Four Forces

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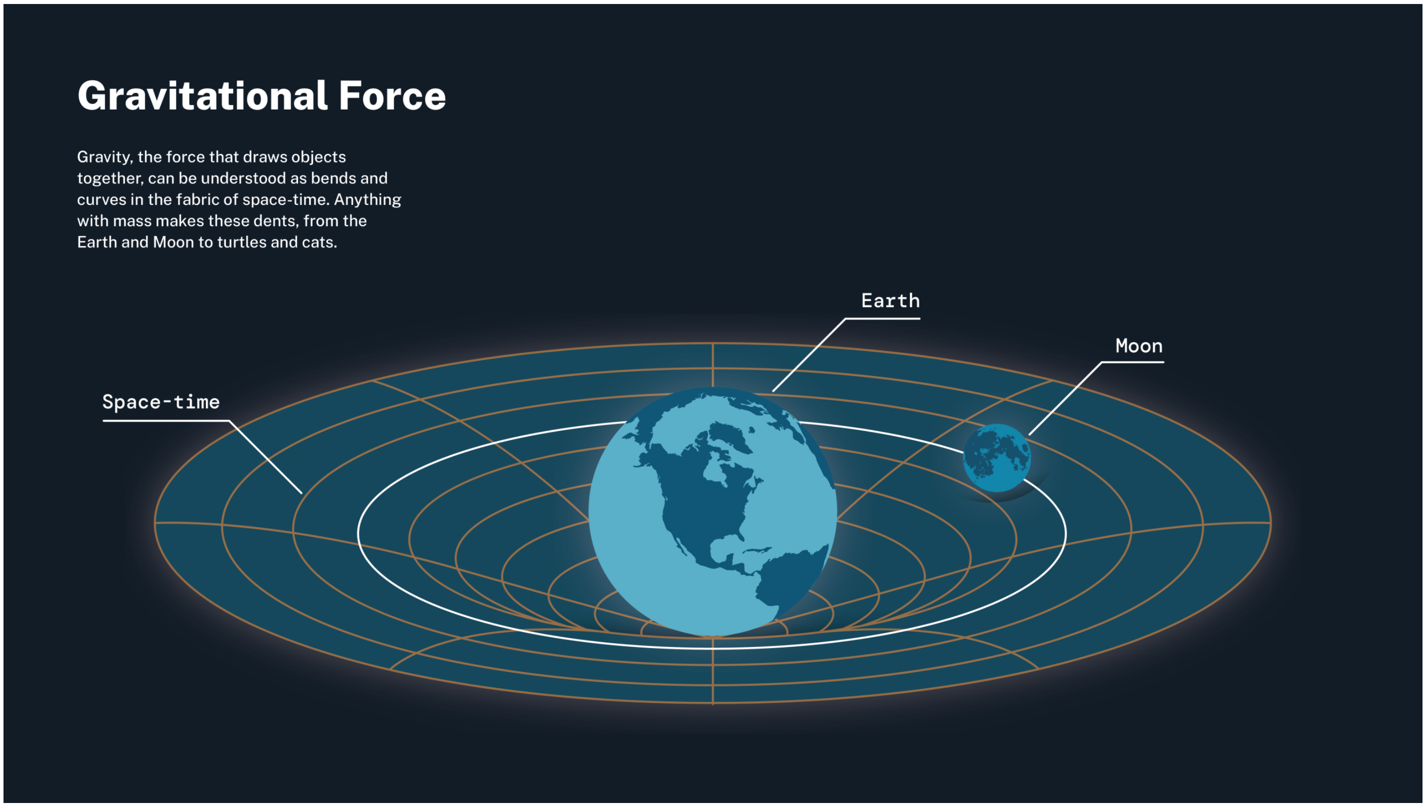
The Four Fundamental Forces

Why does Earth stay in orbit around the Sun? How does light travel? What holds atoms and nuclei together?

For centuries, scientists have sought to describe the forces that dictate interactions on the largest and smallest scales, from planets to particles. They understand that there are four fundamental forces — gravity, electromagnetism, and the strong and weak nuclear forces — that are responsible for shaping the universe we inhabit.

