1.2 Physical phenomena.

There is a well-worn definition of physics that it the study of matter and energy. I do not like that definition, as it is almost misleading unless you already know what matter and energy are—and those questions have not been settled to this day. Physics concerns itself with discovering the most fundamental principles of the universe around us. This boils down to understanding the most elementary constituents of matter and the interactions between them.

Wait a minute! What about energy? The truth is we do not really know what energy is. We can calculate energy for many different situations. We can use these calculations to learn about different situations, but these calculations are completely abstract. They result from the study of matter and its interactions. All we know about energy is that it is some number we can calculate and then use in other calculations.

All attempts to study matter and/or its interactions are either experimental or they are based on attempts to represent physical phenomena mathematically or on a computer. This allows us to use the rules of the type of mathematics being used, or the type of computer simulation, to predict the physical phenomena.

The attempt to understand matter by studying idealized objects without regard to shape or size of the object is called *particle theory*. The first step in understanding any physical phenomena is to try to simplify things by removing as many complications as possible without destroying the phenomena in the process. Then we working out all of the consequences of that simplified phenomena. The particle is this kind of simplification. Often such a simple explanation is very rich in principles and consequences. In the last century, particle theory has also taken on a definition relating to subatomic particles. We only have so many words, and they often must be used in many different ways in the same field. The mathematics of simplified particles is the analytic geometry of points, basic calculus, and ordinary differential equations.

The attempt to understand interactions between collections of matter by examining properties that seem to be everywhere is called *field theory*. Here we look at a property like temperature. If we assume that a temperature exists everywhere we are considering, we call it a temperature field. The mathematics of fields are the theories of scalar, vector, and tensor fields, and partial differential equations.

The theories of matter are the result of the inevitable complication of nature over idealized theories. Once we have studied many simple ideas, we need to make them more realistic by reintroducing some of the complications that we removed in the process of simplification. We can treat matter in bulk as a kind of matter field. This kind of idea is sometimes called a *continuum theory*, based on the idea that matter is continuous when we look at with our eyes. The mathematics of continuous matter is the theory of tensor fields and partial differential equations. We can also examine matter and the interactions of matter at ever smaller scales, where the simple ideas no longer hold—this is called a *quantum theory*. The mathematics of quantum physics is abstract algebra, probability theory, and partial differential equations. We can take the point of few that matter consists of a huge number of fundamental elements and determine the properties of it by examining the collection, this is a *statistical theory*. The mathematics of statistical physics is statistics and probability.

Applied physics is a collection of disciplines that use physics to describe specific phenomena. These have the character of being much more complicated than pure physics, since they deal with situations where the simplifications of pure physics often do not hold anymore. The simplified theories of pure physics have removed complications that must be considered in the more realistic situations covered by applied physics. Here we include astrophysics, atmospheric physics, biophysics, physical chemistry, the physical theory of computation and information, electronics, engineering physics, geophysics, physical hydrology, materials physics, and physical oceanography. The mathematics of applied physics varies depending upon the ideas being used.

So we can expand our definition of physics. Physics is the process of considering some physical phenomena, establishing a theory, predicting its consequences, and either confirming or refuting it. How do we predict the consequences of a physical theory?