Preface

Physics and Models

The whole idea of the study of physics is to understand how the universe operates. We cannot actually ever know for sure how this works, but we play a sort of game: We develop a model that explains why things happen the way they do, and then we test the effectiveness of that model when it comes to predicting how other things will unfold. If the model predicts accurately, it is a "good" model, and if it doesn't, it is discarded.

Inherent to this description is the idea of "accuracy." No model we have ever designed has ever predicted a result with 100% accuracy. Mainly this is because 100% accuracy requires 100% accurate measurements of both the starting conditions and of the results, and this simply isn't possible. What we settle for instead is a sense of what sorts of problems our model is intended to solve. Some models are precise to an incredibly small dimension (like models that predict atomic behavior), but these are not useful for making predictions in the macroscopic world where trillions of trillions of atoms are involved. Conversely, we also make macroscopic models that breakdown when our measurements become too fine.

So all models come with them an understanding that they work "up to a point." When I discuss a problem involving a "frictionless surface," one can certainly argue that no such thing exists, but true as that statement is, it is not relevant. The model of the frictionless surface allows us to answer questions about situations where the amount of friction is small, and our coarse measurements can't distinguish the effects of that small amount of friction. Further, this model can be used as a starting point, to which we can later append a friction effect to make a more inclusive model.

You will sometimes hear me (or future physics instructors) say that such-and-such is true if a certain quantity is "small." This simply means that if the quantity is small enough, the coarseness of our measurements provide too much noise for us to really notice the effect of that small quantity.

Measurement and Units

While we can make some general predictions about the behavior of our universe, these are not usually particularly satisfying. The statement, "If I drop something, it will fall to Earth" can be considered a "theory of gravity," but big deal. How long does it take the dropped object to fall some specified distance? How fast is it going when it lands? How do the motions of two different dropped objects differ from each other? All of these are questions we would like to answer as well, and they all require measurement. But if I measure the time for an object to fall and call it "3," while you measure the same process and call it "17," we are not going to get anywhere. We need a standardized system of units that we can agree upon so that we can compare results.

Many hundreds of years before Galileo, Aristotle sought to explain everything, but he did so descriptively. Galileo was among the first set out to do so mathematically. Galileo was studying the effects of gravity on motion (Aristotle simply said that things that are heavy fall, and things that are light rise), and did experiments where he rolled balls down ramps and timed their journeys. He started zeroing-in on a precise mathematical description, but every time he got close to accepting his results, the experiment would go haywire and his new results would disagree badly with the early ones. It turns out that the problem was that he was using his own heartbeat to time the motion of the ball, and when his predictions started coming true, he got excited, his heart beat faster, and the predictions began to fail.

There are many systems of units available to us. We could for example measure speed (which is a rate of distance covered over time) in units of furlongs per fortnight. But there is one system that we use in physics as the default, from which we only rarely stray. It is called the *Système Internationale d'Unites*, or *SI units* for short. The three most fundamental measurements we have in this system are *meters* (distance), *kilograms* (mass), and *seconds* (time). For this reason, this system of units is also often referred to as *mks units*.

First-time physics students often pay little attention to units when they are solving problems, thinking of them as more of a nuisance than a help. You should fight this tendency. If you are solving a problem to find a speed and you end up with an answer that (because you carefully carried units through the math) came out to be kilograms per meter, then that is an indication that you made a mistake somewhere. Many students plug in the numbers and then throw the proper units in at the end, and this provides them with no opportunity for catching mistakes.