Study Guide: Issac Newton (1643 – 1727 CE)

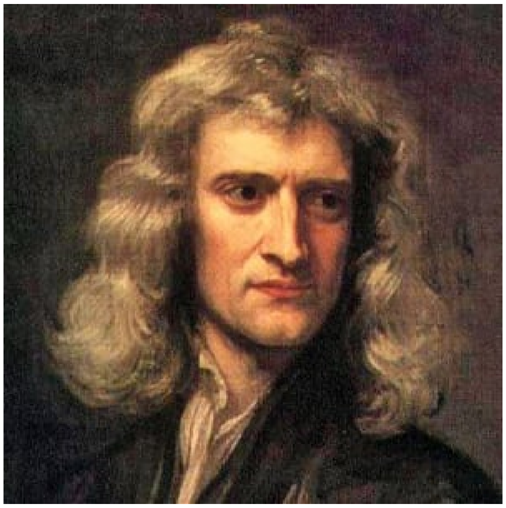

Figure 1: Issac Newton

Sometimes called the father of modern science, Isaac Newton revolutionized our understanding of the world. He was a "Renaissance Person" with major accomplishments in many fields, including astronomy, optics, physics and mathematics. Newton gave the world revolutionary new theories on gravity, planetary motion and optics.

With the publication of *Philosophiae Naturalis Principia Mathematica* in 1687, Newton laid the groundwork for modern physics. The publication become known as the *"first great unification"*, as it unified our understanding of gravity on Earth with the behavior of planets, solar systems, and stars. This publication cemented Newton's position as one of the leading scientists of all time

Early Life

Newton was born on January 4, 1643, in Woolsthorpe, Lincolnshire, England. He never knew his father, who had died three months before he was born. Newton's own chances of survival seemed slim. He was a premature and sickly infant that some thought would not live long.

Newton was dealt another blow when he was only three years old. His mother, Hannah, remarried, and his new stepfather, the Right Reverend Barnabas Smith, wanted nothing to do with the child. This was a time when women and children had no rights in England, and his mother had no choice but to honor the wishes of her new husband. The child was left with his maternal grandmother. The loss of his mother left Newton with a lingering sense of insecurity that stayed with him for the rest of life.

Education

Newton was enrolled at the King's School in Grantham, a town in Lincolnshire, where he lodged with a local apothecary (pharmacist). Here, he was introduced to the fascinating world of chemistry and began his livelong appreciation of science. At the age of 12, his mother pulled him out of school to have him tend the family farm. Newton failed miserably at farming, as he found the work boring and monotonous. He was soon sent back to school to finish his basic education.

Perhaps sensing the young man's abilities, his uncle, a graduate of the University of Cambridge's Trinity College, persuaded Newton's mother to have him enter the university. Newton financed his education by working as a waiter and taking care of the rooms of wealthier students.

Cambridge and the Scientific Revolution

When Newton arrived at Cambridge, the Scientific Revolution was in full force. The heliocentric (Sun at the center) view of the universe—theorized by astronomers Nicolaus Copernicus and Johannes Kepler, and refined by Galileo—was already well known. The philosopher René Descartes had begun to formulate a new concept of nature as an intricate, impersonal and inert machine that humans could learn and understand through reason alone.

At the time, Cambridge still followed the ancient Aristotelian and geocentric (Earth at the center) view of the universe, and science was still studied in qualitative (descriptive) rather than quan-

Figure 2: Cambridge University

titative (measurable) terms. During his first three years at Cambridge, Newton was taught the standard curriculum, but he was fascinated with the newer ideas. In his spare time he read the modern philosophers. The result was a less-than-stellar performance in collage. Clearly, the disdain was two-way. Newton's groundbreaking book, *Principia* begins:

"A stirring freshness in the air, and ruddy streaks upon the horizon of the moral world betoken the grateful dawning of a new ara. The days of a driveling instruction are departing. With us is the opening promise of a better time..."

Source: *Principia*, by Isaac Newton

Quaestiones Quaedam Philosophicae

Newton kept a second and secret set of notes, entitled *"Quaestiones Quaedam Philosophicae"* ("Certain Philosophical Questions"). The *"Quaestiones"* reveal that Newton had already discovered a new conception of nature that would soon provide a solid theoretical framework for the emerging Scientific Revolution.

The Plague and the Apple

Newton completed his bachelor's degree at Cambridge University's Trinity College in 1665 and wanted to continue his studies, but an epidemic of the bubonic plague soon altered his plans. During the first seven months of the outbreak, roughly 100,000 London residents died. The university closed its doors as the disease swept through London.

