Michio Kaku, an American theoretical physicist and Professor at City University of New York, talks about universe in a nutshell…

My name is Professor Michio Kaku. I'm a professor of theoretical physics at the City University of New York and I specialize in something called string theory. I'm a physicist. Some people ask me the question, "What has physics done for me lately? I mean, do I get better color television, do I get better internet reception with physics?" And the answer is yes. You see, physics is at the very foundation of matter and energy. We physicists invented the laser beam, we invented the transistor. We helped to create the first computer. We helped to construct the internet. We wrote the World Wide Web. In addition, we also helped to invent television, radio, radar, microwaves, not to mention MRI scans, PET scans, x-rays.

In other words, almost everything you see in your living room, almost everything you see in a modern hospital, at some point or other, can be traced to a physicist. Now, I got interested in physics when I was a child. When I was a child of eight, something happened to me that changed my life and I wanted to be part of this grand search for a theory of everything.

When I was eight, a great scientist had just died. I still remember my elementary school teacher coming into the room and announcing that the greatest scientist of our era has just passed away. And that day, every newspaper published a picture of his desk. The desk of Albert Einstein. And the caption said, I'll never forget, "*The unfinished manuscript of the greatest work of the greatest scientist of our time*." And I said to myself, "Why couldn't he finish it? I mean, what's so hard? It's a homework problem, right? Why didn't he ask his mother? Why can't he finish this problem?"

So as a child of eight, I decided to find out what was this problem. Years later, I began to realize that it was the theory of everything, the **Unified**

Field Theory.

Unified Field Theory: A Theory of Everything

An equation one inch long that would summarize all the physical forces in the universe. An equation like **$E=mc^2$**. That equation is half an inch long and that equation unlocks the secret of the stars. Why do the stars shine? Why does the galaxy light up? Why do we have energy on the earth? All of it tied to an equation half an inch long.

But then there was another thing that happened to me when I was around eight years old. I got hooked on the Saturday morning TV shows. In particular, Flash Gordon. And I was hooked. I mean, every Saturday morning watching programs about alien from outer space, star ships, ray guns, invisibility shields, cities in the sky, that was for me.

But after a few years, I began to notice something. First of all, I began to notice that well, I didn't have blond hair and blue eyes, I didn't have muscles like Flash Gordon, but it was a scientist who made the series work. In particular, a physicist. He was the one who discovered the ray gun, the star ships. He was the one who created the city in the sky. He was the one who created the invisibility shield.

And then I realized something else. If you want to understand the future, you have to understand physics. Physics is at the foundation of all the gadgetry, the wizardry, all the marvels of the technological age, all of it can be traced to the work of a physicist, including computers, also biotechnology. All of that can eventually trace down to physics.

Physics and the Impossible

Most of science fiction is in fact well within the laws of physics, but possible within maybe 100 years. And then we have type two impossibilities, impossibilities that may take 1,000 years or more. That includes time travel, warp drive, higher dimensions, portals through space and time, star gates, worm holes. That's type two.

And then we have type three, and those are things which simply violate all the known laws of physics, and they're very few of them.

So in my life I've had two great passions. First is to help complete Einstein's dream of a theory of everything. An equation one inch long that would allow us to, "Read the mind of God."

But the second passion of my life is to see the future. You know, if you were to meet your grandparents at the year 1900, they were dirt farmers back then. They didn't live much beyond the age of 40, on average. Long distance communication in the year 1900 was yelling at your neighbor. And yet, if they could see you now, with iPads and iPods and satellites and GPS and laser beams, how would they view you? They would view you as a wizard or sorcerer.

However, if we can now meet our grandkids of the year 2100, how would we view them? We would view them as gods, like in Greek mythology. Zeus could control objects around him by pure thought. Materialize objects just by thinking. And there're perks to being a Greek god, Venus had a perfect body, a timeless body. And we are beginning now to unravel the genetics at the molecular level, of the aging process. And then Apollo, he had a chariot that he could ride across the heavens. We will finally have that flying horse, I mean, that, we will have that flying car that we've always wanted to have in our garage. We will be able to create life forms that don't exist today.

And so in other words, if you want to see the future, you have to understand physics, and you have to realize that by the year 2100, we will have the power of the gods. To paraphrase Arthur C. Clark, "*Any sufficiently advanced technology is indistinguishable from divinity*."

So let's now begin our story.

The History of Physics

The history of physics is the history of modern civilization. Before Isaac Newton, before Galileo, we were shrouded with the mysteries of superstition. People believed in all sorts of different kinds of spirits and demons. What made the planets move? Why do things interact with other things? It was a mystery.

So, back in the Middle Ages, for example, people read the works of Aristotle. And Aristotle asked the question, "*Why do objects move toward the earth? And that's because*," he said, "*objects yearn, yearn to be united with the earth. And why do objects slow down when you put them in motion? Objects in motion slow down because they get tired*."

These are the works of Aristotle, which held sway for almost 2,000 years until the beginning of modern physics with Galileo and Isaac Newton.

