

## Coulomb's Law weblab

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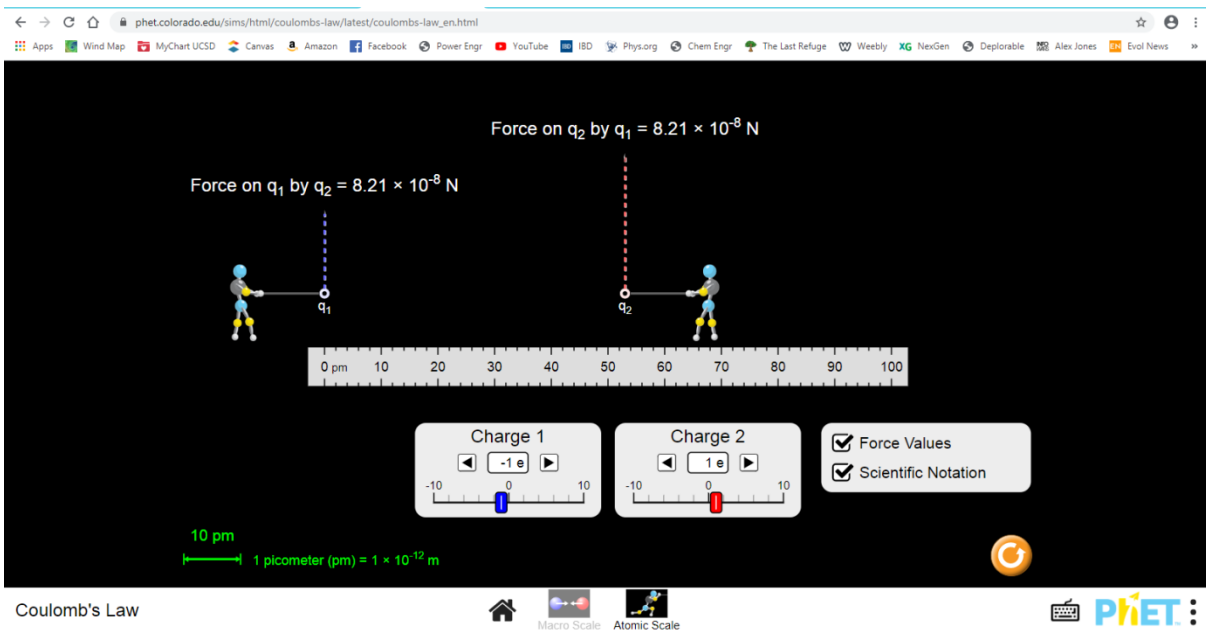
Open the PhET "Coulomb's Law" lab simulation <https://phet.colorado.edu/en/simulations/coulombs-law>

Select "Atomic Scale".

Purpose: You are comparing the forces within an atom.

Instructions: Create space in the Word document below, and write or type your answers to the questions. YOU MUST SHOW YOUR WORK where it is required.

(10 questions)



Equations: Coulomb's Law:  $F_E = k \frac{q_1 q_2}{r^2}$

$$1 \text{ C} = 6 \times 10^{18} \text{ electrons,}$$

$$1 \text{ e} = -1.6 \times 10^{-19} \text{ Coulomb}$$

$$1 \text{ p} = +1.6 \times 10^{-19} \text{ Coulomb}$$

- Using Coulomb's Law, calculate the electrical repulsion between two protons in a nucleus if they are  $1.00 \times 10^{-15}$  m apart. (Hint: 200-300 N)

$$F_e = kq_1q_2/r^2 \quad 1p=1.6 \cdot 10^{-19}c \quad q=1p \quad r=1.0m$$

$$F_e = (9 \cdot 10^9 \text{ Nm}^2/\text{c}^2)(1.6 \cdot 10^{-19} \text{ c})^2/(1.0 \text{ m})^2$$

