Chapter 1

Charge

If you rub a balloon against your hair, then place it next to a wall, it will stick. This is because it stole some electrons from your hair, and now the ballon has slightly more electrons than protons. We say that it has gotten an *electrical charge*. In this case, the balloon has a negative electrical charge.

Objects with slightly more protons than electrons have a positive charge.

This charge is measured in coulombs. The charge of a single proton is about 1.6×10^{-19} coulombs.

An object with a negative charge and an object with a positive charge will be attracted to each other. Two objects with the same charge will be repelled by each other.

Coulomb's Law

If two objects with charge q_1 and q_2 (in coulombs) are r meters from each other, the force of attraction or repulsion is given by

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

where F is in newtons and K is Coulomb's constant: about 8.988×10^9.

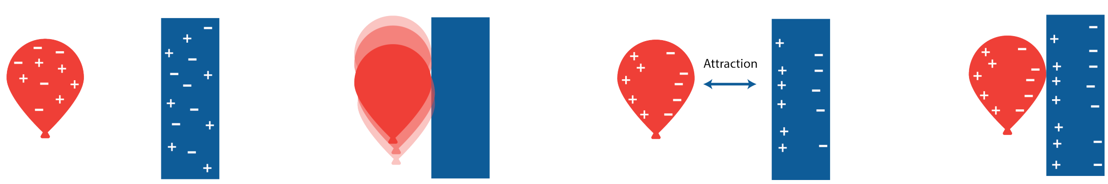
Exercise 1 Coulomb's Law

Two balloons are charged with an identical quantity and type of charge: -5×10^{-9} coulombs. They are held apart at a separation distance of 12 cm. Determine the magnitude of the electrical force of repulsion between them.

Working Space

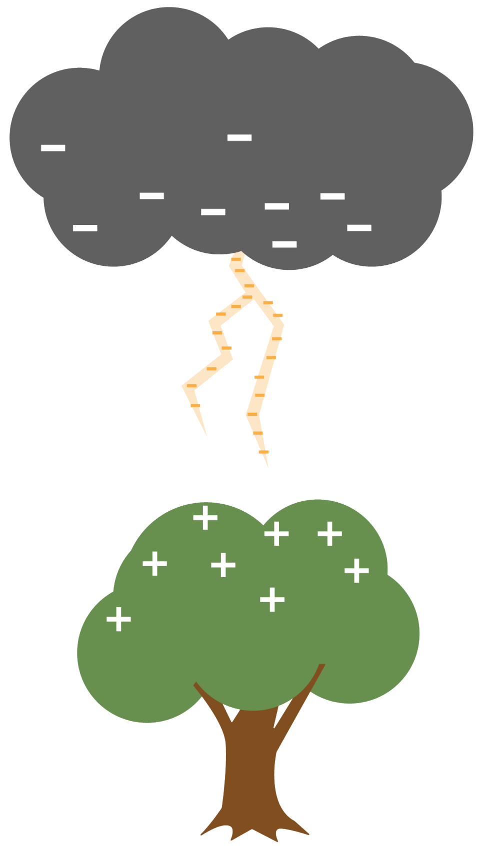
Answer on Page 5

At this point, you might ask "If the wall has zero charge, why is the balloon attracted to it?" The answer: the electrons in the wall move away from the balloon, polarizing the atoms. The negative charge on the balloon pushes electrons away from itself, so the surface of the wall gets a mild positive charge. The negative charge on the balloon is attracted more to the positive charge on the surface of the wall than the negative charge on the inside, thus the balloon sticks. There's some weirdness going on with conductors and insulators here, but we will get to that later.



1.1 Lightning

A cloud is a cluster of water droplets and ice particles. These droplets and ice particles are always moving up and down through the cloud. In this process, electrons get stripped off and end up on the water droplets at the bottom of the cloud (water droplets collect at the bottom because they are denser). The air between the droplets is a pretty good insulator, which means the electrons are reluctant to jump anywhere. However, eventually, the charge gets so strong that even the insulating properties of the air is not enough to prevent the jump, causing lightning.



A great deal of lightning moves within a cloud or between clouds. However, sometimes it jumps to the earth. These bolts of lightning vary in the amount of electrons they carry, but the average is about 15 coulombs.

Thunder occurs because the electrons heat the air they pass through, causing the air to expand suddenly. Tthe resulting shockwave is the sound we know as thunder.

1.2 But...

This idea that opposite charges attract creates some heavy questions that you do not yet have the tools to work with. So to these questions, the answer is basically "Don't ask that yet!"

However, you probably have these questions, so we will point you in the direction of the answers.

The first is "In any atom bigger than hydrogen, there are multiple protons in the nucleus. Why don't the protons push each other out of the nucleus?"

We aren't ready to talk about it, but there is a force called *the strong nuclear force*, which pulls the protons and neutrons in the nucleus of the atom toward each other. At very, very small distances, it is strong enough to overpower the repulsive force due to the protons' charges.

Another question is "Why do the electrons whiz around in a cloud so far from the nucleus of the atom? Negatively charged electrons should cling to the protons in the center, right?"

We aren't ready to talk about this either, but quantum mechanics tells us that electrons like to live in a certain specific energy level. Hugging protons isn't one of those levels.

Appendix A

Answers to Exercises

Answer to Exercise 1 (on page 2)

$$F = K\frac{|q_1 q_2|}{r^2} = (8.988 \times 10^9)\frac{(-5 \times 10^{-9})(-5 \times 10^{-9})}{0.12^2} = \frac{224.7 \times 10^{-9}}{0.0144} = 15.6 \times 10^{-6}$$

15.6 micronewtons.

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