Imam Abdulrahman Bin Faisal University
College of Computer Science & IT
Department of CS
Term 2191

جامعة الإمام عبدالرحمن بن فيصل
IMAM ABDULRAHMAN BIN FAISAL UNIVERSITY

Welcome
to
PHYS 212: Physics

Chapter#21

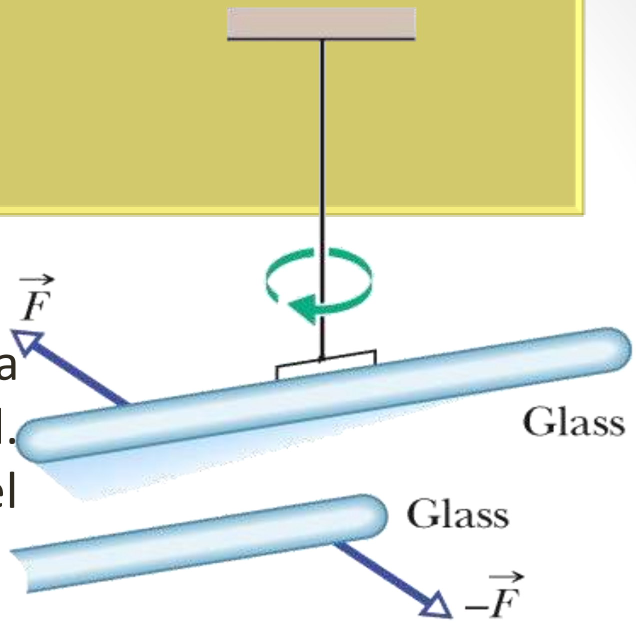
Coulomb's Law

Topics

- Electric Charge
- Conductors & Insulators
- Coulomb's Law
- Charge is Quantized

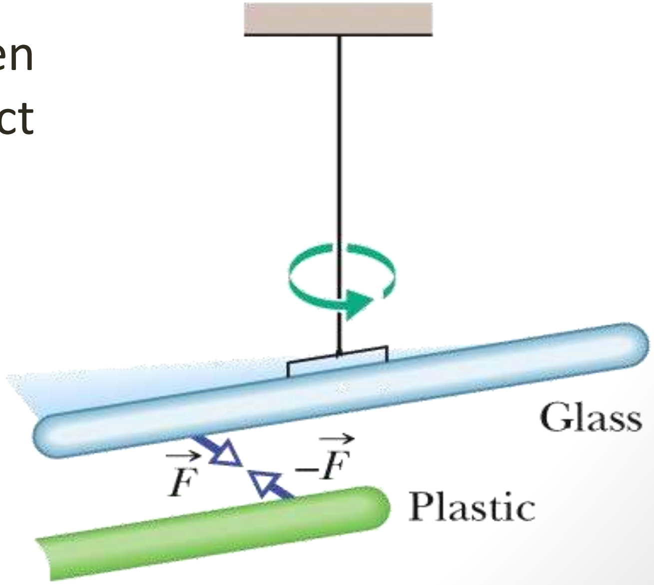
Electric charge

(a) The two glass rods were each rubbed with a silk cloth and one was suspended by thread. When they are close to each other, they repel each other.