Figure 3: The Plague

During the time of the Great Plague, Newton stayed on the family farm. It was during this 18-month break from student life that Newton conceived many of his most important insights—including the method of infinitesimal calculus, the foundations for his theory of light and color, and the laws of planetary motion—that eventually led to the publication of his physics book *Principia* and his theory of gravity.

Newton experienced his famous insight on the nature of gravity while thinking about a falling apple. Legend has it that as he sat under a tree, an apple fell and hit him on the head. The famous "bonk on the head" led him to wonder why, given that the earth was spinning and orbiting the sun at great speed, the apple fell straight down and not at an angle. Consequently, he began exploring theories of motion and gravity.

Return to Cambridge

Once the Plague passed, Newton returned to Cambridge. Slowly, his fortunes improved as his original ideas were noticed by others. Newton received his Master of Arts degree in 1669, before he was 27. During this time, he came across Nicholas Mercator's published book on methods for dealing with infinite series. Newton quickly wrote a treatise, *De Analysi*, explaining his own wider-ranging results. He shared this with his friend and mentor Isaac Barrow, but didn't include his name as author.

Newton's first major achievement was designing and constructing a reflecting telescope in 1668. As a professor at Cambridge, Newton was required to deliver an annual course of lectures and chose optics as his initial topic. He used his telescope to study optics and help prove his theory of light and color.

The Royal Society asked for a demonstration of his reflecting telescope in 1671, and the organization's interest encouraged Newton to publish his notes on light, optics and color in 1672. These notes were later published as part of Newton's *Opticks: Or, A treatise of the Reflections, Refractions, Inflections and Colours of Light*.

In June 1669, Barrow shared the manuscript with British mathematician John Collins. In August 1669, Barrow identified its author to Collins as "Mr. Newton ... very young ... but of an extraordinary genius and proficiency in these things." Newton's work was then brought to the attention of the mathematics community for the first time.

Competition and Conflict

Not everyone was enthusiastic about Newton's discoveries in optics, nor his publication in 1672 of *Opticks: Or, A treatise of the Reflections, Refractions, Inflections and Colours of Light.* Among the dissenters was Robert Hooke, one of the original members of the Royal Academy and a scientist accomplished in several areas, including mechanics and optics. While Newton theorized that light was composed of particles, Hooke believed it was composed of waves. Hooke quickly condemned Newton's paper in condescending terms, and attacked his methodology and conclusions.

Hooke was not the only one to question Newton's work in optics. Renowned Dutch scientist Christiaan Huygens and a number of French Jesuits also raised serious objections. But because of Hooke's association with the Royal Society and his own work in optics, his criticism stung Newton the worst.

Unable to handle the critique, he went into a rage—a reaction to criticism that was to continue throughout his life. Newton denied Hooke's charge that his theories had any shortcomings and argued the importance of his own discoveries to all of science. The exchange grew more acrimonious, and soon Newton threatened to quit the Royal Society altogether. He remained only when several other members assured him that the Fellows held him in high esteem.

The rivalry between Newton and Hooke would continue for years. Finally, in 1678, Newton suffered a nervous breakdown. The death of his mother the following year caused him to become even more isolated, and for six years he withdrew from the world. During this time, Newton returned to his study of gravitation and the planets. Ironically, the ideas that put Newton on the right direction came from Robert Hooke.

In 1679, Hooke had brought up the question of planetary motion, suggesting that a formula involving the inverse squares might explain the attraction between planets and the shape of their orbits. Hooke's idea was incorporated into Newton's work on planetary motion.

In early 1684, in a conversation with fellow Royal Society members Christopher Wren and Edmond Halley, Hooke made his case on the proof for planetary motion. Both Wren and Halley thought he was on to something, but pointed out that a mathematical demonstration was needed.

In August 1684, Halley visited Newton, who was coming out of his seclusion. Halley idly asked him what shape the orbit of a planet would take if its attraction to the sun followed the inverse square of the distance between them (Hooke's theory).

Newton knew the answer, due to his concentrated work for the past six years, and instantly replied, "An ellipse."

Newton claimed to have solved the problem some 18 years prior, during his break from Cambridge and the plague, but he was unable to find his notes. Halley persuaded him to work out the problem mathematically and offered to pay all costs so that the ideas might be published.

