

Part A: Alike and Different

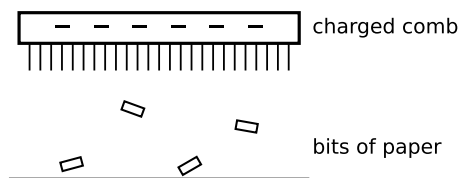
Use the ideas from the lesson notes. Explain your reasoning in complete sentences.

1. Complete the table to compare the two forces.

	Gravity	Electric force
What it acts on	mass	charge
Attract, repel, or both?	only attracts	attracts or repels
Strong or weak?	very weak	very strong
Rules at what scale?	planets, moons, stars	atoms, everyday life
How it changes with distance	inverse square ($1/d^2$)	inverse square ($1/d^2$)

Both forces **act at a distance** and follow the same **inverse square** form, with mass in place of charge and G in place of k .

2. Ava runs a plastic comb through her hair and holds it above some tiny bits of paper. The paper jumps up and sticks to the comb. What does this show about the strength of the electric force compared to gravity? Explain.



The entire Earth (about 6×10^{24} kg) pulls the paper down with gravity, but a tiny amount of charge on the comb pulls it up **harder**. So the **electric force is far stronger than gravity**.

3. If the electric force is so much stronger, why does gravity, not the electric force, keep the Moon in orbit around Earth?

Large objects like Earth and the Moon are almost perfectly **neutral**: they have nearly equal + and – charge, so their electric pushes and pulls **cancel out**.

Mass only comes in one type, so it **always adds up**. With enormous masses, gravity is huge while the net electric force is essentially zero.

4. A book rests on a table. The table pushes up on the book with a normal force. Explain why the normal force is really an electric force. Name one other contact force that is also electric.

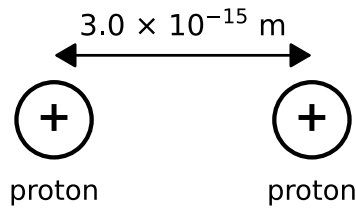
The electrons on the outside of the table's atoms **repel** the electrons on the outside of the book's atoms. That electric repulsion pushes the book up, and we call it the normal force.

Friction and **tension** also come from electric forces between atoms (either one is a correct answer).

Part B: How Much Stronger?

Use $F_e = kq_1q_2/d^2$ with $k = 9.0 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$, and $F_g = Gm_1m_2/d^2$ with $G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$. A proton has charge $1.6 \times 10^{-19} \text{ C}$ and mass $1.67 \times 10^{-27} \text{ kg}$.

5. Inside a helium nucleus, two protons are $3.0 \times 10^{-15} \text{ m}$ apart.



- Find the electric force between the protons. Is it attractive or repulsive?
- Find the gravitational force between the protons.
- How many times stronger is the electric force than gravity?
- If the protons were twice as far apart, would your answer to part c change? Explain.

a. Knowns: $q_1 = q_2 = 1.6 \times 10^{-19} \text{ C}$, $d = 3.0 \times 10^{-15} \text{ m}$. **Equation:** $F_e = kq_1q_2/d^2$

Top: $(9.0 \times 10^9)(1.6 \times 10^{-19})^2 = 2.30 \times 10^{-28}$. **Bottom:** $(3.0 \times 10^{-15} \text{ m})^2 = 9.0 \times 10^{-30} \text{ m}^2$

Answer: $F_e = 2.30 \times 10^{-28} \div 9.0 \times 10^{-30} = \mathbf{26 \text{ N, repulsive}}$ (two positive charges)

b. Knowns: $m_1 = m_2 = 1.67 \times 10^{-27} \text{ kg}$. **Equation:** $F_g = Gm_1m_2/d^2$

Top: $(6.67 \times 10^{-11})(1.67 \times 10^{-27})^2 = 1.86 \times 10^{-64}$. **Answer:** $F_g = 1.86 \times 10^{-64} \div 9.0 \times 10^{-30} = \mathbf{2.1 \times 10^{-35} \text{ N, attractive}}$

c. Ratio = $F_e \div F_g = 26 \text{ N} \div 2.1 \times 10^{-35} \text{ N}$. $26 \div 2.1 = 12.4$ and $10^0 \div 10^{-35} = 10^{35}$, so $12.4 \times 10^{35} = \mathbf{1.2 \times 10^{36} \text{ times stronger}}$

d. No. Both forces are inverse square laws. Doubling d makes each force 4 times smaller, so their ratio stays the same.

6. Two 0.10 kg balloons, each with a charge of $+1.0 \times 10^{-7} \text{ C}$, hang 0.50 m apart.

- Find the electric force and the gravitational force between the two balloons.
- Which force matters more for how the balloons move toward or away from each other? Support your answer with a ratio.

a. Electric: $F_e = (9.0 \times 10^9)(1.0 \times 10^{-7})(1.0 \times 10^{-7}) / (0.50 \text{ m})^2 = 9.0 \times 10^{-5} \div 0.25 = \mathbf{3.6 \times 10^{-4} \text{ N, repulsive}}$

Gravity: $F_g = (6.67 \times 10^{-11})(0.10 \text{ kg})(0.10 \text{ kg}) / (0.50 \text{ m})^2 = 6.67 \times 10^{-13} \div 0.25 = \mathbf{2.7 \times 10^{-12} \text{ N, attractive}}$

b. The electric force. Ratio = $3.6 \times 10^{-4} \text{ N} \div 2.7 \times 10^{-12} \text{ N} = \mathbf{1.3 \times 10^8}$, so the electric push is about 100 million times stronger than the gravitational pull between the balloons. The balloons push apart.