The History of the Twentieth Century
Episode 37
"Year of Wonders"
Transcript

[music: fanfare]

In the year 1900, the most famous scientist of the age, Lord Kelvin, gave a lecture in which he identified two "dark clouds," as he called them, that hung over modern science, the two principal unsolved problems that, once solved, would essentially complete humanity's understanding of the physical universe.

Lord Kelvin would live long enough to see the year 1905, the year that a hitherto unknown theoretical physicist named Albert Einstein would solve both problems. But his solutions would not complete modern physics, far from it. They would instead open a door to a wholly new—and wholly unexpected—understanding of the universe.

Welcome to *The History of the Twentieth Century.*

[music: opening theme]

Episode 37. Year of Wonders.

Albert Einstein was born in the city of Ulm, which lies in the Kingdom of Württemberg in the German Empire, on March 14, 1879. Yes, he was born on pi day, which seems like an omen or something, and if you didn't have enough reason to celebrate pi day before, well, you do now. His parents, Hermann and Pauline Einstein, were nonobservant Jews. When Albert was still an infant, Hermann and his brother Jakob moved their families to Munich, and founded a company to manufacture electrical equipment, which was called J. Einstein and Company.

This company only lasted 14 years, because the Einstein brothers had dedicated it to the manufacture of DC electrical gear. Direct current versus alternating current was to the period what AM versus FM or VHS versus Betamax or HD-DVD versus Blu-ray or iOS versus Android would be to future eras, and in this case DC lost the battle. But that was enough time for Albert to become a teenager. He attended Catholic school for a few years, and when he was eight years old he transferred to the Luitpold Gymnasium. A Gymnasium, or gymnasium, is what the Germans call what we Americans call a high school. And by the way, Luitpold Gymnasium still exists today, except now it's called the Albert Einstein Gymnasium, and I hear they have an awesome jazz band. But jazz hasn't been invented yet, so let's move on.

And speaking of music, young Albert was interested in music and was encouraged to take up the violin, although he resented the rigor and tedium of practice. But when he was a teenager, he discovered the music of Mozart, and fell in love with it, and continued with the violin, self-taught, for the rest of his life. He seldom performed publicly, but those who were fortunate enough to hear him say that his playing was remarkable. Einstein himself said that music helped him to think about physics, and that if he had not gone into science he certainly would have gone into music.

When Einstein and Company failed in 1894, the family moved to Pavia in Italy, but left the now 15-year-old Albert behind in Munich to finish up at the gymnasium. The plan was for Albert to become an electrical engineer, because of course, but unfortunately, the teaching methods at the gymnasium began to grate on young Albert just like the violin lessons had. Too much tedium, too much rote memorization, and none of the joy and beauty of physics and mathematics. He fled the school and joined his family in Italy. At the age of 16, he applied to Zürich Polytechnic in Switzerland, but he couldn't pass the entrance exam, although he aced the physics and mathematics parts. He moved to Switzerland, renounced his German citizenship to avoid the draft, and took one more year of schooling in a Swiss gymnasium. Finally, he was ready, and in 1896, at the still precocious age of 17, he enrolled in a four-year teaching program in mathematics and physics. There he met the woman who would become his first wife, Mileva Marić, an Austrian Serb from Novi Sad – she was the only woman among the six students entering the physics program that year. Albert got his diploma in 1900, but Mileva never finished. Mileva returned to Novi Sad in 1902 and stayed with her parents for a while, and it was only recently discovered that in fact she had become pregnant with Albert's daughter. Whether this child died in infancy or was given up for adoption remains unknown.

Meanwhile, after graduating, Albert searched unsuccessfully for a teaching position. He became a Swiss citizen in 1901, and eventually secured a position in Bern, famously, as a patent examiner. Once he had a steady job, Mileva returned to Switzerland and they married in 1903. They would have two sons together, and divorce in 1919.

He published his first academic paper in 1901, and a second paper in 1905 which won him a PhD from the University of Zürich. Neither of these papers need detain us for very long. What matters are the four other papers that he published in the miracle year of 1905.

The first of these papers was entitled "On a Heuristic Viewpoint Concerning the Production and Transformation of Light," which was published in June. This paper is about the photoelectric effect. What is the photoelectric effect, you ask? Well, hold onto that thought for a minute. Because what this is really about is the black body problem.

