

[SQUEAKING] [RUSTLING] [CLICKING]

**DAVID KAISER:** We'll go ahead and get started. Hello, everyone. Welcome to 8225, which is also STS.042-- Physics in the 20th century.

My name is David Kaiser. Today's class is going to be a little shorter than average. I just wanted to go over a kind of quick introduction for the course, an overview, some logistics, course structure and so on. And then we'll jump in with the first full class session next week.

So I'm going to go ahead and share my screen. I have some slides just to help kind of orient us for today's session. So let's do that and that. And now, hopefully you can see my screen there. Some nods or thumbs up? So far, so good? Thank you. OK, great.

So welcome to the new semester. This is a class I've taught many, many times. I've been teaching at MIT since 2000, which itself is now historical. It feels like a long time.

And I've taught this course probably every other year, more or less, over that time period. So I've taught it at least 10 or 11 times or so. And I have to say, if I may say so myself, it's my favorite course that I teach. Hopefully, it'll be a positive experience for you as well.

I think it's a really fun opportunity to sit with some material that might be familiar to many of you. We have many folks who are physics majors, many of whom are juniors and seniors. It's also hopefully an interesting kind of preview for students who either are not in the physics department, or are newer to MIT and so on. And I think it's just-- it's a kind of remarkable set of ideas and institutions and events and people that we get to sit with over the course of the semester.

So it's a new adventure doing this remotely by Zoom, but I hope we get to really enjoy the kind of pretty wacky ideas and some unusual times and places that we get to immerse ourselves in as well. And I try to just gesture toward that with some of these opening images here on the first slide.

So today, as I mentioned, it's not going to be a full-- I don't expect it to be a full class session. But I do want to give an overview of where we're going, and also, some of the kind of nuts and bolts and logistics.

So anyway, the plan for today-- we'll talk about the course aims. We'll talk a bit about the instructors. Give the teaching assistants a chance to introduce themselves and say a quick hello as well.

We'll talk about the course structure and the requirements of the course. And then I'll give a brief overview of the kinds of material that we'll be engaging with in more detail starting next week. So that's where we're heading.

So here, I'm just taking the subject description right from the front page of the syllabus just to give you a sense of where we're heading over the term. The class is meant to explore the changing roles of physics and physicists over really not just the 20th century anymore. By now, we're going to be up to just about two centuries worth of material.

For the first main class next week, I'll be starting with the 1820s, which it turns out is now 200 years ago. So really, it's an expansive view, not only the 20th century.

We're going to quickly bring ourselves up into what we often call modern physics relativity, quantum theory, again, which might be familiar to many of you, might be new to others. And then we're going to zoom forward even beyond that early ferment in the early 20th century and look at much more recent developments in high-energy physics, in cosmology and astrophysics-- my own personal favorite topics.

And we're going to be examining these intellectual developments, these conceptual and intellectual developments, at each moment trying to understand their kind of embedding in a very messy human world, in a changing human world.

So part of our goal for this semester is both to learn or reiterate some pretty amazing ideas for modern physics-- might be new to some, might be familiar to others. We're going to sit with those ideas, but also do a lot more work in practice of embedding those ideas in an historical kind of development.

And that means looking at institutions, at cultural features of how people have thought about physics and physicists, and how physicists themselves have been part of larger social worlds, political contexts, war time and so on. And so over the course of this semester, we're going to be looking at not just a range of ideas, but a range of places in which those ideas have been pursued or cultivated or argued over or debated or rejected.

So we'll start looking at Britain from-- in the 19th century. That's where we'll begin much of our investigation for this semester. We'll look at newly unified Germany in the 1870s, moving forward in time ultimately to the First World War to the rise of Nazism, to the Second World War.

Lots of big consequential worldly events which, as I hope we'll get to appreciate over the course of the term, had a really quite remarkable impact on the intellectual world of physics and physicists. And we'll bring the story up through the Second World War and into the Cold War and even beyond. So we have a long timeline really, as I say, the better part of two centuries by now to sample over. And I think a pretty nice broad range of ideas in physics as well.

And so just pictorially, some of the early moments we'll be kind of thinking about are the turn of the 19th into the 20th century, when a lot of research was still tabletop scale. Here's a photograph of Pierre and Marie Curie in their laboratory in Paris from right around the year 1900, where the scale of apparatus, if not phenomenal, still felt kind of human-scaled. Also, a bit kind of removed from other elements of human experience. This was a laboratory pursuing esoteric questions in a specialized community.

