# Introduction

Queen's College, the predecessor of Rutgers University, was the eighth college to be founded in the American colonies. The early colonial colleges were founded to meet the emerging needs for an educated clergy, and to provide education to other leaders of the community. The religious leaders of the colonies were foremost in the movements to establish these colleges. Although denominational sponsorship was critical to the founding and early support of the colleges, there were generally no religious tests for students, and the colleges were chartered by the colonies.

Leaders of the Puritan Congregational Church founded Harvard College in 1636 with a bequest of £400 from the Massachusetts Bay Colony. The College was organized and named Harvard College in 1639, and chartered in 1650. The traditional list of colonial colleges that followed Harvard College begins with William and Mary College, which was founded in 1693 by leaders of the Anglican Episcopal Church, followed by Yale College, which was founded in 1701 by leaders of the Puritan Congregational Church. The College of Philadelphia (later University of Pennsylvania) was founded in 1740 by Benjamin Franklin and other leading citizens of Philadelphia, and had the weakest religious connections of the colonial colleges. The College of New Jersey (later Princeton College) was founded in 1746 by leaders of the Presbyterian Church, King's College (later Columbia College) was founded in 1754 by leaders of the Anglican Episcopal Church, and the College of Rhode Island (later Brown College) was founded in 1764 by leaders of the Baptist Church.[1]

## History of Physics and Astronomy

Some elements of physics and astronomy were taught in the colonial colleges from the time they opened. The tenets of physics and astronomy that were taught in the early colonial colleges can be traced back to antiquity, some originating in Egypt, Babylonia, Greece,

[1]Demarest, A *History of Rutgers College*, 6.

Alexandria, and China. The history of some of these ideas is fascinating, and was felt to be important for the education of seventeenth and eighteenth century college students.

Astronomical evidence shows that by 2773 BC the Egyptians had instituted a 365-day calendar. Babylonian astronomers made astronomical observations that can be traced back to about 1800 BC, when star catalogs and planetary records were compiled, including the first accurate records of the rising and setting of the planet Venus.[2]

In ancient Greece, there were periods of great intellectual activity. To the Greeks, philosophy and science were one. Thales of Miletus (c. 600 BC) studied astronomy in Mesopotamia and gained a great reputation with his prediction of a solar eclipse. Early Greek philosophers were concerned about the composition of matter. About 530 BC, Pythagoras held that matter was composed of earth, water, air, and fire. Later, Democritus (470-400 BC) proposed that every form of matter was made up of tiny indivisible particles called atoms. The idea that the earth was a sphere can be traced to the followers of Phythogras in about 500 BC.[3]

The early Greek philosophers were followed by some of the greatest philosophers of all time. The great Athenian philosopher, Socrates (c. 470-399 BC), was responsible for universal definitions and inductive reasoning. Socrates' disciple, Plato (428-348 BC), founded an Academy in Athens, which lasted for nine centuries. Plato supported the idea of the four elements, earth, air, fire, and water, and hinted at a fifth element, the ether.[4]

Aristotle (384-322 BC) studied under Plato and started a new school of philosophy, known as the Peripatetic, from the custom of teacher and students walking together in the gardens. He was the greatest collector and systematizer of knowledge from the ancient world. Until the Renaissance (14th to 17th centuries) no comparable collection of knowledge appeared. His works detailed the learning of the ancient world. Some of his ideas about physics and astronomy were later superseded, but

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[2]Hellemans, *The Timetables of Science*, 10.
[3]Dampier, *A History of Science*, 14, 18.
[4]Ibid., 28.

he made real contributions to many of the subjects that he treated, especially in biology.[5]

In physics, Aristotle rejected the ideas of the atomic theory. Like Plato, he ascribed the motion of a body to its desire to seek its own natural resting-place. He described heaviness or lightness as essential attributes of a body and claimed that heavy bodies fell more rapidly than light bodies. He accepted the spherical form of the Earth, but subscribed to the geocentric theory that set the Earth as the center of the Universe.

Following Aristotle, the Greek astronomer Aristarchus of Samos (c. 310-230 BC) was the first to put forward, about 270 BC, that the sun was the center of the solar system, and that the earth and planets revolved around the sun. His proposal did not supplant the widely accepted geocentric view of Aristotle.[6]

Archimedes of Syracuse (287-212 BC), Greek mathematician and engineer, introduced the idea of relative densities of bodies, and showed that when a body floats in a liquid, its weight is equal to the weight of the liquid displaced. Aristarchus and Archimedes were followed by Hipparchus, the greatest astronomical observer of antiquity. Flourishing in the period 146-127 BC, he discovered the precession of the Equinoxes, and completed the first detailed star catalog, listing about 850 stars.

