1.4: Age of Enlightenment

The Age of Enlightenment is a term used to describe a phase in Western philosophy and cultural life in which reason was advocated as the primary source and legitimacy for authority. It developed simultaneously in Germany, France, Britain, the Netherlands, and Italy around the 1650’s and lasted until the French Revolution in 1789. The intellectual and philosophical developments led to moral, social, and political reforms. The principles of individual rights, reason, common sense, and deism were a revolutionary departure from the existing theocracy, autocracy, oligarchy, aristocracy, and the divine right of kings. It led to political revolutions in France and the United States. It marks a dramatic departure from the Early Modern period which was noted for religious authority, absolute state power, guild-based economic systems, and censorship of ideas. It opened a new era of rational discourse, liberalism, freedom of expression, and scientific method. This new environment led to tremendous advances in both science and mathematics in addition to music (Johann Sebastian Bach, Mozart), literature (Goethe), philosophy (Spinoza, Kant) and art (Rubens). Scientific development during the 17^{th} century included the pivotal advances made by Newton and Leibniz at the beginning of the revolutionary Age of Enlightenment, culminating in the development of variational calculus and analytical mechanics by Euler and Lagrange. The scientific advances of this age include publication of two monumental books "Philosophiae Naturalis Principia Mathematica" by Newton in 1687 and Mécanique analytique by Lagrange in 1788. These are the definitive two books upon which classical mechanics is built.

René Descartes (1596-1650) attempted to formulate the laws of motion in 1644. He talked about conservation of motion (momentum) in a straight line but did not recognize the vector character of momentum. **Pierre de Fermat (1601-1665)** and René Descartes were two leading mathematicians in the first half of the 17^{th} century. Independently they discovered the principles of analytic geometry and developed some initial concepts of calculus. Fermat and **Blaise Pascal (1623-1662)** were the founders of the theory of probability.

Isaac Newton (1642-1727) made pioneering contributions to physics and mathematics as well as being a theologian. At 18 he was admitted to Trinity College Cambridge where he read the writings of modern philosophers like Descartes, and astronomers like Copernicus, Galileo, and Kepler. By 1665 he had discovered the generalized binomial theorem, and began developing infinitessimal calculus. Due to a plague, the university closed for two years in 1665 during which Newton worked at home developing the theory of calculus that built upon the earlier work of Barrow and Descartes. He was elected Lucasian Professor of Mathematics in 1669 at the age of 26. From 1670 Newton focussed on optics leading to his Hypothesis of Light published in 1675 and his book Opticks in 1704. Newton described light as being made up of a flow of extremely subtle corpuscles that also had associated wavelike properties to explain diffraction and optical interference that he studied. Newton returned to mechanics in 1677 by studying planetary motion and gravitation that applied the calculus he had developed. In 1687 he published his monumental treatise entitled Philosophiae Naturalis Principia Mathematica which established his three universal laws of motion, the universal theory of gravitation, derivation of Kepler’s three laws of planetary motion, and was his first publication of the development of calculus which he called “the science of fluxions”. Newton’s laws of motion are based on the concepts of force and momentum, that is, force equals the rate of change of momentum. Newton’s postulate of an invisible force able to act over vast distances led him to be criticized for introducing “occult agencies” into science. In a remarkable achievement, Newton completely solved the laws of mechanics. His theory of classical mechanics and of gravitation reigned supreme until the development of the Theory of Relativity in 1905. The followers of Newton envisioned the Newtonian laws to be absolute and universal. This dogmatic reverence of Newtonian mechanics prevented physicists from an unprejudiced appreciation of the analytic variational approach to mechanics developed during the 17^{th} through 19^{th} centuries. Newton was the first scientist to be knighted and was appointed president of the Royal Society

