

Forces of Nature

NOVA Activity **The Elegant Universe**

The world is made up of elementary particles called *quarks*, which include the up, down, charm, strange, top, and bottom quarks; and *leptons*, which include the electron, the muon, the tau, and their corresponding neutrinos. But how do these particles interact? How do they form the world you see around you? Find out in this activity.

Procedure

- ① Look at the *Finding Forces* activity sheet. The graphic shows four areas of matter (labeled 1, 2, 3, and 4) that are governed by the four fundamental forces of nature.
- ② Read “The Four Fundamental Forces” section that starts below. Then see if you can match each force correctly with the numbers on the *Finding Forces* illustration. Write the letter of each description next to the number you think represents the area of matter governed by that force.
- ③ Once you have labeled the forces, write next to each force the name of the particle that carries (or is believed to carry) that force between the matter particles it governs. The force carrier particles are:

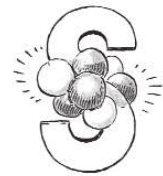
- **photon**
- **gluon**
- **graviton (theorized)**
- **W^- , W^+ , Z^0**

The Four Fundamental Forces

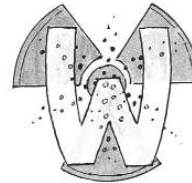
- Ⓐ **Electromagnetism** causes like-charged objects to repel each other and oppositely charged objects to attract each other. The electromagnetic force binds negative electrons to the positive nuclei in atoms and underlies the interactions between atoms. Its force carrier particle is a photon.
- Ⓑ The **strong force** binds quarks together. While the electromagnetic force works to repel the positively charged protons in the nucleus of an atom, the strong force is stronger and overrides these effects. The particle that carries the strong force is called a gluon, so-named because it so tightly “glues” quarks together into larger particles like protons and neutrons. The strong force is also responsible for binding protons and neutrons together in the nucleus.



gravity



strong force



weak force



electromagnetism

- Ⓒ **Gravity** is the phenomenon by which massive bodies, such as planets and stars, are attracted to one another. The warps and curves in the fabric of space and time are a result of how these massive objects influence one another through gravity. Any object with mass exerts a gravitational pull on any other object with mass. You don't fly off Earth's surface because Earth has a gravitational pull on you. Gravity is thought to be carried by the graviton, though so far no one has found evidence for its existence.
- Ⓓ The **weak force** is responsible for different types of particle decays, including a process called beta decay. This can occur when an atom's nucleus contains too many protons or too many neutrons—a neutron that turns into a proton undergoes beta minus decay; a proton that changes into a neutron experiences beta plus decay. This weak force is mediated by the electrically charged W^- and W^+ force carrier particles and the neutral Z^0 force carrier particle.

Questions

Write your answers on a separate sheet of paper.

- ① Which force is responsible for a neutron decaying into a proton?
- ② Which force bonds quarks together into particles like protons and neutrons?
- ③ Which force governs the motion of an apple falling from a tree?
- ④ What are you made of? What forces hold you together?

Finding Forces

NOVA Activity **The Elegant Universe**

There are four fundamental forces that govern the interactions of matter. Read the descriptions of these on your *Forces of Nature* activity sheet (in "The Four Fundamental Forces" section) and assign the correct letter to the number on this page that represents the area of matter governed by that force.

