1.2: Theories, Hypotheses and Models

For the purpose of this textbook (and science in general), we introduce a distinction in what we mean by “theory”, “hypothesis”, and by “model”. We will consider a “theory” to be a set of statements (or an equation) that gives us a broad description, applicable to several phenomena and that allows us to make verifiable predictions. For example, Chloë’s Theory ($t \propto \sqrt{h}$) can be considered a theory. Specifically, we do not use the word theory in the context of “I have a theory about this...”

A “hypothesis” is a consequence of the theory that one can test. From Chloë’s Theory, we have the hypothesis that an object will take $\sqrt{2}$ times longer to fall from 1 m than from 2 m. We can formulate the hypothesis based on the theory and then test that hypothesis. If the hypothesis is found to be invalidated by experiment, then either the theory is incorrect, or the hypothesis is not consistent with the theory.

A “model” is a situation-specific description of a phenomenon *based on a theory*, that allows us to make a specific prediction. Using the example from the previous section, our theory would be that the fall time of an object is proportional to the square root of the drop height, and a model would be applying that theory to describe a tennis ball falling by 4.2 m. From the model, we can form a testable hypothesis of how long it will take the tennis ball to fall that distance. It is important to note that a model will almost always be an approximation of the theory applied to describe a particular phenomenon. For example, if Chloë’s Theory is only valid in vacuum, and we use it to model the time that it take for an object to fall at the surface of the Earth, we may find that our model disagrees with experiment. We would not necessarily conclude that the theory is invalidated, if our model did not adequately apply the theory to describe the phenomenon (e.g. by forgetting to include the effect of air drag).

This textbook will introduce the theories from Classical Physics, which were mostly established and tested between the seventeenth and nineteenth centuries. We will take it as given that readers of this textbook are not likely to perform experiments that challenge those well-established theories. The main challenge will be, given a theory, to define a model that describes a particular situation, and then to test that model. This introductory physics course is thus focused on thinking of “doing physics” as the task of correctly modeling a situation.

Emma's Thoughts

What’s the difference between a model and a theory?

“Model” and “Theory” are sometimes used interchangeably among scientists. In physics, it is particularly important to distinguish between these two terms. A model provides an immediate understanding of something based on a theory.

For example, if you would like to model the launch of your toy rocket into space, you might run a computer simulation of the launch based on various theories of propulsion that you have learned. In this case, the model is the computer simulation, which describes what will happen to the rocket. This model depends on various theories that have been extensively tested such as Newton’s Laws of motion, Fluid dynamics, etc.

- “Model”: Your homemade rocket computer simulation
- “Theory”: Newton’s Laws of motion, Fluid dynamics

With this analogy, we can quickly see that the “model” and “theory” are not interchangeable. If they were, we would be saying that all of Newton’s Laws of Motion depend on the success of your piddly toy rocket computer simulation!

Exercise 1.2.2

Models cannot be scientifically tested, only theories can be tested.

A. True
B. False

Answer