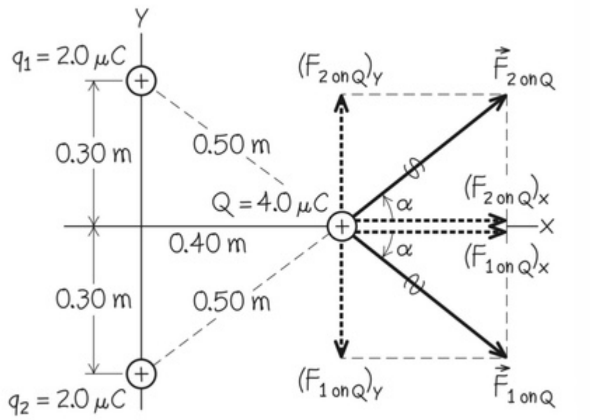
$$= 1.12 \times 10^{-4}\ \text{N} = 112\ \mu\text{N}$$

In the same way you can show that $F_{2\text{ on }3} = 84\ \mu\text{N}$

$$\vec{F}_3 = \vec{F}_{1\text{ on }3} + \vec{F}_{2\text{ on }3} = (-112\ \mu\text{N})\hat{\imath} + (84\ \mu\text{N})\hat{\imath} = (-28\ \mu\text{N})\hat{\imath}$$

Example 21.3 Vector addition of electric forces on a line

Two equal positive charges $q_1 = q_2 = 2.0\ \mu C$ are located at $x = 0$, $y = 0.30$ m and $x = 0$, $y = -0.30$ m, respectively. What are the magnitude and direction of the total electric force that q_1 and q_2 exert on a third charge Q = 4.0 μC at $x = 0.40$ m, y = 0?



$$F_{1\text{ or }2\text{ on }Q} = (9.0 \times 10^9\ \text{N} \cdot \text{m}^2/\text{C}^2)\frac{(4.0 \times 10^{-6}\ \text{C})(2.0 \times 10^{-6}\ \text{C})}{(0.50\ \text{m})^2}$$

$$= 0.29\ \text{N}$$

$$(F_{1\text{ or }2\text{ on }Q})_x = (F_{1\text{ or }2\text{ on }Q})\cos\alpha = (0.29\ \text{N})\frac{0.40\ \text{m}}{0.50\ \text{m}} = 0.23\ \text{N}$$

$$(F_{1\text{ or }2\text{ on }Q})_y = (F_{1\text{ or }2\text{ on }Q})\sin\alpha = (0.29\ \text{N})\frac{0.30\ \text{m}}{0.50\ \text{m}} = 0.17\ \text{N}$$

$$F_x = 0.23\ \text{N} + 0.23\ \text{N} = 0.46\ \text{N}$$

$$F_y = 0.17\ \text{N} - 0.17\ \text{N} = 0$$

The total force on Q is in the +x-direction, with magnitude 0.46 N.

The electric field vector $\vec{E}$ is tangent to the electric field lines at each point.

متجه المجال الكهربائي $\vec{E}$ مماس لخطوط المجال الكهربائي عند كل نقطة

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

عدد الخطوط لكل وحدة مساحة عبر سطح عمودي على الخطوط يتناسب مع شدة المجال الكهربائي في كل منطقة.

(a) For a positive point charge, the lines radiate outward (away from q).

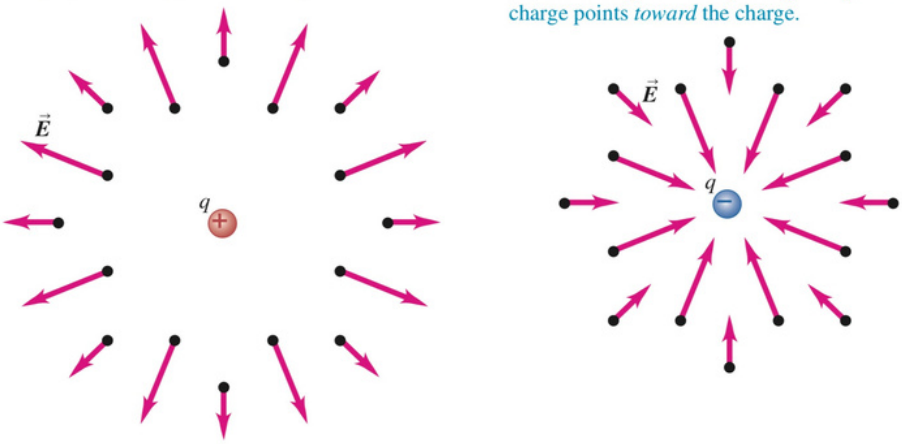
بالنسبة للشحنة النقطية الموجبة، تشع الخطوط للخارج (بعيدا عن q).

