# Conservation of Electric Charge

Principle of Conservation of Electric Charge

The total electric charge of an isolated system remains constant.

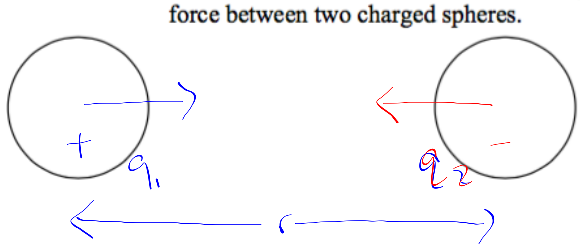
Method of finding final charge

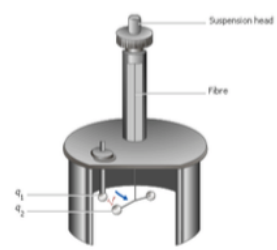
If objects are identical, final charge on each is the average charge (total charge divided by number of objects)

## The Electrostatic Force

Coulomb's torsion balance was used to establish the relationship for the electric force between two charged spheres.

Charles Coulomb
(1736 – 1806)



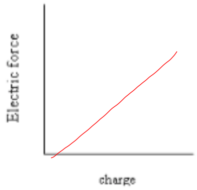



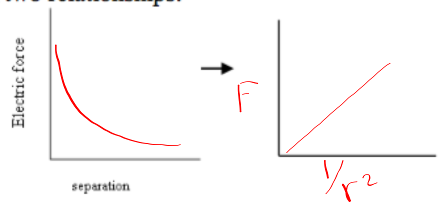

The charged spheres act as if they were *point charges*.

**Point charge:** An object whose charge is concentrated at a single point (r=0)

Coulomb's torsion balance (youtube)

Experimental data showed the following two relationships:




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

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

Electrostatic Constant (Coulomb's constant): $k = 8.99 \times 10^9 \, N\frac{m^2}{c^2}$

Coulomb's Law: The electrostatic force between two charged objects is directly proportional to the product of the two charges and inversely proportional to the square of the distance between their centers and acts along a line joining their centers.

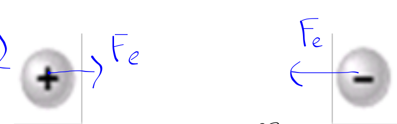
# The Electrostatic Force

1. A proton and an electron are placed $1.0 \times 10^{10}$ meter apart.

   a) Calculate the Coulomb force of attraction between them.

$$F = \frac{8.99 \times 10^9 \, N\frac{m^2}{c^2} (1.6 \times 10^{-19} \, c)(1.6 \times 10^{-19} \, c)}{(10^{-10} \, m)^2}$$

$$\sim 2.3 \times 10^{-8} \, N$$




$$\frac{G M M}{r^2} \quad 10^{-11} \; 10^{-27} \; 10^{-30} \quad (10^{-10})^2 \quad \sim 10^{-48} \, N$$

***NOTE:*** neglect +/- on charges - formula uses magnitude only

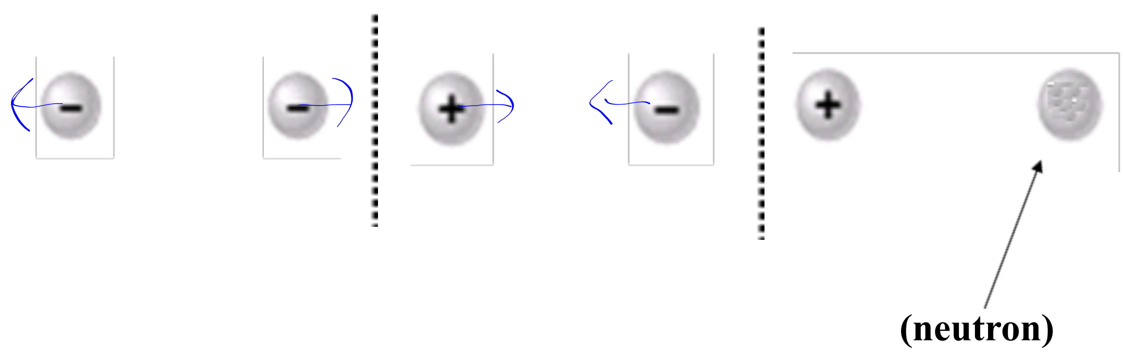
# The Electrostatic Force

1. A proton and an electron are placed 1.0 x $10^{10}$ meter apart.

   b) Calculate the gravitational force of attraction between them.

