OL Academy

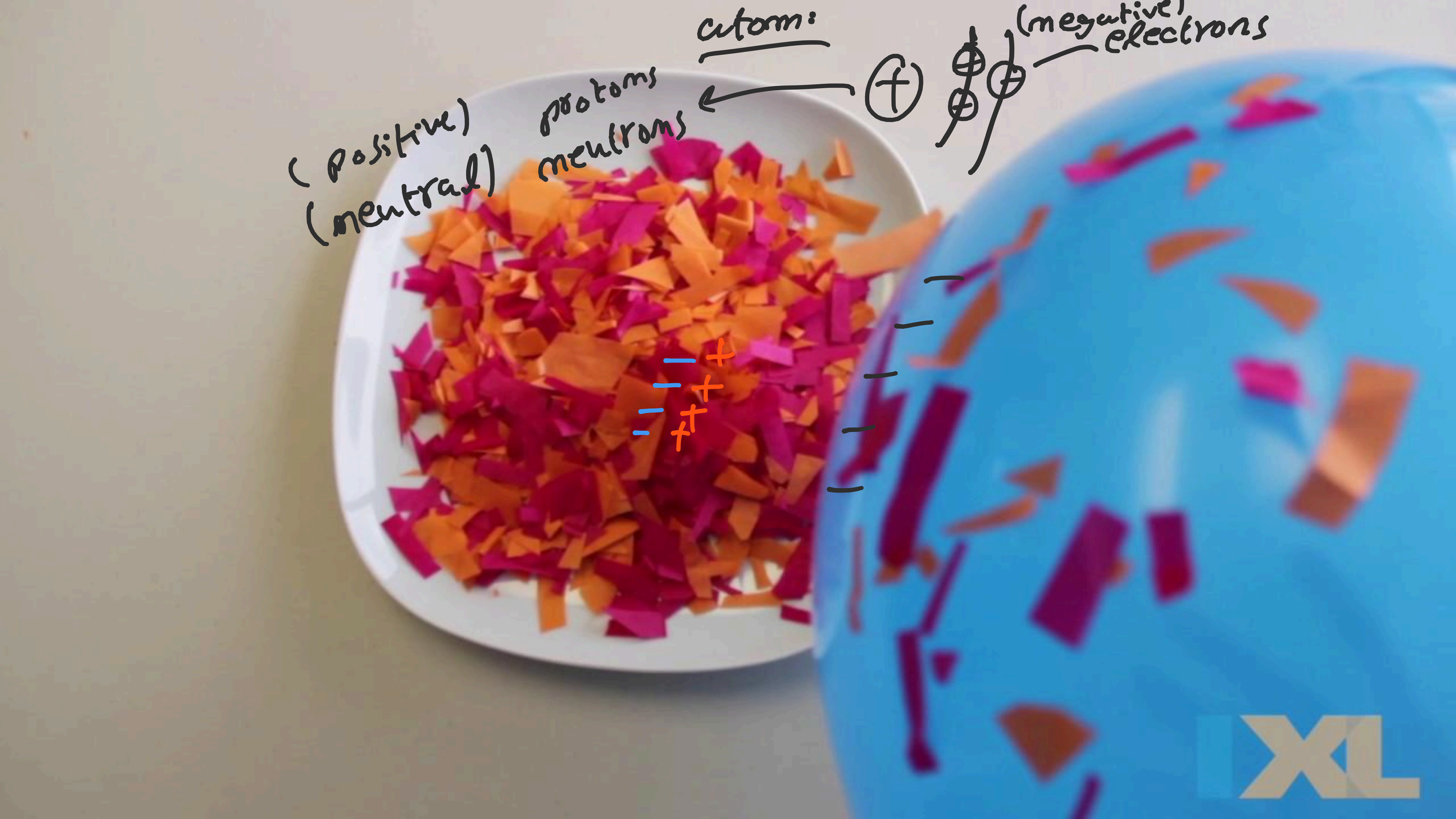
Lesson 1

PHYCS102

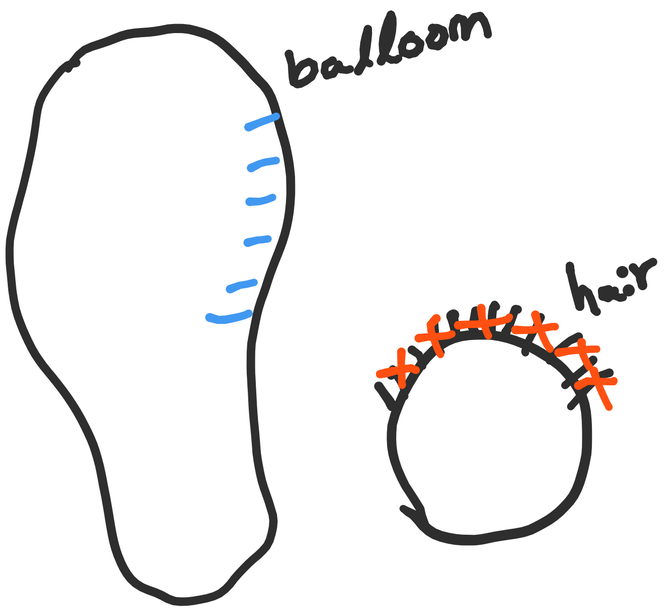
Ch 22 | Electric Fields

22.3 Coulomb‘s Law

T. Sayed Ali Madan


atom:
(positive) protons
(neutral) neutrons
(negative) electrons

① balloon rubs hair



* electrons moved from hair to balloon.