You may recall from episode 9 that the blackbody problem is one of the two unsolved problems of physics that Lord Kelvin cited back in 1900. Basically, the question is, when you heat something up, why does it go from red to orange to yellow to white hot, and why do the colors line up with the temperature of the material, no matter what the material is?

Enter Max Planck. Planck was a German physicist who at this time was a professor at the University of Berlin. At this time he was also an older, much better known, and much more respected scientist than Albert Einstein. Max Planck has been working on the blackbody problem since 1894. The thing is, you can heat materials and study the light they admit and produce graphs that show the distribution of light emitted by the object at different temperatures. The theoretical problem, the one that Lord Kelvin was alluding to, is how to explain these curves mathematically. What we're looking for is a formula that explains why this curve is what it is when we observe a hot object. Because once we have the formula, it should lead us to exactly what the cause and effect relationship between the heat and the light is.

Planck worked on this problem for six years, creating and discarding various formulae that sort of explained blackbody radiation, but he finally worked out the perfect fit. In December 1900, just a few months after Lord Kelvin gave his speech, Max Planck put forward his solution that finally explains the distribution of light emitted by a hot object. But hey, funny thing about this formula. His formula is based on a postulate – which we now call Planck's postulate – that the energy of light is not continuous. Light is made of discrete packets of energy, which had come to be called quanta. Quanta is the plural for quantum. Quantas is the Latin word for how much, and the source of our English word quantity, so quantum is a pseudo-Latin word meaning a defined amount. In other words, the implication of Max Planck's formula is that the energy of light is not continuous, but is made up of discrete packets, in the same way that the Atlantic Ocean may look like a big, continuous quantity of water, but we know that if you zoom down to a very small level, you will find that the Atlantic Ocean is in fact made up of a very large number of tiny little things called water molecules.

Planck's formula tells us what the amount of energy in each one of these packets is. You multiply the frequency of the light by a constant – which we call Planck's constant – and there it is. Higher frequency radiation, like ultraviolet light, is made up of packets that individually have higher energy levels than, say, the packets that make up red light.

So does that mean that light is similarly made up of a large number of little tiny packets called quanta? Now here's where Max Planck missed his chance to be Einstein. He was willing to go there. This was, Planck insisted, just a mathematical model meant to explain the blackbody radiation curve, and should not be understood to be describing reality. And why did Max Planck get cold feet? Well there are several reasons. He was a much older man, and we all tend to get more cautious and conservative as we get older. Also, the idea that energy is made up of discrete packets flies in the face of everything 19^{th} century physics teaches us. Because light is a wave. Maxwell's equations proved that. And waves don't come in packets. Are we sure light is a wave?

We’re as sure as we can be. You can prove it experimentally. Waves can sometimes cancel each other out. And you can do this with light. You can combine two beams of light in such a way that you get a pattern of bright and dark lines, where the waves of the light alternately reinforce and cancel each other. So how do you argue with that?

So light can’t possibly be made up of packets. Not even Max Planck thinks so. To him, this is just a mathematical tool to help produce a formula. This was still an important contribution, good enough to win him the 1918 Nobel Prize in physics.

So his formula describes the blackbody radiation curve, but in the end, it lets us down, because it doesn’t tell us what the cause and effect relationship is between heat and light. Unless of course, you could come up with some sort of experimental proof that light really is made up of packets, like for instance, something that’s completely unrelated to the blackbody radiation problem…

Which brings us to the photoelectric effect. The photoelectric effect is very simple. Certain metals will emit electrons, or develop an electric charge, which is another way of saying the same thing, basically, when you shine light on them. This is the basis of solar cells, and also of those cool night vision goggles the military uses, and those little light sensing devices that back in my day we called “electric eyes.”

Now, 19^{th} century physics doesn’t have any problem with this. Light carries energy, and the energy in the light pushes electrons around. Simple enough, no problem. But here’s the tricky part. There’s a certain minimum frequency of radiation necessary to make the electrical effect happen. For many metals, it has to be ultraviolet light. Some metals react to visible light, but still only above a certain frequency threshold. Red light doesn’t do it, but violet light does. You might be thinking, well okay, violet light has more energy than red light and ultraviolet light has more energy still, so that makes sense. But wait a minute. What I’m saying is, you can shine a 10,000 W red light on a piece of metal and get no reaction, and then shine a 25 W ultraviolet light on it and generate an electrical charge. How is that possible?

