Coulomb's Law

Example: Addition of Electric Charge

- An object contains 500 free electrons and 600 unpaired protons, what's the net charge carried by that object in Coulombs?

$$Q_{net} = \sum Q = Q_1 + Q_2 = -500e + 600e$$
$$= 100e = 100 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-17}\mathrm{C}$$

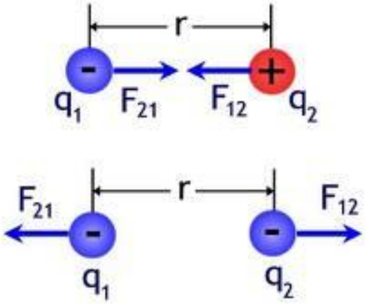
Electrostatic Force: Coulomb's Law

Coulomb's Law: Two charges interact with a force that increases with the amount of the two charges and decreases with the square of distance between them. This force is repulsive between charges of like signs and attractive between those of different signs. Mathematically:

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

q_i are the charges in Coulomb, $k = 8.99 \times 10^9 \mathrm{Nm^2/C^2}$

Charles-Augustin de Coulomb (1736-1806), according to Locomte



Simulation:
http://employees.oneonta.edu/viningwj/sims/coulombs_law_s.html

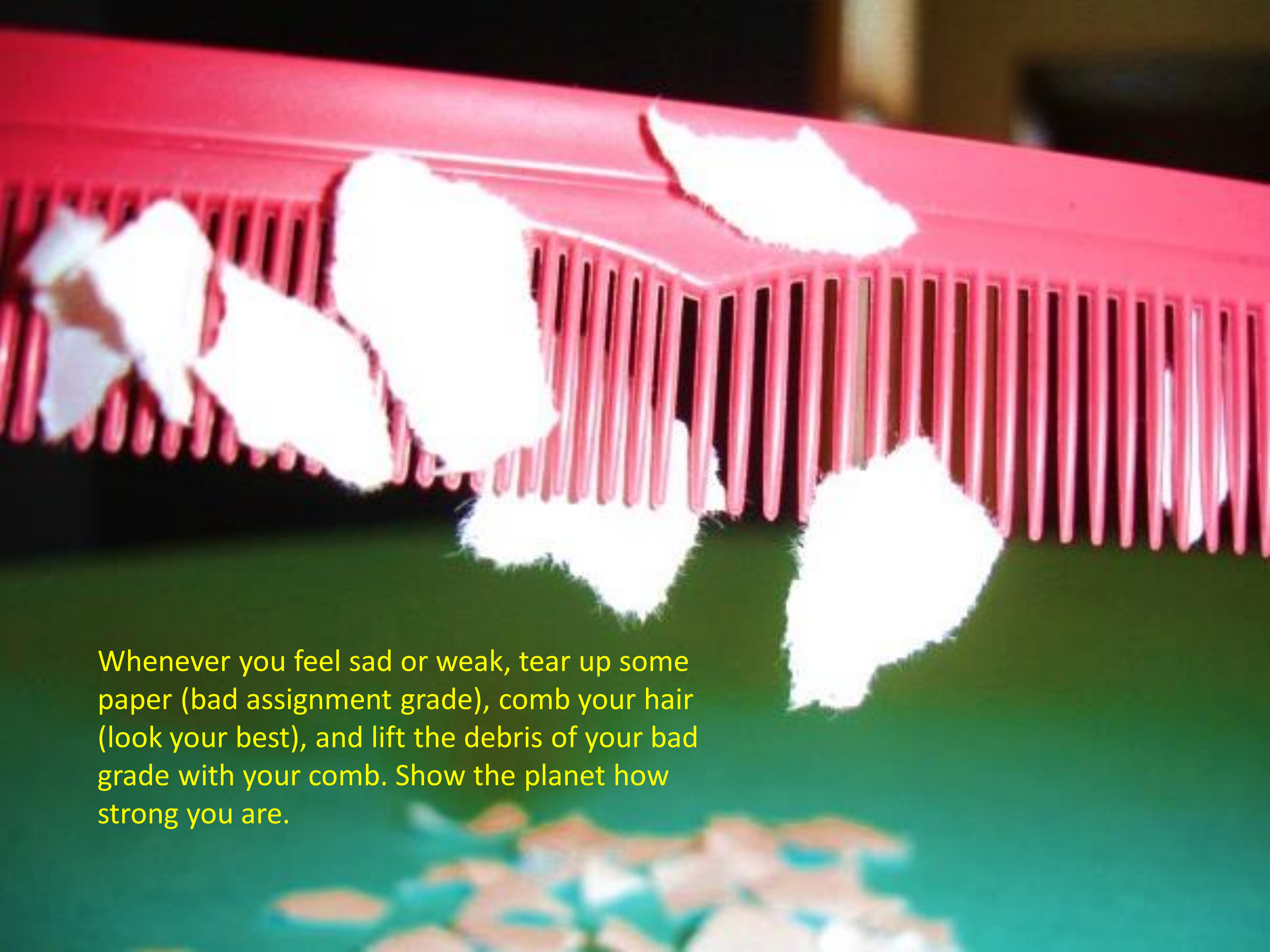
Extra Credit: A World where Gravity and Electricity are Swapped

