PHY122

Chapter 1 Electric Charge

1.1 Static Electricity
1.2 Electric Charge
1.3 Conductor and Insulators
1.4 Coulomb Law

1.1 Static Electricity

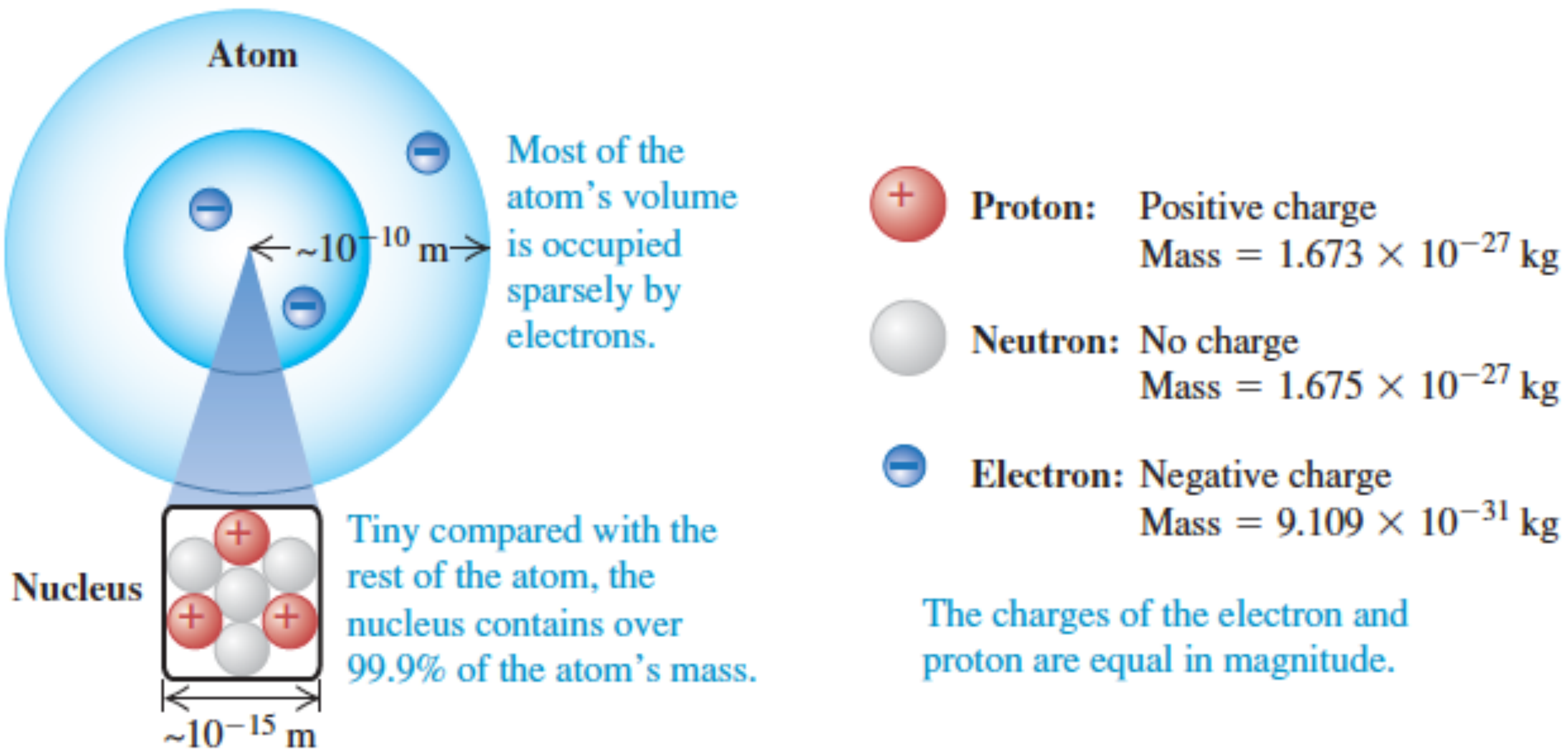
- Electricity is a familiar term
- Modern life depends on electricity

- We all know what electricty does !

Some funny examples ☺

1.1 Static Electricity

Where does static electricity come from ?