So, when the ancients looked at the sky, the sky was full of mystery and wonder, and in the year 1066, the most important date on the British calendar, there was a comet, a comet which sailed over the battlefield of Hastings. It frightened the troops of King Harold, and a young man from Normandy, swept into England and defeated King Harold at the Battle of Hastings, creating the modern British monarchy. In fact, British history dates to 1066 with William the Conqueror.

But the question is, where did the comet come from? What was this comet that mysteriously paved the way for the coming of the British monarchy? Well, believe it or not, that same comet, the very same comet that initiated the British monarchy, sailed over London once again in 1682. This time, everyone was asking the question, "Where do comets come from? Do they signal the death of the king? Why do we have messengers from heavens in the sky?" Well, one man dared to penetrate the secrets of comets, and that was Isaac Newton.

In fact, when Isaac Newton was only 23 years old, he stumbled upon the universal force of gravitation. According to one story, he was walking on his estate in Woolsthorpe, and he saw an apple fall. And then Isaac Newton saw the moon, and then he asked the key question which helped to unlock the heavens. If apple falls, does the moon also fall? And the answer was, “Yes.” And answer overturned thousands of years of mystery and speculation about the motions of the heavens. The moon is in freefall, just like an apple. The moon is constantly falling toward the earth. It doesn’t hit the earth, because it spins around the earth, and the earth is round, but it’s acting under a force, a force of gravity.

So Newton immediately tried to work out the mathematics and he realized that the mathematics of the 1600’s was not sufficient to work out the motion of a falling moon. So what did Isaac Newton do? When he was 23 years old, not only did he stumble upon the force of gravity, but he also created calculus. In fact, he created at the rate at which you learn it, when you are a freshman in college. And why did he create calculus? To calculate the motion of a falling moon.

The mathematics of his age was incapable of calculating the trajectories of objects moving under an inverse square force field, and that’s what Isaac Newton did. He worked out the motion of the moon. And then he realized that if he understands the moon, he also understands the motion of the planets in the solar system.

And Isaac Newton invented a new telescope. It was the reflecting telescope and he was tracking the motion of this comet. Well, it turns out that everyone was talking about the comet, including a rather wealthy Englishman by the name of Edmund Haley. Everyone was talking about the comet, so Edmund Haley, being a wealthy merchant, decided to make a trip to Cambridge to talk to England’s illustrious scientist, Sir Isaac

Newton.

Well, Edmund Haley asked Newton, “What do you make of this comet? No one understands comets, they’re a mystery. They’ve been fascinating people for centuries, for millennia, what are your thoughts?” And then, I paraphrase, but Isaac Newton said something like this, he said, “Oh, that’s easy. That comet is moving at a perfect ellipse. It’s moving in an inverse square force field. I’ve been tracking it every day with my reflecting telescope and the path of that comet conforms to my mathematics exactly.” And of course, we don’t know what Edmund Haley’s reaction was, but I paraphrase, he must have said something like this, he said, “For God’s sake, man, why don’t you publish the greatest work in all of scientific history? If correct, you have decoded the secret of the stars, the secret of the heavens. Nobody understands where comets come from.”

And then Newton responded and said, “Oh, well, it costs too much. I mean, I’m not a wealthy man, it would cost too much to summarize this calculus that I’ve invented and to work out all the motion of the stars.” And then Haley must have said this, he must have said, “Mr. Newton, I am a wealthy man. I have made my fortune in commerce. I will pay for the publication of the greatest scientific work in any language.” And it was **Principia –** *The principles, the mathematical principles that guide the heavens.*

Believe it or not, this is perhaps one of the most important works ever written by a human being in the 100,000 years since we evolved from Africa. Realize that this book sets into motion a physics of the universe. Forces that control the motion of the planets, forces which can be calculated, forces which govern the motion of cannonballs, rockets, pebbles, everything that moves, moves according to the laws of motion and the calculus of Sir Isaac Newton.

In fact, even today, when we launch our space probes, we don’t use Einstein’s equations, they only apply when you get near the speed of light or near a black hole. We use Newton's laws of gravity. They are so precise that when we shoot a space probe right past the rings of Saturn, we use exactly the same equations that Isaac Newton unraveled in the 1600's. That's why we have glorious photographs of the rings of Saturn. That's why we have fly-by's right past Neptune. That's why we've been able to unravel the secrets of the solar system, compliments of the laws of motion of Isaac Newton.

So what Newton did was not only did he set into motion the ability to calculate planets, he also set into motion a mechanics. Machines now operated upon well-defined laws. Newton's three laws of motion. ***The first law of motion*** *says that objects in motion stay in motion forever, unless acted on by an outside force*. You see that in an ice skating rink. You should a puck and it goes all the way down forever, unless acted upon by an outside force. That's different from Aristotle's law of motion.

Aristotle said, "Objects in motion eventually stop, because they get tired." Newton says, "Objects in motion stay in motion forever." Sailing past Pluto, unless acted on by an outside force.

The second law of motion *says, force is mass times acceleration*. And that equation made possible the Industrial Revolution. Steam engines, locomotives, factories, machines, all of it due to the mechanics set into motion by Isaac Newton's second law of motion, force is equal to mass times acceleration.