(b) For a negative point charge, the lines converge inward (toward q).

بالنسبة للشحنة النقطية السالبة، تتقارب الخطوط للداخل (باتجاه q).

(a) The field produced by a positive point charge points *away from* the charge.

(b) The field produced by a negative point charge points *toward* the charge.



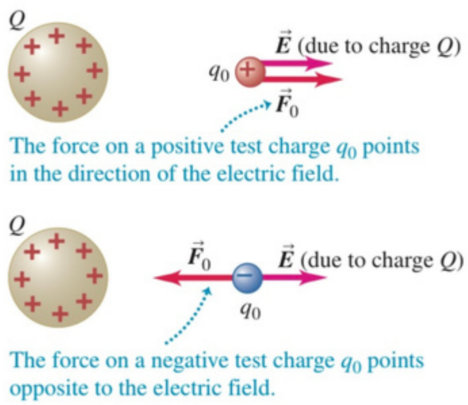
21.4 Electric Field and Electric Forces

The electric force on a charged body is exerted by the electric field created by *other* charged bodies.

تمارس القوة الكهربائية على جسم مشحون بواسطة المجال الكهربائي الناتج عن أجسام مشحونة أخرى.

$$E = \frac{F}{q_o} \qquad E = \frac{1}{4\pi\varepsilon_0}\frac{|q|}{r^2}$$

Figure 21.16 The force $\vec{F}_0 = q_0\vec{E}$ exerted on a point charge q_0 placed in an electric field $\vec{E}$.

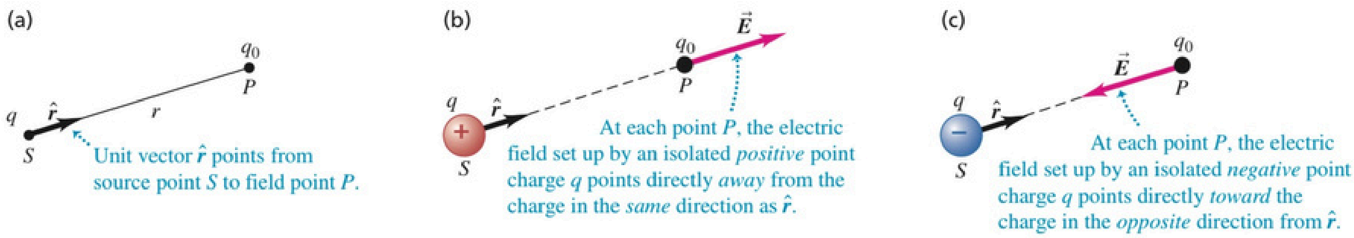


we can write a *vector* equation that gives both the magnitude and direction of the electric field E

يمكن كتابة معادلة متجهة تعطي كلاً من مقدار واتجاه المجال الكهربائي E

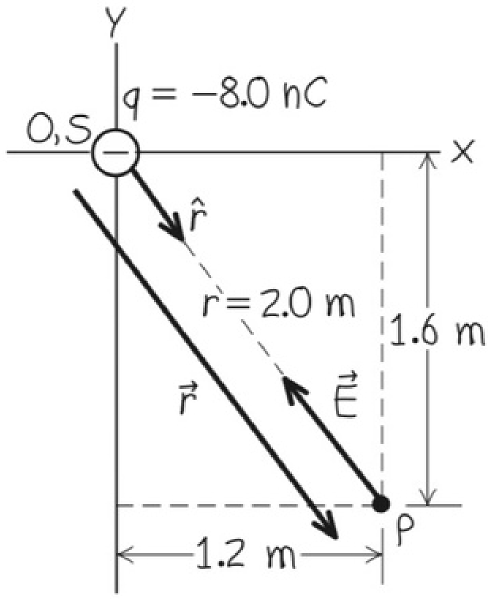
$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

Figure 21.17 The electric field $\vec{E}$ produced at point P by an isolated point charge q at S. Note that in both (b) and (c), $\vec{E}$ is *produced* by q [see Eq. (21.7)] but *acts* on the charge q_0 at point P [see Eq. (21.4)].