Gravitational Force



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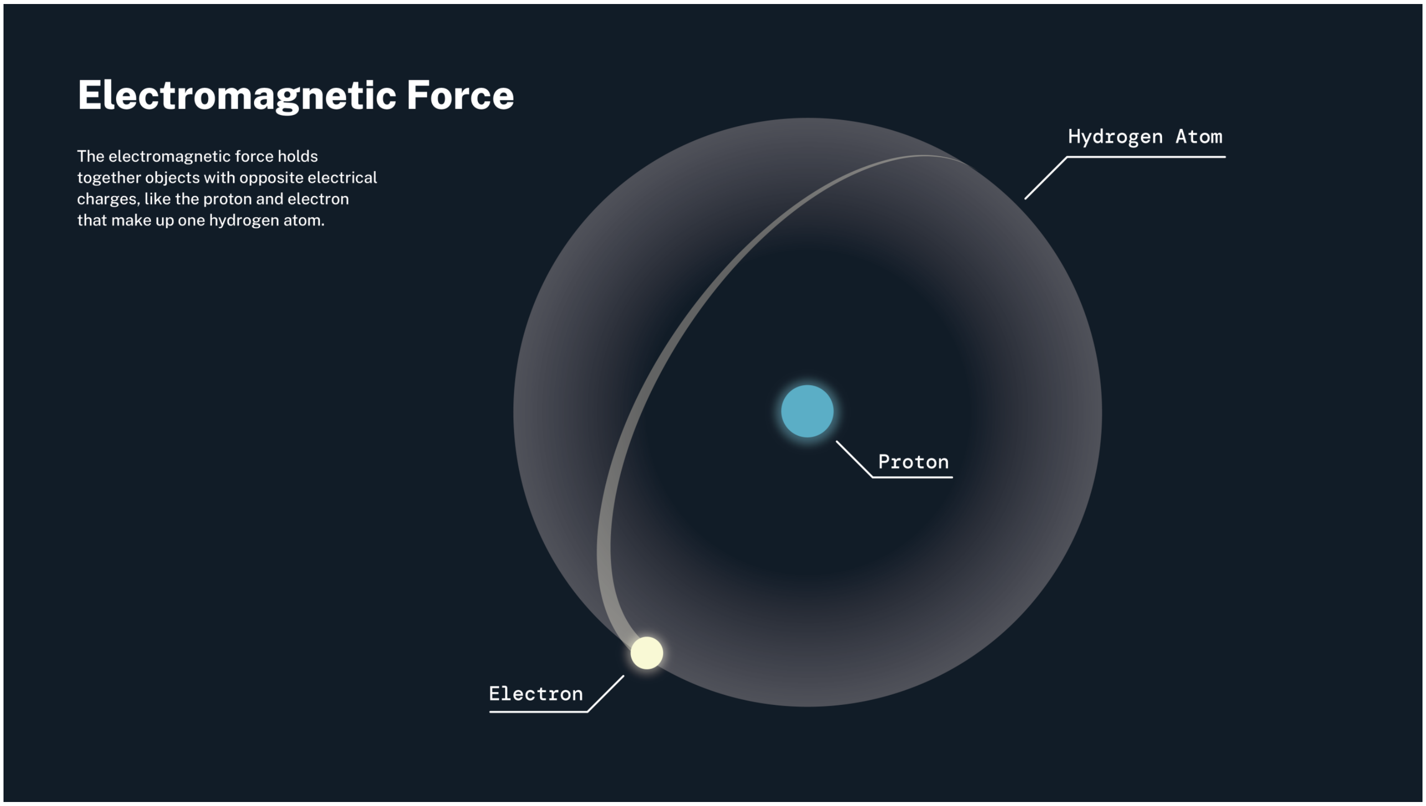
The most familiar force is gravity. It is responsible for keeping our feet on the ground and holding Earth in its orbit around the Sun.

According to the general theory of relativity, gravity can be understood as bends and curves in the fabric of space-time that affect the motions of galaxies, stars, planets, and even light. Anything with mass makes a dent in space-time, causing objects to be attracted to each other.

Gravity is an attractive force that draws two objects together. Its strength approximately increases with the masses of the two objects but decreases with the square of the distance between them. That means that if the Moon were twice its current distance from Earth, the gravitational tug between the two would be just one fourth of what it is now.

Despite being the weakest force, gravity works across infinite distances, making it responsible for the formation of the universe's structure.

