1. The Foundation of Classical Mechanics

1.1 Principia

It was an important event in the history of physics when Sir Isaac Newton in 1687 published his book *Philosophiae Naturalis Principia Mathematica*. In this famous work we find a masterly synthesis of the concepts of motion and force. The Newtonian formulation of the laws of motion has, with superior strength and vitality, survived more than 300 years. Although certain fundamental aspects of Newtonian physics have been revised in this century, Newton's principles still find widespread use both in the basic and in the applied sciences. Just one example: the launching of artificial satellites is based directly on these principles.

Newton's work forms the basis upon which theoretical physics as well as modern engineering science rests. We shall here, without going into details of the historical development, discuss some of the most important steps in the evolution of the Newtonian world picture.

1.2 Prerequisites for Newton

There are two main lines of inquiry that lead towards and form the basis for Newton's efforts: one based on motions here on Earth, and one based on the motions of bodies in the heavens. The first line is associated with the name Galileo Galilei (1564–1642); the other with Nicolas Copernicus (1473–1543), Tycho Brahe (1546–1601) and Johannes Kepler (1571–1630). Before Galileo, the "impetus" concept dominated the thinking on motion. This idea is somewhat related to the later concept of momentum, but although it was thought that a body was given a certain impetus when it was thrown, the body was thought to spend its impetus during its flight. When all the initial impetus was spent, the body would stop and – if it was not supported – fall down.

As for the free fall, it had been held since Aristotle (384–322 B.C.) that a heavy object falls faster than a light object. From immediate everyday experience, both the impetus concept and the idea that a heavy object falls faster than a light one, are not unreasonable.
It was Galileo who cleared away these misconceptions and in this way erected one of the pillars on which the work of Newton rests. Let us here state the laws that Galileo formulated:

1. **The law of inertia:** If a body is left to itself without influence from other bodies it will continue a uniform linear motion if it initially had one, and will remain at rest if it initially was so.

2. **The laws of free fall:**
   a. All freely falling objects will, when starting from rest, fall an equal distance in the same time.
   b. The distance fallen, $S$, is proportional to the square of the time of fall: $S = \frac{1}{2}gt^2$ where $g$ is a constant ($g$ is the acceleration). According to Galileo the constant acceleration $g$ is independent of the nature or composition of the falling object.

What was so revolutionary about Galileo's way of thinking; why is his work today considered as the beginning of modern natural science? There are two basic features which separate Galileo's work from earlier attempts to formulate laws of motion.

First, there is the systematic use of experiments to decide what is true and what is false. Before Galileo — and in particular in the Greek tradition — the view was that the laws of nature could be obtained by pure speculation. Galileo showed that experiments are of fundamental importance for our comprehension of the laws of nature.

The other revolutionary feature of Galileo's work was that he took the bold step of extrapolating to a "pure" or idealized motion by systematically disregarding features of the motion that need separate analysis. Galileo realized that friction stems from the surroundings and is not a fundamental feature of the motion. In other words, no momentum (or "impetus") is lost in motions where no friction is present — e.g. in the motion of the celestial bodies through interplanetary space no friction is present. In free fall on the Earth we can also — in a first approximation — disregard air resistance, if we focus on small, heavy bodies and let them fall through a short distance so that they do not achieve large velocities. The basis for the other main line of thought leading up to Newton's work was laid down even before the birth of Galileo, by the Polish astronomer Copernicus. In his great work *De Revolutionibus Orbium Coelestium* (1543) he replaced a geocentric model of the world with a heliocentric model.

The idea of a heliocentric system, i.e., a system with the Sun at the center, had been put forward in antiquity, but it had been suppressed by the Ptolemean teaching which was dominant up to the time of Copernicus. In the Ptolemean world model the Earth is at the center of the universe. The Earth is at rest, while the celestial sphere turns once every 24 hours around an axis which intersects the celestial sphere near the North Star. This world model could explain several features of the apparent motion of the Sun, the Moon and the planets. With complicated models of uniform circular motions