Before too long, as I'm sure many of you already know, many of those investigations began having much more dramatic worldly impact. And we'll look quite a bit in this course at the work on nuclear weapons, the use of nuclear weapons in the Second World War, a whole different arrangement between scientists, engineers, nation-states, and world affairs.

So within not a long stretch of time, we go from photographs like the Curies over here to something like this where we have Robert Oppenheimer, with his famous pork pie hat, working side by side with the Army General Leslie Groves of the US Army inspecting, in this case, the site of the very first test detonation of a nuclear weapon in July 1945-- just 75 years ago.

Soon after that, as, again, many of you probably know, physics and physicists moved into a new kind of vantage culturally and politically. Here's a famous *Time* magazine cover of Einstein with his most famous equation,  $E = mc^2$ , appearing eerily in the mushroom cloud of a nuclear explosion. So the associations between physics and physicists were changing very quickly, especially after the Second World War. We're going to explore a lot of that over the course of the semester.

And then zooming forward, we get to where the scale of apparatus no longer fits on a Parisian tabletop. But in fact, this is a photograph from what would have been the world's largest particle accelerator. Some of you might have heard of it-- the Superconducting Super Collider, or SSC. If you haven't heard about it, it's because it was never finished. This would have dwarfed even the Large Hadron Collider that is in operation in at CERN in Geneva.

This was a machine-- the Superconducting Super Collider-- that was under construction in Texas not too far from Dallas. And it was actually halted in 1993 after the engineers had already dug a 54-mile circumference tunnel underground-- roughly three times longer than the Large Hadron Collider.

So the scale of our apparatus is no longer fitting on a tabletop. And also, once you need \$8 to \$15 billion to do your experiment, now you have a different place in the world of politics and world affairs as well.

And likewise, the story didn't end, thankfully, with the cancellation of the Super Collider. We have a shift to other kinds of still large-scale research. For example, to push to billion dollar satellites like the Planck satellite shown here in its study of the very earliest moments of the universe.

So that's in kind of a snapshot, kind of picture form, the kinds of terrain that we're going to cover over the course of the term. And I'll say more about that soon, but I just wanted to give you a preview.

OK. Let's talk some nuts and bolts for a little bit. This course has no prerequisites. As I'm sure you know, it's a Communications Intensive subject for physics majors in course eight. But there's no prior coursework required. It's not limited to students in the physics major. It's open to first-year undeclared students and so on. There's no prereqs.

Our aim in the course is really to improve written communication skills rather than to worry too much about things like problem sets or problem solving, which are dearly important to me. But this course has a different kind of center of gravity, so to speak.

I should say I've had-- in the years past, I've had high school students take the course and do very, very well. Really, really no prerequisites. I want to emphasize that.

I want to emphasize it especially because some of the very first readings for the term that you'll have, even in advance of this coming next lecture, might look pretty technical or pretty off-putting. Some-- not all of them, but some of the readings will have lots of equations.

They'll look like and often be taken from old textbooks-- might be on topics you haven't had a chance to have a different formal course in and so on. And I want to emphasize that that's OK. If this looks strange, partly it's designed to look strange, actually.

So the strangeness is meant to trigger some questions about what did people think they were doing when they read texts like those? So if they look either very hard or unfamiliar or technical, that really is kind of part of the point. And part of the point for this particular class is not to worry about reproducing those calculations or understanding every single step of the mathematics.

I like to joke that my very many friends in the physics department, it's their job to help you all learn how to calculate, and many of you, I'm sure, calculate very, very well already. And that's incredibly important. This class has a different set of goals and aims.

And so I want to really emphasize not to be kind of frankly scared off if some of the readings look, at first blush at least, a little overwhelming. They should look strange. And if every step in the derivation is not so clear, that's OK in this class, especially.

So we're going to be focusing on a range of ideas in modern physics and also their changing contexts-- as I mentioned, many kinds of contexts. And it's, of course, always, always OK to ask for clarifications.

The formalism is dear to my heart. Hopefully, dear to many of yours. I'm not saying ignore the equations of mathematics. I'm just trying to emphasize not to worry about getting hung up if at first, especially in a first reading, things look very strange.

For a bunch of the lectures-- not for everyone, but for a bunch of them I'm actually writing up separate little short lecture notes in addition to these lecture slides to go through some more intermediate steps of derivations and so on.

Those are always going to be optional. It really is just to help as a kind of additional resource. And also, we'll have office hours. And you can always make an appointment to meet with me or your teaching assistants directly.

So I just want to emphasize the aims of this course, we're going to work on written communication. And we'll get to do it with some, I think, really juicy amazing fun material. That's our overarching aim for this semester.