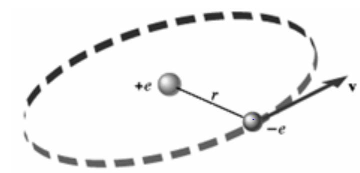
   c) Compare the strengths of the two forces.

2. Sketch the directions of the electrostatic forces and the gravitational forces in each pairing below.



# Coulomb's Laws Practice

3. In the Bohr model of the hydrogen atom, the electron (-e) is in orbit about the nuclear proton (+e) at a radius of r = $5.29\times10^{-11}$ m. Determine the speed of the electron, assuming the orbit to be circular.



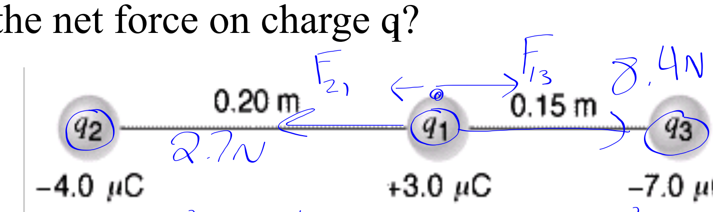

$$\Sigma F = ma$$

$$\frac{KQQ}{r^2} = m\frac{v^2}{r}$$

$$v = \sqrt{\frac{KQQ}{rm}} = 2.2\times10^{6}\ m/s$$

# Coulomb's Laws Practice

4. Three charges are placed along a line at the positions indicated. What is the net force on charge q?




$$\frac{8.99\times10^{9}\ N\frac{m^2}{c^2}\cdot 4\times10^{-6}c\cdot 3\times10^{-6}c}{(.2m)^2}$$

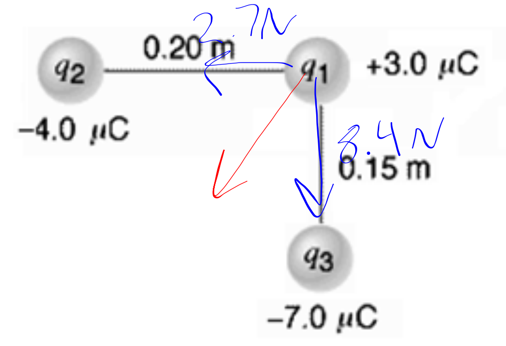
$$\frac{8.99\times10^{9}\ N\frac{m^2}{c^2}\cdot 7\times10^{-6}c\cdot 3\times10^{-6}c}{(.15m)^2}$$

# Coulomb's Laws Practice

5. The three charges are now placed at right angles, as shown. What is the net force on charge q?

$$\Sigma F = \sqrt{(2.7N)^2 + (8.4N)^2}$$

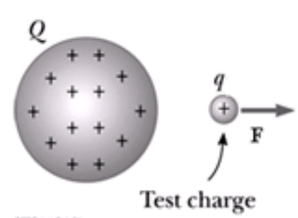
$$= 8.8N$$




# Electric Fields

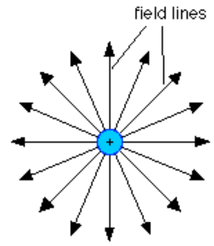
**Electric field:** a region in space surrounding a charged object in which a second charged object experiences an electric force

**Test charge:** a small positive charge used to test electric fields (small enough that its charge does not distort field it's testing)



