Having Spin and Making Stripes:

**Exciting Electron Behavior**

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It’s easy to picture someone spinning, like an ice skater or a ballerina, and it’s easy to picture spinning something, like a top or a coin. Now try to imagine spinning a speck of sand. You could use some tiny tweezers, or roll the sand between your fingers and say it’s spinning, but admit it – it’s difficult to picture.

Now consider that an atom is about 10 million times smaller than a speck of sand, and an electron is the smallest component of an atom. How do you comprehend and converse about something that small spinning? You’d probably have to use some crazy, symbolic language – like math. Until you start developing your own equations and experiments for decoding the laws of nature, let’s look at what scientists have already learned about electrons and spin.

In 1921 Otto Stern and Walter Gerlach experimented with silver atoms and discovered some interesting electron behavior. When they sent a beam of atoms through a magnetic field, the beam split into two. Why did some atoms go one way, and some the other? Because of the way the electrons in the atoms were spinning. If they had had three manners of spinning, they would have split into three directions, but they only had two. While everyday objects can spin faster, slower, or even stop, an electron never stops spinning. Even if you smash it into another particle, it will keep spinning – and only spinning in one of two ways.

If you are picturing two spheres, one spinning to the right and one spinning to the left, you are visualizing the classical model. Visualizing it this way is helpful, but there is also the quantum approach. This perspective sees the electron as a little point with a radius that can’t be measured (at least not yet).

Visualizing this “point” helps you see that an electron is a fundamental particle. Fundamental particles like electrons can’t be divided into smaller particles, while composite particles, such as atoms, can. Scientists determine the spin
of composite particles by examining the spins of their components and the angular momentum of their motion around one another. But since electrons are fundamental particles, spin is an inherent quantum property. So instead of saying an electron spins like a little globe, you say it “has the property of spin.” And you can get a little more complicated and say an electron has “intrinsic angular momentum.”

Once you impress your friends with that manner of speaking, obviously they’ll want to know more about this interesting aspect of subatomic activity. Like, how do you label these two ways of spinning? You can say an electron is either “spin up” or “spin down.” This describes the arrows used when labeling their spins on diagrams, (considering spin is a vector quantity.)

To further impress your friends, tell them that spin-up electrons have 1/2 spin and that spin down electrons have -1/2 spin. Having half-a-spin may seem a little strange to you. This behavior isn’t observed in everyday life. So to understand it, we’ll have to cheat for a second and picture the electron like a classical sphere spinning on an axis. Usually when you spin something 360 degrees, it returns to its starting position. But with an electron, you would have to turn it 360 degrees again, to get it back to its starting position.

How do you visualize the electrons’ spin in relation to the rest of the atom? In an atom, electrons exist in a probability cloud around the nucleus. They settle into “shells” or “orbitals,” as pairs or by themselves. The electrons closest to the nucleus are paired, one up-spin, and one down-spin. Farther away from the nucleus, electrons are generally in their own orbitals, but still have either up-spin or down-spin.

Researchers today have a tool to determine the spin of specific outer electrons. At Ohio University, for example, Dr. Arthur Smith and his graduate students use a scanning tunneling microscope to discover spin directions. The microscope – STM for short – works at the atomic scale, and the enlarged images are observed on a computer screen. To put it simply, the STM’s tip scans a sample surface made up of atoms, reacts to the spin of the electrons in those atoms, and produces images accordingly.

In this case, the image produced is a series of stripes. The researchers design the sample surface into “channels,” half of which accept up-spin and half down-spin electrons from the atoms on the STM’s tip. Since there are more up-
spin electrons than down-spin electrons on the tip, the channels that are designated to receive up-spin electrons collect more, and appear brighter.

Now that scientists have the ability to study spin at a scale this small, interesting technological advancements are right around the corner. Spintronics, a technology that uses the electron’s spin to its advantage, is a growing multi-billion dollar industry. The more our efficiency in spintronics grows, the smaller our electronic devices will get.