Example 21.6 Electric-field vector for a point charge

A point charge q = -8.0 nC is located at the origin. Find the electric-field vector at the field point x = 1.2 m, y = -1.6 m.



$$r = \sqrt{x^2 + y^2}$$

$$= \sqrt{(1.2\text{ m})^2 + (-1.6\text{ m})^2}$$

$$= 2.0\text{ m}$$

$$\hat{r} = \frac{\vec{r}}{r} = \frac{x\hat{\imath} + y\hat{\jmath}}{r} = \frac{(1.2\text{ m})\hat{\imath} + (-1.6\text{ m})\hat{\jmath}}{2.0\text{ m}} = 0.60\hat{\imath} - 0.80\hat{\jmath}$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

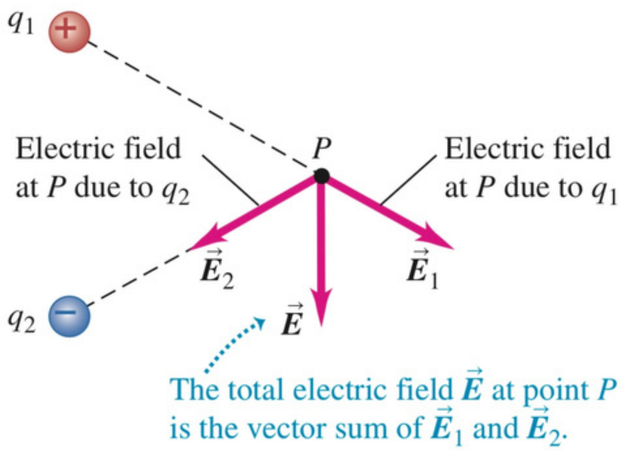
$$= (9.0 \times 10^9\text{ N} \bullet \text{m}^2/\text{C}^2)\frac{(-8.0 \times 10^{-9}\text{ C})}{(2.0\text{ m})^2}(0.60\hat{\imath} - 0.80\hat{\jmath})$$

$$= (-11\text{ N/C})\hat{\imath} + (14\text{ N/C})\hat{\jmath}$$

21.5 Electric-Field Calculations

Principle of superposition of electric fields: The total electric field at a point *P* is the vector sum of the fields at *P* due to each point charge in the charge distribution.

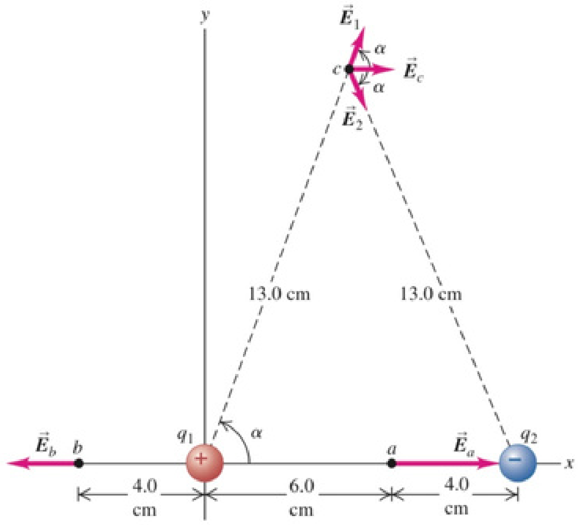
مبدأ تراكب المجالات الكهربائية: المجال الكهربائي الكلي عند نقطة P هو المجموع المتجهي للمجالات عند P الناتجة عن كل شحنة نقطية في توزيع الشحنة



$$\vec{E} = \frac{F_o}{q_o} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \ldots..$$

