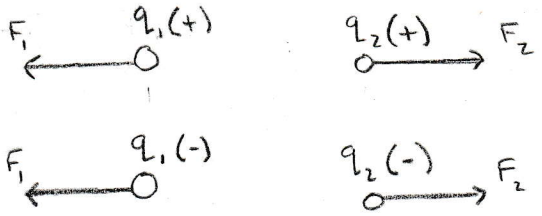
DRAWING #1: FORCES ON PARTICLES I

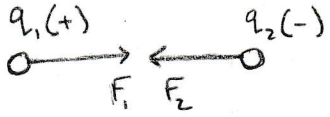
ASSUME IN THE FOLLOWING THAT WE ARE TALKING ABOUT <u>POINT CHARGES</u>.

LIKE KINDS REPEL:

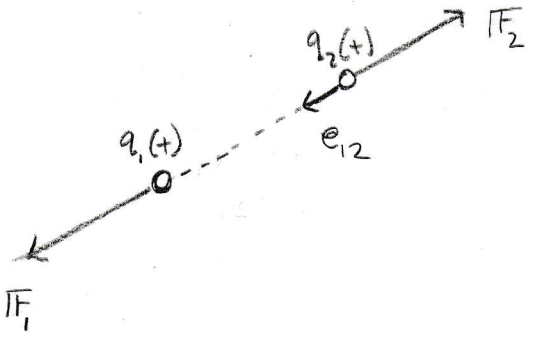


NEWTON'S THIRD LAW: $F_1 = -F_2$

UNLIKE KINDS ATTRACT:



THESE OBSERVATIONS MEAN THAT THE FORCE VECTOR ($\overline{F}$) IS DIRECTED ALONG THE LINE JOINING THE PARTICLES (UNIT VECTOR e_{12}):



DRAWING #2: FORCES ON PARTICLES 2

THE MAGNITUDE OF THE FORCE IS PROPORTIONAL TO THE MAGNITUDE OF THE CHARGES:

$$q_1 = q_2 = +e \text{ (OR } -e)$$

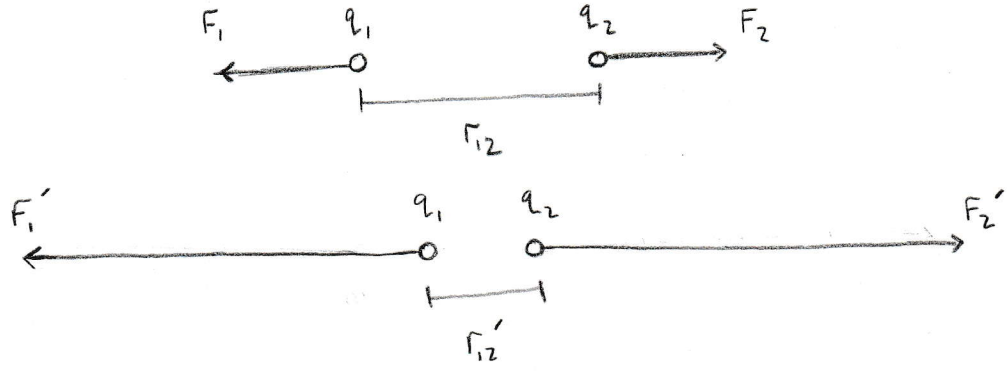
$$q_2' = 2q_2$$

$$F_1' = 2F_1$$

CONSIDERING THIS, AND THE FACT THAT LIKE CHARGES REPEL AND UNLIKE CHARGES ATTRACT:

$$F \propto q_1 q_2$$

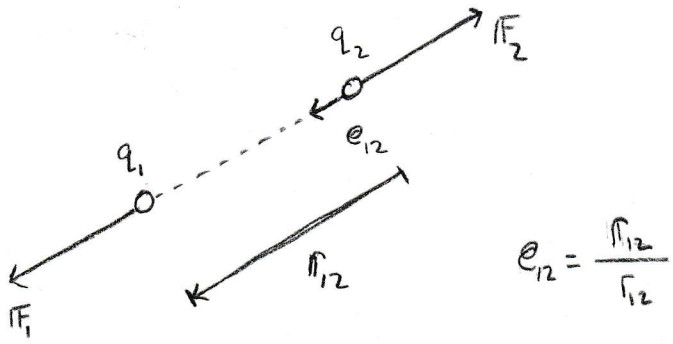
THE MAGNITUDE OF THE FORCE IS INVERSELY PROPORTIONAL TO THE SQUARE OF THE DISTANCE BETWEEN CHARGES (r_{12}^2): $F \propto 1/r_{12}^2$



$$r_{12}' = \frac{1}{2} r_{12}$$

$$F_1' = 4F_1$$

DRAWING #3: COULOMB'S LAW



OBSERVATIONS:

- $\vec{F}$ IS ALONG THE DIRECTION OF e_{12}
- F (THE MAGNITUDE OF $\vec{F}$) IS PROPORTIONAL TO $q_1 q_2$ AND SIGN
- THE MAGNITUDE OF F IS INVERSELY PROPORTIONAL TO r_{12}^2

COULOMB'S LAW

$$\vec{F}_1 = k_e \frac{q_1 q_2}{r_{12}^2} e_{12}$$

k_e: COULOMB'S CONSTANT

$\approx 9 \cdot 10^9 \ N \cdot m^2/C^2$

NOTE: THE FUNDAMENTAL UNIT OF CHARGE e:

$e = 1.60 \cdot 10^{-19} \ C$

NOTE: FOR HISTORICAL REASONS, k_e IS SOMETIMES WRITTEN:

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

ε_0: ELECTRICAL PERMITTIVITY OF FREE SPACE

NOTE: COULOMB'S LAW ONLY WORKS FOR POINT CHARGES.