Gottfried Leibniz (1646-1716) was a brilliant German philosopher, a contemporary of Newton, who worked on both calculus and mechanics. Leibniz started development of calculus in 1675, ten years after Newton, but Leibniz published his work in 1684, which was three years before Newton’s Principia. Leibniz made significant contributions to integral calculus and developed the notation currently used in calculus. He introduced the name calculus based on the Latin word for the small stone used for counting. Newton and Leibniz were involved in a protracted argument over who originated calculus. It appears that Leibniz saw drafts of Newton’s work on calculus during a visit to England. Throughout their argument Newton was the ghost writer of most of the articles in support of himself and he had them published under nonde-plume of his friends. Leibniz made the tactical error of appealing to the Royal Society to intercede on his behalf. Newton, as president of the Royal Society, appointed his friends to an “impartial” committee to investigate this issue, then he wrote the committee’s report that accused Leibniz of plagiarism of Newton’s work on calculus, after which he had it published by the Royal Society. Still unsatisfied he then wrote an anonymous review of the report in the Royal Society’s own periodical. This bitter dispute lasted until the death of Leibniz. When Leibniz died his work was largely discredited. The fact that he falsely claimed to be a nobleman and added the prefix “von” to his name, coupled with Newton’s vitriolic attacks, did not help his credibility. Newton is reported to have declared that he took great satisfaction in “breaking Leibniz’s heart.” Studies during the 20^{th} century have largely revived the reputation of Leibniz and he is recognized to have made major contributions to the development of calculus.

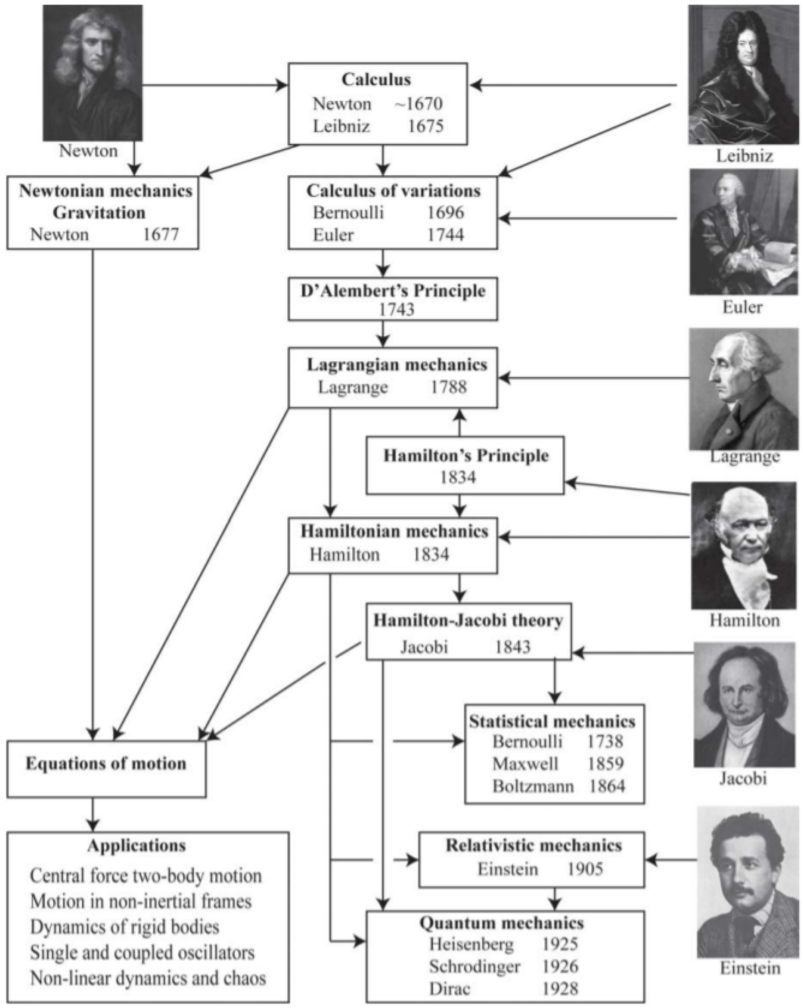

Figure 1.4.1: Chronological roadmap of the parallel development of the Newtonian and Variational-principles approaches to classical mechanics.