Example 21.8 Field of an electric dipole

Point charges $q_1 = +12$ nC and $q_2 = -12$ nC are 0.100 m apart (**Fig. 21.22**). (Such pairs of point charges with equal magnitude and opposite sign are called electric dipoles.) Compute the electric field caused by q_1, the field caused by q_2, and the total field (a) at point a; (b) at point b; and (c) at point c.



$$E_{1a} = \frac{1}{4\pi\varepsilon_0}\frac{|q_1|}{r^2}$$

$$= (9.0 \times 10^9\ \mathrm{N \cdot m^2/C^2})\frac{12 \times 10^{-9}\ \mathrm{C}}{(0.060\ \mathrm{m})^2} = 3.0 \times 10^4\ \mathrm{N/C}$$

We calculate the other field magnitude in a similar way. The results are

$$E_{1a} = 3.0 \times 10^4\ \mathrm{N/C}$$
$$E_{1b} = 6.8 \times 10^4\ \mathrm{N/C}$$
$$E_{1c} = 6.39 \times 10^3\ \mathrm{N/C}$$
$$E_{2a} = 6.8 \times 10^4\ \mathrm{N/C}$$
$$E_{2b} = 0.55 \times 10^4\ \mathrm{N/C}$$
$$E_{2c} = E_{1c} = 6.39 \times 10^3\ \mathrm{N/C}$$

(a)

$$E_a = E_{1a}\hat{\imath} + E_{2a}\hat{\imath} = (9.8 \times 10^4\ \text{N/C})\hat{\imath}$$

(b)

$$E_b = -E_{1b}\hat{\imath} + E_{2b}\hat{\imath} = (-6.2 \times 10^4\ \text{N/C})\hat{\imath}$$

(c)

$$E_{1cx} = E_{2cx} = E_{1c}\cos\alpha = (6.39 \times 10^3\ \text{N/C})\left(\frac{5}{13}\right)$$

$$= 2.46 \times 10^3\ \text{N/C}$$

From symmentry, E_{1y} and E_{2y} are equal and opposite, so their sum is zero. Hence

$$E_c = 2(2.46 \times 10^3\ \text{N/C})\hat{\imath} = (4.9 \times 10^3\ \text{N/C})\hat{\imath}$$

If a charge Q is uniformly distributed throughout a volume V, the volume charge density is defined by:

إذا تم توزيع الشحنة Q بشكل موحد عبر الحجم V، فإن يتم تحديد كثافة شحنة الحجم من خلال:

$$\rho = \frac{Q}{V}$$

the unit of ρ is (C/m^3)

وحدة ρ هي(C/m^3)

If a charge Q is uniformly distributed on a surface of area A, the surface charge density is defined by:

إذا تم توزيع الشحنة Q بشكل موحد على سطح المنطقة A، فإن يتم تحديد كثافة الشحنة السطحية من خلال:

$$\sigma = \frac{Q}{A}$$

the unit of σ is (C/m^2)

وحدة σ هي(C/m^2)

If a charge Q is uniformly distributed along a line of length L, the linear charge density is defined by:

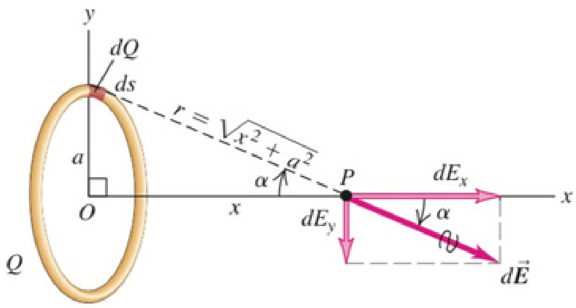
إذا تم توزيع الشحنة Q بشكل موحد على طول خط الطول L، فإن يتم تحديد كثافة الشحنة الخطية من خلال:

$$\lambda = \frac{Q}{L}$$

the unit of λ is (C/m)

وحدة λ هي(C/m)

