1.1: Science and the Scientific Method

Science is the process of *describing* the world around us. It is important to note that describing the world around us is not the same as *explaining* the world around us. Science aims to answer the question "How?" and not the question "Why?". As we develop our description of the physical world, you should remember this important distinction and resist the urge to ask "Why?".

The Scientific Method is a prescription for coming up with a description of the physical world that anyone can challenge and improve through performing experiments. If we come up with a description that can describe many observations, or the outcome of many different experiments, then we usually call that description a "Scientific Theory". We can get some insight into the Scientific Method through a simple example.

Imagine that we wish to describe how long it takes for a tennis ball to reach the ground after being released from a certain height. One way to proceed is to describe how long it takes for a tennis ball to drop 1 m, and then to describe how long it takes for a tennis ball to drop 2 m, etc. We could generate a giant table showing how long it takes a tennis ball to drop from any given height. Someone would then be able to perform an experiment to measure how long a tennis ball takes to drop from 1 m or 2 m and see if their measurement disagrees with the tabulated values. If we collected the descriptions for all possible heights, then we would effectively have a valid and testable scientific theory that describes how long it takes tennis balls to drop from any height.

Suppose that a budding scientist, let's call her Chloë, then came along and noticed that there is a pattern in the theory that can be described much more succinctly and generally than by using a giant table. In particular, suppose that she notices that, mathematically, the time, t, that it takes for a tennis ball to drop a height, h, is proportional to the square root of the height:

$$t \propto \sqrt{h} \tag{1.1.1}$$

Example 1.1.1

Use Chloë's Theory ($t \propto \sqrt{h}$) to determine how much longer it will take for an object to drop by 2 m than it would to drop by 1 m.

Solution

When we have a proportionality law (with a $\propto$) sign, we can always change this to an equal sign by introducing a constant, which we will call k:

$$\begin{gathered} t \propto \sqrt{h} \\ \rightarrow t = k\sqrt{h} \end{gathered}$$

Let t_1 be the time to fall a distance $h_1 = 1\text{ m}$, and t_2 be the time to fall a distance $h_2 = 2\text{ m}$. In terms of our unknown constant, k, we have:

$$\begin{aligned} t_1 &= k\sqrt{h_1} = k\sqrt{(1\text{ m})} \\ t_2 &= k\sqrt{h_2} = k\sqrt{(2\text{ m})} \end{aligned}$$

By taking the ratio, $\frac{t_1}{t_2}$, our unknown constant k will cancel:

$$\begin{aligned} \frac{t_1}{t_2} &= \frac{\sqrt{(1\text{ m})}}{\sqrt{(2\text{ m})}} = \frac{1}{\sqrt{2}} \\ \therefore t_2 &= \sqrt{2}t_1 \end{aligned}$$

and we find that it will take $\sqrt{2} \sim 1.41$ times longer to drop by 2 m than it will by 1 m.

Chloë's "Theory of Tennis Ball Drop Times" is appealing because it is succinct, and it also allows us to make **verifiable predictions**. That is, using this theory, we can predict that it will take a tennis ball $\sqrt{2}$ times longer to drop from 2 m than it will from 1 m, and then perform an experiment to verify that prediction. If the experiment agrees with the prediction, then we conclude that Chloë's theory adequately describes the result of that particular experiment. If the experiment does not agree with the prediction, then we conclude that the theory is not an adequate description of that experiment, and we try to find a new theory.

Chloë's theory is also appealing because it can describe not only tennis balls, but the time it takes for other objects to fall as well. Scientists can then set out to continue testing her theory with a wide range of objects and drop heights to see if it describes those experiments as well. Inevitably, they will discover situations where Chloë's theory fails to adequately describe the time that it takes for objects to fall (can you think of an example?).

We would then develop a new "Theory of Falling Objects" that would include Chloë's theory that describes most objects falling, and additionally, a set of descriptions for the fall times for cases that are not described by Chloë's theory. Ideally, we would seek a new theory that would also describe the new phenomena not described by Chloë's theory in a succinct manner. There is of course no guarantee, ever, that such a theory would exist; it is just an optimistic hope of physicists to find the most general and succinct description of the physical world. This is a general difference between physics and many of the other sciences. In physics, one always tries to arrive at a succinct theory (e.g. an equation) that can describe many phenomena, whereas the other sciences are often very descriptive. For example, there is no succinct formula for how butterflies look; rather, there is a giant collection of observations of different butterflies.

This example highlights that applying the Scientific Method is an iterative process. Loosely, the prescription for applying the Scientific Method is:

1. Identify and describe a process that is not currently described by a theory.
2. Look at similar processes to see if they can be described in a similar way.
3. Improve the description to arrive at a "Theory" that can be generalized to make predictions.
4. Test predictions of the theory on new processes until a prediction fails.
5. Improve the theory.

Exercise 1.1.1

Fill in the blanks:

Physics is a branch of science that ____ the behavior of the universe. When doing physics, we attempt to answer the question of ____ things work the way they do.

A. explains
B. describes
C. how
D. why

Answer

B. describes

C. how