Before Class 1

(A preparation for class—nothing here is for credit, but it’s strongly recommended)

1. First, watch this short clip about how pure math can nevertheless describe the very real world. Feel free to follow up with other related videos that you find.

2. Try the items in Before Class 1 MP (that’s a Mastering Physics assignment). Work as many of them as you need to in order to have a firm understanding.

Where to Start the Story of Physics?

Science studies the consistency of the universe. It observes patterns, describes their relationships, and uses these to explain (and predict!) the behavior of the natural world. Physics looks at the most fundamental of the consistencies—the rules that apparently govern all matter and all space in this universe.

The story of physics is an old one, of course: There have been many persons in history who contributed to our views and knowledge of the physical world—including Aristotle, Ptolemy, Copernicus and Galileo, to name just a few. But the breakthroughs of Isaac Newton in the 17th century are generally regarded as a key turning point.

Setting the Scene…

On a small farm in England, 1665, a young Isaac Newton has fled the plague that is decimating London and other cities. In the two-year period that follows (hey, not much else to do), he basically founds our understanding of the consistency of the language and behavior of the physical universe, by taking a rigorous mathematical approach to describing rates, motion, forces, and gravity—phenomena we call mechanics. As you heard on Monday, there are just four great fundamental “threads of consistency”—mathematically consistent patterns that we call the Conservation Laws—that apparently underlie the mechanical aspects of this universe. This Fall term is all about those mechanics—the behaviors of objects as they move, push, pull, fall, collide, etc.—and Newtonian mechanics is still the centerpiece of our understanding.

So our studies this term will be a sort of “paraphrase” of Newton’s basic thinking as he developed his mathematically based principles of understanding the physical world. We’ll basically “put words into his mouth” here to understand where his thinking led. Having read of the works of Copernicus, Galileo and others (he had just graduated from Cambridge), Newton was convinced that the universe is consistent—if only it were observed consistently and rigorously—with quantitative measurements and calculations.

First of all, what’s a quantity? Basically, it’s anything you can count (apples, raindrops, french fries). And notice that it needs units. If you say “I have 4 apples,” that makes sense. But if you just say, “I have 4,” that makes no sense. 4 what? You need units to tell what the number means. That’s what we mean by a quantity—a number along with the units that tell what the number means.

But not all quantities pertain to the workings of the physical universe. Which quantities do? What’s a physical quantity? Basically it’s anything you have to use a tool to measure—rather than just counting.
3. Check your understanding: Which of these is a physical quantity?
   A. 30
   B. 30 apples
   C. 30 minutes
   D. None of the above.

   A. No. The number 30 by itself lacks units, so it isn’t even a quantity, let alone a physical quantity.
   B. No. You don’t need any tool to measure 30 apples—you just count them.
   C. Yes. You need some other tool or object to measure time—a clock, the earth or sun, your heartbeat, etc.

Now, what should we look at first in mechanics? What did Newton look at? Before trying to explain or predict what we observe, we must agree on what we are seeing. We’ll need to use the universe’s common language (math) and a common measurement system (units) to describe what we’re consistently observing. So we’ll start, then, with the simplest behaviors that we can all agree about when we observe them: motion.

Types of Motion

How does an object move? (Notice that we’re not yet asking why it moves in a certain way. We’re just trying agree on what it’s doing.) What sort of motions can an object undergo?

- It can move from point to point (translate).
- It can spin (rotate).
- It can compress/expand (vibrate).

Start with the most familiar type of motion….

Translation

In translational motion, the entire object moves from one point (one position) to another; that is, all points of the object move (and all points travel a similar distance). A car traveling on a road; a bee flying toward its hive; the earth orbiting the sun—these are all examples of translation.

Notice that the paths can have various shapes (straight or curved). Let’s take the simplest case first: Consider an object that’s in translational motion along a straight line.

If an object is linear translational motion, it is changing position along a single direction.

The Direction Matters!

Notice something already about our language: We’re thinking about some object moving in a straight line—changing its position over time. And how do we describe its position? We need a physical quantity (distance)—that includes units, such as meters—but we also need a direction, as measured from some agreed upon origin. After all a position that is 50 m east of your house is entirely different than a position that is 50 m west of your house. The distance, 50 m, is not sufficient

Naturally, the easiest way to think about that direction is a simple coordinate axis direction (say, the x-direction or the y-direction). That way, we can use the coordinates of that axis to indicate the object’s position during its linear motion. One of Newton’s lasting contributions was recognizing how powerful mathematical descriptions of motion and mechanics can be if we treat direction as part of the quantity itself. We do this by using vectors.
The Power of Vectors

A vector is a physical quantity where you need to know not only how much you have, but in what direction. That is, a vector has two measurements: Magnitude and Direction.

As we’ve already observed above, to use math to describe the position of an object, we must use a vector, because it tells us both the magnitude (distance) and direction of that position along the axis (i.e. measuring from an agreed-upon fixed point: the “origin”). Without both pieces of information, we have just a number with units—what we call a scalar quantity—not sufficient to fully describe an object’s position.

Compare the two types of descriptions:

<table>
<thead>
<tr>
<th>Scalar (magnitude only)</th>
<th>Vector (magnitude and direction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance ( (d) )</td>
<td>Position ( (x) )</td>
</tr>
<tr>
<td>Examples:</td>
<td></td>
</tr>
<tr>
<td>50 m</td>
<td>( x = -50 ) \text{ m}           (that’s 50 m to the left of the origin)</td>
</tr>
<tr>
<td>4 yd</td>
<td>( x = 4 ) \text{ yd}           (that’s 4 yd to the right of the origin)</td>
</tr>
</tbody>
</table>

4. Read in the textbook sections 1.1-1.4.