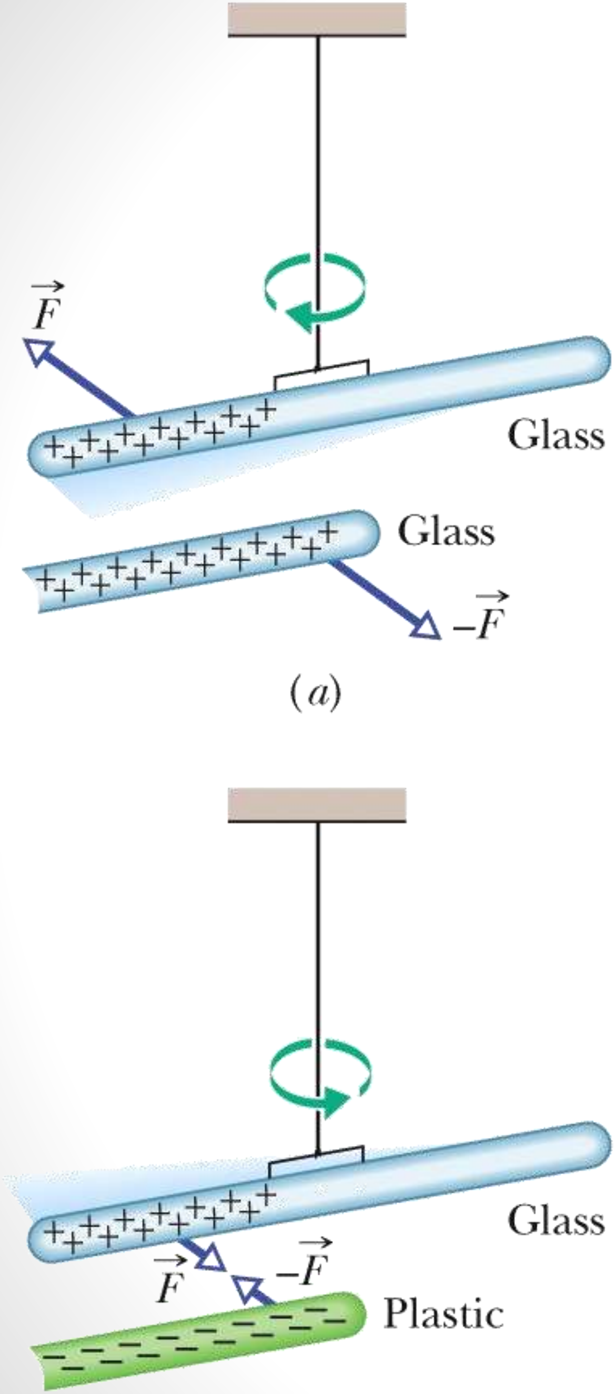


(*a*)

(b) The plastic rod was rubbed with fur. When brought close to the glass rod, the rods attract each other.



8/30/2023



(a) Two charged rods of the same sign repel each other.

(b) Two charged rods of opposite signs attract each other. Plus signs indicate a positive net charge, and minus signs indicate a negative net charge.

- 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.

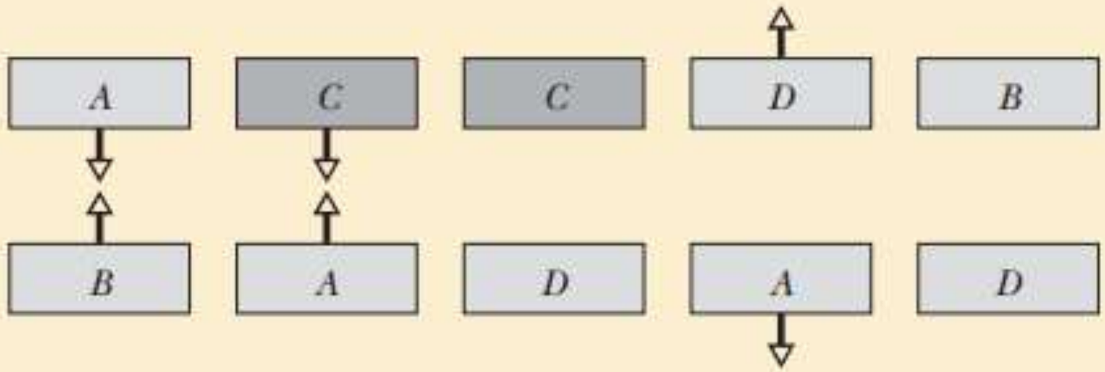
- In a series of simple experiments, it was found that there are two kinds of electric charges, which were given the names positive and negative by Benjamin Franklin (1706–1790).