And then Newton had a third law of motion. *For every action, there's an equal and opposite reaction*, that's the law of rockets. That's why we have rockets that can sail into outer space. In fact, Newton was the first human who could actually calculate how fast you have to run to jump to the moon. That was a number that mystified ancients.

How do you get to the moon? Can you jump to the moon? Well, Newton could have calculated that number, 25,000 miles per hour, that's the escape velocity of the earth, a number which could have been calculated by Isaac Newton himself.

So the lesson here is, when scientists unraveled the first force of the universe, gravity, that set into motion the Industrial Revolution. A revolution which toppled the kings and queens of Europe, which displaced feudalism, ushering in the modern age. All because a 23-year-old gentleman looked up and asked the question, "Does the moon also fall?"

So, rockets, the motion of planets, and even buildings in Manhattan, all of them owe their existence to Newton's laws of motion.

You know, when I was a kid growing up in California, I would see pictures of the Empire State Building. And I said to myself, "How could that possibly build such a big building and not know that it's going to fall? I mean, why doesn't it fall? They didn't build scale models of the thing, you couldn't have an Empire State Building that big to test whether it's going to fall or not. How did they know ahead of time that that building wouldn't fall? And the answer is: Newton's laws of motion.

In fact, today, I teach Newton's laws of motion, and you can actually calculate the forces on every single brick of the Empire State Building. Every screw, every bolt, you can calculate precisely the tension on every single fragment of the Empire State Building, using Newton's second law of motion, force is mass times acceleration. That was the first force – when Newton unraveled the force of gravity, it ushered in the Industrial Revolution.

Now, let's take a look at the second force, an even greater force which has touched all of our lives, and that is the electromagnetic force. Ever since humans saw lightening bolts light up the sky, ever since they were terrified by the sound of thunder, they've been asking, "Do the gods propel lightening bolts and create thunder? Are they angry at us?"

Well, as time went by, scientists began to realize that the lightening bolts and the thunder can be duplicated on the earth. That we can actually create many lightening bolts using electricity. And with magnets, we can also unleash a new kind of force, the force of electricity and magnetism.

But it wasn't until the 1800's that finally we begin to unlock the second great force which rules the universe, the electromagnetic force. So this helped to usher in the age of discovery. Realize that before the compass, if you sailed the ocean blue, you would get lost. With the compass knowing the position of the stars, you can then begin to navigate over hundreds, thousands of miles in the ocean. So the discovery of compasses by the Chinese helped to usher in the Age of Discovery.

And when people like Michael Faraday, who did this, Michael Faraday would give Christmas lectures in London, fascinating everyone from adults to children. And he would demonstrate the incredible properties of electricity. Some people, for example, ask a simple question. If you're in a car or an airplane, you get hit by a lightening bolt, why don't you all get electrocuted? Why don't you all die?

Well, Faraday answered the question. He would create a cage for children. He would walk into this steel cage, electrify it, and he wouldn't get electrocuted at all. That's called a Faraday cage and every time you walk into metal structure, you get shielded by this metal object and that's called a Faraday cage.

Well, what Michael Faraday did was, he helped to unleash the second great revolution with something calls Faraday's Law. If I take a wire and I move a wire in a magnetic field, the magnetic field pushes the electrons in the magnet, creating an electrical current. That simple idea unleashed the electric revolution. A moving wire in a magnetic field, has this electrons pushed, creating a current, and that's why we have hydro-electric generators. That's why we have dams that can produce enormous amounts of power. That's why people build nuclear power plants. That's why we have room — right now. All of it due to the simple observation that a wire moving at a magnetic field, has its electrons pushed, creating an electric current.

On a very small scale, you use that in your bicycle. When you put a bicycle lamp on your bicycle, the turning of the wheel spins a magnet. The magnet then pushes electrons in a wire and that's why electricity lights up in your bicycle lamp. That's exactly the same principle that lights up your house via a hydroelectric dam.

So in other words, electricity and magnetism were unified into a single force. We once thought that electricity and magnetism were separate. Now we know they are in fact the same force. So if a moving magnet can create an electric field, this means that a moving electric field can create a magnetic field. But if they can create each other, why can't they oscillate and create a wave? So that moving electric fields create magnetic fields, create electric fields, create magnetic fields, infinitum to create a wave?

Well, around the time of the American Civil War, a mathematical physicist, James Clerk Maxwell, calculated, using the work of Faraday, the velocity of this wave, that electricity turns to magnetism, turns to electricity, turns to magnetism, creating a wave, and he calculated the velocity of the wave. And in one of the greatest works in the history of humanity, in one of the greatest breakthroughs of all time, James Clerk Maxwell calculated the velocity of this wave and found out it was the velocity of light. And then he made this incredible discovery, this is light. That's what light is. It doesn't by accident travel at the speed of electricity, it is light itself.

