Finally, the gravitational interaction is a long-range interaction with a strength of only about 10^{-38} times that of the strong interaction. Although this familiar interaction is what holds the planets, stars, and galaxies together, its effect on elementary particles is negligible. The gravitational interaction is the weakest of all four fundamental interactions.

A force can be thought of as mediated by an exchange of particles

Notice that in this section, we have referred to a force as an *interaction*. This is because in particle physics the interaction of matter is usually described not in terms of forces but in terms of the exchange of special particles. In the case of the electromagnetic interaction, the particles are photons. Thus, it is said that the electromagnetic force is *mediated* by photons.

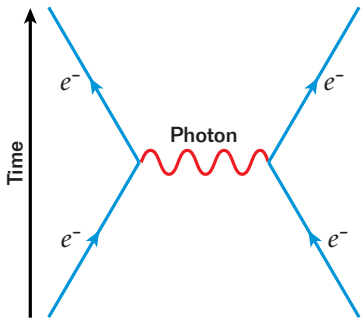

Figure 12
In particle physics, the electromagnetic interaction is modeled as an exchange of photons. The wavy red line represents a photon, and the blue lines represent electrons.

Figure 12 shows how two electrons might repel each other through the exchange of a photon. Because momentum is conserved, the electron emitting a photon changes direction slightly. As the photon is absorbed, the other electron's direction must also change. The net effect is that the two electrons change direction and move away from each other.

Likewise, the strong interaction is mediated by particles called *gluons*, the weak interaction is mediated by particles called the *W* and *Z bosons*, and the gravitational interaction is mediated by *gravitons*. All of these except gravitons have been detected. The four fundamental interactions of nature and their mediating field particles are summarized in **Table 6.**

Table 6 The Fundamental Interactions of Nature

Interaction (force)	Relative strength	Range of force	Mediating field particle
strong	1	≈ 1 fm	gluon
electromagnetic	10^{-2}	proportional to $1/r^2$	photon
weak	10^{-13}	$< 10^{-3}$ fm	$W^{\pm}$ and Z bosons
gravitational	10^{-38}	proportional to $1/r^2$	graviton

Did you know?

The interaction of charged particles by the exchange of photons is described by a theory called *quantum electrodynamics*, or *QED*.

CLASSIFICATION OF PARTICLES

All particles other than the mediating field particles can be classified into two broad categories: *leptons* and *hadrons*. The difference between the two is whether they interact through the strong interaction. Leptons are a group of particles that participate in the weak, gravitational, and electromagnetic interactions but not in the strong interaction. Hadrons are particles that interact through all four fundamental interactions, including the strong interaction.