- On the basis of these observations, we conclude that:-

  charges of the same sign repel each other and charges with opposite signs attract each other.

Checkpoint 1

The figure shows five pairs of plates: A, B, and D are charged plastic plates and C is an electrically neutral copper plate. The electrostatic forces between the pairs of plates are shown for three of the pairs. For the remaining two pairs, do the plates repel or attract each other?



Application

- Attractive electric forces are responsible for the behavior of a wide variety of commercial products.
- For example, the plastic in many contact lenses, is made up of molecules that electrically attract the protein molecules in human tears. These protein molecules are absorbed and held by the plastic so that the lens does not behave as a foreign object to the wearer’s eye, and it can be worn comfortably.

Conductors & Insulators

<u>**Materials classified based on their ability to move charge**</u>

- **Conductors** are materials in which a significant number of electrons are free to move. Examples include metals [Fe, Cu, Al etc.]

- The charged particles in nonconductors (**insulators**) are not free to move. Examples include rubber, plastic, glass, etc.

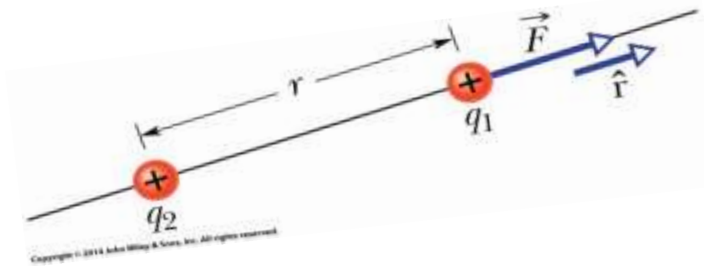
- **Semiconductors** are materials that are intermediate between conductors and insulators; examples include silicon [Si] and germanium [Ge] in computer chips.

- **Superconductors** are materials that are perfect conductors, allowing charge to move without any difficulty. Examples are Mercury [Hg], Lead [Pb] etc.

Coulomb's Law

- Coulomb's law describes the **electrostatic force** (or **electric force**) between two charged particles. If the particles have charges q_1 and q_2, are separated by distance r, and are at rest (or moving only slowly) relative to each other, then the magnitude of the force acting on each due to the other is given by

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



where $\boldsymbol{\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N.m^2}$ is the permittivity constant.
The ratio $1/4\pi\varepsilon_0$ is often replaced with the electrostatic constant (or Coulomb constant)
$\boldsymbol{k = 8.99\times10^{9}\ N.m^2/C^2}$ Thus $\boldsymbol{k = 1/4\pi\varepsilon_0}$

Problem-1:

A particle of charge $+3.00 \times 10^{-6}$ C is 12.0 cm distant from a second particle of charge -1.50×10^{-6} C. Calculate the magnitude of the electrostatic force between the particles.

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

Answer:

$$F = 2.81\,\mathrm{N}$$

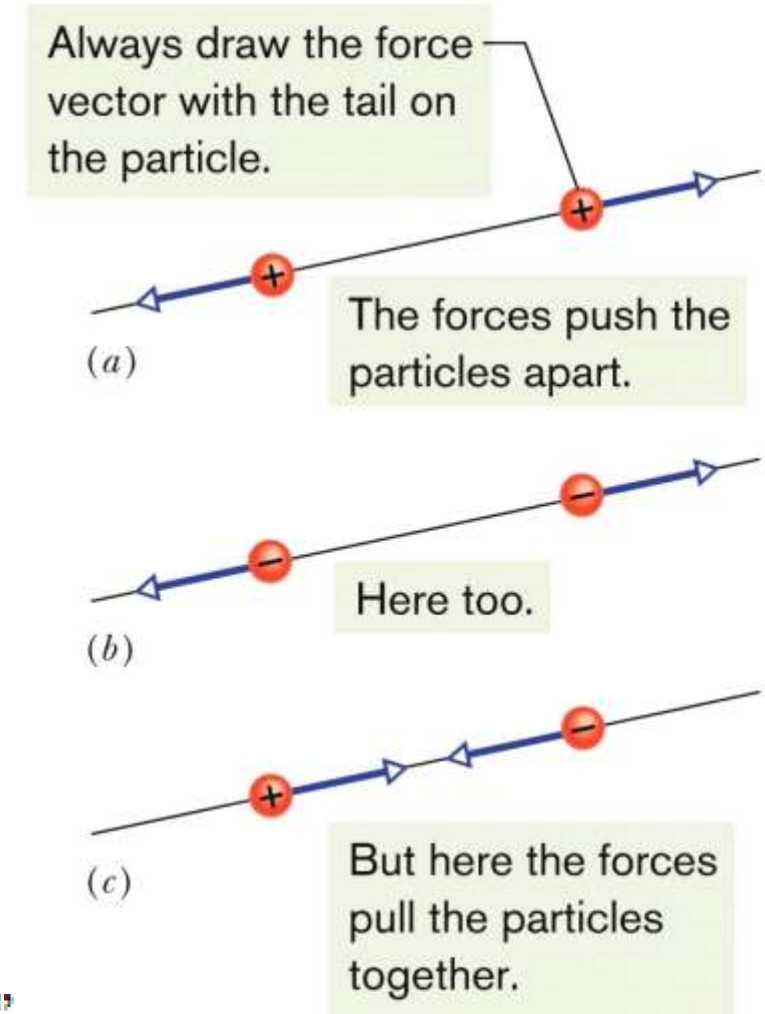
8/30/2023

Coulomb's Law

- The electrostatic force vector acting on a charged particle due to a second charged particle is either directly toward the second particle (opposite signs of charge) or directly away from it (same sign of charge).

- If multiple electrostatic forces act on a particle, the net force is the **vector sum** (not **scalar sum**) of the individual forces.

$$\vec{F}_{1,\text{net}} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \vec{F}_{15} + \cdots + \vec{F}_{1n},$$



Two charged particles repel each other if they have the same sign of charge, either (a) both positive or (b) both negative. (c) They attract each other if they have opposite signs of charge.

Problem-4:

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.

Hint:

Newton's law of universal gravitation $F_g = G\frac{m_e m_p}{r^2}$

Where

$G = 6.67 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$

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

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

Answer:

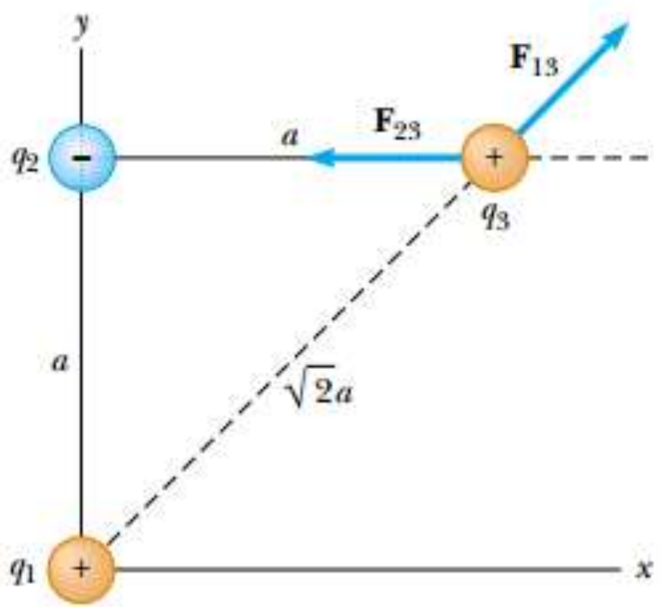
$F_e = 8.2 \times 10^{-8}$ N

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

8/30/2023

Problem-5:

Consider three point charges located at the corners of a right triangle as shown in Fig, here q1 = q3 = 5.0 µC, q2 = -2.0 µC, and a = 0.10 m. **Find the resultant force exerted on q3.**



The force exerted by q_1 on q_3 is $\mathbf{F}_{13}$. The force exerted by q_2 on q_3 is $\mathbf{F}_{23}$. The resultant force $\mathbf{F}_3$ exerted on q_3 is the vector sum $\mathbf{F}_{13} + \mathbf{F}_{23}$.