If I have a light beam right here and I could look at it with a super-microscope, I would see oscillating electric fields, magnetic fields, turning into each other creating a wave, and that wave is called light. And the equations were written down by James Clerk Maxwell. Unfortunately, Michael Faraday himself did not have a formal education. He could not put into mathematical form his own work. James Clerk Maxwell was a theoretical physicist, just like myself. He wrote down the mathematical physics of oscillating electric fields and magnetic fields and they are called **Maxwell's equations**. These equations have to be memorized by every physicist in grad school. You cannot get your PhD without memorizing these equations. Every engineer who designs radio, radar, every engineer who deals with radar and radio has to memorize these equations. And so, if you go to Berkley, where I got my PhD, you can buy a T-shirt which says, "*In the beginning God said, the four-dimensional divergence of an anti-symmetric, second rank tensor equals zero, and there was light, and it was good. And on the seventh day he rested*." Ladies and gentlemen, this is the equation for light.

In the same way that Newton found a one inch equation that governed the motion of the planets, in the same way that Maxwell discovered a one inch equation that unlocked the secret of light, we physicists today want to have a one inch equation that summarize all physical reality.

Well, Michael Faraday in his own lifetime was heralded as a great scientist, and how many scientists do you know appear on money? Well, there he is, on the British 20-pound note. So it's very rare that a scientist appears on a nation's currency, but so great was a contribution of Michael Faraday that there he is on the 20-pound note.

The Electromagnetic Revolution and The Nuclear Age

The consequences of the electromagnetic revolution touch all of us. This is a picture of the earth from outer space. Look at this picture. Europe electrified, you can actually see the fruits of all of our efforts to create electricity, to energize our lives, in one picture, seeing the earth from outer space.

So let's now talk about how Faraday and Maxwell's work touches your life as well. This is the internet. The internet is a simple byproduct of the electromagnetic force. It's a solution of Maxwell's equations and you can see that where there is the internet, there is prosperity. There is science, there's entertainment, there's economic activity.

Where there's no internet, there's poverty. And in the future, the internet will be miniaturized and it will be placed in your glasses. Your glasses will recognize people's faces and display their biography next to the image as you talk to them, and then when they speak Chinese to you, your glasses will translate Chinese into English and print out subtitles right beneath their image. So in the future, you will know exactly who you are talking to without even talking to them, and this means that at a cocktail party, if you're looking for a job, but you don't know who the heavy hitters are, in the future you will know exactly who to suck up to.

Well, maybe you don't want to look like a refugee from Star Trek, kids of course love the electromagnetic force, they want to make it fashionable. Fashion models will adopt the technology, kids will say, "What? You're not wired up? You can't download videos and websites on your glasses? What's wrong with you?"

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So, the electromagnetic force can be beamed right into your eyes via laser beams, or through an eyepiece, or by using the glasses as a screen. These are internet glasses, this is the future of your home office, the future of your home entertainment center.

But let's say you don't like glasses. Let's say you don't wear glasses. Then how will you access the internet, the electromagnetic force of the future? You will do it in your contact lens. You will blink and you will go online. And who will buy these internet contact lenses? College students studying for final examinations. They will blink and they will see all the answers appear in their contact lens.

Who else will buy these internet contact lenses? Artists will buy them. Because by moving their hands, they will make the electromagnetic force turn into all the different kinds of artistic endeavors they engage in. Paintings, drawings, sculptures, all done by waving their hands. Not to mention that architects will line up to get these things. Instead of having to redesign a model every time they move something, they'll simply wave their hands and their buildings, their skyscrapers, will simply rearrange themselves.

Tourists will line up for these glasses because via the electromagnetic force, you will see the Roman Empire resurrected as you walk through the streets of Rome looking at the ruins. So tourists will be able to resurrect all the wonders of the past. And the military, hey, let's be blunt about this. The military sees the importance of this, the military is also perfecting their version of this, and I had a chance to take a film crew from the Science Channel, fly down to Fort Benning, Georgia, and have a demonstration of the military's version. You put on a helmet, there's an eyepiece on the helmet, you flick the eyepiece down and in a half a second, you see now the entire battlefield on the internet right inside your eyepiece. Friendly forces, enemy forces, airplanes, artillery, all of it, the battlefield laid out for you right inside your lens. All of it, compliments of Faraday's electromagnetic force.

And of course, you've seen this before, where have you seen this before?

This is the governor of California in a very bad mood. This is the Terminator robot. And how did the Terminator robot view you? When the Terminator robot looked at you, there were subtitles giving you the name of the person you were looking at. Here is John Connor located by internet contact lenses inside a robot. So you've seen this before. This is called augmented reality and in the future, that's where we will spend most of our life. We will spend most of our life in augmented reality. When we blink, we can download any movie, any website, any piece of information. We blink, we can recognize any object, recognize any person, translate any language, this is the future, compliments of Faraday's electromagnetic force.