Triboelectricity: Charging by friction

Materials tend to take electron
→ More negative

Materials tend to give electron
→ More positive

1.1 Static Electricity

Electrostatic precipitator

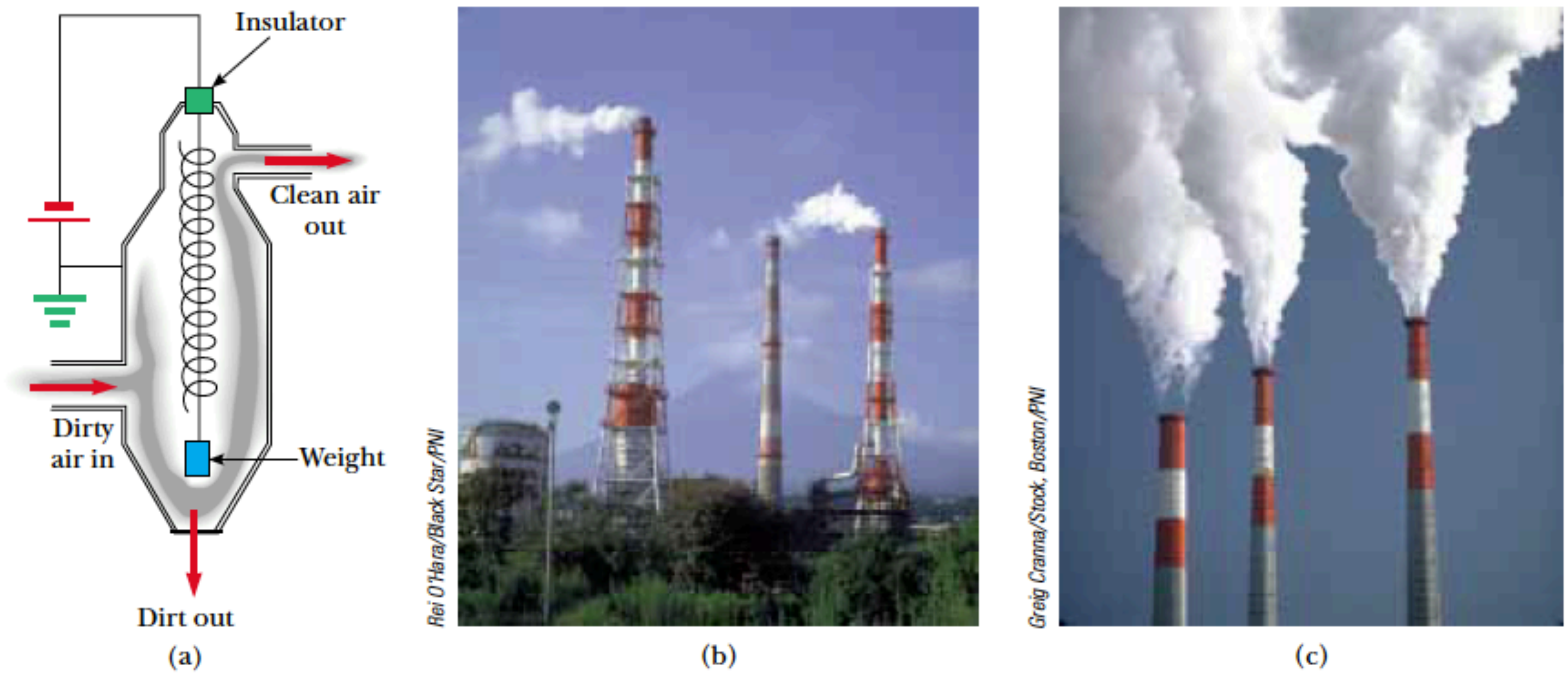
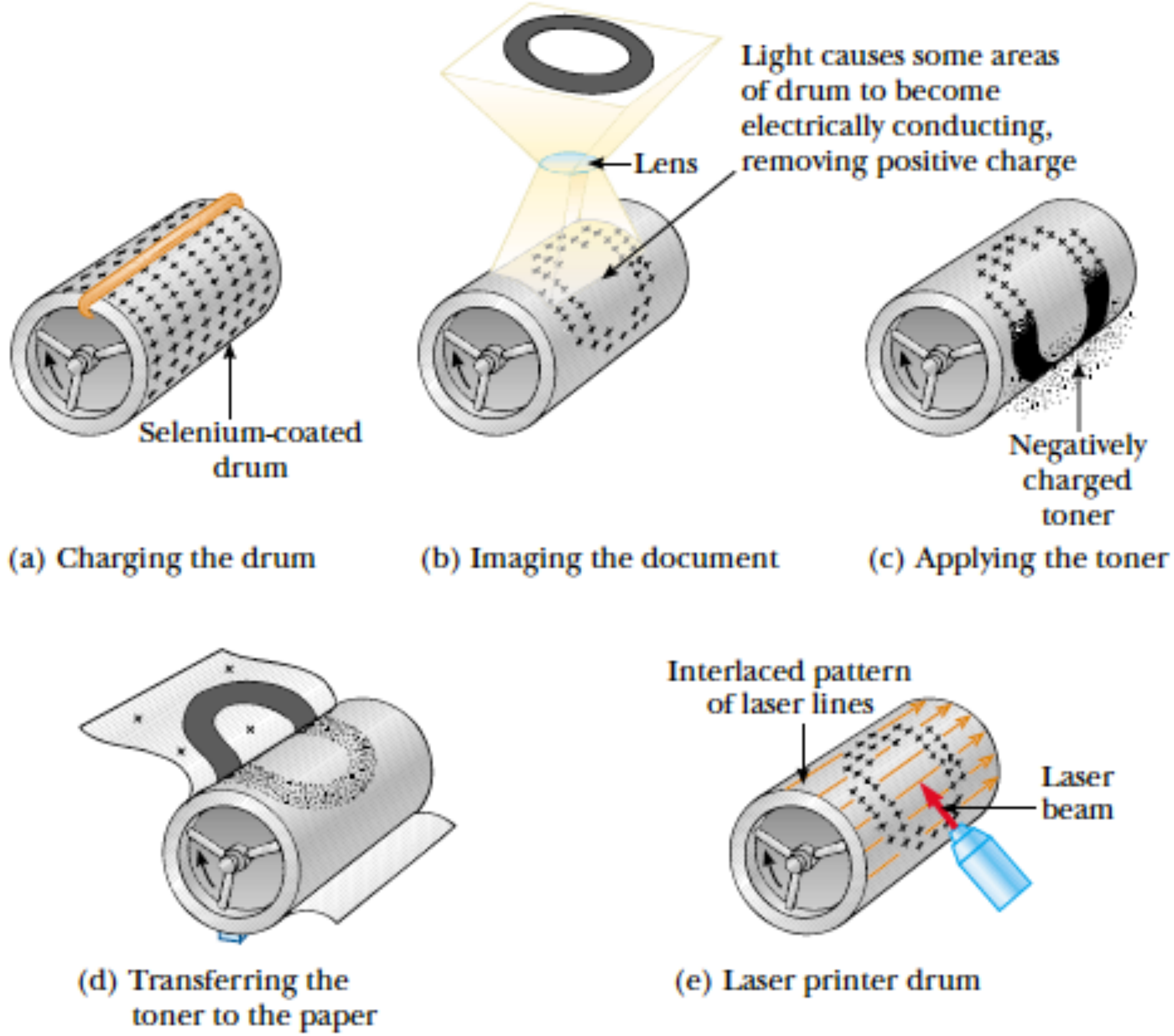