Einstein’s paper demonstrated that you can explain the photoelectric effect by applying Max Planck’s quanta. If light is made up of discrete packets, and electrons are moved when one of these packets gives up its energy to the electron, well, that explains everything. You can shine as much red light as you like on the metal and nothing will happen, because none of the individual packets of energy falling on the metal are strong enough to push an electron. But a much weaker violet light will work because, although there are fewer packets falling on the metal, each and every packet has the capacity to move an electron. Einstein showed that this is so, and that Plank’s formula applies just as well to the photoelectric effect as it does the blackbody problem.

So Max Planck was correct to be careful when he said his formula was just a useful bit of mathematics and didn't necessarily apply to anything real. But Einstein showed that his formula explains some entirely different phenomenon – the photoelectric effect – just as well. This strongly suggests that these quanta *are* a real thing, and light really is made up of particles.

And that's your solution to the blackbody problem. The molecules inside an object vibrate at a certain rate that's related to the temperature – hotter objects have faster vibrating molecules. These molecules emit packets of light, but one molecule can only emit one packet. You can't get two atoms or two molecules to combine their energies together into one bigger, stronger packet. So at a certain temperature, red is the most energetic packet the molecules are capable of emitting, and that's why red hot is a thing.

And you should be thankful that light is made up of packets, because if 19th century physics held, and molecular energy from multiple molecules could combine into higher frequency radiation, then every time you turned on your stove, it would be emitting x-rays, and every time you cooked dinner, you'd be giving yourself radiation poisoning. So, yay packets! Thank you for not killing us.

And you might object that I already said that there's good solid experimental proof that light is a wave. So how can light possibly be a wave and a particle at the same time? Well, that's a really good question, and it will preoccupy every theoretical physicist in the world for the next 30 years, including Albert Einstein.

Miracle number one.

[music: Mozart Violin Sonata no. 26 in B♭]

Einstein's second paper was entitled "On the Motion of Small Particles Suspended in a Stationary Liquid, as Required by the Molecular Kinetic Theory of Heat," and was about Brownian motion.

Brownian motion is easy to explain. The name comes from Robert Brown, a 19th century Scottish botanist. Brown was using a microscope to study the structure of pollen grains, and as he was looking at the pollen grains suspended in water, he noticed that tiny particles that came from within the pollen grains would move around the water spontaneously in a jerky motion. At first he thought that perhaps these tiny objects within the pollen grain might be alive, but he quickly determined that tiny particles from other sources, like little particles of charcoal, behave in exactly the same way.

We have come to call this phenomenon Brownian motion, which isn't entirely fair, as other researchers before Brown had noticed the same thing. But in any case, it was widely believed that this jerky motion was caused by vibrating water molecules too small to see that bumped the particle around. A large object floating in water, like, you know, a battleship, is not likely to get moved around very much by bouncing water molecules, but a very small and light object like Brown's pollen particles suspended in water might indeed get bounced around.

But this was just conjecture; there was no way to prove it. Indeed, as early as 60 BC the Roman poet Lucretius contemplated the dancing of dust particles in a beam of sunlight and conjectured that their motion was due to the invisible blows of atoms of air. Actually, the motion of dust particles in the air is more often driven by air currents than by Brownian motion, but Brownian motion does indeed play a role, and I think you have to say that for 60 BC, Lucretius was being pretty darn perceptive.

Where Einstein comes into this, is that he worked out the mathematical formula describing how a small particle suspended in water would behave if it really was being bombarded by tiny water molecules too small to see, and invited experimenters to measure the behavior of the particles subject to Brownian motion to see if they fit what is formula described. It took a few years, but experimenters determined that these tiny particles jiggling around in water were behaving exactly the way Einstein's formula predicted.

You may have noticed that in previous episodes I have gone out of my way to emphasize that although the science of this time believes that all objects are made of atoms and molecules, there has been no direct observational proof of this. Einstein showed that Brownian motion is the long sought-after proof of the existence of atoms and molecules.

This is not terribly surprising, as most chemistry of the time was based on atomic theory, and if atoms turned out not to be real, a whole lot of chemistry was going to have to get done over again. You might be tempted to say that Einstein only confirmed what everyone already knew, but the fact is that everyone also knew that light was a wave until Einstein showed it was more complicated than that. So it must've come as a great relief to chemists everywhere that Einstein showed them they were not going to have to rethink everything they thought they knew about molecules in the same way he was making physicists rethink everything they thought they knew about light.

Miracle number two.