This is your living room, by the way, of the future. You're going to be surrounded by the electromagnetic force, 360 degrees surrounded by wall screens and how will you decorate your room? Well, you'll decorate your room with images, cell phone screens, this is a typical cell phone of the future, and wallpaper of the future will be flexible. It turns out that transistors can be made out of plastic. And with plastic transistors come e-paper, electronic paper. Paper that you can scroll right out of your cell phone, or for that matter, decorate your home. This is the future of wallpaper. In the future, chips will only cost a penny, because we can manufacture tinier and tinier transistors, and use Faraday's electromagnetic force in plastic to create flexible paper. So in the future, you will go to the wall and say, "Change color. I don't like this color, I don't like this design," so redecorating your house has never been so simple.

This will also affect your love life. On Friday night, we all know what college students when there's no date, they get stone drunk. In the future, they'll go to the wall, conjure up a wall screen, and say, "Mirror, mirror on the wall, who's available tonight?" The wall screen will then contact all the other wall screens of everyone else who's lonely that night, the wall screen knows the desires that you want, the kind of person you like to go out with, and bingo! You have a date. So in the future, this will also change your love life.

And it'll also affect medicine. You will have Faraday's electromagnetic force inside your body. This is a pill. It has a chip in it, the chip is smaller than an aspirin pill, it also has a TV camera, and a magnet. When you swallow it, the magnet guides the camera, taking pictures of your stomach, your intestines, because we all know what middle aged men fear the most, colonoscopies. And this gives new meaning for the expression, ***Intel Inside***.

Now, let's talk about the next great forces which rule the universe. We talked about gravity, which allows us to calculate the motion of the planets. The mechanics created by Newton helped to unleash the Industrial Revolution. Michael Faraday worked out the electromagnetic force, which gave us the wonders of the electric age.

Nuclear Age, The Stars and The Sun

And now, let's talk about the nuclear age, the stars and the sun. People have been fascinated by the sun, Apollo was the god that strode across the heavens in his fiery chariot. But hey, when you calculate how long coal or oil will burn like the sun, you realize that in just a few hundred years, the sun would burn to a crisp. So what could possibly last for billions of years? There must be a new force, a nuclear force.

Einstein and others helped to unravel the secret of the stars. The nuclear force comes in two types, weak and strong. Both of them are involved in the creation of the sun. The equation which allows for the liberation of energy is Einstein's famous equation, $\mathbf{E=mc^2}$.

What Einstein showed was that the faster you move, the heavier you get. So your weight is not a constant. When you move very rapidly, you get heavier, something which we measure every day in the laboratory. Now, this means that the energy of motion transformed into mass, because you get heavier.

Now, listen carefully. The faster you move, the heavier you get. Which means that the energy of motion, "E" turns into "m", your mass. And the relationship between E and m is very simple, it takes one second to write it down on a sheet of paper, it is exactly $E=mc^2$.

So the derivation of one of the greatest equations of all time takes less than a page. Once you understand the basic principle behind relativity, bingo! The equation just falls right out.

So the nuclear force helped to explain the secret of the sun. But it also created a Pandora's box, because inside the nucleus of the atom, are particles. And when you smash these particles, what do you get? More particles. And when you smash them, what do you get? More particles. In fact, we are drowning in subatomic particles, hundreds, thousands of subatomic particles every time we smash atoms.

Now, we smash atoms using something called atom smashers, or particle accelerators. I built my own particle accelerator when I was in high school. When I was in high school, I went to my mom one day and I said, "Can I have permission to build a 2.3 million electron volt betatron particle accelerator in the garage?" And my mom said, "Sure, why not? And don't forget to take out the garbage."

So I went to Westinghouse, and as a high school kid, I asked for 400 pounds of transformer steel. I asked for 22 miles of copper wire, because I wanted to create a 6 kilowatt, 10,000 GOz magnetic field to energize my atom smasher. With 22 miles of copper wire, how could you wind it? We did it on the high school football field. I put 22 miles of copper wire on the goal post, gave it to my mother, she ran to the 50-yard line, unraveling the spool of wire, she gave it to my father, who then ran to the goal post, and we wound 22 miles of copper wire on the high school football field.

Well, finally my atom smasher was ready. It consumed 6 kilowatts of power, that's every single ounce of power that my house could deliver. I plugged my ears, I closed my eyes, I turned on the power, and I heard this huge crackling sound as 6 kilowatts of power surged through my capacity bang. And then I heard a pop, pop, pop sound as I blew out every single circuit breaker in the house. The whole house was plunged in darkness.

My poor mom, every time she'd come home, she would see the lights flicker and die. And she must have wondered, "Why couldn't I have a son who plays baseball? Why can't he learn basketball? And for God's sake, why can't he find a nice Japanese girl? I mean, why does he have to build these machines in the garage?"

Well, these machines that I built in my garage earned the attention of a physicist. And my career got a head start. This physicist helped to build the atomic bomb, and he arranged for me to get a scholarship to Harvard. He knew exactly what I was doing. I didn't have to explain to him that I was experimenting with anti-matter. I was creating anti-electrons in my mom's garage and using atom smashers to eventually create beams of anti-matter, he knew exactly what I was doing.

Well, his name was Edward Teller, father of the hydrogen bomb. But, hey, that's another story.

