Can Science Explain It All?

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Science and technology affect almost every aspect of our lives. Our food has been grown using fertilizers and pesticides, it is prepared with additives and preservatives, and is packaged in plastic. Our communication via telephone, radio, television, fax, electronic mail, and photocopy machines is fast and efficient. Our transportation is rapid. Computers do much of our bookkeeping and word processing. Our entertainment comes from CD players, VCRs, and high-tech amusement parks. Even our health and the length of our lives have been dramatically improved by medical science discoveries such as penicillin and the polio vaccine. And then there are simple things like ballpoint pens and drip-dry clothes.

Because the scientific method works, both government and private industry are willing to invest millions of dollars into scientific research. Much of scientific study displays the elegance, logic, and self-consistency of the natural world. The lure of probing the secrets of nature and developing them for the benefit of humanity surmounts political barriers and provides a brotherhood of science. No wonder some feel that the scientific method can be used to solve all of our problems. But no matter how impressive scientific achievements are, science has limitations.

A Christian, of course, believes that there is more to reality than science can address. The miracles recorded in the Bible, especially the incarnation and the resurrection of Jesus Christ, which constitute the heart of Christianity, cannot be studied by the scientific method. These supernatural events are not presently occurring and thus are not observable, repeatable, falsifiable events that science can control. In addition to "miraculous" events, science provides no absolute standard for answering moral and ethical questions. Perhaps most importantly, science has difficulty in providing purpose and meaning to life since it cannot conquer death.

Even if the limitations of science were to be ignored, the inductive nature of science presents intrinsic limitations. These are best illustrated by studying the history of a scientific model, for example, the model of light in physics.[1]

The Wave Model of Light

All the simpler properties of light had been observed by the end of the 17th century. Light travels in *straight lines* at a *finite speed*. Light is *reflected* as from a mirror. It is *refracted* or bent as it passes from one medium to another, such as from air into water or glass. This property accounts for rainbows and is now used in eyeglasses and telescopes. Light is *diffracted*, or spread, as it passes through a small opening, just as water waves can spread around a turn in a river. This same property of sound allows one to hear noise around a corner. Light demonstrates *interference* phenomena in the same way as the two sets of waves created by two rocks dropped in a pond will interfere with each other, but will continue to travel independently. A piano tuner uses the interference of sound waves, or the beat frequency, to tune a piano. The interfering property of light accounts for the colors seen in oil slicks, soap bubbles, and peacock wings, and is the physical basis for holograms. Light can be *polarized* or forced to vibrate in a single plane, just as a guitar string can be forced to vibrate in only a horizontal direction. This property is used to reduce glare in polaroid sunglasses.

These properties of light have been explained at various times both in terms of discrete, bullet-like particle models as well as continuous, water-like wave models. In the late 17th century, Isaac Newton developed a particle model for light that became the accepted model during the 18th century. Living at the same time as Newton, Christian Huygens felt that light was better described as a wave, such as a water or sound wave. This wave model of light gained favor in the early 19th century, and was the only accepted model by the end of that century.

The late 19th-century wave model was comprehensive enough to explain most observations of physics at the time. One simple wave property is the relationship: *velocity* = *frequency* x *wavelength*. Imagine water waves coming in to the beach. The frequency is the number of waves hitting the beach each minute. The wavelength is the distance from one wave to the next. Multiplying these two quantities together gives the velocity of the waves. Similarly, the sound waves from a piano come from vibrations in the strings and travel to the ear at a constant velocity. Shorter strings in the piano give a sound with a small wavelength, resulting in a larger or higher frequency. Longer strings give a sound with a larger wavelength and lower frequency. The approximate frequency of "middle C" on the piano is 262 vibrations per second or Hertz, and its wavelength in air is about 1.3 meters. Its velocity then is about 340 meters per second. (Most people can hear from about 20 Hz to 15,000 Hz, while dogs and bats can hear much higher frequencies.)

The concept of wave frequency can be generalized to light. Red light has the lowest frequency of light visible to humans, violet has the highest. And just as there are sound frequencies higher than those found on the piano, sunburn-causing ultraviolet light is at a higher frequency than violet light. X-rays used for medical diagnosis and gamma rays from radioactivity have even higher frequencies. In the other direction of the spectrum frequencies lower than red, begin with infrared rays which we sense as heat, then the microwaves used in cooking, and then radio waves. Notice that multiplying a common AM radio frequency, such as 1000 kHz (or one million cycles per second) by its wavelength of 300 meters (or about 1000 feet) gives the velocity of light at 300 million meters per second.

