JOURNAL OF THE TENNESSEE ACADEMY OF SCIENCE
VOLUME 52, NUMBER 2, APRIL, 1977

PHYSICS IN 1776*

ROBERT T. LAGEMANN
Vanderbilt University
Nashville, Tennessee 37240

As a background let us examine some of the factors which affected the pursuit of science—in particular, physical science—in the Colonies in 1776. By 1700, the population of the Colonies was about 220,000, a figure which almost doubled every twenty years, so that by 1776 there were about 2,700,000 people in what was to become the United States. Of these, slightly more than half were below Mason and Dixon's line. This growth was not the consequence of extraordinary fecundity, but of immigration from Europe, chiefly from England and Scotland; as a result, the scientific knowledge of the Colonists, their books, and their instruments were largely those of the mother country. The people themselves, however, were not a cross-section of the English-Scottish population. In 1785, when Thomas Jefferson went to France, he observed that European scientists were well ahead of those in America. "In science," he wrote, "the mass of people [of Europe] is two centuries behind ours, their literati, half a dozen years before us." A New Haven magazine averred in 1788 that the people at large (in America) were "more intelligent, inquisitive for knowledge, and more willing to embrace new opinions, founded on reason and experience, than those of any other country." If what they claimed were indeed true, there existed a propitious climate for the development of science. But in the view of Brooke Hindle, there was in America at the time only one scientist of first rank; moreover, American libraries and scientific societies were inferior to those to be found in London, Edinburgh, and Paris. Even the basic instruments needed for research in many of the branches of science were not available. And only two years after Jefferson had praised the American people, there occurred in Philadelphia the mobbing and death of an old woman accused of being a witch. In the field of witchcraft, at least, the application of rational thought had not yet triumphed.

If the people at large were more ready than those of other countries for science, one circumstance which militated against the development of physical science, at least, was the restriction by the mother country on the growth of technology in the American Colonies. Technology and physical science go forward hand in hand, each benefiting from the other. But although Colonists were permitted to produce certain raw and unprocessed materials, they were not allowed to make certin manufactured items. For example, the Iron Act of 1750 encouraged the production of pig and bar iron in the Colonies by dispensing with duty on such iron; but at the same time, the Act prohibited the building of plants for the production of finished products from that iron. The Colonists were allowed to produce iron, but steel and steel products could be made only by Englishmen. What was more, foreign countries—France, for example—who wished to trade with the American Colonies had to ship their goods to an English port and there reload them on a British or American ship—and pay a fee, as well. Thus, the growth of science was hindered by difficulty of access to non-British books and instruments, while technology was held back by restrictions on the bringing of designs and drawings of machinery to America and by the lack of problems and new ideas arising from the manufacture of finished products.

What societies were there in the Colonies to foster the growth of science? There were only two of any significance. One, the American Philosophical Society, founded in 1769, was confined largely to members from Philadelphia. The other, the American Academy of Arts and Sciences, was begun in 1784 and drew its members mostly from Boston. Both were patterned after the Royal Society of London. A third, of lesser importance, was the Connecticut Society of Arts and Sciences, established in 1786.

The American Philosophical Society had 244 members in 1771, with 157 from Pennsylvania, 11 each from New York and New Jersey, 10 from Massachusetts, lesser numbers from Maryland, South Carolina, Virginia, Delaware, Rhode Island, and Georgia, and 35 from the West Indies and Europe. Beginning in 1786, the Society offered a prize of the annual income from 200 guineas "to the author of the best discovery, or most useful improvement to navigation, or to Natural Philosophy, mere Natural History on excepted." Also, in the same year, it built its own building in Philadelphia (although not without considerable difficulty until a member, B. Franklin by name, came forward with partial funding). The Society had a cabinet for the deposition of instruments which could be borrowed by the members. Gradually, though, this became a museum of apparatus and of objects in the field of natural history. In addition, the Society published a journal, the Transactions of the American Philosophical Society, which included papers from all the sciences represented in the parent society. But of the sciences represented, there were more papers on astronomy than on any other single topic. This proclivity was also evident in the papers of Americans published in the Transactions of the Royal Society, a circumstance perhaps in part due

* Highlights of a presentation made at the General Session of the Tennessee Academy of Science, November 1976.

to the fact that America offered one-third more days of good weather for observing than could be found in England. The Boston-based Academy had its journal also, Memoirs of the American Academy of Arts and Sciences, whose first volume appeared in 1785.

Beyond the publications of the two societies, there were no other scientific journals of national significance until 1815, when Samuel L. Mitchell's "Medical Repository" began publication, and 1818, when Silliman's Journal first appeared.

In Colonial times, then, Americans depended largely on the Transactions of the Royal Society for publication of their high grade work. As for books—textbooks as well as others—these, too, originated in England.