Antimatter is the opposite of matter, it has the opposite charge. So an electron has negative charge, the positron, or anti-electron, has positive charge. This means that you can now create anti-molecules and anti-atoms. Anti-hydrogen was made at CERN outside Geneva, Switzerland, and also at Fermi Lab outside Chicago, where they have anti-electrons circulating around anti-protons.

And in Brookhaven National Laboratory in Long Island just recently, they detected anti-helium. We have two anti-protons with two anti-neutrons to create anti-helium. So in principle, you can create anti-people, anti-universes, anti-everything. For every piece of matter, there's a counterpart which is made out of antimatter. And when the two collide, by the way, it releases the greatest energy source in the universe.

So the collision of matter and antimatter releases energy, which may one day take us to the stars. It is 100% conversion of matter to energy by Einstein's equations, $E=mc^2$.

The Standard Model

So where we last left off, we were talking about the fact that inside the nucleus of the atom, we have particles upon particles when you smash them apart. In the 1950's, we were drowning in subatomic particles. In fact, J. Robert Oppenheimer, the father of the atomic bomb, once made a statement. He declared that the Nobel Prize in Physics should go to the physicist who does not discover a new particle this year. That's how many particles were being discovered.

Particle Zoo

So let's talk about the particle zoo. Right now, we physicists have unlocked hundreds, thousands of subatomic particles and we've been able to piece them together into a jigsaw puzzle. It's an ugly jigsaw puzzle, it's horrible, but hey, it works! It describes all the subatomic particles. But look at this mess, it's called the standard model. It has 36 quarks, 19 free parameters, 3 generations of **** no rhyme, no reason, but this is the most fundamental basis of reality that we physicists have been able to construct. Billions of dollars, 20 Nobel Prizes have gone into the creation of the standard model, and it is the ugliest theory known to science, but it works.

There's one piece missing, and that one piece that's missing is called the ***Higgs Boson***.

We expect to find it, but it's still damn ugly. We want to create a higher version of this theory. And that theory, we think, is string theory.

String Theory: A Theory of Everything?

String theory is based on the simple idea that all the four forces of the universe, gravity, the electromagnetic force, the two strong forces, can be viewed as music. Music of tiny, little rubber bands. So if I had a super-microscope shown here and I could look right into the heart of an electron, what would I see? I would see a vibrating rubber band. And if I twang it, it turns into a neutrino. I twang it again, it turns into a quark. I twang it again, it turns into a Yang-Mills particle. In fact, if I twang it enough times, I get thousands of subatomic particles that have been catalogued patiently by physicists. So these are not ordinary strings, however. They're not ordinary piano strings or violin strings, they are super strings. They vibrate in hyperspace, a dimension beyond physical comprehension. 10, maybe 11 dimensional hyperspace. The world I live in, as a theoretical physicist, is not quite the world that you live in. I live in a world that is 11 dimensional. All the equations I write down, all the physical pictures that I construct are 11 dimensional, existing in hyperspace.

We know that physical reality is three dimensional. We have length, width, height. Einstein gives us time as a fourth dimension. But we physicists believe that the instance of the Big Bang, the universe was not 3 dimensional, was not 4 dimensional, it was 11 dimensional.

So string theory says that all subatomic particles of the universe are nothing but musical notes. A, B-flat, C-sharp, correspond to electrons, neutrinos, quarks, and what have you. Therefore, physics is nothing but the laws of harmony of these strings. Chemistry is nothing but the melodies we can play on these strings. The universe is a symphony of strings and the mind of God, the mind of God that Einstein eloquently wrote about for the last 30 years of his life, for the first time in history, we now have a candidate for the mind of God. It is cosmic music resonating through 11 dimensional hyperspace. That is the mind of God.

And how will we test it? How will we know that the universe is 10 or 11 dimensional? Because we are building a machine. The biggest machine of science ever built in the history of the human race, outside Geneva, Switzerland. It is the large Hadron Collider. And no matter how big it is, however, it is a pea shooter compared to an even bigger machine that we physicists wanted to build outside Dallas, Texas. Ronald Reagan wanted to build the Super Collider, a much bigger machine, outside Dallas, Texas, however, Congress cancelled it in 1993. Congress gave us a billion dollars to dig a huge hole, a smaller version shown here. Congress cancelled our machine in 1993, and then gave us a second billion dollars to fill up the hole. Two billion dollars to dig a hole and to fill it up. I can't think of anything more stupid than that for the United States Congress.

But what happened? In 1993, just before the final vote was taken, a congressman asked a physicist, "Will we find God with your machine? If so, I will vote for it." The entire fate of an $11 billion machine rested on this last final question. Will we find God with your machine?

Well, the physicist didn't know what to say, so he said, "We will find the Higgs Boson." Well, you could almost hear all the jaws hit the floor on the United States Congress. Everyone was saying, "$11 billion for another god darned subatomic particle!" And the machine was cancelled the next day.