$$F_e = \frac{kq_1q_2}{r^2} \quad vs. \quad F_g = \frac{Gm_1m_2}{r^2}$$

- Similarities:
  - Both are ***inverse-square*** laws
  - Both depend on the ***product of charges (masses)***
  - Both act ***along the lines connecting the centers*** of the two interacting objects
- Differences:
  - There's only ***one type of mass***, but ***two types of charge***
  - ***Gravity*** is always ***attractive***, ***electricity*** can be ***attractive or repulsive***
  - ***Gravity is extremely weak*** (G is small compared to k)
- Forces between two electrons:

$$\frac{F_e}{F_g} = \frac{k(-e)(-e)/r^2}{G(m_e)(m_e)/r^2} = \frac{ke^2}{Gm_e^2} \approx \frac{9\times10^9\times(1.6\times10^{-19})^2}{6.67\times10^{-11}\times(9\times10^{-31})^2} \sim 10^{42}$$

- Using the understanding you've gained in 111/112 so far, write a detailed description of a world just like ours except with the roles of electricity and gravity swapped. Brief uncreative description gets no credit.



Whenever you feel sad or weak, tear up some paper (bad assignment grade), comb your hair (look your best), and lift the debris of your bad grade with your comb. Show the planet how strong you are.

How to use Coulomb's Law

Use $|F_e| = \frac{k|q_1|\,|q_2|}{r^2}$ with magnitudes of charges q_1 and q_2 to find magnitude of the electric force

Then assign direction of electric force by hand: like charges repel, opposite charges attract

If more than one force on a charge, add the forces as vectors to find the net force (Superposition Principle)

Quickuiz

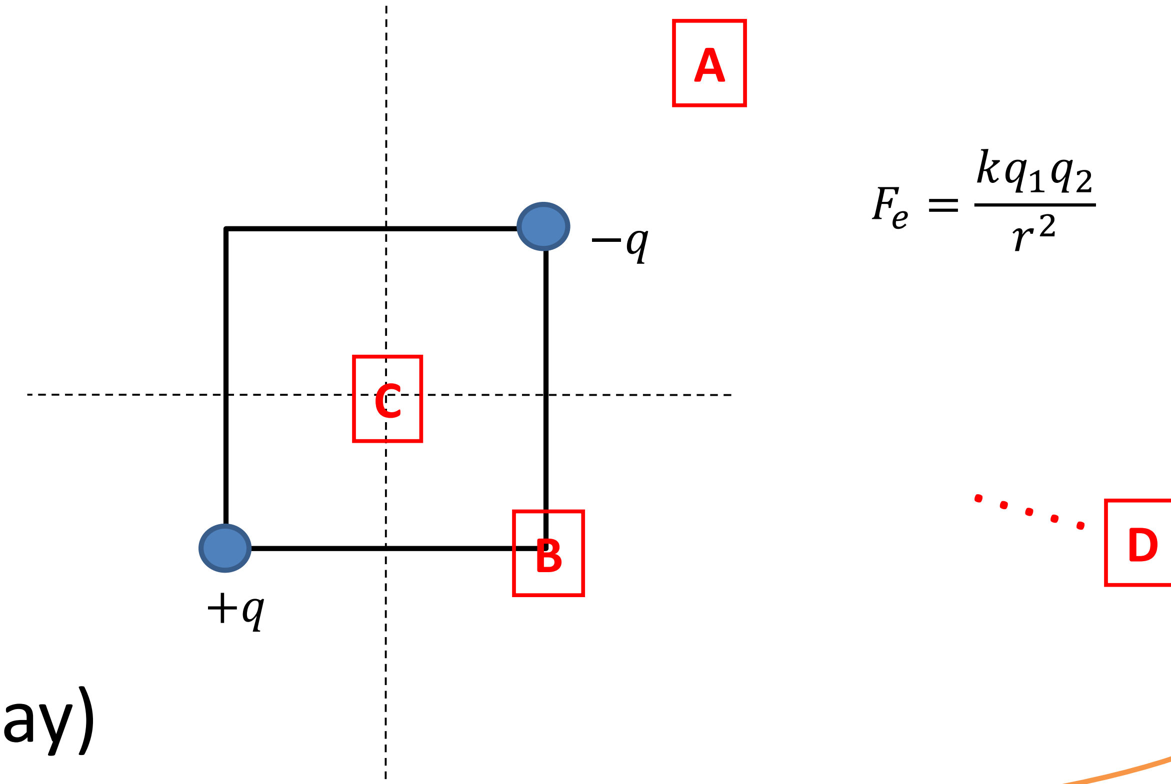
A charge $+q$ and a charge – q are fixed at opposite corners of a square. A third charge $+q$ will experience a total electrical force of the greatest magnitude if it is placed at which point?