The Alexandrian astronomer, Claudius Ptolemy, solidified the geocentric view of the universe. He taught and made observations in the period of 127 to 151 AD. His encyclopedia of astronomy, based on the work of Hipparchus, took the earth as the center of the universe, and had the sun and planets move about the earth in complex cycles and epicycles. His work was the accepted treatise on astronomy until the days of Copernicus and Kepler.

In the years that followed Ptolemy, the great centers of learning disappeared. The Academy in Athens was closed by emperor Justinian in 529 AD, and the Museum of Alexandria was destroyed by the Arabs in 641. Thereafter, there was no significant advance in science in Europe until the fifteenth century. Science did, however, flourish in the Islamic empire between 700 and 1300. Many of the works of the ancients were

[5]Dampier, *A History of Science*, 29.
[6]Hellemans, *The Timetables of Science*, 38.

translated into Arabic, and were thus preserved. In astronomy, the Arabs made a large number of accurate observations.[7]

The Chinese made a number of advances in science and technology. Around 100 BC they discovered that a magnet orients itself towards the North Pole. They discovered paper as early as 105 AD, and the first printed text appeared in 868 AD. Newton's first law of motion, that a body will not stop moving unless stopped by an opposing force, was stated by Chinese philosophers almost 2000 years before Newton. Chinese astronomy reached a high level during the eighth century B.C. with a number of observations of high quality.

In Europe, the Christian Church inhibited the development of science, but was responsible for the preservation of ancient learning. Emperor Charlemagne decreed, in 787, that every monastery must establish a school. These cathedral schools became the forerunners of the first universities. Oxford University was founded in England in 1167, and the University of Paris was founded in 1170. Other universities were founded at Padua (1222), Naples (1224), Toulouse (1229), Cambridge (1231), and Rome (1244). A large number of the early Greek works became available to European scholars in the period between 1150 and 1270, as the Arabic translations were translated into Latin, the language of scholars in Europe.[8]

Between the middle of the 11th century and the middle of the 15th century, Scholasticism came to be the dominant philosophy in the Christian schools and universities of Europe. This philosophy attempted to use natural human reason to understand the supernatural content of Christian revelation. Thomas Acquinas (1225-1274), the Italian theologian, brought Scholasticism to its highest level. Acquinas held the chief exponents of human reason to be Plato and Aristotle. He accepted the physics of Aristotle, that motion implies the continual exertion of force, and that things are essentially heavy or light and seek their natural places. He also accepted the Ptolemaic system of astronomy, in which the earth was the immovable center of the universe. The surviving scholastics opposed the new experimental science that developed after the

[7]Hellemans, *The Timetables of Science*, 58.
[8]Ibid., 60.

Renaissance. They continued to deduce by logical reasoning propositions that could better be tested by experiment.[9]

The renaissance in Europe (c. 1300-1600) brought renewed interest in religion, politics, the arts, science and technology. Movable type was reinvented in Europe around 1440, with the printing and distribution not only of the Gutenberg Bible, but also scientific treatises. In 1453 a number of Greek-speaking scholars escaped from Constantinople, following the capture of the city by the Turks. They brought with them to the West classical manuscripts in Greek, along with the ability to translate these ancient writings into Latin. It is likely that modern science, which had its origins in the sixteenth century, came to transform European civilization more fundamentally than religion. It came to provide mankind with new ways to manipulate the natural world, and it provided an abundance of facts and ideas that called into question long-held views of nature.[10]

One of the great Florentine artists of the renaissance was Leonardo da Vinci (1452-1519), who was also a scientist who used the experimental method a century before Francis Bacon philosophized about it, and Galileo put it into practice. He had wide-ranging studies in the fields of anatomy, optics, and hydraulics.[11]

Da Vinci was followed by Nicholas Copernicus (1473-1543), the Polish astronomer, and founder of modern astronomy, who began the great change in scientific outlook after the Renaissance. Copernicus supported the propositions of the fourth century BC that the earth was a sphere that rotated daily on its axis (Exphantus), and that the earth rotated yearly about the sun (Aristarchus). His famous treatise, *On the Revolutions of Celestial Bodies*, was published in 1543 as he was on his deathbed. By 1616, Copernicus's famous treatise was on the Catholic Church's index of prohibited books, not to be removed until 1835.[12]