Ever since then, we physicists have been playing that scene over and over and over in our minds. How should we have answered that question? I don't know. But I would've answered it differently. I would've said this, I would've said, "This machine, the Super Collider, will take us as close as humanly possible to the Deity's greatest creation, Genesis. This is a Genesis Machine. It will celebrate the greatest moment in the history of the universe, its birth." Instead we said, "Higgs Boson," and our machine was cancelled. Sorry about that.

So the Higgs Boson, we think, will be created by the Large Hadron Collider. A tube 17 miles in circumference with two beams of protons circulating in opposite directions, then slamming together right here, creating a shower of particles. And among these particles, we hope to find the Higgs Boson. But not only that, we hope to find particles even beyond the Higgs Boson. The next set of particles beyond the Higgs Boson are sparticles, super particles, nothing but higher vibrations, higher musical notes of a vibrating string.

And what else could we do? We can also unlock the secrets of the Big Bang. You see, Einstein's equations break down at the instant of the Big Bang at the center of a black hole. The two most interesting places in the universe are beyond our reach using Einstein's equations, we need a higher theory, and that's where string theory comes in. String theory takes you before the Big Bang, before Genesis itself.

And what does string theory say? It says that there is a multi-verse of universes. Where did the Big Bang come from? Well, Einstein's equations give us this compelling picture that we are like insects on a soap bubble. A gigantic soap bubble just expanding and we are trapped like flies on fly paper, we can't escape the soap bubble. And that's called the Big Bang theory.

String theory says there should be other bubbles out there in a multi-verse of bubbles. When two universes collide, it can form another universe. When a universe splits in half, it can create two universes, and that, we think, is the Big Bang. The Big Bang is caused either by the collision of universes or by the fusioning of universes.

String theory, we think, is a theory of everything. It unites all forces, gravity, the electromagnetic force, the weak and the strong force into one comprehensive picture and that pyridine is music. That all the forces of the universe are nothing but different musical notes on a vibrating string, but it also gives us a picture of the universe itself. That the universe is a soap bubble, like what Einstein predicted, but there are other soap bubbles out there. And when these soap bubbles collide, when these soap bubbles fission, it creates a violent burst of energy which we think could be the Big Bang.

Now, string theory, in turn, can be summarized in an equation about an inch long, that's my equation. That's just called **String Field Theory**. It is an equation that allows you to summarize all the wondrous properties of string theory into one equation.

If you were to summarize the march of physics over the last 10,000 years, it would be the distillation of the laws of nature into four fundamental forces. Gravity, electricity and magnetism, and the two nuclear forces. But then the question is, is there a fifth force? A Fifth Force? A force beyond the forces that we can measure in the laboratory. And believe it or not, there are physicists who have actually looked very carefully for a fifth force. Some people think maybe it's psychic phenomena. Maybe it's telepathy. Maybe it's something called sci-power. Maybe it's the power of the mind, maybe consciousness.

Well, I'm a physicist. We believe in testing theories to make sure that they are falsifiable and reproducible. We want to make sure that on demand, your theory works every single time without exception. And if your theory fails one time, it's wrong. In other words, Einstein's theory has to work every single time without exception. One time Einstein's theory is proven to be wrong, the whole theory is wrong.

Well, so far, we can reproduce these four physical theories, but a fifth theory cannot be reproduced, we've looked for it. Some people think that maybe a fifth force may be short range, like not over the nucleus of the atom, but ranging over several feet, so we've tried. We've looked for a gravitational force of some sort that acts not over stars and galaxies, not over nuclear distances, but over these distances. And we can't find any.

Today, however, we have membranes, and we don't yet understand how membranes fit into this picture, but we think our universe is a membrane of some sort. So strings can coexist with membranes. Then the question is, if there are other dimensions, if there are other universes, can we go between universes? Well, that of course is very hard, however, Alice In Wonderland gives us a possibility that maybe one day we might create a worm hole between universes. This is a worm hole. Think of taking a sheet of paper and putting two dots on it. The shortest distance between two points is a straight line. But if I can fold that sheet of paper, then perhaps I can create a shortcut. A shortcut through space and time is called a worm hole, this is a genuine solution of Einstein's equations. We can actually see this in string theory.

The question is, how practical is it to go through one of these things. We don't know. In fact, there's a debate among physicists today, Steven Hawking, many physicists are jumping into the game, trying to figure out whether it's physically possible to go through a worm hole. Because if you could, then you might be able to use this as a time machine. Since string theory is a theory of everything, it's also a theory of time. And time machines aren't allowed in Einstein's equations, but to build one is extremely difficult. Far more energy is required than a simple DeLorean with plutonium.

But then the question is, if you go backwards in time and meet your teenage mother before you are born and she falls in love with you, how can you be born if your teenage mother just fell in love with you? Or for that matter, if you think you're so smart, here's the mother of all time travel stories, and let's see whether you're smart enough to figure this one out. So listen carefully.

The year is now 1945, it's a dark and stormy night. A drifter comes in carrying a baby girl in a basket that he lays at the doorstep of an orphanage. Well, the next day, the nuns at this orphanage pick up this baby girl. They don't know where she came from, they don't know what to call her, so they call her Jane. And Jane grows up in the orphanage wondering, "Who is my mother, my father, who is my family, where did I come from?" Well, when Jane is 19, she turns into this beautiful young girl and she falls in love. A handsome drifter comes into her life, sweeps her off her feet, but it was not meant to be. They quarrel and the drifter stomps out never to be seen again. But it is a very sad story.