Let us turn to the colleges where the science of the day was formally taught. The Colonial colleges—Harvard, William and Mary, Dartmouth, to name some—were formed largely to train clergy for the Christian ministry. The heads and the professors were usually clerics; in their libraries, theological titles predominated. Even though the professors were, with a few exceptions, not themselves scientists, they not only fostered an education which embraced the sciences but also attempted to provide cabinets of minerals and apparatus for teaching. In part, the inclusion of science in the curricula can be attributed to the presence of many Scottish teachers on the faculties. The Scottish teachers and physicians whose disposition it was to emigrate to America brought with them an educational background which gave considerable attention to the sciences, whereas the English universities of the period still offered a predominantly literary education.

What, then, was included in the subject matter of a college course in Natural Philosophy? A description of one such course can be found in a notebook still preserved at Harvard, which contains the summary of a "Course in Experimental Philosophical Lectures" given in 1746 by Professor John Winthrop. A condensed list of the topics includes mechanical powers (mechanical advantages of simple machines); the laws of motion, gravity and the movements of planetary systems; attraction and cohesion; hydrostatics; pneumatics; fluids; magnetism; electricity; optics; descriptive astronomy; and astronomical calculations. In brief, one can say that the physics and astronomy taught under the name of natural philosophy was an attempt to explain Newton's Principia, which, as someone has remarked, was more revered than understood. This accounts for the emphasis on mechanics, on optics, on astronomy. It should be noted that to understand the Principia properly required a good knowledge of Euclidian geometry, of algebra, and of the new calculus, not to mention facility in Latin.

There were no student laboratories of physics during this period. These were not established until 1869 at MIT. Teaching was done by close adherence to a textbook, although the teacher might possess the only copy, and by use of demonstrations of known principles with specially designed apparatus. The names of the pieces used (at Harvard and Dartmouth, for example) are known; nearly all of them were obtained from England. Harvard had the best such collection, it is claimed. Its greatest rival in the apparatus collection was William and Mary, where Dr. William Small taught from 1758-1764. When he returned to England in 1764, to become associated with James Watt, he carried a commission from the College to purchase for it a collection of scientific apparatus. A listing of the items indicates the subject matter taught in a course of that period: an achromatic telescope (3½ ft. focal length), a best double microscope (i.e., a compound microscope), a solar microscope, a set of prisms, a pendulum to swing in vacuo, the fountain experiment, plates of attraction and cohesion, a dipping needle, six pounds of quicksilver, an electrical machine, two glass models of pumps, and an inclined plane.

The colleges, however, were not the only means whereby an interest in physics was encouraged. Science was taught in night or evening classes to satisfy the needs of working people, and there were many itinerant lecturers who travelled about the Colonies giving talks in rented halls and supporting themselves from the fees charged. In 1767, there were at least eleven such night schools in Philadelphia, for in that year eleven combined to set standard hours and charges for instruction. The topics presented in these schools were often practical in nature: surveying, navigation, and practical mathematics; sometimes they were even entertaining: as when the phenomena of static electricity were displayed, people received startling electrical shocks, and women's hair was made to stand on end. In any case, much knowledge was imparted, and most craftsmen and apprentices were literate.

Despite the evidences of interest in science, its full-time pursuit did not occupy many people. According to a knowledgeable observer, in 1802 there were only about 21 full-time jobs in science in the United States, all academic positions. (This figure does not include physicians, but does include those teaching botany or chemistry in medical schools.) The characteristic scientist was a gentleman amateur who had other interests as well as other means of livelihood.

The utilitarian aspect of science was widely accepted in the Colonies. Isaac Newton, says one commentator, "was not worshipped because of the simple beauty of his laws alone, but because he had provided a key which promised to unlock the wisdom of the ages and to permit man to put that wisdom to work." This aim is exemplified in the names of the societies, as for example "The Virginia Society for Promoting Useful Knowledge," founded in 1773 at Williamsburg. Did this attitude lead to the education of engineers and proliferation of inventors? As a matter of fact, the Revolutionary War revealed a startling lack of engineers, if we exclude land surveyors. And as for inventors, although a patent system was introduced by Congress in 1790, they too were few in number. We can mention, nonetheless, Franklin's lightning rod and Godfrey's quadrant, the latter a navigation instrument which was simultaneously invented by Hadley in England and which subsequently bore his name above. Another invention was a submarine. In 1775, David Bushnell "reached the heights

of Yankee inventiveness," as one writer describes it, when he built a man-propelled submarine called the American Turtle. During trials, it actually operated. It was propelled by foot pedals operated by a lone occupant, could and did submerse, and carried on the outside (since it was to be used against the British ships) a bomb and its clockwork detonating machanism that could be attached to a ship's hull. This "amazing engine of destruction" actually made contact with Admiral Howe's flagship in New York harbor in 1776, but the attempt to blow up the ship was unsuccessful. The Admiral's secretary recorded only that "the rebels fired two Bombs this Evening, probably as an experiment. . . ."