A. Point A

B. Point B

C. Point C

D. Point D (very far away)



$$F_e = \frac{kq_1q_2}{r^2}$$

Demo Problem

Three charges $Q_1 = -1.0\ \mathrm{nC}$, $Q_2 = -1.0\ \mathrm{nC}$ and $Q_3 = +2.0\ \mathrm{nC}$ are located in the x-y plane at the points $P_1 = (0.0\ \mathrm{mm}, 0.0\ \mathrm{mm})$, $P_2 = (1.0\ \mathrm{mm}, 0.0\ \mathrm{mm})$ and $P_3 = (0.0\ \mathrm{mm}, 1.5\ \mathrm{mm})$, respectively. Recall: $F_e = \frac{kq_1q_2}{r^2}$, $k = 8.99 \times 10^9 \mathrm{Nm^2/C^2}$

- Find the magnitude, the direction angle, and the x- and y- components of the electrical force exerted on charge Q_1 by charge Q_2.

$$F_{12} = \frac{kQ_1Q_2}{r_{21}^2} = 9.0 \times 10^{-3}\mathrm{N}, \qquad \theta_{12} = 180°$$

$$F_{12,x} = -9.0 \times 10^{-3}\mathrm{N}, \qquad \mathrm{F_{12,y}} = 0$$

Demo Problem

Three charges $Q_1 = -1.0 \text{ nC}$, $Q_2 = -1.0 \text{ nC}$ and $Q_3 = +2.0 \text{ nC}$ are located in the x-y plane at the points $P_1 = (0.0 \text{ mm}, 0.0 \text{ mm})$, $P_2 = (1.0 \text{ mm}, 0.0 \text{ mm})$ and $P_3 = (0.0 \text{ mm}, 1.5 \text{ mm})$, respectively. Recall: $F_e = \frac{kq_1q_2}{r^2}$, $k = 8.99 \times 10^9 \text{Nm}^2/\text{C}^2$

- Find the magnitude, the direction angle, and the x- and y- components of the electrical force exerted on charge Q_1 by charge Q_3.

$$F_{13} = \frac{kQ_1Q_3}{r_{21}^2} = 8.0 \times 10^{-3}\text{N}, \qquad \theta_{13} = 90°$$

$$F_{13,x} = 0, \qquad \text{F}_{13,y} = +8.0 \times 10^{-3}\text{N}$$

Demo Problem

Three charges $Q_1 = -1.0 \text{ nC}$, $Q_2 = -1.0 \text{ nC}$ and $Q_3 = +2.0 \text{ nC}$ are located in the x-y plane at the points $P_1 = (0.0 \text{ mm}, 0.0 \text{ mm})$, $P_2 = (1.0 \text{ mm}, 0.0 \text{ mm})$ and $P_3 = (0.0 \text{ mm}, 1.5 \text{ mm})$, respectively. Recall: $F_e = \frac{kq_1q_2}{r^2}$, $k = 8.99 \times 10^9 \text{Nm}^2/\text{C}^2$

- What are the x- and y- components of the net electrical force on charge Q_1?

$$F_{1,net,x} = -9.0 \times 10^{-3}\text{N},$$

$$F_{1,net,y} = 8.0 \times 10^{-3}\text{N}$$

Demo Problem

Three charges $Q_1 = -1.0\ \mathrm{nC}$, $Q_2 = -1.0\ \mathrm{nC}$ and $Q_3 = +2.0\ \mathrm{nC}$ are located in the x-y plane at the points $P_1 = (0.0\ \mathrm{mm}, 0.0\ \mathrm{mm})$, $P_2 = (1.0\ \mathrm{mm}, 0.0\ \mathrm{mm})$ and $P_3 = (0.0\ \mathrm{mm}, 1.5\ \mathrm{mm})$, respectively. Recall: $F_e = \frac{kq_1q_2}{r^2}$, $k = 8.99 \times 10^9 \mathrm{Nm^2/C^2}$

- What are the magnitude and direction angle of the net electrical force on charge Q_1?

$$F_{1,net} = \sqrt{F_{1,net,x}^2 + F_{1,net,y}^2} = 1.2 \times 10^{-2}\mathrm{N},$$

$$\theta_{1,net} = \tan^{-1}\left(\frac{F_{1,net,y}}{F_{1,net,x}}\right) = -41.6° + \ 180° = 138.4°$$