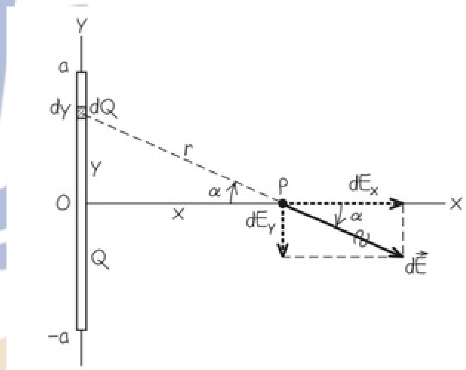
Example 21.9 Field of ring of charge



$$E = \frac{1}{4\pi\varepsilon_0}\frac{Qx}{(x^2 + a^2)^{3/2}}\hat{\imath}$$

If $x >> a$; $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{x^2}\hat{\imath}$

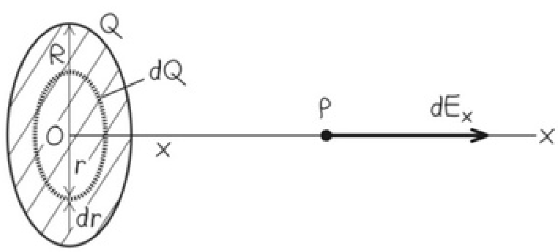
Example 21.10 Field of a charged line segment



$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{x\sqrt{x^2 + a^2}}\hat{\imath}$$

If $a >> x$; $E = \frac{\lambda}{2\pi\varepsilon_0 x}\hat{\imath}$

Example 21.10 Field of a uniformly charged disk



$$E = \frac{1}{2\varepsilon_0}\left[1 - \frac{1}{\sqrt{(R^2/x^2) + 1}}\right]$$

If $R >> x$; $E = \frac{\sigma}{2\varepsilon_0}$

21.6 Electric Field Lines

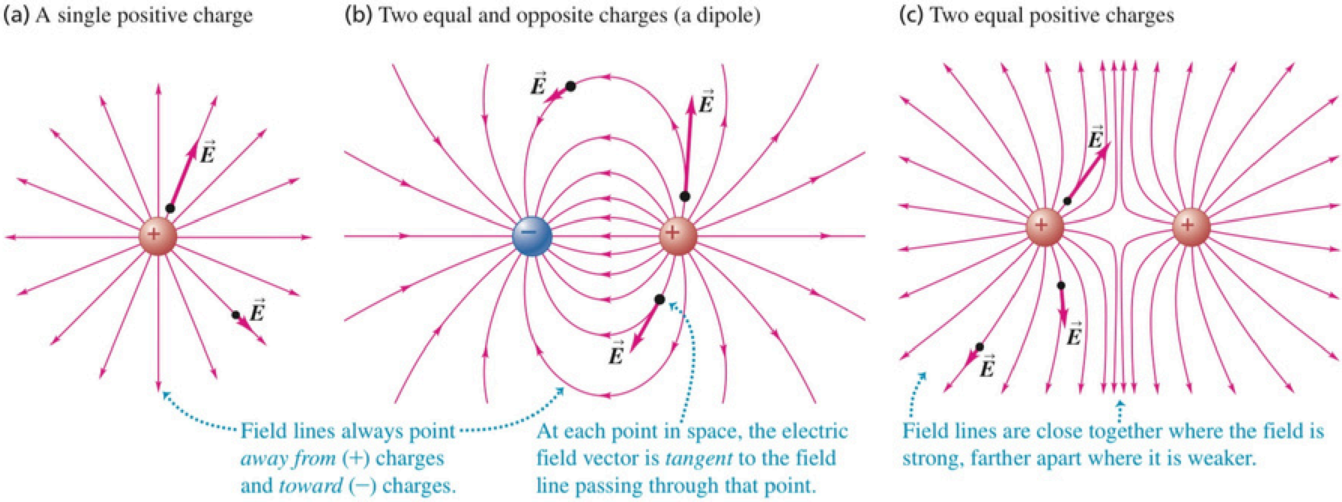
The number of lines that begin at the positive charge must equal the number that terminate at the negative charge.