I like to think of this class as a kind of roadmap. And it turns out, roadmaps work in at least two directions. It could be a map of where you're heading if you're new to MIT, or new to the physics department, or just curious and coming in from a different field. It can be a kind preview of some pretty awesome cool stuff that could be ahead of you.

It could also be a kind of look in the rear view mirror for juniors or seniors in the physics department. You will have seen some of this material in other courses already. But this is a chance to begin kind of seeing perhaps how different pieces fit together to synthesize a map of it might have been kind of separated or disparate parts until now.

So I like this idea of a roadmap either whether you're starting a journey or looking back how you got to where you are now. Hopefully, this course will help with some of that as well.

OK. So let me pause and ask for any questions. If you do have questions, please try to raise your blue hand. I'm going to ask the teaching assistants who are co-hosts of this Zoom session to recognize you, and then they can ask you to unmute yourself. Any questions so far?

I hear a resounding silence, so I'm going to charge ahead. But if you do have questions, again, please feel free to use the chat or the blue hand-- raise hand icon.

Oop. OK. So for this part-- sorry-- I want to just take a few moments and introduce the whole team. I'm very excited to work with I think a really terrific team of instructors for this class. It's a big group. We have four teaching assistants in addition to myself.

So I'll just say a little bit about my own research. I am a professor at MIT. I teach both in our Program in Science, Technology, and Society-- STS. In that department, I conduct research and work with students in the history of science, and particularly, the history of modern physics.

I've written a few books. I've edited other books. A lot of the material that we'll cover in this semester-- this term comes, not surprisingly, from things that I have a particular interest in, I've written about, or very dear friends of mine have written about. So I'm sort of-- I like-- I'm very lucky to get to be immersed in the history of modern science when I wear my STS cap.

I'm also a member of the Physics Department, a Professor of Physics. Up here, I have a picture of my research group. This is actually a somewhat old photo. You probably won't recognize the faces because even the UROP students in this photo have all graduated by now.

I work very closely with Alan Guth in our Center for Theoretical Physics within the department. We work on many aspects of early universe cosmology. We'll actually come to some of those topics near the end of this semester because I couldn't resist. I love it so much.

I've also been working for a number of years on foundations of quantum theory, including new experimental tests of topics like quantum entanglement. We'll talk about some of that this semester as well.

So on the physics side, I am especially interested in theoretical early universe cosmology and astrophysics, and also, various aspects of quantum theory, and even some interesting recent work on quantum information science. So that's where I'm coming from.

Now let's get to what are you going to do in this class? The one thing you're going to do is read-- not a ton. We've worked very carefully to make the reading list, we think, really kind of curated and not overwhelm students with a large page count.

And so the best thing you can do is read the generally rather brief reading assignments in advance of the class with which they're associated. It'll help if you've been able to do the readings ahead of the class session.

What are the actual subject requirements in addition to keeping up with the reading? As I mentioned, this is a CI course for physics majors. So our main emphasis is on written communication. It will not be on oral communication partly because there's 100 of us by Zoom. So it really will be on written communication, which had always been the overwhelming majority of the course structure even in previous years.

So like nearly all CI courses, we have a number of pages of writing over the course of the semester. The way we do it in this term is to break it up into a number of assignments that kind of build up.

They build both in length, but also in the nature of the assignment, in the type of writing that we'll be working on, and the nature of, say, the kinds of sources we'll be working with, or the nature of the argument we want to be able to articulate. And these really quite amazing teaching assistants are here to work very closely with you on each of these papers. So we're not going to expect you to do it every step on your own.

So you can see now the due dates, the structure. The first-- of course, we'll hand out the assignments well in advance of each of the due dates-- the actual kind of prompt. So pretty soon, we'll finalize the prompt for paper one.

We'll make sure it's easy for you to find on the Canvas site. That one will be four or five double-spaced pages-- really, a handful of paragraphs-- not a very long essay. That will be due electronically near the end of September.

The second paper we do a couple of weeks after that-- a little bit longer-- six or seven double-spaced pages, and a little more complicated range of types of sources to make use of as you build your argument. Because it's a CI course, like usual, we'll have a mandatory rewrite of that paper two assignment. That'll be due-- handed in separately several weeks after the first iteration. And then finally, the final paper is due on the last day of classes, December 9.

So please note, there is no midterm. There are no problem sets. There's no final exam. The student work you'll be handed in will be exclusively these essays-- this series of essays. And again, we'll be working with you along the way.

