Commentary: Relativity

There are two theories of relativity, special and general, which the German physicist Albert Einstein discovered in the early 20th century. He proposed special relativity in 1905 when working as a patent clerk, while general relativity took ten more years of work before being completed in 1915. Both theories describe how space and time depend on the motion of an observer relative to the object he/she is measuring.

Special relativity

Special relativity describes how space is unified with time, and how distances shorten and clocks slow when moving very fast. In everyday situations, like driving a car, these effects are far too small to be noticed. Instead, relativity becomes important for objects moving at speeds near that of light. Most 20th century theoretical physics uses special relativity. Einstein also recognized that the 19th century laws of electricity and magnetism were already compatible with special relativity. Evidence for special relativity is overwhelming—most results in particle and nuclear physics would not hold without it. Furthermore, scientists have directly measured time delays of accurate clocks on fast-moving aircraft.

The main idea in special relativity is that two observers moving with different velocities measure space and time differently. They will therefore disagree about how long an object is or how quickly a clock ticks. This idea follows from a simple postulate: no matter how fast an observer travels, light will always seem to move at a fixed speed—the speed of light, around 186,000 miles/sec (300,000 kilometers/sec) in vacuum. At first sight this seems impossible because, for example, a person running towards a moving car would see the car moving faster towards them. However, Einstein said the way an observer measures space and time changes to make the speed of light look constant.

General relativity

General relativity describes gravity as a bending of space and time. Unlike special relativity, it has remained fairly separate from other 20th century theoretical physics, such as quantum and nuclear physics. Experimental evidence for general relativity is good, but not as overwhelming as for special relativity. The main evidence comes from astronomy—for example, Einstein explained an anomaly in the orbit of mercury and successfully predicted that starlight is bent when passing close to the sun. There have also been more direct tests, such as time delays from GPS satellites caused by Earth’s gravity.

The main idea in general relativity is that acceleration and gravity are equivalent. Two observers accelerating relative to each other will feel different strengths of gravity. Einstein then went further to say that all gravity is from acceleration, and this acceleration is caused by space and time being bent by nearby mass. For example, the Earth bends space and time to make an object accelerate downwards and thus appear to fall. Mathematically, general relativity is formulated around the idea that all objects move in straight lines, called geodesics. Because space and time are bent, these straight lines appear curved. Hence balls curl when thrown and planets circle the sun.