What is light? Scientists have been trying to answer this question for hundreds of years. The process goes a little like this: we set up an experiment and make observations about what light does. Then, using the data from our experiment and all the previous experiments, we make a modelâ€”or modelsâ€”of what we think light is. This process continues as more experiments are done and the models are refined. In this video, we'll use everything we know about what light does to explain the different models of what light is. This video is part of the Representations video series. Information can be represented in words, through mathematical symbols, graphically, or in 3-D models. Representations are used to develop a deeper and more flexible understanding of objects, systems, and processes. Hello. My name is Paola Rebusco. I am a physics instructor in the Experimental Studies Group at MIT. Today I'll be talking with you about different models of light. In order to understand this video, you'll need to be familiar with the electromagnetic spectrumâ€”particularly, the idea that there are varieties of light that our eyes cannot see. You should also be familiar with the behavior of waves, especially diffraction and interference. Finally, you should have some experience solving problems with collisions, so that you better understand how particles interact with each other. After watching this video, you should be able to explain the major models of light, and should also be able to explain the different facets of light in terms the models that best describe them. This video should also help you to understand how models are used and verified in science. Let's start by looking at the things that light does. We cannot expect to describe what light is without having a good picture of its behavior. We are going to make a list and refer to it later, so be sure to take notes. First, we know that light moves very quickly. When it reaches an object, light can interact in many ways. It might be transmitted through the object, be reflected off, or be absorbed. However, beams of light that pass through each other come out unchanged. Light can refract, changing directions as it moves from one material to another. It can also diffract as it passes through small openings. When light passes by a charged particle, it can make that particle oscillate back and forth. There are many kinds of light, some of them invisible to us. It can strip electrons away from atoms, ionizing them almost instantly. Light can collide with particles. Finally, light can transfer energy and momentum almost instantaneously, but it can also do so in a gradual way. Some of the atomic-scale phenomena listed are actually the reason for the macroscopic phenomena. For instance, light that strips away electrons from atoms is absorbed in the process. Take a moment to make sure you have all of this in your notes. These observations can help us create a model for light. When we talk about "what light is," what we're really doing is creating a model. A model in physics is a representation -- a mental analogy that we can use to better understand the physical world. Once we have a model, we can predict the behavior of an object or phenomenon based on the ways that the model would behave. It's important to understand that no model is perfect -- all models go through cycles of testing and refinement. There are typically conditions under which a model can break down, giving incorrect results. However, because models are just analogies, we often create a new and improved one to better describe how something works. A single phenomenon can be modeled in many different ways, with different assumptions or simplifications. Therefore, we can even use more than one model for the same thing. To give an example, imagine describing gravity as an invisible rope holding objects together. There are several good things about this model. Ropes can only pull, not push, and this is true for gravity. Ropes can be used to swing objects in curved paths, the same way that gravity makes the planets move in curved paths. Unfortunately, the model breaks down quickly. The amount of force a rope exerts does not change with the length of the rope, whereas gravity's force definitely does depend on distance. Ropes can become tangled, whereas gravity has nothing to tangle. We can see that this model works for some purposes, but not for others. Let's consider some of the things we might want to use to build our model for light. We know from our list that light can pass through other light, can diffract and refract, and that it can make charged particles oscillate. You may have heard light described in terms of rays of light, or waves, or particles called photons. Which one of these models seems to fit these observations? Pause the video to consider. If we consider waves, we know that waves can pass through each other, that they diffract and refract, and that waves can make particles oscillate. These match the properties of light that we chose very well. The fact that light specifically makes charged particles oscillate is an indication that we are likely dealing with an electromagnetic phenomenon. Therefore, we can model light as an electromagnetic wave. As you probably know, this is a common model for light. We imagine a situation similar to the animation shown to the right, where electromagnetic waves propagate in the direction that the light is shining. This animation shows the electric field vectors as the wave moves to the right. Below is another image that shows the electric field in red and the magnetic field in blue, perpendicular to each other. However, there is a problem. Light cannot be just a wave. Let's look at the reasons why. In addition to the aspects that are wave-like, light has other properties. Light can also collide with particles of matter. Waves, on the other hand, move through or around particles. Light can transfer momentum and energy almost instantaneously through these collisions; waves must transfer energy and momentum gradually. Finally, light can ionize atoms almost instantly, but electromagnetic waves would need more time to do this because of that gradual energy transfer. It is clear that light cannot be just a wave. Waves model some aspects of light well, but not others. How else might we model light? Consider the aspects that we just discussed, and try to come up with an alternative model. Pause the video here to discuss. The other major model for light is the particle model. Particles can collide with each other, and in the process, they transfer momentum and energy almost instantly. Through these collisions, they can quickly knock electrons loose from their atoms. It is because of this that a beam of light can also be modeled as a large number of tiny particles, called photons. If we return to our list, we can see that some of the items, shown in red, are described well by the wave model. Others, shown in blue, are the items we just discussed for the particle model. We cannot deny that light does all of these things. Experiments show us that it behaves like a particle in some ways, and like a wave in other ways. This leads to a phenomenon called "wave-particle duality." In some situations light seems to behave in a manner predicted by the wave model. At other times it behaves in a particle-like way. We cannot rely just on the wave model of light, or just on the particle model. Neither of our models works in every possible situation. Scientists and engineers typically set up situations to take advantage of one model or the other, using the particle-like or wave-like behaviors of light to their advantage. We should also mention here that it's not just light that has the properties of both particles and waves. All things -- electrons, protons, any form of matter -- can be made to behave like particles or like waves. This was one of the driving forces behind the development of quantum physics in the early 19th century. One of the most striking experiments in this area is the double-slit experiment, in which light is directed towards a pair of thin slits and a pattern appears on a detecting screen. The screen is capable of detecting individual photons one at a time, which can be explained by the particle model. However, the pattern is created through the interference and diffraction of light, which can only be explained through the wave model. This experiment gives the same results with matter as with light. If we use an electron source rather than a laser, we can create a beam of electrons forming the same pattern. This shows that matter can also be represented as a particle and as a wave. In the modern view of quantum physics, objects are often represented as "probability wave packets." These are localized collections of waves that describe where those objects may be found. The wavepacket approach is more accurate than the wave model or the particle model, but is also difficult to fully understand and to make calculations with. The separate wave and particle models are both still in common use today. Models are useful for many purposes. Two of the most common are describing the mechanism for an existing phenomena and predicting new phenomena that may be discovered. Rather than ask you to come up with entirely new predictions of what light might be able to do, we will instead look at some known phenomena that we have not yet discussed. Each of the four phenomena listed here can be described using either the wave model or the particle model of light. Your professor will lead the class in a debate as to which model is most could best describe each phenomenon. Pause the video here. Let's look at #3 on that list: that an accelerating electric charge can generate light. Would the wave model or the particle model predict this result? The fact that an electric charge is involved definitely points toward an electromagnetic wave description of light. We know that moving electric charges create both magnetic and electric fields. If our charge is accelerating, then the fields that it creates must be changing. As we learned earlier in this course, changing electromagnetic fields obey a wave equation. It seems like this particular phenomenon is best described using a wave model. Let's review. The core idea for today's video was the concept of a model. We saw that light can be modeled as an electromagnetic wave, or as a particle. Models like these are used to describe existing phenomena and to improve our understanding. They can also be used to predict new phenomena. I hope you have enjoyed this introduction to light and wave-particle duality. Good luck in your further studies of physics.