You can see the kind of distribution here about how the different papers contribute to your overall final course grade. Obviously, if any questions come up along the way, of course, of course, please don't hesitate to ask me about it or your teaching assistant. That's the stuff you'll be working on concretely over the course of the term.

So again, I'll pause. Any questions on any of those items? So far, so good? And so good. So Sava asks a question. There's zero difference for the mechanics of the course between grading or homework or content between STS and the course 8. It is literally one class. It's just jointly listed.

And in fact, I don't even know-- I mean, I'd have-- it would take work for me to figure out which version a given student's actually registered in. We just-- we treat it as one class, as one set of materials, one set of course aims.

So as far as we're concerned on this shared screen, it's one class. We're going to work on this cool stuff together. The tricky part gets how do how do the different kind of requirements get counted for different kinds of students. But it's one class, one set of aims, one set of materials. Any other questions on this? All excellent questions.

Yes. Definitely, flood Sean's inbox. I see someone helpfully put Sean's email address in there. OK. I'm going to I'm going to move on. If you have more questions, again, please keep chiming in. But I think I'll go back to screen sharing. Those are excellent good questions to get us going. OK.

So hopefully, you can see my screen again. So last part. Again, I won't take too too long. We'll finish up early today. I just want to say a little bit more about the kinds of material that we'll get to really kind of chew on, get to really explore over the coming weeks.

So we'll be starting with a 19th-century legacy. And, in fact, starting fairly early in the 19th century, going back to the 1820s and '30s-- not for too long. We'll kind of gallop forward in time pretty quickly.

But the main question we'll be asking in that unit is what did people think the world was made of? What did they think it was their job to study? And what counted as a compelling explanation?

And equally interesting, I think, or equally important, who were the kinds of people who did that, and where did they do it? And what kinds of settings or institutions? How did they work together? What did they think their job was?

So of all the many topics we could focus on within the study of the natural sciences or the physical sciences in the 19th century, we're going to look fairly narrowly at examples from electricity and magnetism and optics, partly because that becomes super important for things like relativity where we do want to get to fairly quickly. And also, because I think they're just fascinating in their own right.

So we'll be talking about some names and some ideas that, again, are likely familiar to many of you. We'll start with some discussions of Michael Faraday and his ideas about lines of force and the luminiferous ether. We'll spend a long time talking about the ether.

We'll talk about James Clerk Maxwell. You're going to read a short excerpt from his famous treatise on electricity and magnetism. We'll about William Thompson, later known as Lord Kelvin, and others.

We'll also talk about how did those folks get into their line of work, especially the generation of Maxwell Thompson and some of their own colleagues. So what was it like to become a young, say, mathematical physicist, or eventually theoretical physicist, during the second half of the 19th century? How did they do that? Where? Why? According to who's criteria?

Another thing I want to really emphasize, and this one I find incredibly fun, is that many of you probably own Maxwell's equations on a T-shirt-- always in fashion. We still use Maxwell's equations. They're so-called his equations.

But what I want to sit with for the first few classes is how remarkably different Maxwell and his contemporaries interpreted those very same mathematical symbols. So we still put his equations on our T-shirts so to speak.

Yet, what we think they mean, or what we think they're good for, what we think they're talking about, what they tell us about the world is almost exactly opposite to how Maxwell himself imagined them, or how generations of Maxwellians treated them.

So we have this kind of continuity in some instances in the equations we use, sometimes even the T-shirts we wear. And yet, what we think those equations or those ideas tell us about the world, those actually have been anything but static or constant over time. I find that just mind-boggling, to be honest. I love that.

We're going to have a bunch of examples of that throughout this whole semester. And one of the first kind of juicy ones we get is with Maxwell's equations. So we'll sit with Maxwell and electromagnetism for the first couple of lectures-- the first few sessions.

OK. Before too long, we'll get into what is often called modern physics-- the quite dramatic intellectual changes taking place, roughly speaking, in the first 25 years of the 20th century-- roughly, with some error bars on that estimate.

So we'll talk quickly about work by Albert Einstein, and indeed, a circle of colleagues, what became known as the special theory of relativity, and even some general relativity-- very near to my heart and Tiffany's heart, maybe to many of your hearts.

How did Einstein come to these ideas? With whom? To what end? What was he doing? Literally, what path was he walking each day as he began contemplating space, time, and matter?

We'll then shift to early quantum theory, as the next main kind of set within this unit. And again, some remarkable familiarity, some equations we still use 100 to 120 years later. But what we think those equations are telling us, that actually has not been so constant.