Light is produced from changing electric and magnetic fields, so the wave model of light includes electricity and magnetism as well. Radio waves are produced by the electricity in a radio station transmitter antenna, and visible light comes from electricity in a light bulb or in lightning. Electricity is produced by moving magnets in a steam or hydroelectric generator. The light waves from gamma rays, to visible light, to radio waves are all part of the electromagnetic spectrum.

Almost all of the observed phenomena of light, electricity, and magnetism were described 100 years ago by James Clerk Maxwell using a set of four equations. His wave model of electro-magnetic radiation was comprehensive, unifying, elegant, and logical. Considering all the phenomena that the wave model of light could explain, it obviously seemed much better than the obsolete particle model of light suggested by Newton. In the late 19th century, scientists felt comfortable with their understanding of light; they believed there was little new to learn about it. The wave model appeared to be complete and in need of little more than minor modifications.[2]

A Revolution in Light Models

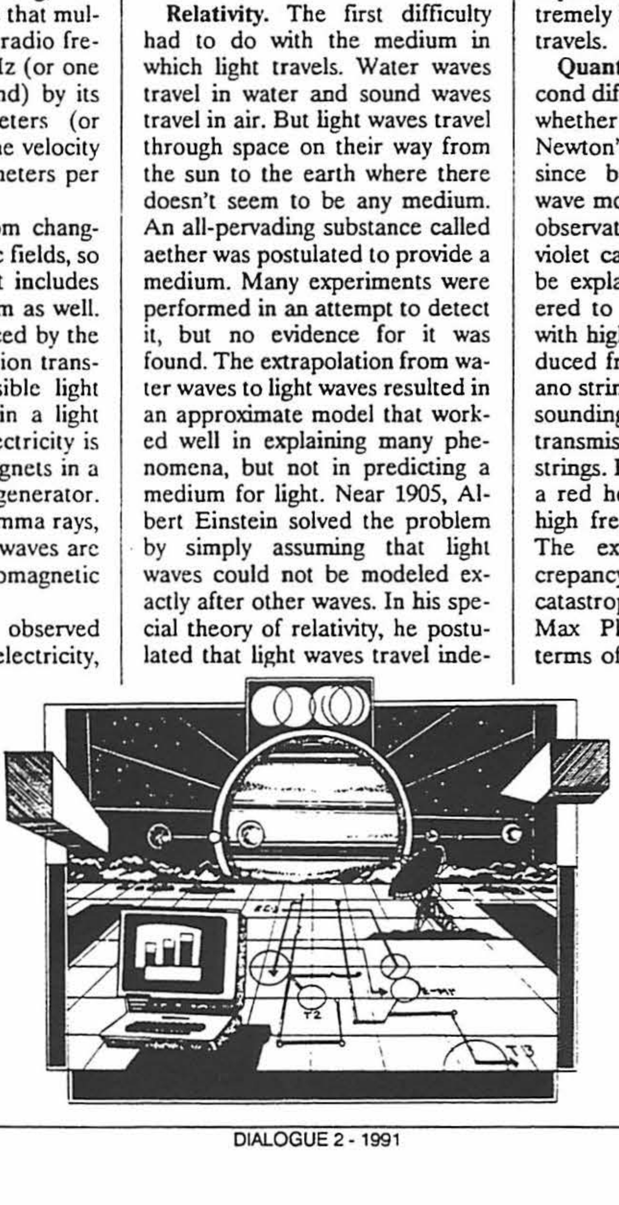
Several pieces of data, however, had not yet been explained. Attempts to deal with these remaining problems led to two major revolutions.[3]

Relativity. The first difficulty had to do with the medium in which light travels. Water waves travel in water and sound waves travel in air. But light waves travel through space on their way from the sun to the earth where there doesn't seem to be any medium. An all-pervading substance called aether was postulated to provide a medium. Many experiments were performed in an attempt to detect it, but no evidence for it was found. The extrapolation from water waves to light waves resulted in an approximate model that worked well in explaining many phenomena, but not in predicting a medium for light. Near 1905, Albert Einstein solved the problem by simply assuming that light waves could not be modeled exactly after other waves. In his special theory of relativity, he postulated that light waves travel independently of any medium (or reference frame).[4]

The special theory of relativity made the extremely non intuitive prediction that while observing an object moving at high speeds close to that of light, the mass of the object would appear to increase, its length would shorten, and its time would move more slowly. This prediction has been experimentally confirmed, and the equations of special relativity are now routinely used to describe experiments in particle accelerators. Observations at "every day" speeds do not explain what happens at the extremely high speeds at which light travels.