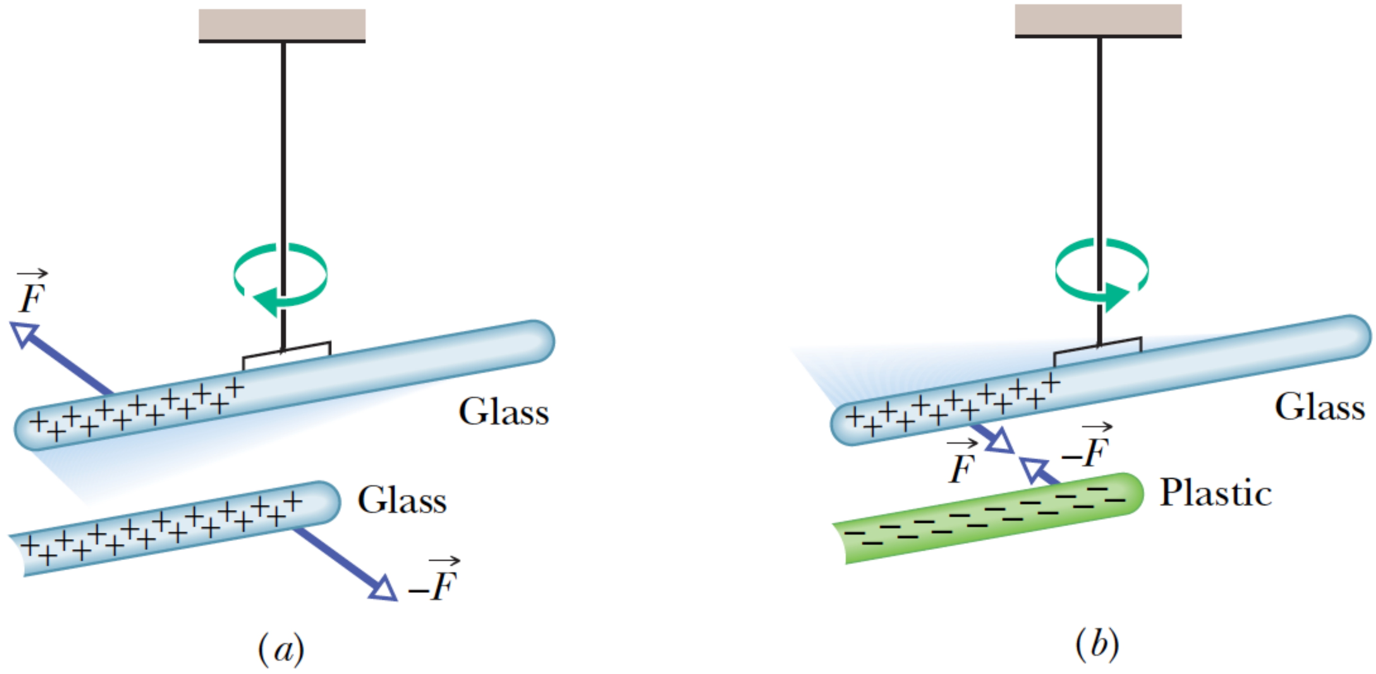
Figure 25.30 (a) Schematic diagram of an electrostatic precipitator. The high negative electric potential maintained on the central coiled wire creates a corona discharge in the vicinity of the wire. Compare the air pollution when the electrostatic precipitator is (b) operating and (c) turned off.

Photocopy or laser printing.



It can be used to spray a car with paint.

1.2 Electric Charge



- There are two type of charge in nature: Positive and negative
- Charges with the same electrical sign repel each other, and charges with opposite electrical signs attract each other.
- Electric charge is quantized (Milikan experiment)
- Electric charge is conserved.

The magnitude of charge

The smallest unit of charge *e* known in nature is the charge on an electron.

The SI unit of charge is the coulomb (C).

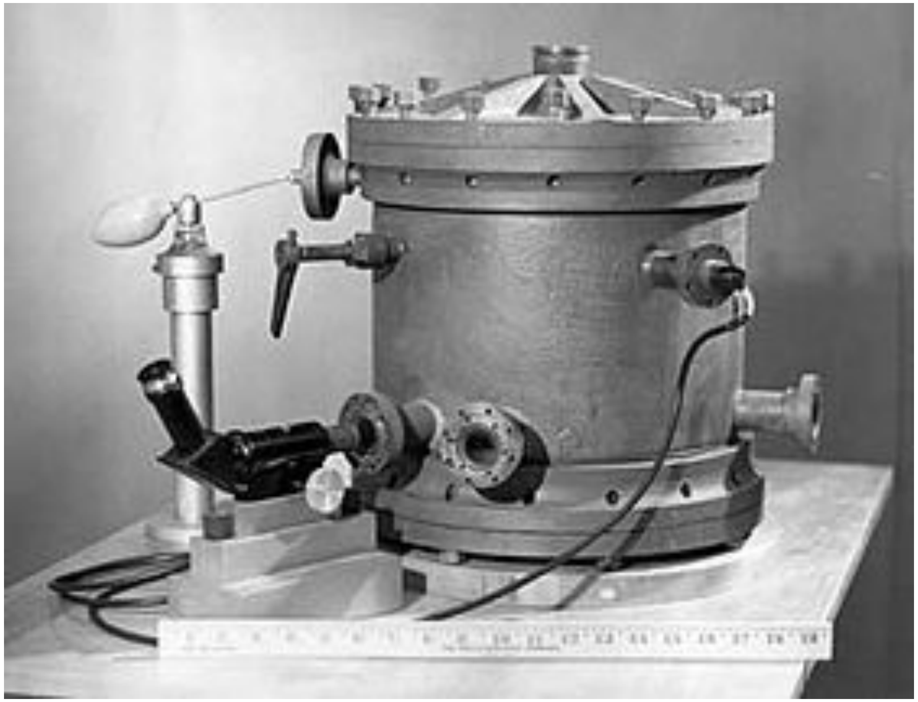
The magnitude of charge on one electron is:

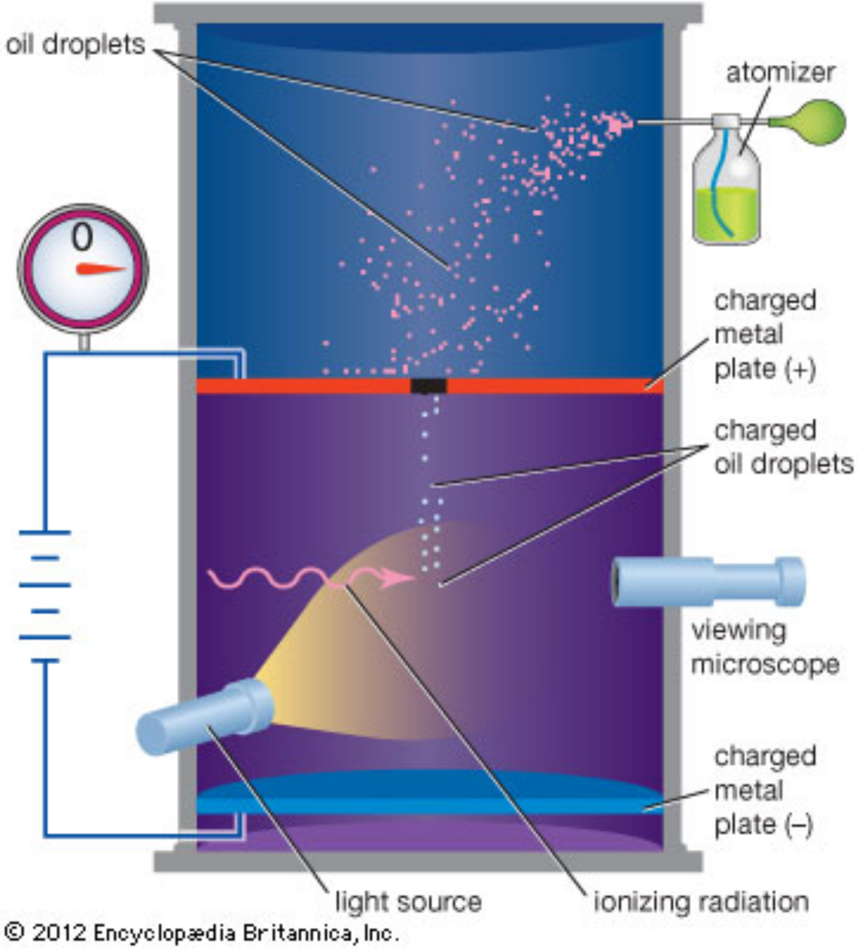
$$e = 1.6x10^{-19}\,C$$

Table 23.1

Charge and Mass of the Electron, Proton, and Neutron		
Particle	**Charge (C)**	**Mass (kg)**
Electron (e)	$-1.602\,191\,7 \times 10^{-19}$	$9.109\,5 \times 10^{-31}$
Proton (p)	$+1.602\,191\,7 \times 10^{-19}$	$1.672\,61 \times 10^{-27}$
Neutron (n)	0	$1.674\,92 \times 10^{-27}$

- Electric charge is quantized (Milikan experiment)





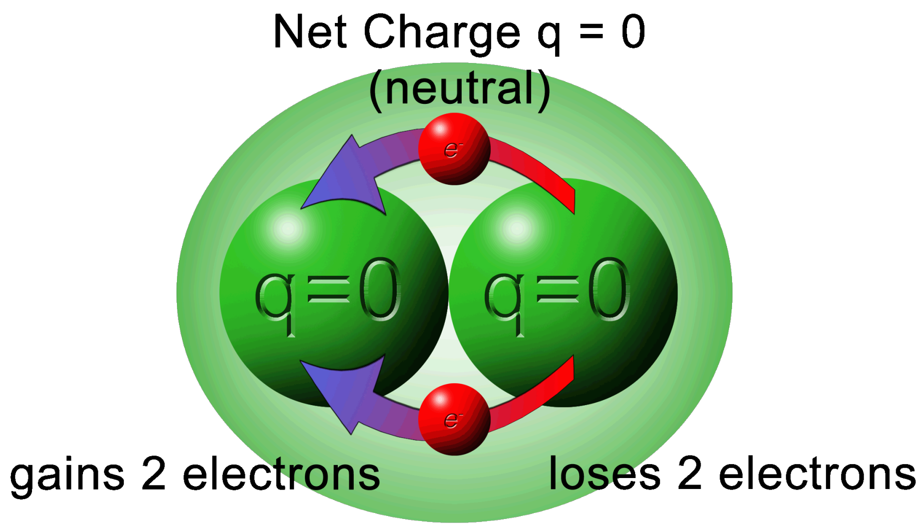
1.5 Charge is Quantized

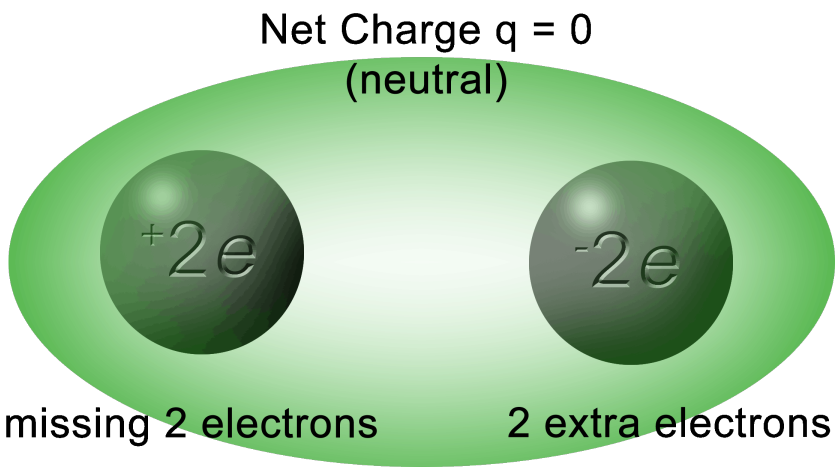
R. Milikan
1923 Nobel Price

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

$$e = 1.6x10^{-19} C$$

- **Electric charge is conserved.**





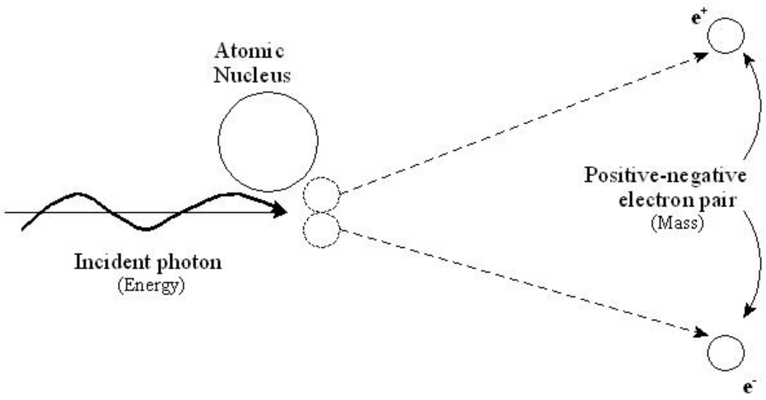
1.2 Electric Charge

A nuclear reaction:

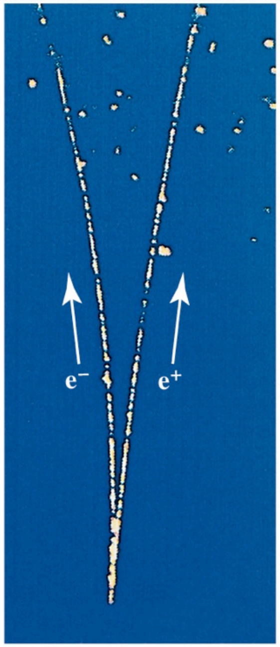
$$n + {}^{235}_{92}U \rightarrow {}^{143}_{56}Ba + {}^{90}_{36}Kr + 3n + energy$$

The number of protons on two side f reactions are 92 !