Solution:

The resultant force $\mathbf{F}_3$ exerted on q_3 is the vector sum $\mathbf{F}_{13} + \mathbf{F}_{23}$.

The magnitude of $\mathbf{F}_{23}$ is

$$F_{23} = 9.0 \text{ N}$$

The magnitude of the force $\mathbf{F}_{13}$ exerted by q_1 on q_3 is

$$F_{13} = 11 \text{ N}$$

The repulsive force $\mathbf{F}_{13}$ makes an angle of 45° with the x axis. Therefore, the x and y components of $\mathbf{F}_{13}$ are equal, with magnitude given by $F_{13} \cos 45° = 7.9$ N.

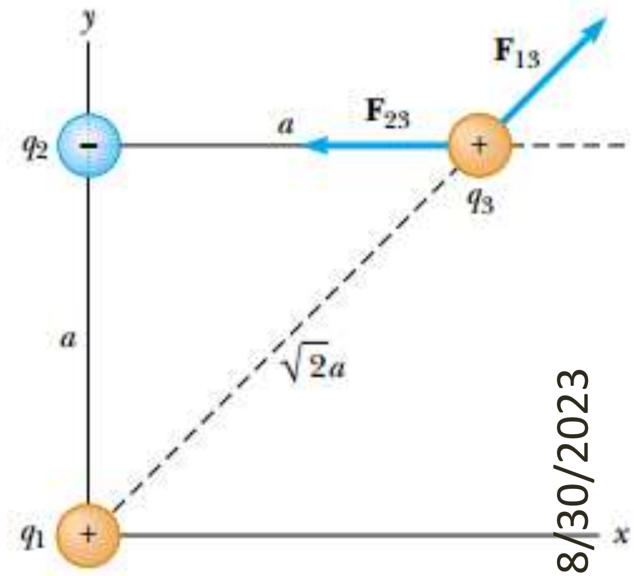
Combining $\mathbf{F}_{13}$ with $\mathbf{F}_{23}$ by the rules of vector addition, we arrive at the x and y components of the resultant force acting on q_3:

$$F_{3x} = F_{13x} + F_{23x} = 7.9 \text{ N} + (-9.0 \text{ N}) = -1.1 \text{ N}$$

$$F_{3y} = F_{13y} + F_{23y} = 7.9 \text{ N} + 0 = 7.9 \text{ N}$$

We can also express the resultant force acting on q_3 in unit-vector form as

$$\mathbf{F}_3 = \boxed{(-1.1\hat{\mathbf{i}} + 7.9\hat{\mathbf{j}}) \text{ N}}$$



Charge is Quantized

- Electric charge is quantized (limited to certain values).

- The charge of a particle can be written as (**ne**), where ***n*** is a positive or negative integer and ***e*** is the elementary charge.
  Any positive or negative charge ***q*** that can be detected can be written as

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

in which ***e***, the elementary charge, has the approximate value

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

Table 21-1 The Charges of Three Particles

Particle	Symbol	Charge
Electron	e or e^-	$-e$
Proton	p	$+e$
Neutron	n	0

8/30/2023

Charge is Quantized

When a physical quantity such as charge can have only discrete values, we say that the quantity is **quantized**.

It is possible, for example, to find a particle that has no charge at all or a charge of *+10e* or *-6e*, but not a particle with a charge of, say, *3.57e*.

