Chapter 11

THE ELUSIVE ETHER

"*One thing we are sure of, and that is the reality and substantiality of the luminiferous ether .... You may regard the existence of the luminiferous ether as a reality of science.*"

Lord Kelvin (1824-1907)

Maxwell's equations predicted a single definite value for the speed at which electromagnetic waves, and light in particular, propagate in a vacuum: c = 186,000 miles per second (c is the letter traditionally used to represent the speed of light).

By Newton's mechanics, the speed of light ought to vary with the speed of the "platform" on which it is measured. Let's say that a beam of light is traveling at 186,000 miles/second with respect to some platform A. If some platform B is traveling in the direction of the beam of light with a speed of 100,000 miles/second with respect to platform A, an observer on B should measure the speed of the beam of light to be 86,000 miles/second. If he knows that platform A has measured 186,000 miles/sec., he can conclude that his platform is moving at 100,000 miles/sec. with respect to platform A.

Using the speed of light derived from Maxwell's equations, one ought to be able to do what was not possible using only Newton's laws of mechanics, namely, to detect uniform motion.

The Ether

The speed of light is 186,000 miles per second. But with respect to what? Earlier, we defined a wave as a disturbance of some kind that propagates through a medium (like the ripples that propagate on the surface of a pond). If light was a wave, it seemed only natural to assume that it too had to have a medium in which to "wave." A medium had to be invented so that physicists could visualize the propagation of light. Then, the speed predicted by Maxwell's equations might be the speed of light relative to this medium, which, as previously mentioned, was called the "ether". This medium was supposed to be some invisible substance filling all space, a form of matter, probably composed of particles.

In the latter part of the 19th century, belief in the existence of the ether

became firmly entrenched in the minds of scientists. In Maxwell's words, "there can be no doubt that the interplanetary and interstellar spaces are not empty, but are occupied by a material substance or body, which is certainly the largest and probably the most uniform body, of which we have knowledge."

And yet, as mentioned in Chapter 8, the ether was a most peculiar substance on which to place such total faith! Since the motions of the planets had been observed over millennia without noticing any change, the ether must offer at most an infinitesimal resistance to the motion of the planets. Most likely, the ether could freely penetrate ordinary matter, as "the water of the sea passes through the meshes of a net when it is towed along by a boat", in Maxwell's words. The ether had to be very low in density, and yet very hard, since both of these properties result in a high speed for waves. The ether made it possible to visualize the propagation of light, but was itself most difficult to visualize, because of the contradictory properties it had to possess.

If the ether really existed, the Earth should be moving through it at some definite speed. To an observer on Earth, the ether should appear then to be moving toward the Earth. If we are riding, for instance, in an open car and there is no wind, it feels to us, however, as if a wind were blowing against the car. Similarly, there should be an ether "wind" or "stream" blowing against the Earth.

Physicists felt that the ether "wind" ought to be strong enough to have some observable effect. A number of very ingenious experiments were devised to detect the motion of the Earth through the ether. The first and most famous of these experiments was carried out by an American physicist, Albert Michelson (1852-1931), with the aid of an American chemist, Edward Morley (1838-1923). The results of their experiment were announced in 1887.

The Michelson-Morley Experiment

Born in Germany, Michelson came to the United States with his parents when he was only two years old. In 1873, he graduated from the Naval Academy in Annapolis. Six years later, he took a leave for a few years of study in Germany and France, where he became intrigued by the problem of detecting the ether. After returning to the United States, he resigned his Navy commission to become in 1883 the first physics professor at the newly founded Case Institute in Cleveland, Ohio. In 1907, he became the first American to receive the Nobel Prize for Physics.

[The Nobel Prize is named after Alfred Bernard Nobel (1833-1896), a Swedish chemist, engineer and industrialist, who accumulated an immense fortune from his invention of dynamite and other explosives. Being somewhat of a recluse, he never married; when he died, he left the bulk of his estate to establish what have become the most prestigious international awards. These are given annually to those who "have conferred the greatest benefit to mankind" in the fields of physics, chemistry, medicine, literature, economics,

and the promotion of peace.]

To explain his experiment to his children, Michelson compared it to a race between two swimmers. We will talk, instead, of two identical race boats, both set to move at exactly the same speed with respect to the water. Starting from one bank of a river, one boat goes straight across to the other bank, and back. The other boat goes the same distance (as measured from the ground), but in the direction of the river, once upstream and once downstream.

Although the two boats travel at the same speed with respect to the water, they travel at different speeds with respect to the land because of the current. When the boat that travels along the river is going downstream, the speed of the current must be added to that of the boat. When the same boat is going upstream, the speed of the current must be subtracted from that of the boat. The boat that goes across, instead, is slowed down in both directions, because it must always be aimed a little upstream in order to prevent the current from pulling it off course.

Note that, we have combined speeds by addition or subtraction in Newtonian fashion. It can be shown mathematically that the boat that goes across will win every time, because it actually travels a shorter distance with respect to the water. Only if the river were still, would the two boats finish at the same time.

The basic idea of the Michelson-Morley experiment was to set up a race between two beams of light. The whole planet Earth corresponds to the river banks of our boat race, and the ether "stream" corresponds to the flowing river. Instead of the two race boats, we have two beams of light making round trips of equal lengths, but in perpendicular directions, through the ether, which is streaming by the Earth. The beams are then rejoined.

If there is indeed any relative motion between the ether and the Earth (the river and the banks), by Newton's mechanics, one beam should "win the race". This means that the two emerging beams would be out of step to some extent and would interfere with one another. Very ingeniously, the experiment took advantage of the interference of waves to reveal extremely small time differences by means of concentric dark and light interference rings.

To Michelson's great surprise, however, the race had no winner! The observations were continued over a long period of time - with the Earth going in one direction and, six months later, in the opposite direction. The experiment has since been repeated many times in various ways. No motion of the Earth with respect to the ether, however, has ever been observed.

Later, the hypothesis of the ether - as a physical medium in which electromagnetic waves "wave" like ripples on the surface of a pond - was deemed unnecessary, and was abandoned.

The "Conspiracy" of Nature

Various attempts were made to explain the unexpected failure of the Michelson-Morley experiment. Many other experiments were designed to detect an ether stream, but they all failed. It appeared that nature was in a conspiracy to defeat all such attempts: it always seemed to introduce some new phenomenon to undo whatever ought to have made possible the detection of the ether stream.

The French mathematician and theoretical astronomer Henri Poincare' realized that a total conspiracy is itself a law of nature. In the late 1800's, he restated Newton's special principle of relativity more broadly as follows:

The laws of physical phenomena must be the same for a fixed observer A as for an observer B who has a uniform straight motion without rotation relative to A. We do not have, nor can we possibly have, any way of determining whether or not we are carried along in such a uniform straight motion.

There did not seem to be any way of detecting an absolute motion, in particular, that of the Earth with respect to the ether. And yet, knowledge of the speed of light should have made it possible!