[music: Mozart Violin Sonata no. 26 in B♭]

Einstein's third paper was published in September. It was entitled "On the Electrodynamics of Moving Bodies," and this paper tackled the Michelson-Morley experiment. Now, you may have noticed that I've already ducked two opportunities to explain the Michelson-Morley experiment, but I guess it's time to bite the bullet, so here goes.

I've already talked about how Maxwell's equations in the 19th century beautifully described electricity and magnetism, and showed that light and other forms of electromagnetic radiation were waves of various frequencies. You can even derive the speed of light in a vacuum from the properties of electricity and magnetism, using Maxwell's equations.

Now here's the thing. We keep saying that light's a wave, and there's good experimental evidence that light is indeed a wave, but waves propagate through materials. Ocean waves propagate through the ocean. Sound propagates through a variety of materials, including the air, the ground, the water, the bones in your body, just to name a few, but in space, where there is vacuum, there is no sound. That's why in space, no one can hear you scream. But there *is* light in space. So what is that light propagating *through?*

And here's a related question. I said that Maxwell's equations give you the speed of light. But relative to what? When you're driving your car on the highway, your speedometer might say 60 mph. But relative to what? If you look in your rearview mirror, you see the car behind you and you might notice that your speed is zero relative to that car. If you look at a car coming toward you in the opposite lane, you might be moving at 120 miles an hour relative to *that* car. Well, of course we all know that the speedometer is giving your speed relative to the ground, and that's usually the most important number, for example, if you want to know how long it's going to be before you reach your destination 40 miles away. But for that driver behind you who's thinking about passing you, at that moment, for her, her speed relative to your car might be the more important measure. It depends.

Nineteenth century physicists had an idea for how to answer these questions: what is the medium that light is propagating through, and speed of light relative to what. They proposed that all space is filled with an insubstantial and undetectable material which they called ether. We're not talking about the stuff anesthetists use to make you pass out. They picture a universe full of this mysterious stuff from one end to the other and light waves pass through it.

By the late 19th century, the theory that the universe is full of ether stands pretty much in the same place as the theory that all matter is made up of atoms and molecules. That is, physicists are pretty convinced that it's true, because it explains many things that otherwise would be difficult to explain, but ironclad proof still eludes them.

But here's an interesting question. We know that the Earth is moving around the sun. And we know the sun is moving through space. That's about all we know at the turn of the 20^{th} century. But what is the sum total of the Earth's motion? If there really is an ether, then it sits at rest like the ground underneath your car. And the earth and the sun and beams of light and everything else in our universe are zipping back and forth through this motionless ether. That implies that anyone riding on the surface of the earth as it zips through the ether, say you or me, has an ether wind blowing through them, in the same way that if you drive a convertible down the highway, you get wind blowing through your hair. Wouldn't it be interesting if we could detect this ether wind? First of all, it would prove the existence of ether, and it would also tell us, in absolute terms, what direction and speed the Earth is moving through the universe. That would be interesting to know.

This brings us to Albert Michelson. Albert Michelson was born in 1852 in what was then Prussia. He and his parents were nonobservant Polish Jews, who emigrated to the United States when Albert was just two years old. When he grew up, he attended the United States Naval Academy, taught physics there for a while, studied in Europe, and eventually resigned from the Navy and became a physics professor at the Case School of Applied Science in Cleveland, Ohio, one of the forerunners of what we now call Case Western Reserve University.

One of Michelson's areas of expertise was precise measurement of the speed of light, work he began on at the Naval Academy and continued at the Case School. As an offshoot of that work, Michelson began trying to detect the ether wind. His apparatus was basically two devices that both measured the speed of light and were oriented at a 90° angle. The principle here is, if you fire a beam of light into the ether wind, the ether wind will slow it down, like a headwind slows down an airplane. But if you fire a beam of light at a 90° angle to the ether wind, the wind should not affect its speed at all. So if you keep measuring the speed of light this way and that way, then turn the device and measure it this way and that way again, and keep it up, you will eventually identify the direction where light moves fastest and the direction where light moves slowest, and *voilà*, you have detected the ether wind and you should be able to work out from your data how fast it is blowing.

Michelson's early results were inconclusive, because his apparatus wasn't sensitive enough. This is where another American scientist, Edward Morley, who was born in Newark, New Jersey in 1838, and was a fellow physics professor at the Case School, joined in to help Michelson perfect his apparatus. Hence the name, Michelson-Morley experiment. In 1887, Michelson and Morley conducted a series of careful measurements, looking for that ether wind. To everyone's amazement, they found nothing whatsoever. The speed of light was exactly the same in every direction.

