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MARKUS KLUTE: Welcome to 8.20. Welcome to Special Relativity. And let me start by wishing you all a happy New Year, happy New Year 2021. I'm pretty sure this is going to be an exciting year with a lot of changes ahead and a lot of exciting events. My name is Markus Klute, and I will guide you through this IAP lecture on special relativity.

This is very likely my favorite class at MIT, A, because it's IAP, and we start a new year. There's a lot of excitement in the air. And we have a chance to focus for this one month of January on this specific subject. B. I have a chance to introduce a man, Albert Einstein, through a discussion of his physics, through discussion of him as a person, and also through a discussion of the historic context in which he developed special relativity. And C, if this is the first time you encountered special relativity, it will blow your mind. And it actually is quite fun as an instructor to do a little bit of a transformation in your understanding on physics.

So let's get started with a quote, with an Einstein quote. I have a number of those as we go through the class. This one here is really kind of the theme of the class. Let me just read this to you. "It is not the result of scientific research that ennobles humans and enriches their nature, but the struggle to understand while performing creative and open-minded intellectual work."

It is really the struggle with the ideas, really the trying to get understanding which ennobles humans and enriches their natures. And let me add here that, through your own work, through your own mind, you can transform yourself and your understanding of physics in general. This first video and this first lecture will mostly be concerned with organizational topics. So I'll lay out the schedule of the class and also how you get a grade, of what kind of PSETs we have in mind and so on.

Let's get started. So I introduced myself already-- again, Markus Klute. You can reach me by email. It's klute@mit.edu. We have a graduate TA, Justin. His email is given on the slide, as well. And then we have, too, graders and TAs-- Mohit. Zach, YuQing, and Stephen. Those four will guide us through the class, as well. And especially when we go into breakout rooms in the live class, they will help you in the discussion.

The class hours are from 3:00 to 4:30 PM on Zoom. And you can-- I encourage you to join the class, to participate, to be active in the class. But you will also be able to get through the material through recordings. I will not record the live class, because I want to encourage you to be just as open as possible. But I pre-record the class, and after the class time is over, I'll upload those videos for your reference. And also, if you live in a different time zone, you have a chance to listen to the class.

Office hours will be Tuesday at 9:00 AM and Friday at 5:00 PM. Tuesday, you reach me, and Friday you reach Justin. Will set up a Slack workspace which we use for our internal discussions with a teaching staff. But there's also going to be channels for you to discuss PSETs as channels we discussed for physics. And there's going to be a channel, which will be important when we go to the exam discussion.

The expectation is that you spend about 30 hours a week during IAP. Some will find the PSETs very straightforward and quickly to do. Others will need more time. So not a-- don't set your stopwatch for 30 hours. That's just an average guide.

I will evaluate you at the end of the term, and I will use this metric here. 50% of your grade will come from the homework. There's going to be five different homework assignments. There's going to be two midterms with 15% each and one final that's 20%. If I do the math correctly, this should lead us to 100%. You earn an A with 90%, a B with 75%, a C with 60% or higher, a D with 50% or higher, and then a failing grade with less than 50%.

So all lectures will be on Zoom. You'll find the Zoom links on the Canvas page. And you probably found this already. Otherwise, you wouldn't be able to find this video. And again, as I was saying, the recordings will be available after class.

This is the schedule. Let me start by explaining this picture. That's Little Thomas here and then a German ICE train. This class-- the way I look at this class is that it's a train which is just leaving the station right now. And it will very slowly pick up pace. But you want to make sure that you stay on the train and you don't jump off, because this will, once it's picked up its pace, will be a fast moving train. And missing a few days in IAP will cause you to have trouble following along with the material.

We'll start today with this introduction. Tomorrow, we have a very interesting lecture by David Kaiser. This is the only one where we actually record the live event. So we record the Zoom session. And then the rest will unfold, I was about to say.

You find this red block here. Those are our midterms and the final. On those days, there's not going to be a live class. But I will make the final-- sorry, the exam available for about 24 hours. You should not spend more than an hour, maybe an hour and a half on the exam. And then submit once you are done.

The exams are open book in a sense that you can look at the textbooks, and you can look at the course material. But you are not supposed to do an online search for the solutions, and you're also not supposed to discuss with your peers. You can ask clarifying questions on one of the Slack channels, and we will be happy to answer as quickly as we see them. But again, this is an evaluation of your own performance, and you should submit your own performance.

The PSETs are different in a sense that I encourage that you guys build small groups and work on them together. Each PSET then has to be submitted by you as an individual, meaning that I don't want to see copies of PSETs of other folks. I want your own answers in your own words to the questions we pose.

Very important day in January is Martin Luther King Day, and IAP gives us all a little bit of a breathing room and extra free day. And you see that there's going to be, after the discussion at the very end, after the final, a special lecture where I introduce the topic of general relativity, which is not part of the core content, especially of this special relativity class.

Textbooks-- I will not really follow the textbooks line by line or chapter by chapter. But I encourage you-- and I give you an outline-- to read them, especially the first two ones. The first one is by French. The second one is by Resnick. The first one is the former MIT professor. You are supposed to read this book cover to cover, and I give reading assignments on this. Resnick has a lot of good examples and problems, and we will focus on the first four chapters of that book.

There is a lot of literature out there on special relativity, as a slew of textbooks available. If you have one at hand, you can also use that and find the relevant chapter in there. I give you one extra book here, which is nice because it is an excellent explanation of the mathematics involved. If you're more inclined to course 18, that might be an interesting textbook for you. Again, there's many, many resources on the topic of special relativity, and I'll point out a few as we go.