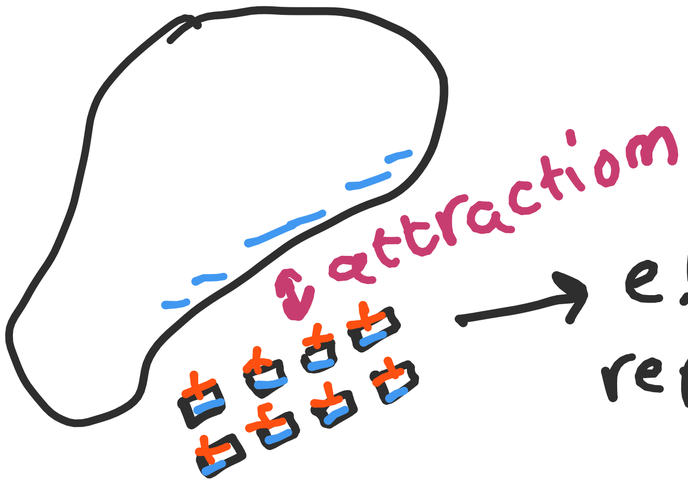
** Smallest charge is electron charge

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

C : Coulomb

SI unit

②



→ electrons repel by the balloons atoms

Outline

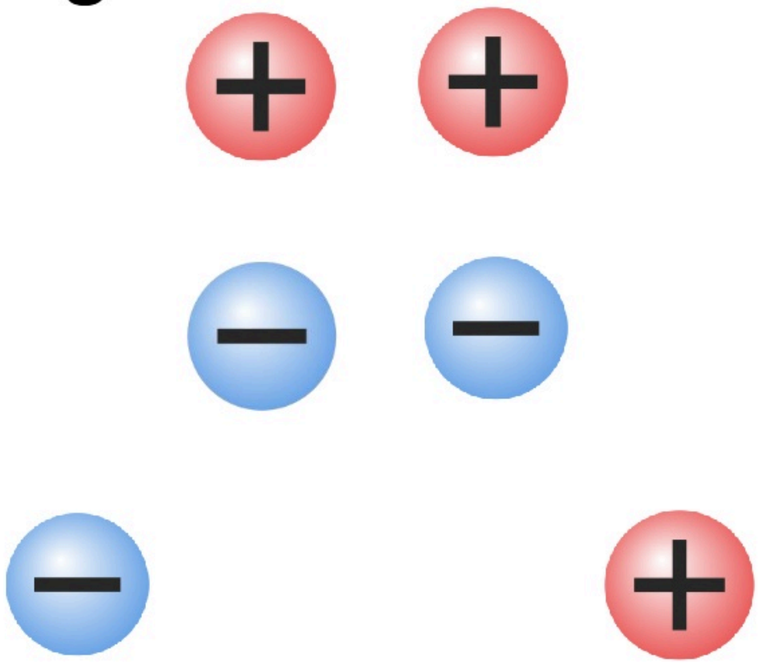
- Coulomb’s Law
- Examples
- Revision of vectors