Copernicus was followed by a number of individuals who carried out experiments and made observations. The Dutch mathematician, Simon Stevinus (1548-1620), performed (1586) the key experiment in

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[9]Dampier, *A History of Science*, 88.
[10]Roberts, *A History of Europe*, 233.
[11]Hellemans, *The Timetables of Science*, 90.
[12]Ibid., 128.

understanding gravity, dropping two different weights at the same time and noting that they strike the ground at the same time. He also showed that the pressure of a liquid on a given surface depended on the height of the liquid and on the area of the surface. William Gilbert of Colchester, England (1540-1603), experimentally determined the nature of forces between magnets, and the electric forces that arise when bodies such as amber are rubbed. In his book, *Concerning Magnetism* (1600), he collected all that was known about magnetism and electricity, and added from his own experimental observations. The testing of scientific ideas through ob-servation was taking hold. Francis Bacon (1561-1626), Lord Chancellor of England, strongly advocated the experimental method as the way to develop the laws of nature. This point of view was articulated in Bacon's *Novum Organum*, published in 1620.[13]

Following Copernicus, the new astronomy was put on a sound footing by Brahe, Kepler, and Galileo, although stoutly resisted by the Catholic Church. Tycho Brahe (1546-1601) of Copenhagen was the first astronomer to record details of planetary motions with a high degree of accuracy. His *Introduction to the New Astronomy* was published posthumously in 1602. Johannes Kepler (1571-1630), German astronomer, studied the motions of the planets, and formulated the three laws of their motion that served as the foundation for Newton's astronomy. Kepler's *Epitome of Copernican Astronomy* was published in 1619-21 and put on the list of prohibited books by the Roman Catholic Church.[14]

One of the greatest figures in the development of science was Galileo Galilei (1564-1642), the Italian astronomer and physicist. He combined the experimental and inductive methods of Gilbert with mathematical deduction, and established the experimental method of physical science. His chief and most original work was the foundation of the science of dynamics. He showed that it was the change of motion that required an external force. His *Mathematical Discourses and Demonstrations on Two New Sciences* included his presentation of the laws of motion and of friction, correcting many of Aristotle’s errors. With the telescope he confirmed the ideas of Copernican astronomy. Galileo's *Dialogue Concerning the Two Chief World Systems, Ptolemaic and*

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[13]Hellemans, *The Timetables of Science*, 130.
[14]Ibid., 130.

*Copernican*, was published in 1632. In 1633 the pope called Galileo to appear before the Inquisition, which forced him to recant his Copernican view that the earth moves about the sun.[15]

**Physics and Astronomy in American Colleges**

In the American colonies, Harvard College was founded in 1636, three years after the Inquisition of Galileo, and instruction began about 1638. Some elements of physics were taught to first-year students and astronomy to third-year students. The early instruction at Harvard presented the ideas of Aristotelian and Scholastic physics, which attempted to determine the "why" of nature, and Ptolemaic astronomy, which held that the earth was the center of the universe. By today's standards the textbooks were quite unscientific. The textbooks were in Latin, and contained no mathematics, problems, experiments or experimental results, and few illustrations.[16]

The beginning of the end of the Aristotelian science at Harvard came in 1659 when the works of Copernicus, Galileo and Kepler were taught. The College had a telescope as early as 1664. Results of observations of comets at Harvard were communicated to the Royal Astronomer at Greenwich, and were referred to by Newton in *The Principia*. Natural science entered a new phase at Harvard in 1686 when Charles Morton came to teach. His semi-scientific textbook *Compendium Physicae*, was adopted in 1687, and remained as the textbook in natural science for about forty years. The book included Galileo's theory of the planets, a discussion of Toricelli's experiment (1643), and a chapter on the earth that included a discussion of gravity.[17] For a time, there was a transition period, in which an attempt was made to teach both Aristotelian physics and the physics of Newton and the others. In this period, geometrical optics was taught very much as it is today, and there was an increasing use of apparatus for instruction. There is a mention of some philosophical apparatus being used at Harvard in 1727.[18]

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[15]Hellemans, *The Timetables of Science*, 134.
[16]McCarthy, "Physics in American Colleges Before 1750", 101.
[17]Morison, *Harvard College in the Seventeenth Century*, 223.
[18]McCarthy, "Physics in American Colleges Before 1750", 103.