يجب ان يساوي عدد الخطوط التي تبدأ عند الشحنة الموجبة عدد الخطوط التي تنتهي عند الشحنة السالبة

The same number of lines emerges from each charge because the charges are equal in magnitude.

يظهر نفس عدد الخطوط من كل شحنة لأن الشحنات متساوية في المقدار

Figure **21.28** Electric field lines for three different charge distributions. In general, the magnitude of $\vec{E}$ is different at different points along a given field line.



21.7 Electric Dipoles

An **electric dipole** is a pair of point charges having equal but opposite sign and separated by a distance.

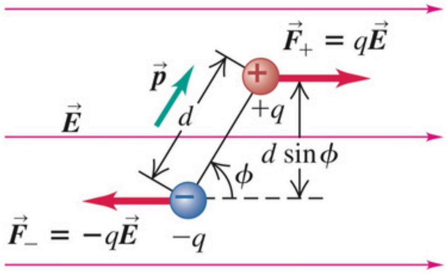
ثنائي القطب الكهربائي هو زوج من الشحنات النقطية لهما نفس الإشارة ولكن متعاكستان وتفصل بينهما مسافة

$$p = qd$$

the unit of p are (C • m)

وحدة p هي (C • m)

Figure **21.31** The net force on this electric dipole is zero, but there is a torque directed into the page that tends to rotate the dipole clockwise.



The net force on an electric dipole in a uniform external electric field is zero

القوة المحصلة المؤثرة على ثنائي القطب الكهربائي في مجال كهربائي خارجي منتظم تساوي صفرا

Torque on an Electric Dipole:

عزم الدوران على ثنائي القطب الكهربائي

$$\tau = qEd \sin\theta \qquad \tau = pE \sin\theta \qquad \vec{\tau} = \vec{p} \times \vec{E}$$

Potential energy for an Electric Dipole:

الطاقة الكامنة لثنائي القطب الكهربائي

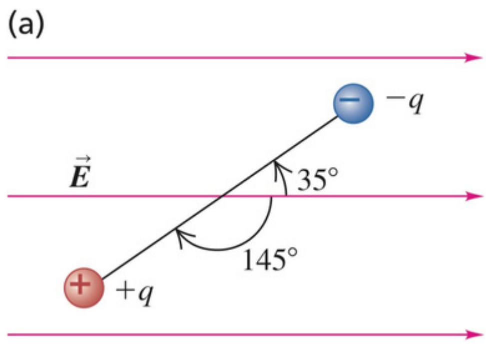
$$U = -\vec{p} \cdot \vec{E}$$

Example 21.13 Force and torque on an electric dipole

Figure 21.32a(next page) shows an electric dipole in a uniform electric field of magnitude 5.0×10^5 N/C that is directed parallel to the plane of the figure. The charges are $\pm 1.6 \times 10^{-19}$ C; both lie in the plane and are separated by 0.125 nm = 0.125×10^{-9} m. Find (a) the net force exerted by the field on the dipole; (b) the magnitude and direction of the electric dipole moment; (c) the magnitude and direction of the torque; (d) the potential energy of the system in the position shown.

(a)

The field is uniform, so the forces on the two charges are equal and opposite sign. Hence the total force on the dipole is zero



(b)

$$p = qd = (1.6 \times 10^{-19}\ \text{C})(0.125 \times 10^{-9}\ \text{m})$$
$$= 2.0 \times 10^{-29}\ \text{C} \bullet \text{m}$$

(c)

$$\tau = pE \sin \theta = (2.0 \times 10^{-29}\ \text{C} \bullet \text{m})(5.0 \times 10^5\ \text{N/C})(\sin 145^\circ)$$
$$= 5.7 \times 10^{-24}\ \text{N} \bullet \text{m}$$

(d)

$$U = -pE \cos \theta$$
$$= -(2.0 \times 10^{-29}\ \text{C} \bullet \text{m})(5.0 \times 10^5\ \text{N/C})(\cos 145^\circ)$$
$$= 8.2 \times 10^{-24}\ \text{J}$$

ARMS
ACADEMY

GENERAL PHYSICS

Chapter 23

استثمر في تعليمك اليومٍ ،لتحصد ثمار ذلك غداً

Our Groups