$$F_e = 230.4 \text{ N}$$

2. If you were holding these protons, do you think you could feel the effect of this force?

Yes very much so

3. How many pounds would the force be? (Hint: 50-75 lbs)

$$1\text{N} = 0.2248\text{lbs}$$

$$F_e = 230.4(0.2248\text{lbs}) = \sim 52\text{lbs}$$

4. Now using the PhET simulation by positioning the 'atomic men' and adjusting the charges, find the electrical attraction that a proton in a nucleus exerts on an orbiting electron if the two particles are  $1.00 \times 10^{-10}$  m apart. (Hint:  $1.0$ - $5.0 \times 10^{-8}$  N)

$$2.31 \times 10^{-8}\text{N}$$

5. If you were holding the electron, do you think you could feel the effect of this force?

$$2.31 \times 10^{-8}(0.2248\text{lbs}) = 5.19288 \times 10^{-9}\text{lbs}$$

6. Conclusion to the above: How do the forces in the nucleus of an atom compare with the forces that corral/confine the electrons?

They are much weaker

7. Use the PhET simulation to determine the electrostatic attraction between the lone electron and lone proton in a Hydrogen atom. The electron orbits at a distance of 0.529 Angstroms (1 Angstrom is  $10^{-10}$  m) from the nucleus. You will need to convert this to picometers to use the simulation. (Hint:  $8.0$ - $10.0 \times 10^{-8}$  N)

$$1\text{ang} = 10^{-10}\text{m} \quad 1\text{pm} = 10^{-12}\text{m}$$

$$100\text{pm} = 10^{-10}\text{m} = 1\text{ang}$$

$$0.529\text{ang} \times 100 = 52.9\text{pm}$$

$$\text{Measured Attraction: } 8.21 \times 10^{-8}\text{N}$$

8. Use Newton's law of gravity  $F_G = G \frac{m_1 m_2}{d^2}$  to compute the gravitational attraction in Newtons between the proton and electron above, using a distance of  $0.529 \times 10^{-10}$  m. You will need to look up the mass of a proton and electron, and the value for 'G', in the back of the book. (Hint:  $1.00$ - $2.00 \times 10^{-47}$  N)

$$F_G = G m_1 m_2 / d^2 \quad G = 6.6743 \times 10^{-11} \text{Nm}^2/\text{kg}^2 \quad d = 0.529 \times 10^{-10} \text{m} \quad m_e = 9.1 \times 10^{-31} \quad m_p = 1.672 \times 10^{-27}$$

$$F_G = (6.6743 \times 10^{-11} \text{Nm}^2/\text{kg}^2)(9.1 \times 10^{-31} \text{kg})(1.672 \times 10^{-27} \text{kg}) / (0.529 \times 10^{-10} \text{m})^2$$

$$F_G \sim 1 \times 10^{-88} \text{N}$$

9. Conclusion to the above: How does gravitational force compare with electrostatic force? Try to be specific as to 'order of magnitude'.

$$F_G \sim 1 \times 10^{-88} \text{N}$$

$$F_e = 230.4 \text{N}$$

$$\text{Magnitude spans } \sim 2 \times 10^{90}$$

10. Two electrons and one proton are in the configuration shown below. Use the PhET simulation to determine the attractive forces between  $e_1$  and  $p$ , and  $e_2$  and  $p$ , and calculate the magnitude and direction of the net electrostatic force they will exert on the proton.

$$5 \times 10^{-11} \text{ m} = 9.23 \times 10^{-8} \text{ N (opposite)}$$

$$9 \times 10^{-11} \text{ m} = 2.85 \times 10^{-8} \text{ N (adjacent)}$$

$$\arctan(9.23/2.85) = 72.4 \text{ deg}$$

$$(9.23 \times 10^{-8} \text{ N}) \sin(72.4 \text{ deg}) = F_{\text{mag}} = 8.8 \times 10^{-8} \text{ N}$$