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One of the reasons that science did not advance during the middle ages was that few people learned of any new discoveries. The development of the printing press in the fifteenth century provided for wider dissemination of scientific ideas and discoveries. In the seventeenth century the first scientific societies made their appearance in Europe, providing an important avenue for the exchange of information between scientists. The early scientific societies included the Academy of the Lynxes in Rome (1603), the Academy of Experiment in Florence (1630), the Royal Society in England (1660), and the Royal Academy of Sciences in Paris (1666). This period marked the separation of science (physics) and metaphysics (philosophy).[19]

In Europe there were continued advances in physics. Robert Boyle published his *Hydrostatical Paradoxes* (1662), asserting that in an ideal gas under constant temperature, volume and pressure vary inversely. In 1678, Christian Huygens (1629-1695) wrote his *Treatise on Light*, not published until 1690, explaining the wave theory of light.

The most important scientific work of the seventeenth century was the *Principia*, (The mathematical principles of natural philosophy), published in 1687 by Isaac Newton (1642-1727). This work became the foundation of physics for 200 years and formed the basis for the scientific method. Newton enunciated his three laws of motion and the law of universal gravitation, showing how a single law gave an accurate description of phenomena on earth as well as in celestial space. His law of gravitation gave a theoretical basis for the Copernican system and for Kepler's laws. In 1704 Newton published his *Optics*, which combined mathematics with experiment and held that light was particulate in nature.[20]

In 1682 Edmund Halley observed the “great comet”, which was later named for him. In 1705 he predicted the return of the comet in 1758 or 1759. The observation of the comet in 1759 was one of the most convincing validations of Newton’s theory of gravitation.

For many centuries after Aristotle, “philosophy” included all of what is now called science. The term “natural philosophy” was used in the 17th century to refer to the new natural science of Galileo and Newton, as well as astronomy, optics, statics, hydraulics, and mathematics. At that

[19]Hellemans, *The Timetables of Science*, 146.
[20]Ibid., 147.

time the phrase "moral philosophy" was used to refer to Aristotle's "ethics" and "politics," as well as to psychology and the other parts of philosophy except for logic. The term "natural philosophy" was widely used until the middle of the nineteenth century when it was gradually replaced by the term "physics."

In the American colonies, William and Mary College, founded in 1693, taught Aristotelian physics at the outset. The transition to the new physics is indicated by the mention of philosophical apparatus at the College in 1705. Yale College, founded in 1701, also taught Aristotelian physics at the beginning, using Pierson's *Manuscript of Physicks*, an Aristotelian text. There is, however, a record of philosophical apparatus at Yale by 1719.[21]

In Europe there continued to be advances in physics. Charles François de Cisternay Du Fay discovered, in 1733, that there were two types of static electric charges, with attraction and repulsion, caused by two "fluids." Pieter van Mussachenbroek published his *Essay on Physics* in 1737, one of the first books of his time that used the term "physics" instead of natural or experimental philosophy. In 1738 Daniel Bernoulli explained the relationship between the pressure and velocity of fluids in motion.[22]

The transition period between Aristotelian and the experimental science at Harvard and Yale ended before 1740, when students were taught using van s'Gravesande's *Mathematical Elements of Natural Philosophy*. This was a scientific work, first published by the Dutch physicist in 1721. The book relied on experiments to prove its principles, rather than the opinions of authorities. It treated topics in astronomy, optics, and mechanics. Sound, electricity and heat received a few pages each, and magnetism was briefly mentioned.[23] By 1750 physics had changed from a metaphysical subject, not very different from that taught in the medieval universities of the thirteenth century, to a full-fledged science.[24]

[21]McCarthy, "Physics in American Colleges Before 1750", 101.
[22]Hellemans, *The Timetables of Science*, 183, 187, 195, 197.
[23]van s'Gravesande, *Mathematical Elements of Natural Philosophy*.
[24]McCarthy, "Physics in American Colleges Before 1750", 104.

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The College of Philadelphia (Pennsylvania), founded in 1740 by Benjamin Franklin, and all colleges established thereafter, taught scientific physics from the beginning.[25] At the College of New Jersey (Princeton), which opened in 1747, there is clear evidence that natural philosophy (physics) was a part of the earliest curriculum. Letters in 1750-53 from a student at the College of New Jersey indicated that Martin's book on Natural Philosophy and Watt's book on Astronomy were used for instruction. Martin's book included Newton's laws of motion,[26] and Watt's book described the sun, planets, and stars on a celestial sphere, but described both the Ptolemaic and Copernican schemes.[27] The 1750-53 Princeton letters also mentioned apparatus that included globes and a small electrical machine.[28] Because the first tutors at Queen's College were graduates of the College of New Jersey, it is likely that they taught the physics and astronomy that they learned there.