Where people were working or coming up with the ideas or with whom they were interacting is also not so constant. So we'll talk about some shifting institutions, like the Physikalisch-Technische Reichsanstalt. That reminds me to apologize to any people on the call who actually speak German. I speak incredibly bad German, but I love trying.

We'll have-- especially this first unit-- a lot of German that I will likely mangle. If you know zero German, then you're actually closer to me than you might think. But nonetheless, we'll have some German stuff. Don't worry if it literally sounds foreign or unfamiliar.

The point is there were some new institutions, new priorities, new national scale investment in things like physics and related fields of engineering. What role did that play in the kind of heady years of the early onset of quantum theory and modern physics? And then where do those ideas lead some of the leading thinkers?

We'll talk, of course, about things like Schrodinger's cat, or quantum entanglement, or Einstein-Podolsky-Rosen, and many, many really quite delicious and delightful elements of quantum theory that I still wrestle with and get to play with with my own students and colleagues to this day.

So that's the first kind of main unit. We'll have a quick introduction with this 19th-century legacy, really to set the stage for what we might call the emergence of modern physics as was recognized even in its day. That's the first main unit and the second unit of class.

Then we're going to shift again in remarkably rapid order. I mean, to an historian, the time delay was vanishingly short-- a matter of 10 to 20 years, depending on how one counts. Some of those previously very heady, very esoteric or abstract ideas about atoms, about parts of atoms, about nuclei and nuclear forces, they began having an import and a priority well beyond professional physicists and chemists or other engineers and so on, in ways that, again, I'm sure are, at least in part, familiar to you.

We're going to sit quite a while with the development of nuclear weapons, nuclear physics more broadly, but especially the weapons projects during the Second World War. The unbelievable transformation of the kind of research and development infrastructure, which really starts setting a kind of blueprint for many features that we would recognize today, even though they were forged during a war that itself ended 75 years ago.

So we see a change in what it means to try to do physics, for whom, to what ends, with what kind of support, and with what kind of institutional settings, leading to, among other things, the use of these very new types of weapons, again, just 75 years ago, against the Japanese cities of Hiroshima and Nagasaki in the summer of 1945.



So that second main unit-- third unit of course-- the second kind of big juicy thick unit that we'll sit with for quite a while is the kind of new enrollment, the new engagement of physicists, chemists, various kinds of engineers with the nation-state in times of war. And what did that mean for the ideas of physics, for the population of physicists, for the institutions of physics and so on.

That's a big-- there's a lot to try to really understand, including a lot of, again frankly, very fascinating cutting-edge science and engineering, but it was being done in very specific contexts toward very particular ends. So we'll spend some time around middle of the semester on that material.

The last main unit is then expanding outward from the end of World War II. Here, I was a little more selective. I wanted to cover topics that frankly I like most. And that means the topics are very much biased towards particle physics, high-energy physics, and astrophysics and cosmology.

Because, first of all, they're just objectively the most interesting. That was a joke. I just think they're actually awesome. Those are the areas that I am most familiar with, both historically and also in terms of more contemporary research.

And so, again, it's an opportunity to take a sample, to explore some material that might be quite new to many of you. You might not have had a chance to have a full semester course on quantum field theory or particle theory or contemporary cosmology. Some of you might have. But there's, again, no need to have already seen this material.

And we'll be able to sample some of these still changing ideas within, again, some still changing institutions. Who wanted to pursue those questions? Why? To what ends? And in what facilities?

So now, we get to a place in time like the Large Hadron Collider at CERN. The device was completed in the first decade of the 21st century. You see an aerial shot here.

What brought us from an era when particle accelerators still were on the size of a kind of person, more or less, to when they actually crossed national borders, where the accelerated protons crossed between the Swiss and French borders billions of times per second. So we'll end the course looking outward toward the cosmos that way.

So here's the very last slide. I always like to say this course has one actual goal, which is to make sense of this quotation. I never tire of repeating this quotation. It was published in *Harper's Magazine* just months after the end of the Second World War observing what had become a real sea change in the place of physics, and especially physicists in broader society.

So this kind of witty, kind of pundit columnist wrote in the spring of '46, that "physical scientists are in vogue these days. No dinner party is a success without at least when physicist." And really, I want to know what happened? How can so many people have dinner now without inviting us?

That's really why I put this whole course together. Together, we'll try to answer that question. That's only modestly tongue in cheek. Any questions about any of that material, course logistics, course overview, any of that kind of stuff?

All righty. Well, thank you everyone. Good to see you, at least in small little squares. Stay well. Good luck with the rest of the start of the term. And I look forward to seeing you next week. Stay well, everyone. Take care.