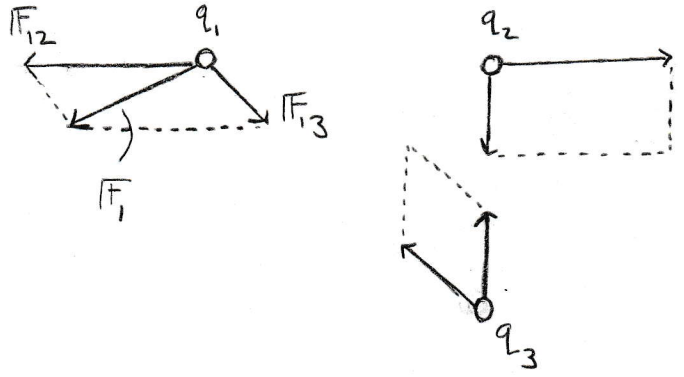
NOTE: THE CHARGES MUST BE STATIONARY

DRAWING #4: THE PRINCIPLE OF SUPERPOSITION

ELECTRICAL FORCES, LIKE OTHER FORCES, OBEY THE SUPERPOSITION PRINCIPLE:

$$\mathbf{F}_1 = \sum_{i=2}^{N} \mathbf{F}_{1i}$$

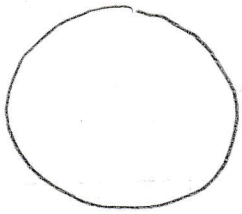
$\mathbf{F}_{1i}$: THE FORCE ON PARTICLE 1, DUE TO PARTICLE i



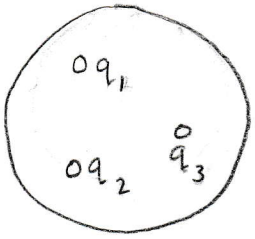
COULOMB'S LAW PLUS THE SUPERPOSITION PRINCIPLE ARE ALL THERE IS TO ELECTROSTATICS : THE PHENOMENA AND PROPERTIES OF STATIONARY ELECTRIC CHARGES.

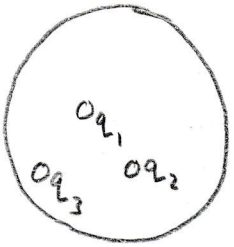
DRAWING #5: REAL ELECTROSTATIC PROBLEMS

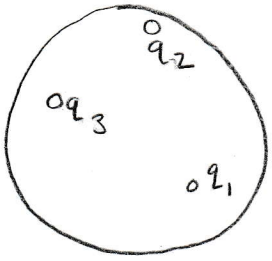
OFTEN (IN REAL ELECTROSTATIC PROBLEMS), WE DON'T KNOW THE CHARGES ARE:



CHARGES EXIST INSIDE

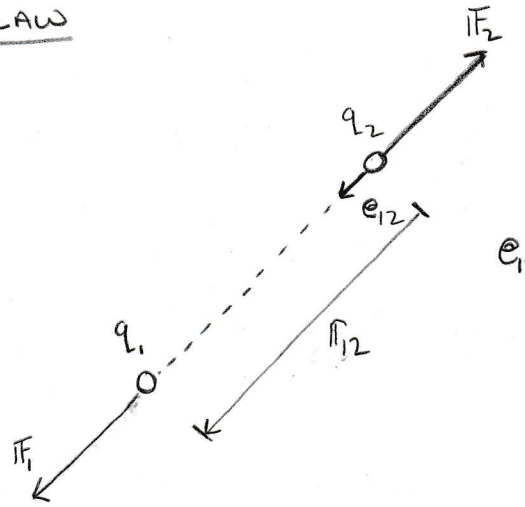






DRAWING #6: COULOMB'S LAW VS NEWTON'S LAW OF UNIVERSAL GRAVITATION

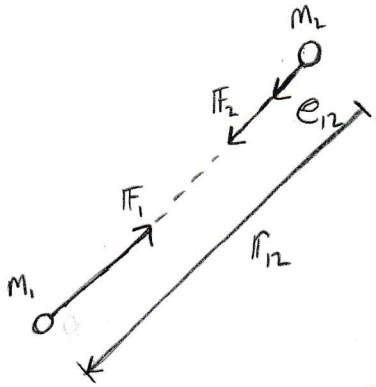
COULOMB'S LAW



$$e_{12} = \frac{\vec{r}_{12}}{r_{12}}$$

$$\vec{F}_1 = k_e \frac{q_1 q_2}{r_{12}^2} e_{12}$$

NEWTON'S LAW OF UNIVERSAL GRAVITATION



$$e_{12} = \frac{\vec{r}_{12}}{r_{12}}$$

$$\vec{F}_1 = -G \frac{m_1 m_2}{r_{12}^2} e_{12}$$

SIMILARITIES

- LONG-RANGE FORCES
- ... OBEYING AN INVERSE-SQUARE LAW ($1/r_{12}^2$)
- DIRECTLY PROPORTIONAL TO THE PRODUCT OF THE PARTICLES PROPERTIES (q vs m)

DIFFERENCES

- THE GRAVITATIONAL FORCE IS ALWAYS ATTRACTIVE
- " IS MUCH WEAKER (e.g., FOR ELECTRONS $F_g \approx 8 \cdot 10^{-37} F_e$)