Pair production



$$\gamma \rightarrow e^{-} + e^{+}$$



1.2 Electric Charge

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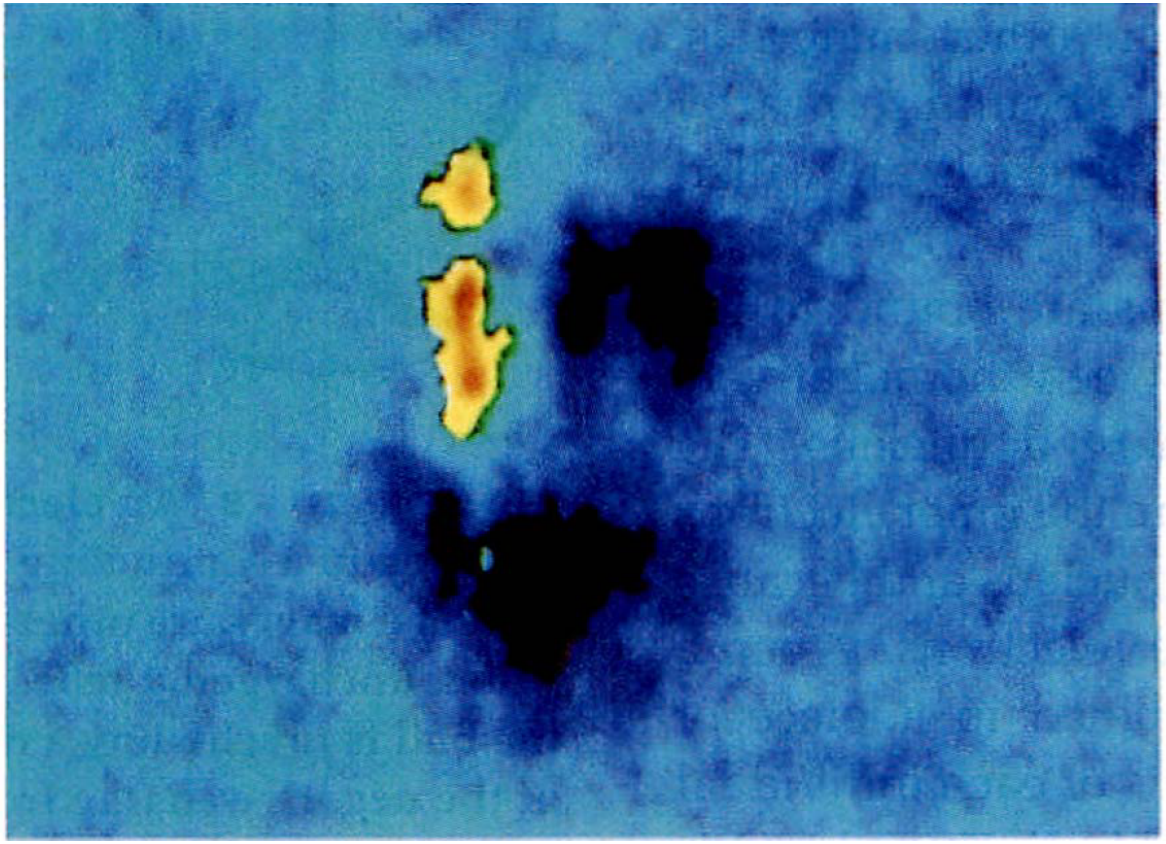
1.2 Electric Charge



A piece of plastic was charged by contact with a piece of nickel. Although the plastic carries a net positive charge, regions of negative charge (dark) as well as regions of positive charge (yellow) are indicated. The photograph was taken by sweeping a charged needle of width 10^{-7} m over the sample and recording the electrostatic force on the needle.

Example:

A glass rod is charged by friction with a silk. If the total charge on glass is +110 nC, how many electrons are transferd from glass to silk ?

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Answer:

The number of electrons, transferd from glass to silk= net charge / e

$$N = Q / e$$

$$N = (110x10^{-9}C) / (1.6x10^{-19}C / electrons)$$

$$N = 6.9x10^{11} electrons$$

Example:

A copper piece has a mass of 3 grams. What is the total charge of all electrons in the copper piece ? (Atomic mass of copper is 29 and molecular mass of it is MA_{cu}=63.5 g/mol)

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Answer:

The number of copper atoms in 3 g of copper

$$N_{Cu} = 3g\frac{6.02x10^{23}}{63.5g/mol} = 2.84x10^{22}\,atoms$$

The number of electrons N_e:

$$N_e = ZN_{Cu} = 29x(2.84x10^{22}\,atoms) = 8.24x10^{23}\,electrons$$

The total charge is the number of electrons times the electron charge

$$Q = N_e(-e) = (8.24x10^{23}\,electrons).(-1.6x10^{-19}\,C/electrons)$$

$$Q = -1.32x10^{5}\,C$$

1.3 Conductors and Insulators

•**Conductors:**

These are materials through which charge can move rather freely.
Examples: metals like Cu, the human body, tap water…