Quantum Mechanics. The second difficulty was the question of whether light is actually a wave. Newton's particle model had long since been superseded by the wave model, but there were some observations, such as the ultraviolet catastrophe, that could not be explained if light was considered to be a wave. Sound waves with high frequencies can be produced from a single vibrating piano string on a poorly constructed sounding board that allows the transmission of energy to all the strings. However, light waves from a red hot iron include very little high frequency ultraviolet waves. The explanation for this discrepancy (the "ultraviolet catastrophe") came in 1900 when Max Planck modeled light in terms of particles of energy, with higher frequency light having more energy per particle. High frequency ultraviolet light would require too much energy per particle to be readily produced.

The model of light as a particle or quantum of energy was part of the development of quantum mechanics[5] that also made some very non intuitive predictions about the small-scale



physical world. For example, quantum mechanics predicted that particles such as electrons should sometimes be treated as waves, thus making their exact location impossible to identify, and electrons in an atom could orbit only in certain discrete shells. These predictions have since been verified. Now quantum mechanics is used to understand chemical bonding, the electron microscope, the laser, the transistor, nuclear power, and radioactivity. But in so doing, it has incorporated some of Newton's particle model of 200 years before. Today, we find that light is treated as a wave under certain conditions and as a particle under others, since a simple understanding of water waves cannot be extrapolated to the extremely small scale.

Analysis of These Revolutions

Even if the possiblity of supernatural intervention is ignored, several limitations of science become apparent in the light of these two revolutions.

Even in the natural world, much data is unavailable. One hundred years ago, there had been no observation of particles traveling close to the speed of light or of the small particles in the atom or nucleus. Since science is inductive, a model can be correct (in that it explains all present observations) without being complete (in that it is unable to explain all future observations or past unobserved occurrences).

Even for some of the available data, explanations are lacking. Light arriving from the sun cannot be explained without a medium for light. The ultraviolet catastrophe cannot be explained in terms of a wave model for light.

Even for good explanations, simplified approximations (models) are used. The wave model of light was only an approximation. As science progressed to the unusual and extreme conditions of high speeds and energies and small sizes, different laws became important. Intuition and reasoning from everyday events were no longer sufficient. Extrapolation from the known and understandable to the unknown and extreme was useful, but only approximate.

Even though one model is used, other models are possible. The wave model for light worked well a century ago, but now we know that a particle model must be used to explain some observations.

Although revolutions in scientific interpretations have occurred in the past, it is always tempting to feel that present interpretations are so much superior that they won't need to be revised. However, even recently, several revolutions have unarguably changed the perspectives of science in major ways. A new branch of science sometimes labeled "chaos" is studying scientists' observation that infinitesimal changes in initial conditions can completely change the final results, and that some deeper order can be found in phenomena previously thought too complex to model.[6] Geology has recently been including unusual and extreme processes, such as plate tectonics to explain mountain building and mid-oceanic ridges, and extraterrestrial impact to explain the extinction of the dinosaurs.[7]

The scientific method of using experiments to study cause and effect relationships is useful and beneficial, as is obvious from the advantages of our technological society. But even so, we must not forget that science is limited because it is a human endeavor. It is not exhaustive because it is inductive. It doesn't include all possible models, complete models, complete explanations, all obtainable data, and it leaves no room for the supernatural.

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NOTES

1. See George Gamov, *The Great Physicists From Galileo to Einstein* (New York: Dover, 1988); see also Edmund T. Whittaker, *A History of the Theories of Aether and Electricity* (New York: Dover, 1989).
2. See Nathan Spielberg and Byron D. Anderson, *Seven Ideas That Shook the Universe* (New York: Wiley, 1987).
3. See Bernard I. Cohen, *Revolution in Science* (Cambridge, Mass.: Harvard University Press, 1985); see also Richard Morris, *Dismantling the Universe* (Simon and Schuster, 1984); Thomas S. Kuhn, *The Structure of Scientific Revolutions*, 2nd ed. (Chicago: University of Chicago Press, 1970).
4. See Clement V. Durell, *Readable Relativity* (New York: Harper and Row, 1960).
5. See George Gamov, *Thirty Years That Shook Physics* (New York: Dover, 1966); see also Richard P. Feynman, *QED: The Strange Theory of Light and Matter* (Princeton, N.J.: Princeton University Press, 1985).
6. See James Gleick, *Chaos: Making a New Science* (New York: Penguin, 1987); see also Kevin C. de Berg, "A Random Universe? Order and Chance in Nature and Scripture," *Dialogue* 2:3 (1990), pp. 10-12.
7. See A. Hallam, *Great Geological Controversies* (New York: Oxford, 1989).