

Preliminaries

Welcome to Physics

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My name is Steve Pollock. I'm a nuclear physicist. I work at the University of Colorado in Boulder. And I want to teach you some physics. What is Physics? I would define Physics as the science, which describes and explains the nature and the behavior of physical systems. It's about science. You go in the laboratory and you make measurements and you ask quantitative questions. What is the world made of? You look around, you know, and you see "stuff." What's it built out of? And, how does it work? When you push on something, how does it respond? How do we understand physical things? It's a pretty broad definition. If a biologist was listening to this, they'd say, "Hey, wait a minute, I'm doing science. I'm describing and explaining the behavior of physical systems." And I would agree. In fact, I would say that's what all of science is doing. I think of Physics as sort of the underlying or fundamental science, upon which biology and chemistry and other sciences are building. At the bottom. What are the fundamental laws, what are the primary ideas, how do we understand how things work and why they work the way they do. Now that to me is what Physics is about.

Sometimes the distinction between Physics and other fields of science gets a little bit confused or vague. If you're watching an Olympic high-diver and they're doing some cool stuff, doing spins and twists – if you're studying that, are you doing Physics or are you doing biology? I would argue that that's Physics. And the coach, who wants to help the athlete improve their performance, really should be, among other things, studying some Physics, understanding what's required to make things turn and follow the pattern and behavior that you want. So, when you have complicated systems – you might be doing Physics, you might be doing biology, you might be doing chemistry, and there's lots of room for connections between these different kinds of science.

Ultimately, when you watch a high-diver going off the board and doing their stuff, you say, this is a really complicated system. Is it possible for me as a mere mortal to really understand that system? And you start looking around the world and asking what other things can Physics describe and you realize it's overwhelming.

Physics is about how things work and what they're made of. So, you look around the room. There's a computer terminal. It seems awfully complicated. Can Physics really help us understanding that complex system? There's more than just technology that Physics is trying to explain and help us to describe. How about the table, its color, its properties? Why is it hard? Why is your hand softer? Why is the air softer still, you can barely feel it. Physics is about all of these things. And so you can sort of feel like it's just got to be this big hodgepodge of ideas and I'm never going to really be able to understand everything. And, on the contrary. Physics is really not about the complexity of the world, it's about the simplicity of the world. All of these things, anything physical that you can talk about, ultimately has some underlying properties which we can describe.

It doesn't really take all that much, a single semester of Physics really, to know what are the basics of behavior and properties of lots of things. You can go back to that high-diver. I claim that the physics of that high diver is fundamentally the same physics as the physics of a ball, a baseball that's just been tossed and it's following a much simpler arc. Or the moon, going around the earth. And, even more complicated systems, like the fireworks display on the 4th. All of these systems, even weirder things like you've got a law sprinkler going back and forth with really bizarre patterns. All of that can be understood just by knowing a few laws.

The person who really discovered and laid out these few basic laws that we need to understand was Isaac Newton. He's the hero of this course. Isaac Newton, in the late 1600's, was really just writing down a small set of laws, we'll call them Newton's Laws, and from these basic principals, we will be describing an awful lot of science. In this course, we're going to begin purely descriptively. We will begin with what's called kinematics. It's a fancy word for describing systems. You need some sort of a language, an economical, efficient language that's quantitative – where is something? How fast is it moving? Which way is it going?

So, that's the first step in understanding the world. But it's just the first step. It's by no means the end of the story. Just describing stuff isn't what we're about. We want to understand it. Newton's laws will help us really understand when you push on something and it accelerates. I can understand why and then, in much better detail, be able to explain and describe results of various physical experiments and physical systems. Once we've talked about forces and pushes and pulls, basically, we'll go on and we'll talk about more complex ideas, energy, power, momentum. You know, in the English language, people use those words as almost synonyms, but in Physics, we'll define them rigorously and they will be useful quantities, which we can use to help us to understand the behavior and the nature of physical systems.



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In order to be quantitative, we will be using some math in this course. Nothing very fancy, I will be using some basic algebra, solving equations, you know, an equation with one unknown, maybe even two equations, and two unknowns. You draw a right triangle and I give an angle and the hypotenuse and I'll have to be able to find the other two sides. Pretty basic stuff. The most sophisticated mathematics we'll be using is a little bit of calculus. We will be describing things, which change with time. Rates of change and that's what calculus is all about. We'll be taking derivatives and doing integrals from time to time. You'll need some passing familiarity with that, but as we get to these topics, I will give you the physicist's view. I will explain what's a derivative and how you take it, what's an integral and how do you do one. So, you need to know a little bit about that stuff, but it's not going to be a particularly fancy level of mathematics.

When we have described and defined these new ideas, ideas like momentum and energy, then we're going to be able to start getting a little bit more realistic. When we start off, I'm a physicist, I really do like to keep things simple. I'm going to talk about point objects, with no friction. I'm going to make many, many approximations in the beginning to try to get at the essence of what's going on. But, once we understand that essence, then we can start adding all sorts of realistic complexity. We can add friction, that's part of Physics. We can talk, not about point like objects, but realistic objects, rigid bodies or human bodies, even fluids. We'll be able to describe the physics of fluids and even the waves, like waves on water. So, this is where we're headed. In fact, along the way, we will even discover that Newton's Laws, which are really the core of this course, have some very subtle issues. If you start pushing off to extremes, like super high velocity, then yes Newton's Laws begin to break down, only in those extreme cases is there anything that you have to fix up. And it was Albert Einstein who figured out what you need to do. And the basic picture is the same. A few new ideas introduced by Einstein and all of Physics, once again, becomes this sort of simple, coherent whole. So, I'm going to argue that Physics, as we go along, a very beautiful science. And I know that when you're working in a Physics course for the first time, you're saying "Beautiful? It looks to me like we've got a jillion equations and I'm plugging numbers in with my calculator." Don't lose the forest for the trees. The beauty of Physics is the simplicity, which underlies all of this. It's not about memorizing any equations and there's really only a few equations that you need and it's not really the equations, it's just these concepts. Newton's Laws and Einstein's additions to Newton's Laws, which allow us to quantitatively describe and understand, what are things made of, how do they work, why do they work that way?