Electric force between two point charges:

vector quantity

magnitude

direction



5 N to the right

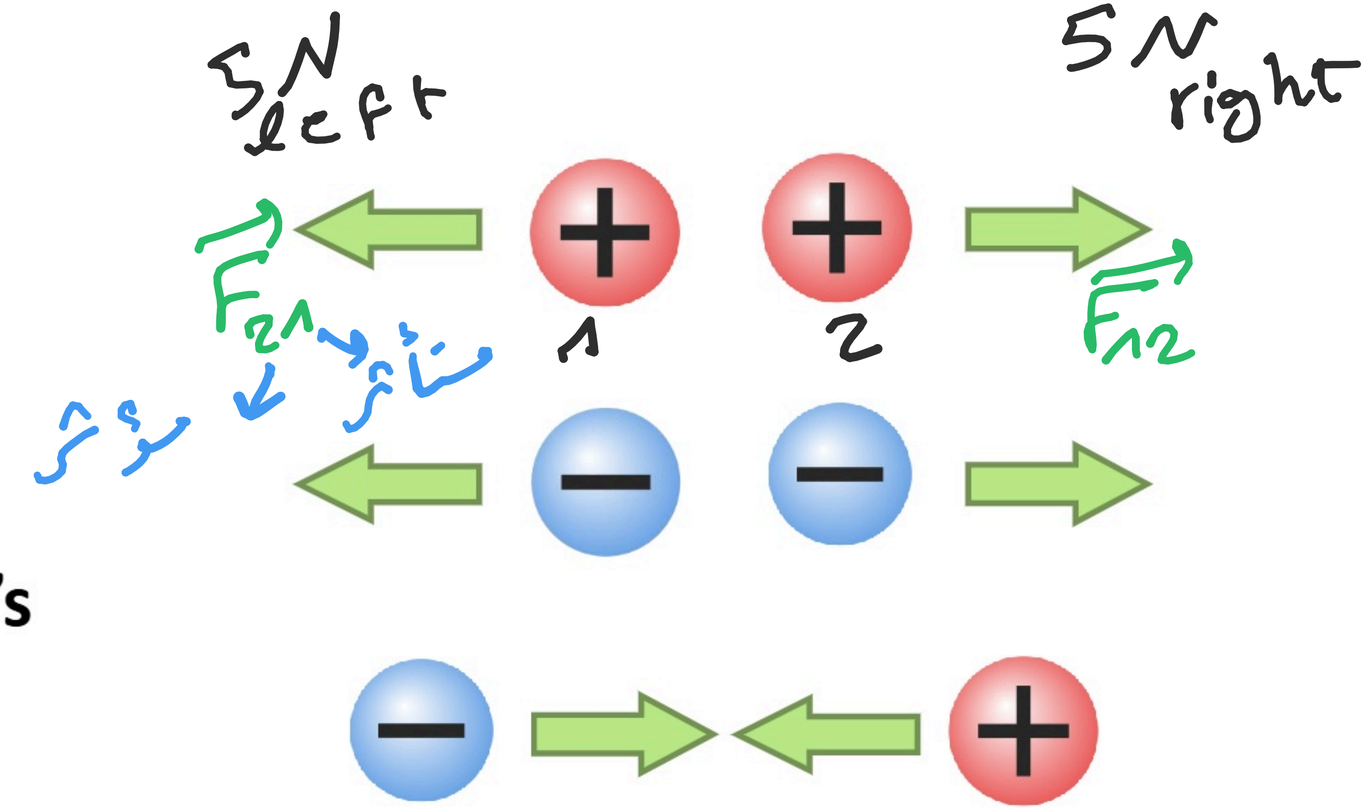
m

d

Section 23.3: Coulomb's Law

Direction of electric force:

- Similar repels
- Different attracts



Electric forces follow Newton's Third Law:

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

$\vec{F}_{12}$: Electric force by charge 1 on charge 2

$|F_{21}| = |F_{12}|$

Section 23.3: Coulomb's Law

Magnitude of electric force between two *point* charges:

$\boldsymbol{F_e}$**:** electric force

$\boldsymbol{q_1}$: charge 1

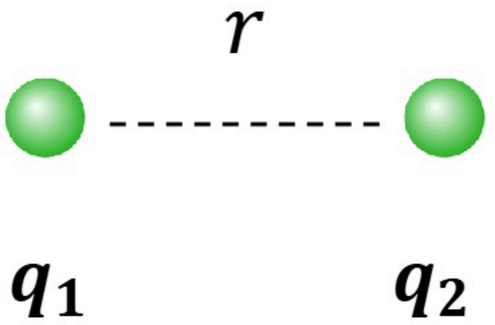
$\boldsymbol{q_2}$: charge 2

