[SQUEAKING]

[RUSTLING]

[CLICKING]

MARKUS KLUTE: Welcome back to 8.20, special relativity. So we're starting a new chapter in which we look at tests and implications of special relativity. We started the entire discussion and evaluation of Lorentz transformations and the description of the paradoxes based on Einstein's postulates.

Those are not axioms, which means that we do actually have to verify. They are a prediction of how nature functions, and experimental verification is needed to gain confidence that those postulates are actually correct or realized in nature.

And we have studied some of those tests already. And this serves as a little bit of a review of the discussions we had to this point. One experimental test is stellar aberration, which we discussed can be explained by special relativity and by velocity addition. So this gives us some idea about what light is.

Light isotropy is being tested in a variety of different experiments, starting from Michelson-Morley, which basically tests that the speed of light is independent of the orientation of the apparatus. We have not discussed in detail another experiment, which is very similar. It's the Kennedy and Thorndike experiment, which tests that the speed of light is also independent of the velocity of the apparatus itself.

As one of the homework assignments, we looked at de Sitter who tested that the speed of light is independent of the speed of the source. And that has been tested, for example, with the motion of binary stars, as we did in our pset, in our homework assignment.

We can look in particle physics at the decay of a pion into two photons. And those pions, they can have a lot of energy, for example, with a beta of 0.999 times the speed of light. And still the photons are of this decay. They behave like any other photon. They move with the speed of light.

Let me discuss the Doppler effect and relativistic Doppler effect and analyze light with various frequencies. And one of the hypotheses you could have is that the photon actually is a massive particle. This would directly modify Coulomb's laws, which are tested experimentally. And those results would be dependent on the frequency.

There is weird electromagnetic effect if you introduce a mass to the photons like torque on a magnetic ring Again, here precision measurements have been performed. And they're all in agreement with the hypothesis that the photon is massless. And we talked about the Doppler shift and redshift for light.

Another class of experiment is where we look directly at time dilation, for example, in the decay of the muon. As we discussed, we have cosmic muons to study, or we can produce muons in the laboratory as well and study them. Or we can put very precise clocks on planes, fly them around the globe, and compare them with stationary and just simply measure the effect of special relativity on those clocks.

In all of this experimentation and experimental verification, it's important to understand the importance of uncertainties in the scientific process overall. I think that-- remember, when one has the historic perspective on science, one often forgets that a specific measurement comes with an uncertainty, often, a statistical uncertainty or systematic effects, which are quite important to quantify the level of verification of the theoretical hypothesis.

One example here is-- and experiments can have biases as well. And one example of a biased experiment is here one by Walter Kaufmann who tried to measure e/m, the electric charge over the mass of the electron. But he had a rather strong theoretical bias. And he conducted the experiment at the time Einstein was proposing his theory.

The bias really came from the model of an electron at the time. And, as experiments, they were inconsistent with Einstein. So he said Einstein is wrong. Einstein and Lorentz are wrong.

Planck looked at this and said maybe, but Einstein's conclusion immediately by looking at this was, no, this cannot be. And it took a little bit of time to tee up those experiments until 1940. You can read more about this in this Wikipedia article about Walter Kaufmann's experiments, but let me just read this to you.

"The prevalent results decidedly speak against the correctness of Lorentz's assumption, as well as Einstein's. If, on account of that, one considers this basic assumption refuted, then one would be forced to consider it a failure to attempt to base an entire field of physics, including electrodynamics and optics, upon the principle of relative movement."

We now know this was wrong, but scientific process happens in scientific environment. And I started this class by explaining that one needs to be open minded to learn and to study and to grow scientifically. And one has to question the assumptions, understand the assumptions when then go into measurements.

So this is the first part of this chapter where we talk about tests. We will have a discussion of implications of special relativity as we move on from here.