Electromagnetic Force



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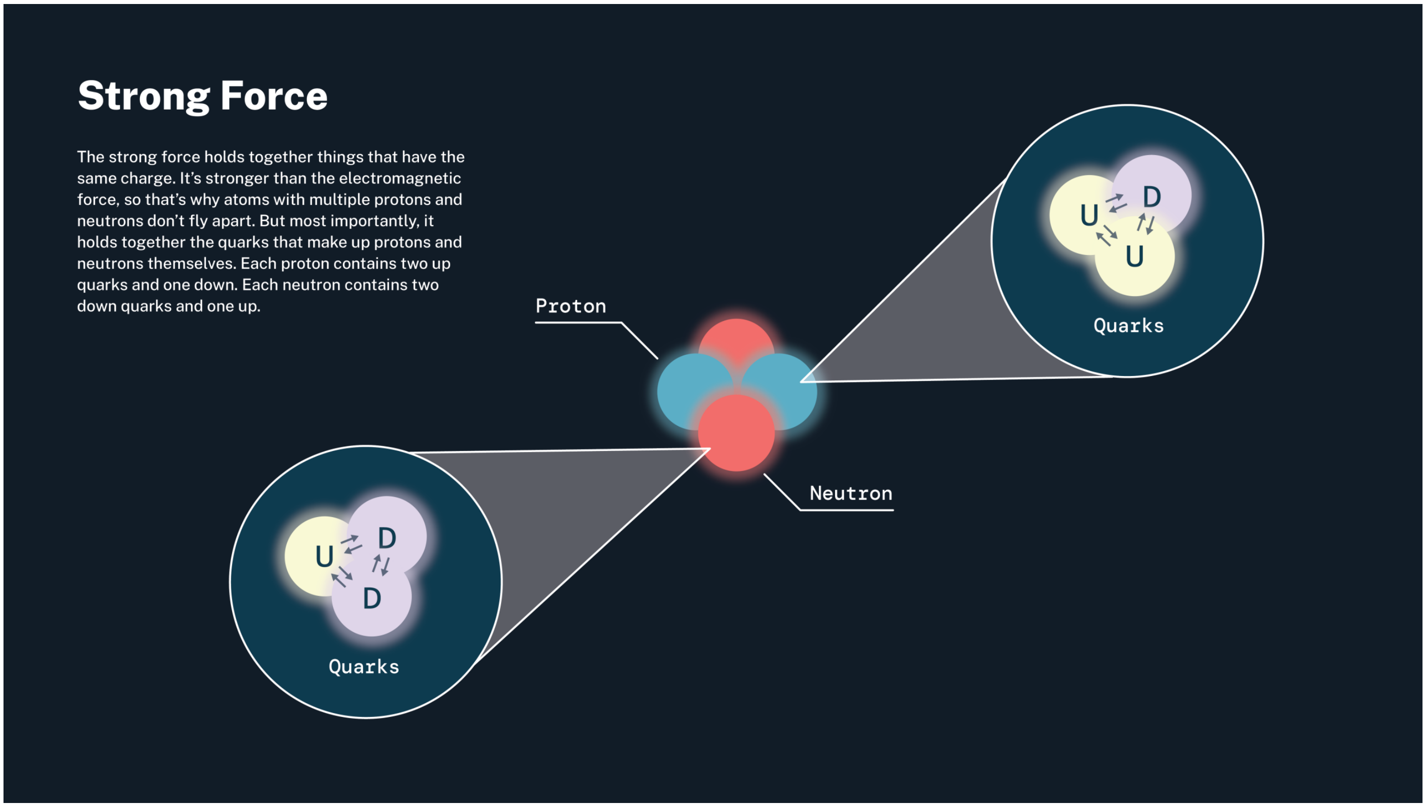
Our television sets are powered by electromagnetism. Light carries this force, which illuminates our houses at night, keeps electrons in orbit around atomic nuclei, and allows chemical compounds to form.

As the name implies, electromagnetism is the force that includes both electricity and magnetism. They are intertwined — a moving electric field produces a magnetic field, and vice versa.

Like gravity, the strength of electromagnetism drops off with the square of the distance between objects and works at infinite range. However, electromagnetism only comes into play for charged objects, and whether it attracts or repels depends on the charges of each. Two negative or positive charges repel each other; one of each attracts.

While electromagnetism is stronger than gravity, it is often balanced out in large objects by the equal numbers of positive and negative charges that form neutral atoms. For example, Earth has a magnetic field due to electric currents in its liquid core; however, Earth itself is electrically neutral.