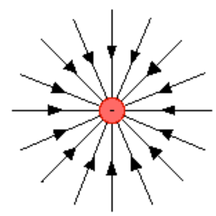
# Electric Field Diagrams

1. Electric field around a positively charged object

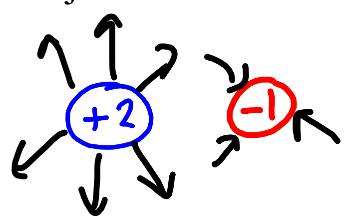



The electric field from an isolated positive charge

2. Electric field around a negatively charged object

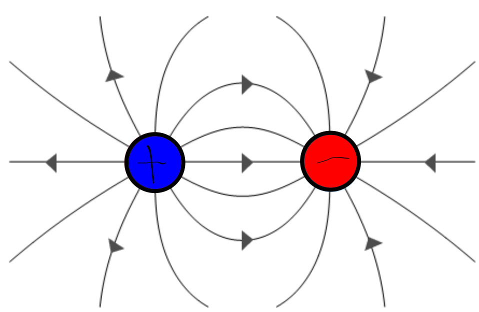



The electric field from an isolated negative charge

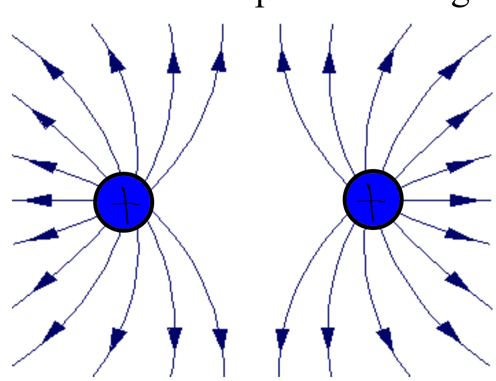



# Electric Field Diagrams

3. Electric field around unlike charges

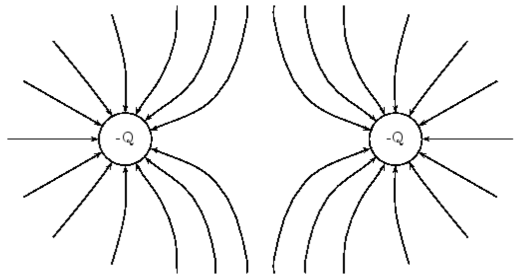


4. Electric field around two positive charges

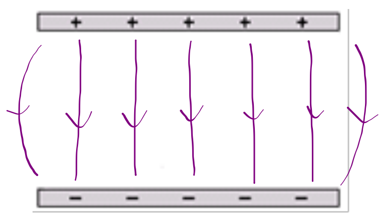


# Electric Field Diagrams

5. Electric field around two negative charges




6. Electric field between two oppositely charged parallel plates




# Electric Field Diagrams

## Properties of Electric Field Lines:

1) They show the direction of the resultant force on a small positive test charge (out of positive, into negative).

2) They never cross since this would indicate that the resultant forceis in two different directions at once.

3) The direction of the electric field at any point is tangent to the field lines.

4) The density of the field lines is proportional to the strength ofthe field (density = intensity). The field is most intense where the field lines are most dense.

# Electric Field Strength

Electric Field Strength (Intensity):

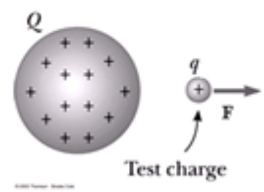
Electric force per unit charge exerted on a small positive test charge

Formula:

$$\vec{E} = \frac{\vec{F}_e}{Q}$$

Alternate Formula for **point charges**:

$$\vec{E} = \frac{F = \frac{KQq}{r^2}}{Q} \qquad \vec{E} = \frac{KQ}{r^2}$$




# Electric Field Strength

| Variable: | $F_e$ | E | $q_1$, $q_2$ |
|---|---|---|---|
| Quantity: | Electrostatics Force | Electric Field | electric charge |
| Units: | [N] | [N/C] | [C] |
| Type: | vector | vector | scalar |

1. What is the magnitude and direction of the electric field at a distance of 7.0 nm from a proton? Sketch a graph of the relationship between electric field strength and distance from the proton.

$$\vec{E} = \frac{KQ}{r^2} = \frac{8.99\times10^{9}\,\frac{Nm^2}{C^2}\;1.6\times10^{-19}\,C}{(7\times10^{-9}\,m)^2}$$

$$2.9\times10^{7}\,N/C$$