This was Lord Kelvin's other dark cloud in 1900. Thirteen years after this experiment, theoretical physicists were still scratching their heads over how to explain it. One possibility is that it just so happens out of all the objects in the universe, the Earth is the one and only that is standing perfectly still, relative to the ether, and everything else is moving all around it, but nobody likes this idea very much. It's really just a rehash of the ancient Greek idea of the Earth standing still in the center of the universe while everything else circles around it, and nobody wants to go there.

Another possibility, which physicists were taking more seriously, is that when a massive object like the Earth moves through the ether, maybe its gravity drags some ether along with it, in the same way that the earth drags its atmosphere along with it. So maybe there is no ether wind at the surface of the earth, because the local ether is riding along with the Earth. The problem with this idea is that it means there would be some kind of ether shear, turbulence where the ether that the earth is dragging along interacts with the ether that standing still. That turbulence should mean that light from distant objects, like the stars, would be distorted as it passed through the turbulence. And there actually were some tiny discrepancies in the observed locations of stars that physicists thought might be evidence of ether turbulence, and so people were trying to put together a mathematical model that would show how these discrepancies were being caused by ether turbulence.

Of course, a third explanation might be that there is no such thing as ether. But that leaves you back where you started. If light is a wave, what is it propagating through?

Unless light is a particle and not a wave, as Planck and Einstein seem to be suggesting. But that gets into the whole wave and particle thing that's giving everyone a headache.

There is another way of looking at this, one that several physicists were thinking about in 1905, most notably, the Dutch physicist Hendrik Lorentz. Lorentz was one of the first physicists to propose that atoms were made of smaller particles that have electric charges, like, you know, the recently discovered electron. He proposed that the reason light and other electromagnetic radiation interacted with atoms was because of these electric charges. Lorentz's work in this area won him a share of the 1902 Nobel Prize in physics.

When Lorentz considered the results of the Michelson-Morley experiment, he, and some other physicists, began to consider another possible explanation. What if the ether wind actually makes Michelson's experimental apparatus shrink a little bit? All it would take would be a tiny, almost infinitesimal, shrinking when the apparatus is pointed in the direction of the ether wind to cancel out the slowing in the speed of light.

Back in episode 26, I mentioned the French mathematician Henri Poincaré, who lectured at the St. Louis World's Fair in 1904 on what even then he was calling the principle of relativity.

Poincaré argued that the real meaning of the Michelson-Morley experiment is that an experimental apparatus in motion can't tell whether it is moving or at rest, just in the same way that if you're riding in a jet plane at 500 mph and you throw a ball up in the air it goes up and comes back down to your hand just the same way as it would if the plane were sitting on the runway. There's no experiment you can perform on the ball that would tell you whether or not the plane is moving.

What Poincaré called the principle of relativity gets further developed by Einstein in his paper, into what we now call the special theory of relativity. It embraces Poincaré's concept that you can't tell experimentally whether you are moving or not, and adds to it the principle that the speed of light always measures the same, no matter how you are moving. This explains the Michelson-Morley experiment, but it also implies some really crazy and counterintuitive things. It implies, as Lorentz suggested, that a moving object shrinks a little bit in the direction it's moving. It also implies that moving objects gain mass, and, most astonishingly of all, that the rate that time passes slows down for an observer as the observer moves faster. The net effect of all of these peculiar changes is that no matter how fast or how slow you are moving, the speed of light always looks the same to you.

There is no such thing as a universal frame of reference. The universe has no ground underneath it, so to speak. Everything is in motion, and nothing is a reference point. You can observe the universe from the Earth or from the Moon or from Alpha Centauri or from any other moving object in the universe, and no one set of observations is any different or more special than any of the others. Your one and only universal reference point is not a place; it is the speed of light, which never, ever changes.

Miracle number three.

[music: Mozart Violin Sonata no. 26 in B♭]

Einstein's fourth paper was published in November, and was titled "Does the Inertia of a Body Depend upon Its Energy Content?" And I can explain what it proved in one short equation: $E=mc^2$, the most famous equation in science.

Energy equals mass times the speed of light squared. That means that mass and energy are really the same thing. Mass is just a sort of frozen, concentrated form of energy. Very concentrated, since c^2 is a very big number.

But that's not all it means. It also means that when you put energy into an object, you're making it a tiny bit heavier. If you put an electric charge on an object, you've made it a tiny bit heavier. If you put it into motion, it's a tiny bit heavier. If you move it from the bottom of a valley to the top of a mountain, it’s a tiny bit heavier. If you take two magnets and pull them apart, you’ve made them a tiny bit heavier.