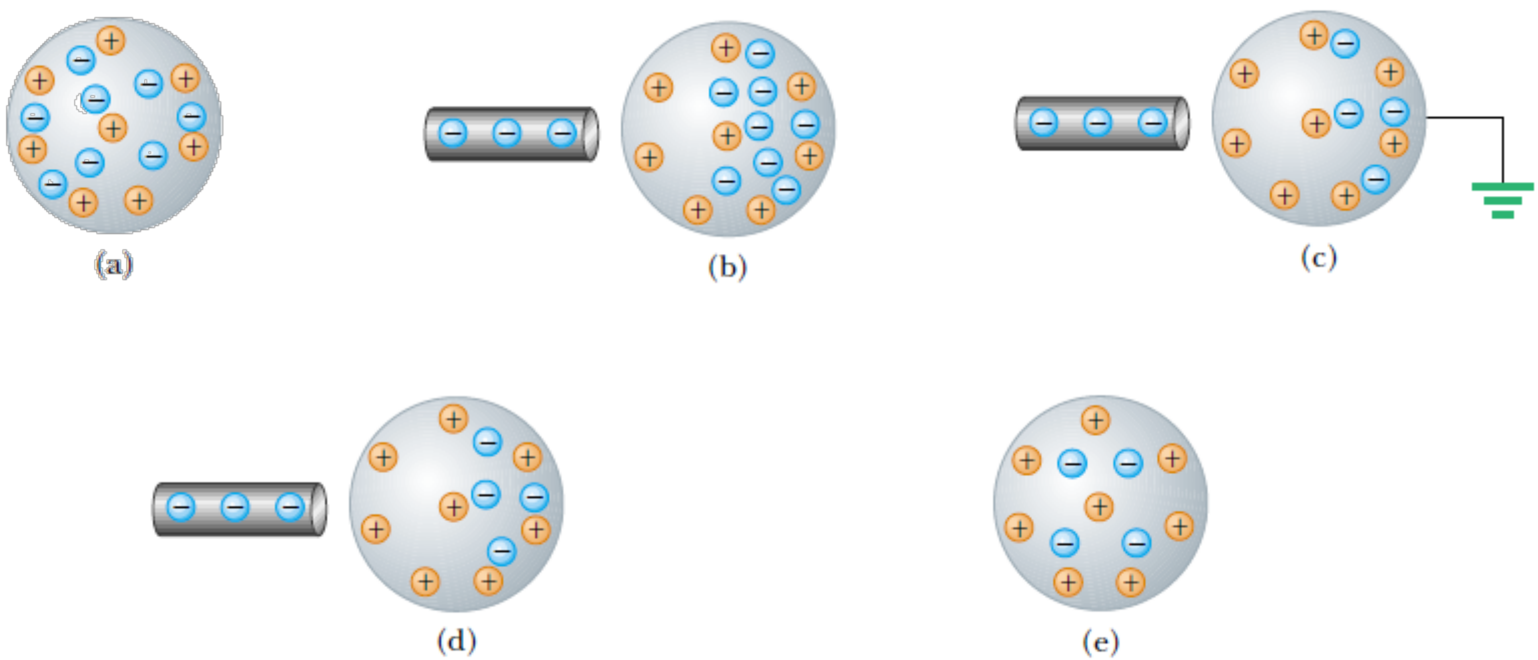
•**Insulators**

These are materials through which charge cannot move freely.
Examples: Glass, wood, plastic…

•**Semiconductors**

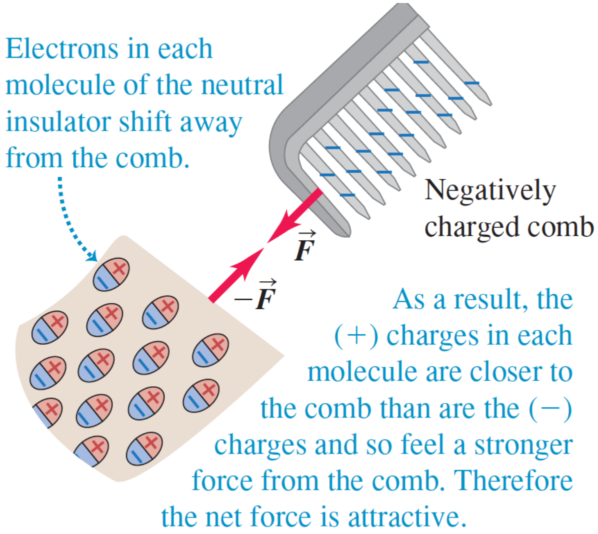
These are materials that are intermediate between conductors and insulators.
They are very important for our electronic world. Examples: Si, Ge, GaAs...

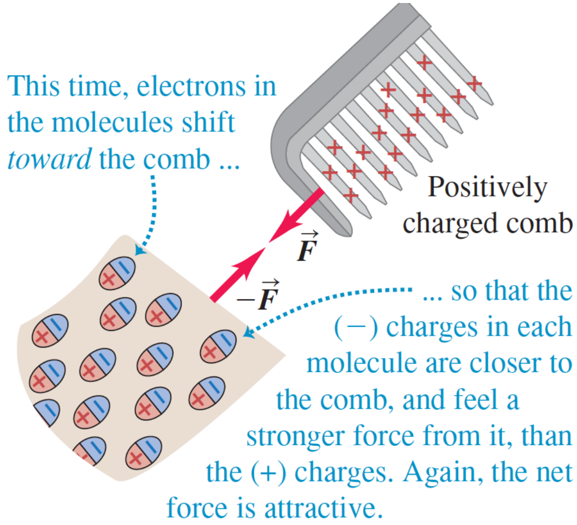
Charging Objects By Induction for Conductors



(a) A neutral metallic sphere, with equal numbers of positive and negative charges. (b) The electrons on the neutral sphere are redistributed when a charged rubber rod is placed near the sphere. (c) When the sphere is grounded, some of its electrons leave through the ground wire. (d) When the ground connection is removed, the sphere has excess positive charge that is nonuniformly distributed. (e) When the rod is removed, the remaining electrons redistribute uniformly and there is a net uniform distribution of positive charge on the sphere.

Charging Objects By Induction for Insulators





Example:

Two identical conducting spheres, one with an initial charge + Q, the other initially uncharged, are brought into contact.

(a) What is the new charge on each sphere?

(b) While the spheres are in contact, a negatively charged rod is moved close to one sphere, causing it to have a charge of +2Q. What is the charge on the other sphere?

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Answer:

(a) +1/2Q. Since the spheres are identical, they must share the total charge equally.

(b) -Q, which is necessary to satisfy the conservation of charge

Example:

Two uncharged metal spheres are in contact. A positively charged rod is brought near one of the spheres.

(a) Show the distribution of charge on each spheres schematically.

(b) When the rod is removed and the spheres are far apart, show the distribution of charge on each sphere schematically.

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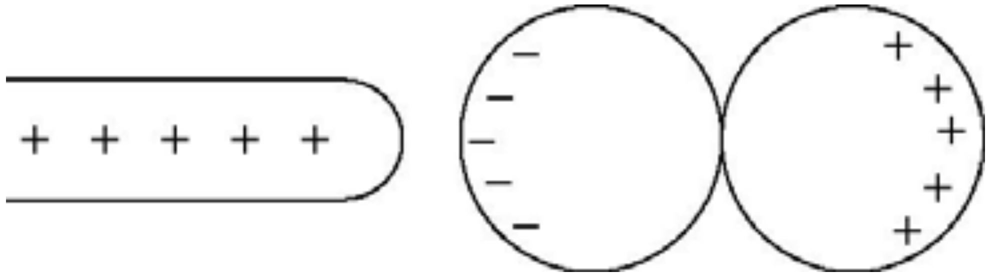
Answer:



Homework 1:

Two identical spheres are charged by induction and then separated; sphere 1 has charge +Q and sphere 2 has charge -Q. A third identical sphere is initially uncharged. If sphere 3 is touched to sphere 1 and separated, then touched to sphere 2 and separated, what is the final charge on each of the three spheres?