$\boldsymbol{r}$: distance between the two charges

$$|F_e| \propto |q_1|$$

$$|F_e| \propto |q_2|$$

$$|F_e| \propto \frac{1}{r^2}$$



Section 23.3: Coulomb's Law

Coulomb's Law:

always positive

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

F_e: Electric force

q_1: Charge 1
q_2: Charge 2

r: Distance between the two charges

k: Coulomb constant

ϵ_0: Permittivity of free space

$$k = 8.987 \times 10^9\ N \cdot m^2/C^2$$

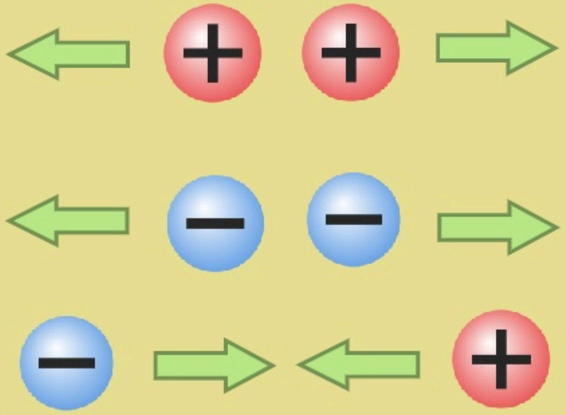
$$k = \frac{1}{4\pi\epsilon_0}$$

$$|F| = \frac{|q_1||q_2|}{4\pi\epsilon_0 r^2}$$

$$\epsilon_0 = 8.85 \times 10^{-12}\ \frac{C^2}{N \cdot m^2}$$

Recall: Rule of thumb:

- Similar repels
- Different attracts

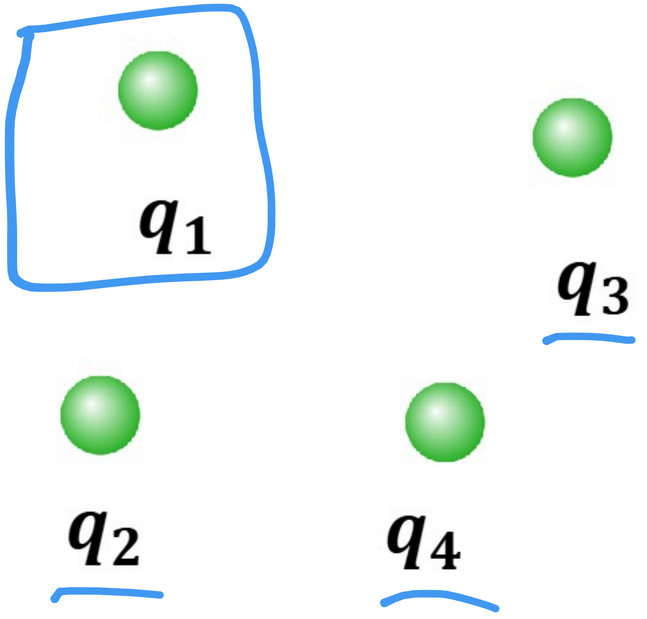


By: Sayed Ali Madan

Section 23.3: Coulomb's Law

If there are more than two charges, then the electric force between each pair of them is given by Coulomb's Law:

$$|F_{23}| = k\frac{|q_2||q_3|}{r^2} = |F_{32}|$$



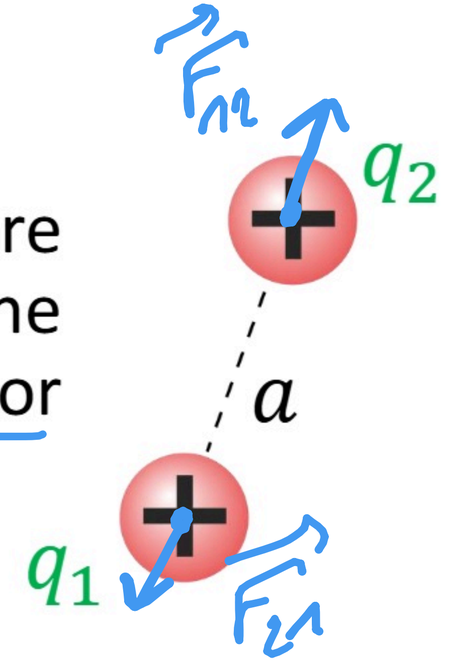
The net/resultant force exerted on a charge is give by the vector sum of all forces by other charges:

$$\vec{F}_1 = \vec{F}_{21} + \vec{F}_{31} + \vec{F}_{41}$$

Example 1: Two charges

Consider two **positive** point charges as shown in the figure, where $q_1 = 2\mu C$, $q_2 = 3\mu C$ and $a = 0.5m$. Find the magnitude of the electric force on q_1 by q_2. Is the force between them attractive or repulsive? What is $|F_{12}|$?

$\mu = 10^{-6}$



$$* \; |F_{21}| = \frac{k|q_1||q_2|}{r^2}$$

$$= \frac{(9\times10^9)(2\times10^{-6})(3\times10^{-6})}{(0.5)^2} = 0.22N$$

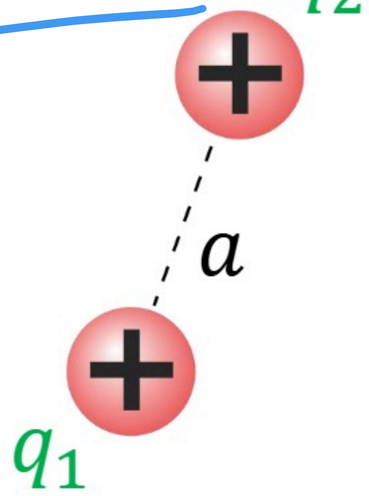
$$* \; |F_{12}| = |F_{21}| = 0.22N$$

* The force is repulsive

$$|F_{12}| = \frac{k\,q_2 q_1}{r^2}$$

Example 2: Two charges

$|F_{21}| = 0.22$ slide q



In the **same** previous configuration, what will happen if:

(a) q_1 increased by double

(b) a is decreased by half

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

(a)

$|q_1| \rightarrow 2|q_1|$ $\quad |F| \propto |q_1|$

$$|F_{new}| = 2|F_{21}| = 2(0.22) = 0.44$$

(b)

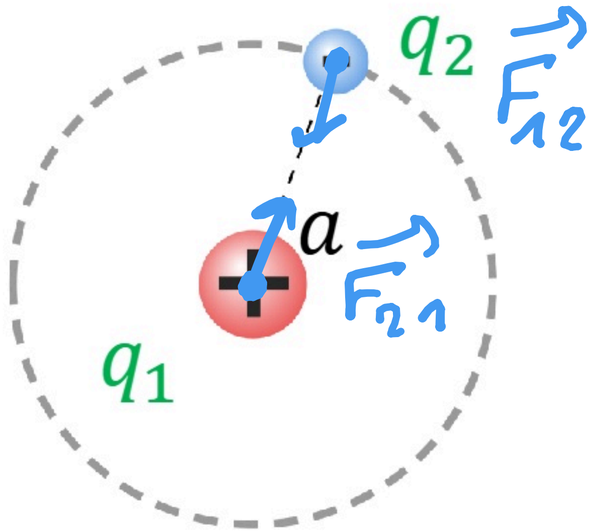
$a \rightarrow \frac{1}{2}a$ $\quad |F| \propto \frac{1}{r^2}$

$$|F_{new}| = \frac{1}{(\frac{1}{2})^2}|F_{21}| = 4(0.22) = 0.88\,N$$

$\frac{1}{(0.5)^2} = 4$

Example 2: The Hydrogen Atom

The **electron** and **proton** of a hydrogen atom are separated by a distance of $\mathbf{a = 5.3 \times 10^{-11} m}$. Find the magnitude of the electric force between the two particles. Is the force between them attractive or repulsive?



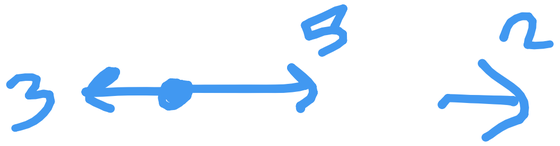
Particle	Charge (C)	Mass (kg)
Electron (e)	-1.60×10^{-19}	9.11×10^{-31}
Proton (p)	1.60×10^{-19}	1.67×10^{-27}

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

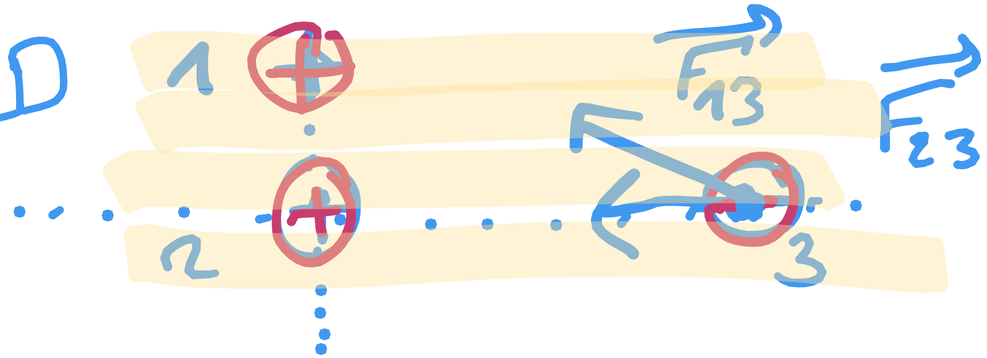
$$= \frac{(9\times10^9)(1.6\times10^{-19})(1.6\times10^{-19})}{(5.3\times10^{-11})^2} = 8.2\times10^{-8}\ N$$

attractive

1D



2D



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