Another inventor was Peter Carnes, who in 1784 sent a 13-year-old boy aloft in a balloon in Baltimore. This first successful ascent in America came only a year after the Montgolfier brothers made their first public flights in a small hot-air balloon in France. Three weeks after sending the boy aloft, Carnes decided to make a free ascent himself, this time in Philadelphia. He was thrown out of the balloon when it was only ten feet from the ground, a fortunate thing indeed, for when the balloon got well up into the air, it burst into flames and was consumed.

Science and technology are of course critically dependent upon scientific instruments. Needed in the Colonies were apparatus for observation, experimentation, and teaching in educational institutions—what were called "philosophical instruments"—and "mathematical instruments" for land surveying and navigation. The apparatus for teaching came almost all from England.

King George III himself had an unequaled collection of philosophical instruments made largely by George Adams before 1768. If intended to amuse, they were also used to teach the children in the royal household; not only were they sturdy, but they were also beautifully constructed of fine woods and splendid yellow brass, all esthetically designed. There were not enough institutions of learning in America to support a George Adams, however; although by 1776, every state had at least one college. The only examples of high craftsmanship during this period are orreries made by David Rittenhouse and John Pope and repairs made by the extremely skilled Professor John Prince of Harvard. Since Englishmen of the day had a great interest in the weather and the sea, the English barometers, thermometers, and navigation instruments were of very high quality. These came often to the Colonies—with immigrants, at first; but the Colonial demand for mathematical instruments was so large that a considerable number of these used before 1800 were of native production. Silvio Bedini, who has made a careful study of newspapers, signatures on instruments, and civil records, has located 134 instrument makers who flourished in the Colonies prior to 1800, most of them in business in 1776. Often, these instrument makers copied a model brought from England or followed descriptions in an English translation of a famous book on instruments written by the Frenchman, Nicolas Bion.

Let us now turn to those who made fundamental discoveries in physics and astronomy in the Colonies two hundred years ago. Three were outstanding: John Winthrop, David Rittenhouse, and Benjamin Franklin, all born in America.

The first, John Winthrop (not to be confused with earlier members of his family bearing the same name), was Hollis Professor of Mathematics and Natural Philosophy at Harvard College from 1739 to 1779. His scientific fame was as an astronomer, although he was also knowledgeable in mathematics, meteorology, and geology. He was offered the presidency of Harvard, but declined it. He published eleven papers in the Transactions of the Royal Society. In 1739, he made his first recorded scientific observation on sunspots. He thought, and reported, that he had discovered the fifth moon of Jupiter, although this is discounted by modern astronomers. He calculated the quantity of matter in comets. He observed and reported on the transits of Mercury of 1740 and 1743. He went to Greenland in 1763 to observe the transit of Venus, travelling there in a sloop furnished by the State of Massachusetts. All these observations helped to establish the absolute values of the distance between the planets and the sun, whereas formerly only the relative distances were known.

The second of our outstanding trio of physical scientists was David Rittenhouse (1732-1796). At first a watchmaker and mechanician, he became treasurer of Pennsylvania and served as director of the U.S. Mint at Philadelphia from 1792-1795. Among his accomplishments were the following: He devised a metal thermometer and a hygrometer; he constructed a diffraction grating by which he attempted to explain in terms of Newton's theory the nature of light (in 1786—some thirty years before Josef Fraunhofer); he built an orrery, a mechanical model of the solar system; he is credited with introducing in 1786 the use of "spider lines" in the focus of a transit instrument; he constructed surveyor's compasses; he took a leading part in important land surveys; he built a telescope and clock for his observations of the 1769 transit of Venus at the time when the first observatory in America was being erected, at public expense, in the State House Yard in Philadelphia.

Acknowledged by historians of science to have been the greatest scientist produced by Colonial America, Benjamin Franklin was born in 1706 and died in 1790. Early in his long life he established income-bearing businesses which allowed him to devote much time to political and diplomatic services to his country-men and to his own studies in scientific matters. Among his lesser scientific accomplishments were the following: He studied the desirability of wearing white clothing in a hot climate; he investigated the cooling effects of rapid evaporation of liquids; he correctly interpreted the cause of the aurora borealis; he recommended daylight saving time; at the age of 78, after wearing ordinary glasses for 25 years, he invented the first bifocals; he invented the pointed lightning rod; he devised the first flexible catheter recorded in American medicine.

His greatest contributions were in the field of electricity. He first became interested in the subject when