THE NEWTONIAN ART OF CLASSICAL PHYSICS

CLASS 1

INTRODUCTION

In the first astronomy sequence presented on this site, we saw what it means to call astronomy a "liberal art." That course took us through the principal contributions of Ptolemy, Copernicus, and Kepler. We are now at the next step in the journey: Isaac Newton. This course is a tour through some of the central material in his *Principia Mathematica Philosophiae Naturalis*, or "Mathematical Principles of Natural Philosophy." Although we will be learning plenty about astronomy from Newton, the very title of his work shows that it is not restricted to astronomy. It is nothing less than classical physics in its first form. This prompts the question: "Is physics a liberal art?"

There is one sense in which mathematical physics is not a liberal art. Sometimes this phrase means "one of the seven traditional liberal arts," that is, one of the Trivium or Quadrivium. Mathematical physics is not simply identical with any one of these. But the reasons for that are accidental and historical rather than essential. Despite early intimations of mathematical physics such as we find in Archimedes, the science was not really developed as a whole until Galileo; even in his *Two New Sciences* mathematical physics exists only in its most nascent and embryonic form. The seven traditional liberal arts, on the other hand, come down to us from Plato and before. Among these, the one most similar to mathematical physics is obviously astronomy. Although the principles of mathematical physics apply to the heavens, as we shall see, they also apply to terrestrial phenomena—to sound, light, magnetism, and on and on. We cannot, then, simply reduce mathematical physics to astronomy. That would be to reduce the whole to the part. On the other hand, mathematical physics *does* make models of things for the sake of understanding them, which was the main reason why astronomy was called an "art." Mathematical physics can also bring to light many things worth understanding for their own sake, which is the main reason astronomy can be called "liberal."

The mistaken dichotomy of the ancients between terrestrial and celestial materials and natures is also a factor. Aristotle and Ptolemy, for example, believed that from the Moon upward celestial bodies were immortal, indestructible things constituted of entirely different stuff from the materials of which earthly bodies were made. But that turned out to be wrong. Jupiter is not made of any elements other than those which could be found here on Earth. Newton himself, we shall see, will still be anxious to train us out of the notion that the heavens are fundamentally "other." Once we accept this, we are ready to see that the physical laws governing motions here on Earth apply just as well to the heavenly bodies, and we are prepared to understand their motions in light of physical causes similar to those we find operating on sticks and stones. That would have been an unthinkable thought to the ancients.

Kepler was the first to pave the way to this new astronomical thinking—he thought the motions of the heavenly bodies were due to a power which was magnetic in nature. At any rate, if it is right that the heavens and the earth do not operate on fundamentally distinct natural principles, then astronomy turns out to be nothing but an application of physics to the universe in its large-scale parts—whether the scale is that of suns and planets, or of galaxies and super-clusters and the expansion of all space. The liberal art of astronomy, in other words, is one part of a larger liberal art, mathematical physics. Mathematical physics is nevertheless still essentially astronomical. That is, it is essentially about the universe, since its purpose is to discover the mathematically expressible natural laws that govern all bodies, not just some.

A word or two now about the nature of this course should be helpful to anyone wishing to pursue it.

Our author is Isaac Newton. We shall say more about him when we begin the course proper.

Our text is *Principia*, whose full title I mentioned earlier. The work is divided into three books (more on this later). It is a good idea for the reader to have a copy of the whole text handy, since we will be reading only a slim selection from it in this course, and I will not always quote in full even those texts I will be commenting on. We will pursue the main principles of the book and their principal application, that is, we will be tracing the main steps in Newton's long argument for universal gravitation. Consequently we will skip the entirety of Book 2 of *Principia*, and most of Books 1 and 3. It is good to see just how small a portion of Newton's book we will be reading together, to get a sense of the sheer magnitude of his work. Physicists and mathematicians continue to study it today, and to discover things in it that no one has understood, probably, since Newton himself. It is also good to have a copy handy for those times when Newton refers to things outside our selection, in case the reader wishes to refer to these.

Our translator is Ronald J. Richard, my friend and former colleague, who has accurately rendered into English the portions of Newton's *Principia* which we will study together, and who has generously given me permission to quote his translation at length. If you have another translation, that is good, too. You can see how different translators render Newton's Latin. I will frequently cite the text of the Richard translation in full, and sometimes mention the Latin, in order to see the exact words of Newton we are trying to understand.

Our mode will be to proceed slowly and carefully, often by asking questions about the text and answering them one at a time. The reading to be discussed on a given class day will be listed at the heading of the notes for that class. Probably it is a good idea for you to read the assignment in Newton first, and then read the class notes commenting on the reading afterward, to make my questions and comments more intelligible.

There are several prerequisites to this course. The first of these is elementary geometry, as presented, say, in Euclid's *Elements*, or else as presented on this website. Another is elementary astronomy, as presented on this website (the course on Ptolemy, Copernicus, and Kepler). A further prerequisite is algebraic geometry, as one finds it in the geometry of Descartes—but I will try to supplement the basics of algebraic geometry in our next class, that is, Class 2. Still another prerequisite is a familiarity with the basics of conic sections, as found, for example, in the first three books of *Conics* by Apollonius of Perga. For those unfamiliar with his work, I have supplied my own (so far quite unpolished!) notes on his book here on this site. Knowledge of calculus is *not* a prerequisite, since we will be developing the principles of the calculus with Newton, who is one of its principal discoverers.

That brings us to the fruit we should hope to gather from this course. One of these is to learn the calculus from the ground up. It is rarely taught that way, since in most cases the emphasis is on smooth calculation—"getting the right answer," rather than understanding the philosophical principles underlying the techniques. Here the focus is on understanding the underlying principles. Another fruit we shall reach for is seeing the next phase in the story of astronomy that began with Ptolemy, and progressed through Copernicus and Brahe and Kepler. Still another is to catch a glimpse of an important phase in the history of science. In a way, we will be witnessing the very birth of modern physics. Galileo got the ball rolling, to be sure, but it was only in Newton's *Principia* that the main principles were set down explicitly and in order, and the main elements of the method codified, and an abundance of results discovered, and the fertility of the science abundantly and convincingly demonstrated. Finally, one of the main sights to see will be the amazing argument showing that the same tendency making a stone plummet is also holding the Moon in its orbit—and it is also holding all planets in their orbits around the sun, and shaping and influencing all things in the universe.

Finally, a word of caution. Modern physics retains many things from Newton, although it has altered some, and added much. What vocabulary and notation it retains often comes with some subtle difference from Newton's original ideas. We cannot assume that when we see "force" or "mass," for example, it means exactly what we find it means in a current physics textbook. We must read what Newton himself actually says, and we must read him very carefully.