In addition to the textbooks, I give you a number of papers-- for example, the paper in which Einstein explains or describes the concept of the theory of special relativity. And there's a few others which I'd like you to read. They're interesting because they introduce the physics, but they're also interesting as they have been written more than 100 years ago in a slightly different language than we would be using today. And Einstein, specifically, doesn't even write papers the way other people wrote papers at the time. He had his own style in writing papers. And we will see that.

So here is the reading assignment week by week. We start in week one by Resnick Chapter 1, French Chapter 2. There's two papers, the Michelson Morley paper and the Einstein paper on special relativity. And then we go on as we go through IAP.

Your homework schedule is here. I hand out PSET number 0 today, and I'll explain it on the next page. This is a PSET which allows-- I mean, this is a PSET which will keep you busy for the entire month, or most of it. The other PSETs are shorter, and they are more pointed. And you get the PSET, you work on it, and your hand in the solution. And by the time you have done that, the next PSET rolls around.

I would use the PSET load a little bit, because I want to acknowledge the fact that it will be harder for you to work in teams. I still encourage this. You find yourself on Slack. You find yourself on Zoom channels. Some of you might have housing together. I really encourage you guys to discuss the physics. There are some really difficult concepts which just need you to think through and to talk through. And the talking through best happens with your peers. And you will see that that will be very beneficial, especially when it comes to the PSET.

But here is homework number 1. I've done this now a few times, and I really, really enjoy the solutions given by the students. So this is a creative project. You have basically almost all of IAP to hand it in. And the idea is to be creative around a topic relating Einstein, or/and the theory of special relativity.

The project might be a video. It might be a poem. It might be a musical piece, artwork, animations, a game, a structure-- you name it. What I really want is that you take something you do very well and combine it with the topic of this class. I want you to take something where you are very familiar with where you are feeling comfortable and then enter this new topic, this new topic of special relativity.

I will rate it based on your creativity, on the quality, and on your effort. And again, please hand this in by January 22. I really encourage you to not wait to the last minute to start working on those topics, those creative projects. They always take a little bit more time than you might expect.

This class will have an interactive component. And we will use breakout rooms for discussions and smaller problems as you would be doing in the classroom, as well. Here is the very first one. People who are taking this class asynchronously, I encourage you to stop here and work through the problem. And then look at the solution afterwards, or look at the discussion of the solution afterwards.

So this first Gedanken experiment, thought experiment, is about the topic of relativity. And you want to first understand what that is, what relativity is, before you discuss what special relativity is. So imagine you wake up inside a room with no windows and one locked door. You checked. You make sure that the door is locked. You cannot get out. You cannot see outside.

Looking out around, you see a table with a number of items on it. There's a desk lamp plugged in and turn on. There's a tennis ball. There's a bunch of string. There's a pitcher of water. There's a cup. There's a candle. There's a box of matches. And there's a music player with headphones.

A skateboard and a wooden stool are also in the room. The music player has a sign on it saying turn it on for instructions. So you do. You're told that you are in a specially designed vibration-proof and noise-proof train car [COUGH]-- sorry-- on a set of straight and level train tracks.

Your task is to use one or more of the items in the room, perhaps in combination with each other, to determine whether the train car is stationary or is moving on the tracks. There's a 30 minute time limit on your test or tests. And you cannot destroy or you cannot modify the walls or the floors or the ceiling of the car. That is not permitted.

So the question to you is, can you think of some creative way to use the items that might indicate whether or not you are moving. Think about this and discuss in your breakout rooms-- that is, for the live session here. Again, I want to encourage you to stop and to think about a solution. Can you think about a creative way to work with this? The typical time is about 10 minutes. You might think about it. You might want to take some notes.

All right, the answer is you cannot figure it out. Every reference frame by itself is inert. You cannot figure out whether or not you are in a moving or in a stationary reference frame. And as long as you cannot feel vibrations, or you hear the sound, or you have some other internal, external indication, you will not be able to figure out whether or not the room is moving with a constant velocity. You will be able to feel or measure accelerations.

And so now you could argue that since the train track is on Earth, and the Earth is actually-- since you are on Earth, and if you're moving, you would be able to feel the rotation of the Earth, there might be a way to figure this out. But that will be very, very hard to do. So the answer is you cannot. You cannot distinguish one reference frame from another. You don't know what an absolute velocity is.

So another way we will interact in this class is through concept questions. So here, concept questions are meant to give you a little bit of a checkpoint to encourage you to think about what I just explained in a video or in the class and to stimulate some sort of discussion. Sometimes you will use contact questions in breakout rooms for the discussion part sometimes you just use Zoom features in order to figure out what the answer is. But besides the technology, those concept questions are really for you to figure out whether or not you just understand the concept. So again, I encourage you to pause the video to think about the concept question and then move on with the answer.

Here's an example. A new *Star Wars* movie came out, 2019. And I ask you to pick the answer closest to your level of *Star* Wars expertise. I saw the movie, and I consider myself a *Star Wars* fan. I saw the new movie, but I do not know much about *Star Wars.* I heard about *Star Wars,* but I didn't see the movie yet. Always liked *Star Trek* better. What? *Star Wars?*

OK, so very straightforward-- here I would give you an option-- 1, 2, 3, or 4. You collect the answers, and we get some feedback. This is obviously-- there's no right answer here. There can be concept questions where there is a right and a wrong answer. And again, for you, this is supposed to give you feedback on how well you understood the concept.

All right, before we close this first video, I want to introduce players, Alice and Bob. We will have, often, discussions of reference frames. Typically Alice or Bob are in one reference frame. And then the other person is in the other reference frame. I want you to think about those *Star Trek* figures. We will use spacecrafts. We will use light-- so phasers or light pistols-- in order to demonstrate the impact of special relativity and understand the concepts.