Problem-2:

Identical isolated conducting spheres 1 and 2 have equal charges and are separated by a distance that is large compared with their diameters (Fig. 21-22*a*). The electrostatic force acting on sphere 2 due to sphere 1 is *F*. Suppose now that a third identical sphere 3, having an insulating handle and initially neutral, is touched first to sphere 1 (Fig. 21-22*b*), then to sphere 2 (Fig. 21-22*c*), and finally removed (Fig. 21-22*d*). The electrostatic force that now acts on sphere 2 has magnitude *F′*. **What is the ratio *F′*/*F*?**

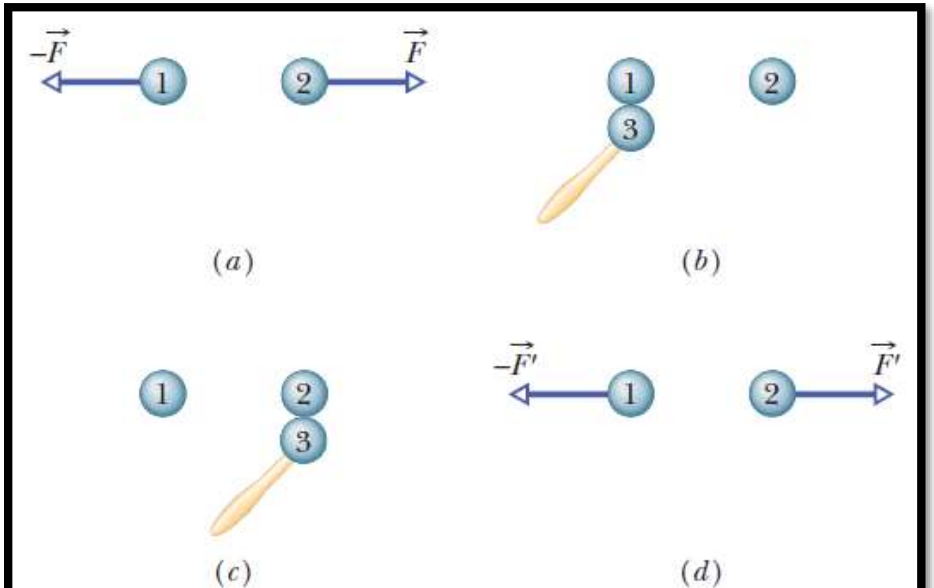
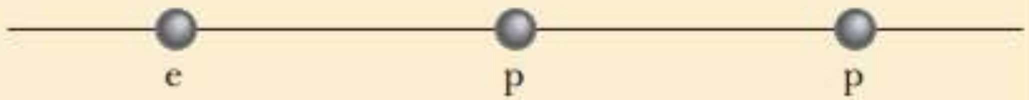


Figure 21-22 Problem 2.

Answer:

$$\frac{F'}{F}=\frac{3}{8}=0.375$$

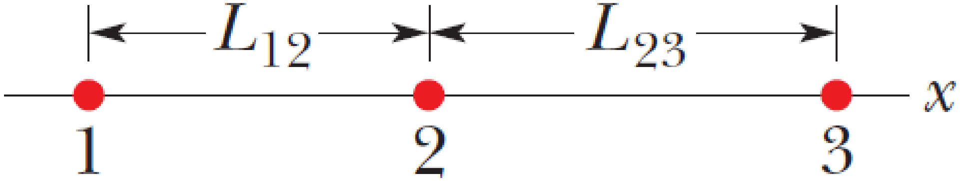
Checkpoint 2



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

Problem-3:

In Figure, three charged particles lie on an *x* axis. Particles 1 and 2 are fixed in place. Particle 3 is free to move, but the net electrostatic force on it from particles 1 and 2 happens to be zero. If $L_{23} = L_{12}$, **what is the ratio q_1/q_2?**



Answer:

$$\frac{q_1}{q_2} = -4.00$$