Upon the publication of the first edition of *Principia* in 1687, Robert Hooke immediately accused Newton of plagiarism, claiming that he had discovered the theory of inverse squares and that Newton had stolen his work. The charge was unfounded, as most scientists knew, for Hooke had only theorized on the idea and never found a mathematical proof.

The Great Unification

"Every particle attracts every other particle in the universe with a force that is proportional to the product of their masses and inversely proportional to the square of the distance between their centers."

Source: *Principea*, by Issac Newton

$$F = G\frac{m_1\ m_2}{r^2}$$

Where F is the gravitational force acting between two objects, m_1 and m_2 are the masses of the objects, r is the distance between the centers of their masses, and G is the gravitational constant.

A theory capable of unifying all of observable reality is one of the primary goals of physics. The "first great unification" was Isaac Newton's 17th century unification of gravity, which brought together understandings of gravity on Earth with the observable behavior of celestial bodies in space. This process of "unifying" forces continues today, with the ultimate goal of finding a theory of everything.

Old Age and Death

By the end of his life, Newton was one of the most famous men in England, his pre-eminence in matters of science was unchallenged. He had also become wealthy, and invested his income wisely. He had enough to make sizable gifts to charity and leave a small fortune in his will.

Whether he was happy or not is another question. He never made friends easily, and in his later years his peculiar combination of pride, insecurity, and distraction interfered with his relationships. He never married, and lived as the "monk of science," having channeled all his energy into his work.

In later life, he ate mainly vegetables and broth, and was plagued by a stone in the bladder. In 1725 he fell ill with gout, and endured hemorrhoids the following year. Meanwhile, the pain from his bladder stones grew worse, and on March 19, 1727, he blacked out, never to regain consciousness.

He died on March 20, at the age of eighty-five, and was buried in Westminster Abbey. His funeral was attended by all of England's *self-described* "most eminent", and his coffin was carried by those who fancied themselves "noblemen." It was, as a contemporary noted, a funeral fit for a king.

"If I have seen further it is by standing on the shoulders of Giants."

Source: Isaac Newton[1]

Discoveries

Newton's fame grew after his death, as many of his contemporaries proclaimed him the greatest genius who ever lived. This may be a slight exaggeration, but his discoveries had a huge impact on Western thought, modern science and technology, and shaping of the modern world. He made significant discoveries in astronomy, optics, physics of motion, and mathematics.

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1. He theorized that white light was a composite of all colors of the visible spectrum, and that light was composed of particles.
2. His momentous book on physics, *Principia*, contains information on nearly all the essential concepts of physics except energy, helping him explain the Laws of Motion and the Theory of Gravity.
3. Along with Leibniz, Newton developed the modern mathematics of calculus.
4. In 1687, he published his most acclaimed work, *Philosophiae Naturalis Principia Mathematica* (*Mathematical Principles of Natural Philosophy*), which is the single most influential book on physics of all time.
5. In 1705, he was knighted by Queen Anne of England, making him Sir Isaac Newton.

Legacy

Newton's Law of Gravitation has since been superseded by Albert Einstein's Theory of General Relativity, but it continues to be used as an excellent approximation of the effects of gravity in most situations. Relativity is required only when extreme accuracy is needed, or when dealing with very strong gravitational fields, such as near very massive and dense objects (such as Black Holes), or at relatively small distances (such as Mercury's orbit around the Sun).

In time, Newton was proven wrong on some of his key assumptions. As Hooke thought, light energy does act like a wave. More significantly, Albert Einstein overturned Newton's concept of the universe, stating that space, distance and motion were not absolute but relative, and showing that space and time are one fabric, now known as "space-time," and that the universe was a larger and far more fantastical place than Newton could have dreamed. Yet, perhaps these later discoveries would not have surprised the great scientist. As an old man, when asked for an assessment of his achievements, Newton replied:

"I do not know what I may appear to the world; but to myself I seem to have been only like a boy playing on the seashore, and diverting myself now and then in finding a smoother pebble or prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me."

Seeing Further...

- *Principia* in English (PDF)[2]
- *Principia* in English (HTML)[3]
- *Principia* in Latin at Project Guttenberg (PDF)[4]
- *Opticks* in English at Project Guttenberg (HTML)[5]

Sources

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- https://en.wikipedia.org/wiki/Newton%27s_law_of_universal_gravitation
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[3] https://en.wikisource.org/wiki/The_Mathematical_Principles_of_Natural_Philosophy_(1846)
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