### Development of Rutgers University

While the first seven colonial colleges were founded primarily by religious leaders of English descent, Queen's College was founded by religious leaders of Dutch descent. It was leaders of the Dutch Reformed Church who obtained a charter for the College from the Governor of New Jersey. The first charter was granted in 1766, and a second, slightly revised charter, was issued in 1770.[29]

Instruction at Queen's College began in New Brunswick in 1771. Because of the Revolutionary War, the College suspended its instruction for periods in 1775 and 1776, and relocated to Raritan and Millstone for short periods of time. Because of difficulties in obtaining financial support, the College ceased to function at three different periods, 1784-1786, 1795-1807, and 1816-1825. In 1825 the College reopened as Rutgers College.[30]

There was very gradual transition of Rutgers College from a small, private, colonial college to a major state university. The first step in this

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[25] McCarthy, "Physics in American Colleges Before 1750", 101.
[26] Martin, *Philosophical Grammar*.
[27] Watts, *First Principles of Astronomy and Geography*.
[28] MacLean, *History of the College of New Jersey from its Origin in 1746*, 139-142.
[29] Demarest, A *History of Rutgers College*, 6.
[30] Vittum, *The Development of the Curriculum of Rutgers College*, 1.

transition was the creation of the Rutgers Scientific School in 1864, which was designated by the State Legislature as the land-grant college for New Jersey. A number of years later, in 1917, the State Legislature designated the Rutgers Scientific School [only] as "the State University of New Jersey."

The transition to a state university continued when the New Jersey College for Women (NJC) opened to female undergraduate students in 1918. In 1924 the Trustees of Rutgers College authorized the adoption of the title, "Rutgers University," for all of its colleges, schools, and departments. In 1925 the faculties of the Colleges of Arts and Sciences, Agriculture, and Engineering were organized. In 1929, following the creation of the State Board of Regents, relations with the State were bad for a time, and the title of State University of New Jersey, conferred by the Act of 1917, was repealed. Eventually, relations with the State improved, and in 1945 the State Legislature designated the entirety of Rutgers University as the State University of New Jersey. The University largely maintained its autonomy, subject to the general oversight of the State Board of Education.

Finally, in 1956, the University was reorganized, with the responsibility for the operation of the University transferred to a publicly controlled Board of Governors. The corporate title of the University was changed from "The Trustees of Rutgers College in New Jersey" to "Rutgers, the State University," and the University became known as "Rutgers, the State University of New Jersey."

The term "Rutgers College" has been used to represent a number of different entities. It was part of the corporate title, "The Trustees of Rutgers College in New Jersey," from 1825 to 1956. It was the generally accepted name of the undergraduate college from 1825 until the establishment of the College of Arts and Sciences in 1925. The College of Arts and Sciences, College of Engineering, College of Agriculture, and School of Education were then collectively known as the "Colleges for Men" until 1957 when they were called "Rutgers College." Finally, beginning in 1971, the term "Rutgers College" referred only to the Liberal Arts and Science College.

From the opening of Queen's College, physics (natural philosophy) and astronomy were taught by a tutor or professor of the College. Beginning with the appointment of Robert Adrain in 1809, physics (natural philosophy) and astronomy were taught by a professor of mathematics. In 1880 physics became the province of a professor of physics, while astronomy was still taught by a professor of mathematics. Instruction in astronomy was taken up by the Physics Department in 1932, and continued, with some interruptions, to the present time. The Department officially became the Department of Physics and Astronomy in 1977. Astronomy was also taught for periods in the Mathematics Department at N.J.C. and Douglass College, and in the Geology Department at the College of Arts and Sciences.

The following chapters detail the development of the program in physics and astronomy at Rutgers from 1771, when Queen's College opened, until the year 2000. These chapters describe the evolution of the physics program at Rutgers from a one-man program, primarily focused on instruction, to a faculty of over 60 men and women engaged in teaching and research programs that have achieved substantial national recognition. This history tracks this development of physics and astronomy to the advance of Rutgers from a small private colonial college to a very large major state university.