1.3: Middle Ages

The decline and fall of the Roman Empire in ~410 A.D. marks the end of Classical Antiquity and the beginning of the Dark Ages in Western Europe (Christendom) while the Muslim scholars in Eastern Europe continued to make progress in astronomy and mathematics. For example, in Egypt, **Alhazen (965 - 1040 A.D.)** expanded the principle of least time to reflection and refraction. The Dark Ages involved a long scientific decline in Western Europe that languished for about 900 years. Science was dominated by religious dogma, all western scholars were monks, and the important scientific achievements of Greek antiquity were forgotten. The works of Aristotle were reintroduced to Western Europe by Arabs in the early 13^{th} century leading to the concepts of forces in static systems which were developed during the fourteenth century. This included concepts of the work done by a force, and the virtual work involved in virtual displacements. **Leonardo da Vinci (1452-1519)** was a leader in mechanics at that time. He made seminal contributions to science, in addition to his well known contributions to architecture, engineering, sculpture, and art.

Nicolaus Copernicus (1473-1543) rejected the geocentric theory of Ptolomy and formulated a scientifically based heliocentric cosmology that displaced the Earth from the center of the universe. The Ptolomic view was that heaven represented the perfect unchanging divine while the earth represented change plus chaos and the celestial bodies moved relative to the fixed heavens. The book, "De revolutionibus orbium coelestium "(On the Revolutions of the Celestial Spheres), published by Copernicus in 1543, is regarded as the starting point of modern astronomy and the defining epiphany that began the Scientific Revolution. The book "De Magnete" written in 1600 by the English physician **William Gilbert (1540-1603)** presented the results of well-planned studies of magnetism and strongly influenced the intellectual-scientific evolution at that time.

Johannes Kepler (1571-1630), a German mathematician, astronomer and astrologer, was a key figure in the 17^{th} century Scientific Revolution. He is best known for recognizing the connection between the motions in the sky and physics. His laws of planetary motion were developed by later astronomers based on his written work "Astronomia nova", "Harmonices Mundi", and "Epitome of Copernican Astrononomy". Kepler was an assistant to **Tycho Brahe (1546-1601)** who for many years recorded accurate astronomical data that played a key role in the development of Kepler's theory of planetary motion. Kepler's work provided the foundation for Isaac Newton's theory of universal gravitation. Unfortunately Kepler did not recognize the true nature of the gravitational force.

Galileo Galilei (1564-1642) built on the Aristotle principle by recognizing the law of inertia, the persistence of motion if no forces act, and the proportionality between force and acceleration. This amounts to recognition of work as the product of force times displacement in the direction of the force. He applied virtual work to the equilibrium of a body on an inclined plane. He also showed that the same principle applies to hydrostatic pressure that had been established by Archimedes, but he did not apply his concepts in classical mechanics to the considerable knowledge base on planetary motion. Galileo is famous for the apocryphal story that he dropped two cannon balls of different masses from the Tower of Pisa to demonstrate that their speed of descent was independent of their mass.