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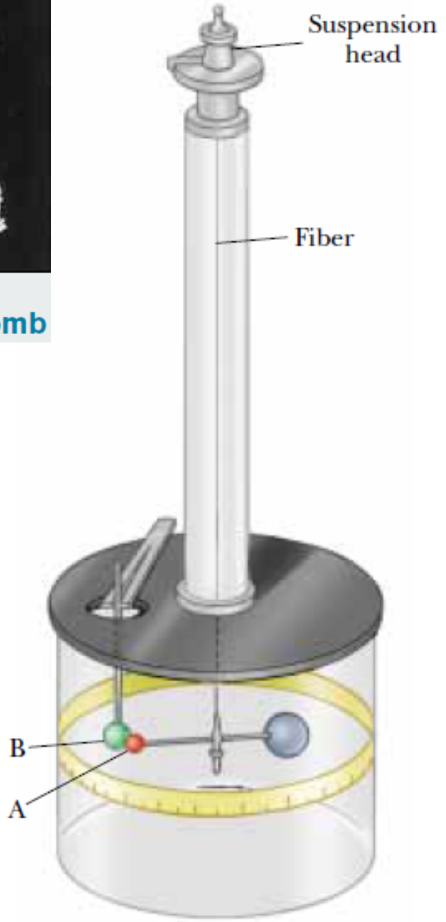
Two identical spheres are charged by induction and then separated; sphere 1 has charge +Q and sphere 2 has charge -Q. A third identical sphere is initially uncharged. If sphere 3 is touched to sphere 1 and separated, then touched to sphere 2 and separated, what is the final charge on each of the three spheres?

Answer of Homework 1:

$Q_1=+Q/2$, $Q_2=-Q/4$ $Q_3=-Q/4$

1.4 Coulomb Law

Charles Coulomb



Experimental observation of Coulomb

(1) The force exerted by one point charge on another acts along the line between the charges and it varies inversely as the square of the distance separating the charges

(2) it is proportional to the product of the charges

(3) The force is repulsive if the charges have the same sign and attractive if the charges have opposite signs.

1.4 Coulomb Law

Mathematical expression of these observation:

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

where k Coulomb constant:

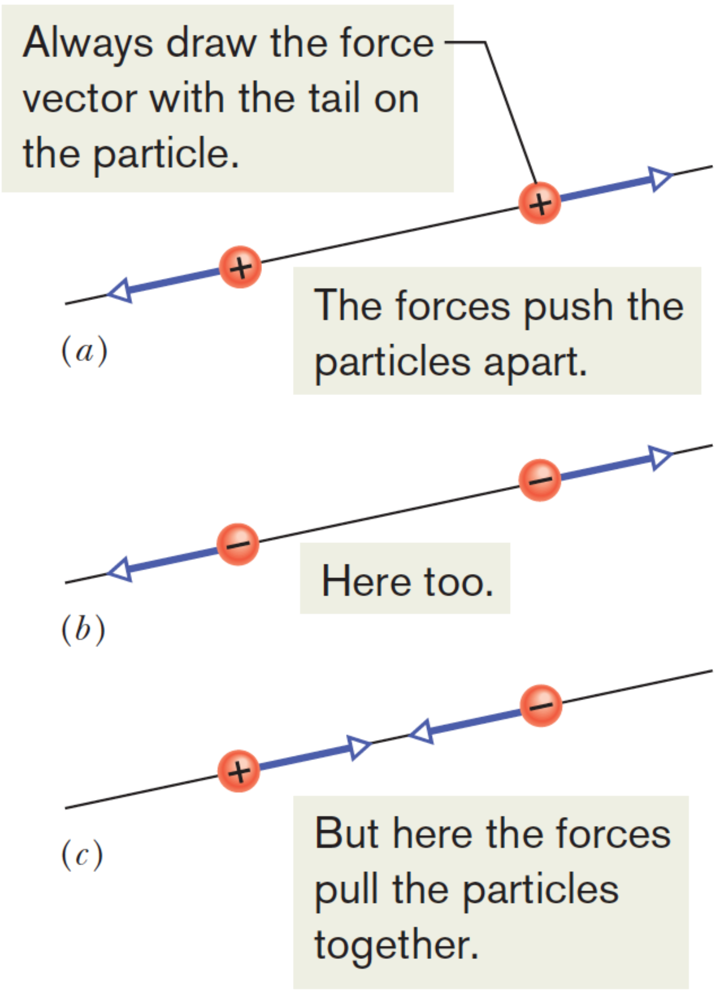
$$k = 8.9875x10^9\, Nm^2 / C^2$$

This constant is also written in the form

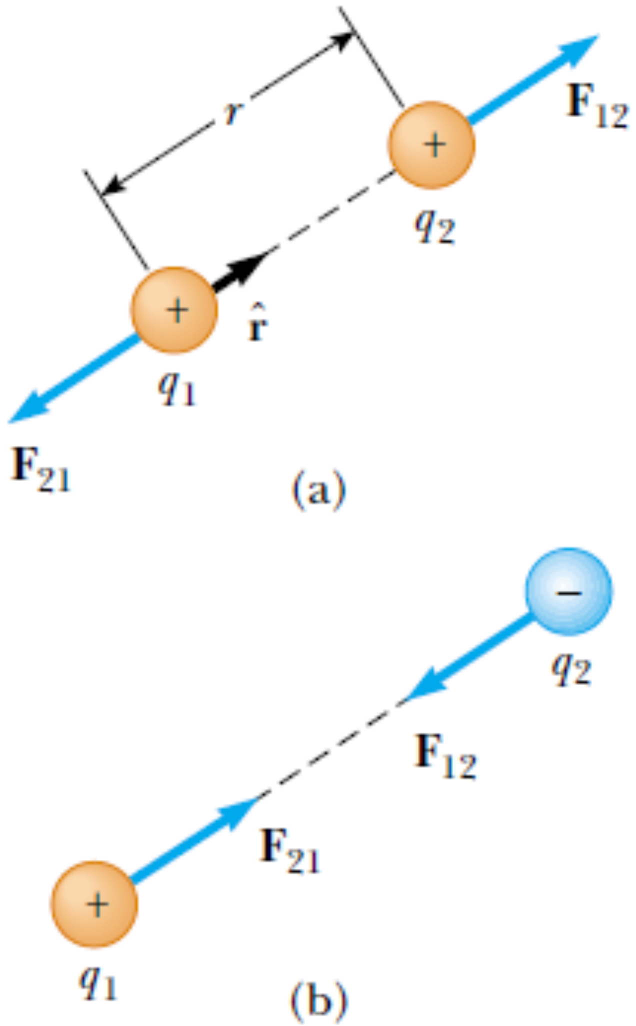
$$k = \frac{1}{4\pi\varepsilon_0}$$

where ε_o

$$\varepsilon_0 = 8.8542x10^{-12}\, C^2 / N.m^2$$



Vector form of Coulomb's law



Vector form of Coulomb law

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

If we have n charged particles, they interact independently in pairs, and the force on any one of them, let us say particle 1, is given by the **vector sum**

$$\vec{F}_{1,net} = \vec{F}_{21} + \vec{F}_{31} + \ldots + \vec{F}_{n1}$$

Example:

The electron and proton of a hydrogen atom are separated (on the average) by a distance of approximately 5.3×10^{-11} m. Find the magnitudes of the electric force and the gravitational force between the two particles

1.4 Coulomb Law

Example:

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Answer:

The magnitude of the electric force is

$$F_e = k\frac{q_1 q_2}{r^2} = (8.9 \ldots \frac{\ldots 10^{-19}C)^2}{\ldots 10^{-11}m)^2} = 8.2x10^{-8}N$$

$$\frac{F_e}{F_g} \approx 2x10^{39}$$

The magnitude of the gravitatio…

$$F_g = G\frac{m_1 m_2}{r^2} = (6.67x10^{-11}Nm^2/kg^2)\frac{(9.11x10^{-31}kg).(1.67x10^{-27}kg)}{(5.3x10^{-11}m)^2} = 3.6x10^{-47}N$$

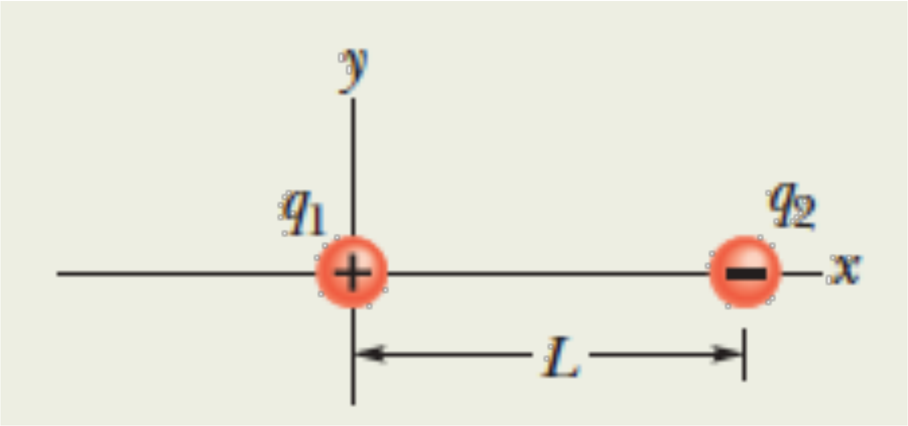
Example:

Two identical conducting spheres, one carrying charge q and the other carrying charge 3q, are initially held a distance d apart. The spheres are allowed to touch briefly and then returned to separation distance d. Is the magnitude of the force they exert on each other after the touching greater than, smaller than, or the same as the magnitude of the force they exerted on each other before the touching?

Discussion:

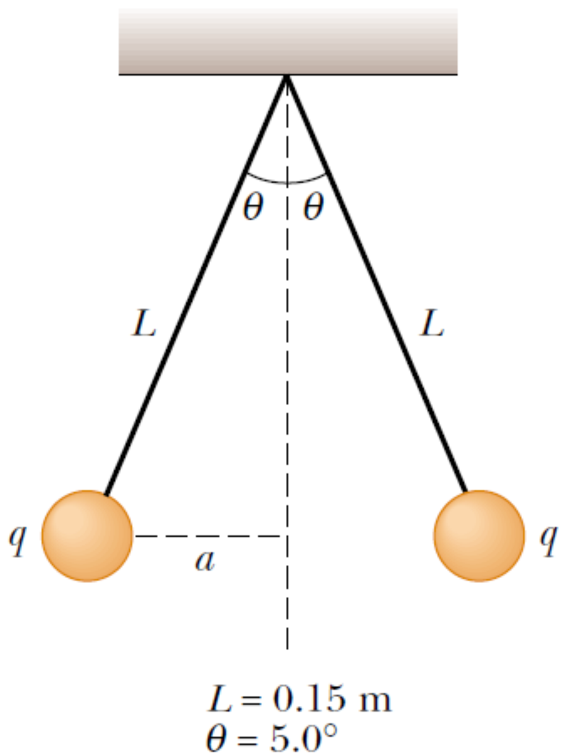
Homework 2:

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?)



Homework 3:

Two identical small charged spheres, each having a mass of 3.0×10^{-2} kg, hang in equilibrium as shown in figure below. The length of each string is 0.15 m, and the angle θ is 5.0°. Find the magnitude of the charge on each sphere.

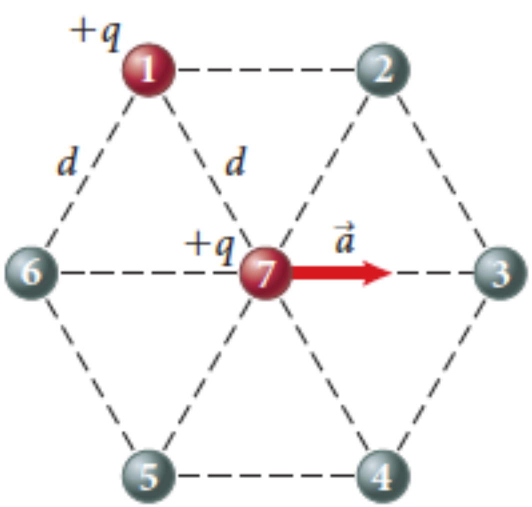


Homework 4:

Seven small metal spheres are arranged in a hexagonal pattern as illustrated in Figure below. Spheres 1 and 7 carry equal amounts of positive charge; the other spheres are uncharged.

(a) To give sphere 7 an acceleration **a** that points to the right, what (single) other sphere must be charged? There may be more than one possibility.

(b) What are the sign and magnitude of that charge?



SUMMARY

•Elektrik yükleri aşağıdaki özelliklere sahiptir:
✓Zıt işaretli yükler birbirini çekerken, aynı işaretli yükler birbirini iter
✓İzole bir sistemde yük korunumludur
✓Yük kuantumlanmıştır
✓Doğadaki en küçük yük elemanter yük olarak bilinir ve değeri

$$e=1.6\times10^{-19}\ C$$

•Elektrik yüklerin hareket kabiliyetine göre malzemeler sınıflandırılabilir
✓İletkenlerde elektronlar rahatça hareket edebilir.
✓Yalıtkanlar elektronların hareket etmekte zorlandıkları malzemelerdir

•Coulomb yasası iki yük arasındaki elektrik kuvvetini ifade eder

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