Strong Nuclear Force



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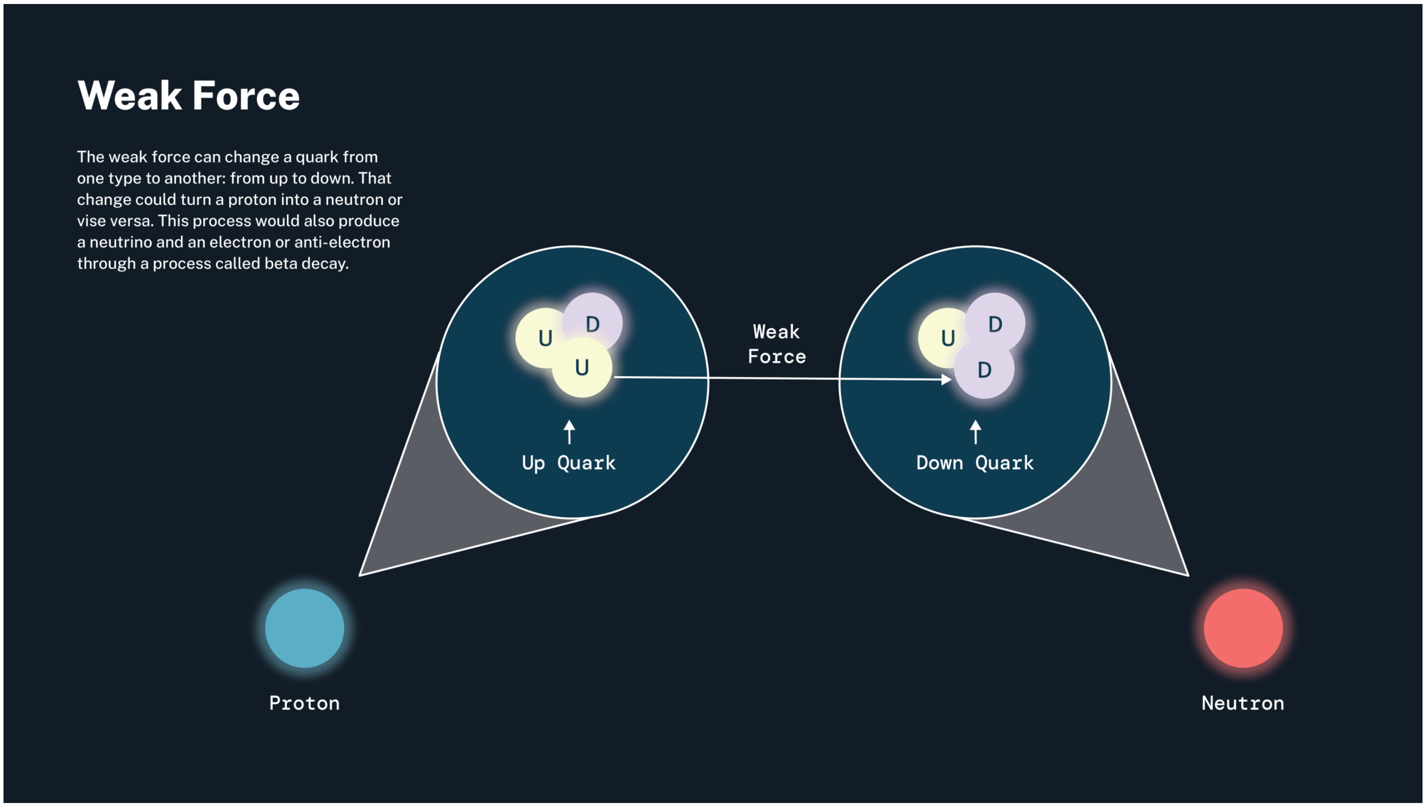
Nuclear forces affect our daily lives, but they work on distances smaller than atoms.

The strong nuclear force, or strong force for short, holds together the building blocks of atoms. It always attracts and works at two different size scales in atoms. At the level of an atomic nucleus, the strong force holds together the protons and neutrons that form the essence of the elements. On an even smaller scale, the strong force holds together the oppositely charged quarks that make up the neutrons and protons themselves.

As suggested by its name, the strong force is the strongest of the fundamental forces. It is about 100 times stronger than electromagnetism and 100 trillion trillion trillion times stronger than gravity.

However, the strong force only has influence over very, very small distances. For anything larger than the nucleus of a medium-sized atom (about 100 million times smaller than the width of a human hair), its influence quickly drops, and other forces will be stronger.

Weak Nuclear Force



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The weak force is responsible for interactions between subatomic particles – the tiny particles that are the building blocks for matter, like protons, neutrons, and electrons.

In particular, the weak force can change one quark type into another. Protons and neutrons are made of two quark varieties, up and down. The weak force can turn a down quark in a neutron into an up quark, which would change the neutron into a proton and switch its electric charge from neutral to positive. If that neutron were in the nucleus of an atom, the change to a proton would turn that atom into a different type of element. Such reactions are happening all the time in our Sun, giving it the energy to shine. This type of action also occurs in radioactive decay, which happens when atoms spontaneously shed energy and subatomic particles.

The weak force works on the smallest distance scales, another 1,000 times smaller than the strong force. It is about a million times weaker than the strong force, too, though it is still considerably stronger than gravity.

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