And here is the explanation for Marie Curie’s radioactivity. Where does that energy come from? As a sample of uranium emits radioactivity, it is continually getting a teeny bit lighter and lighter. This could open up a whole new source of energy that would render existing sources, like coal, trivial in comparison. We’ll have to see how that goes.

And that is miracle number four.

[music: Mozart Violin Sonata no. 26 in B♭]

The year of wonders established Einstein’s place as the greatest scientist since Isaac Newton and the most important scientist of the 20th century, even as that century was barely getting off the ground. And he’s not done yet.

Albert Einstein would be awarded the 1921 Nobel Prize in physics for the paper on the photoelectric effect. In 1921, relativity was still considered a controversial theory, and the Nobel committee was not ready to give a prize for it. Sadly, outrageously, Einstein never was awarded the second Nobel Prize he was certainly due for his work on relativity. He probably should’ve gotten a third one, for working out $E=mc^2$.

At the end of the 20th century, *Time* magazine would name Albert Einstein the Person of the Century, as the most important scientist in the century where scientific progress was the most important story.

Einstein’s very name has become synonymous with genius, as in “Way to go, Einstein.” I’ve been trying to think of some other historical figure, *any* historical figure, whose name is used in a similar way, and I can’t think of one. The only one I can think of is Sherlock, which of course is a reference to a fictitious character.

The image of Albert Einstein, with his wild, unkempt hair, and his reputation for absentmindedness, has become the archetype for the theoretical scientist in our popular culture. Einstein himself became a pervasive cultural icon. Schools, streets, and hospitals around the world are named after him. American composer Philip Glass wrote an opera in 1976 entitled *Einstein on the Beach*. Einstein appeared on the cover of the Beatles 1967 album, *Sergeant Pepper’s Lonely Hearts Club Band*, and made two appearances on the holodeck of the *USS Enterprise* on *Star Trek: The Next Generation*. Doc Brown named his dog Einstein in the 1985 film *Back to the Future*, and the character of Doc Brown himself, with his wild hair and eccentricities, is clearly modeled on Albert Einstein. In 1988, Australian filmmaker Yahoo Serious released the biographical film *Young Einstein*, with himself in the title role. The film takes so many historical liberties that it got Yahoo Serious’s poetic license revoked.

But my favorite is the 1994 American film *I.Q.*, where Einstein was portrayed by Walter Matthau. The film has essentially the same plot as the 1992 animated film *Aladdin*, except that instead of a genie, the young man pining for love has…Albert Einstein.

Einstein was known for his humility and his gentle sense of humor. In the 1930s, the *New York Times* reported that Einstein was so well known in that city that people would repeatedly stop him on the street and ask him to explain the theory of relativity. He eventually dealt with this problem by answering, "Pardon me, sorry! Always I am mistaken for Professor Einstein."

We'll have to stop there for today. You might have noticed that I am now adding transcripts of new episodes to the website as I post them. That's because a couple of you have asked for transcripts. You're welcome. With the assistance of helpful and energetic listener K.G., I will try to add transcripts for back episodes, and I hope one day we will be all caught up. I have also added a reading list to the website, which features some books I have found helpful in creating this podcast, and recommend to anyone who is interested in doing further reading. The reading list includes links to Amazon, where you can buy the book, and if you click through and buy, I get a commission. The money comes out of their pocket, not yours, so that's another way you can help support the show, if you are so inclined. There's only two books on the list right now, but I plan to add to it as we go along.

Next weekend is Independence Day weekend in the United States, and so I'm going to take the week off. But now that I've given you books and transcripts to read, you should have no trouble filling in your empty hours, and I hope you'll join me in two weeks' time on *The History of the Twentieth Century* as we return to the United Kingdom and take a look at the political situation in that country as the heady days of the Khaki Election give way to rising discontent with the status quo. That's in two weeks' time, on *The History of the Twentieth Century*.

Oh and one more thing. Yes, Albert Einstein is a genius, but let us not overlook our other Albert, Albert Michelson. His work on measuring the speed of light won him the Nobel Prize in physics in 1907, making him the second American to win a Nobel Prize, and the first American to win one in the sciences. The first American to win any Nobel Prize was, of course, Theodore Roosevelt.

[music: Mozart Violin Sonata no. 26 in B♭]