Jane is left pregnant. She's rushed to the hospital nine months later, delivers a beautiful baby girl, but that very same night, somebody smashes open the window of the hospital and steals her precious baby girl, and it's even worse than this. It turns out that Jane is bleeding. She's about to die. She's not normal. The doctors have to change Jane into Jim in an emergency operation. Well, Jim wakes up the next day with a huge headache, left as a young baby girl at an orphanage, no father, no mother, lover gets her pregnant, leaves her abandoned, someone steals her baby girl, and now she's not even Jane any more, she's Jim.

Well, Jim gets into bar room fist fights every time someone says, "Jim, where did you come from anyway? Who's your mother, your father, your brother, your sister, who are you, Jim?" Well, Jim becomes a bar room drunk. But then one day, a bartender comes up to him and he says, "Jim, Jim, wake up. I'm really a time traveler. Come into my machine and let us solve the mystery of who is Jane/Jim." So they spin the dial, they go way back into the past and then poor Jim is left somewhere in the past, he doesn't know where. But then he meets this beautiful 19-year-old girl and it's love at first sight. But, you know, it was not meant to be. They quarrel and Jim stomps off, but then he finds out through the grapevine that his girlfriend is pregnant and he realizes, "Oh, my God, history is repeating itself. I want to make sure that my kid gets the best education possible."

So Jim goes to the hospital nine months later, smashes the hospital window, kidnaps his own precious baby girl, and he goes back into the time machine. And they go back, back, way back into the past until it is 1945. Jim comes in from the darkness carrying his precious baby girl that he drops off at an orphanage. Well, the next day, the nuns at the orphanage see this baby girl, they don't know what else to call her, so they call her Jane. And Jane grows up wondering, "Who is my mother, my father, my family? I was left as a foundling on the doorstep of this orphanage."

Well, Jim finally says to himself, you know, time traveling is kind of nice. I'm going to stop being this drunk and I'm going to do something constructive. I'm going to join the Time Travelers Corp. So Jim has many exploits, heroic exploits in the annuls of time. But now Jim is an old man, he's an old man about to retire. So on his retirement day, they give him a gold watch. But then Jim asks for permission for one final mission in time. And that is to go back in time to meet a certain bar room drunk who gets into fist fights any time someone says, "Who are you, Jim? Who is your mother? Your father? Your brother, your sister, your aunt, your uncle, where did you come from?"

Well, if you get a sheet of paper and you draw the family history of Jane, what you find out is Jane is a family tree unto herself. She is her own mother, her own father, her own son, her own granddaughter, her own great-great-great grandfather, her own great-great-great grandmother. She's a family tree unto herself.

And can you imagine what happens if they have a family get together and they have a food fight and someone says, "You did this to me!" "No, you did that to yourself." And they would all be right. Because if time travel is possible, it means you can be your own mother or your own father.

But what does string theory say about this? That's science fiction. What does string theory say about this? Well, string theory says, like Einstein, that time is a river. We're all swept up in the river of time. Time can speed up and slow down. Time beats faster on the moon than it does on the earth. Time beats slower on Jupiter than it does on the earth. And we measure it with your cell phone. Your cell phone picks up GPS signals from satellites. Satellites beep at different rates than your cell phone and your cell phone has to compensate for that. So your cell phone has to include Einstein's theory of general relativity in its computer software and hardware.

So to sum up, Einstein's equations allow for time travel. Time is a river. The river of time can fork into two rivers and if the river of time forks into two rivers, that answers all the time travel paradoxes. Because if you hop into a time machine, go backwards in time, you cannot change your own past, you're changing someone else's past in another time stream. So the river of time forks into two rivers and there are no paradoxes in time travel if you start to use something called string theory.

But then the question is, what would it take to one day perhaps go from one universe to another? You know, trillions of years from now, the universe is going to get awfully cold. We think the universe is headed for a big freeze. Trillions of years from now, all the stars will blink out, they'll be dead stars, neutron stars, black holes. Stars will cease to twinkle, the universe will be so big, it'll be very cold. At that point, all intelligent life in the universe must die. The laws of physics are a death warrant to all intelligent life. The universe must eventually approach the heat death predicted by physicists years ago.

But there's one loophole. Only one. There's only one way to escape the death of the universe, and that is leave the universe. Well, you're now of course entering the realm of science fiction, but at least we now have equations. The equations of string theory, which will allow us to calculate if it is possible to go through a worm hole to go to another universe where it's warmer and perhaps we can start all over again. Because perhaps one day we will be able to play with entire universes. String theory is a theory of an entire universe. Therefore when you solve the equations of string theory, you find entire universes emerging from string theory.

Now, then people ask the question, "When? When might we have this cosmic power?" And the answer is, it depends on your energy. When we physicists look at outer space for energy, we realize that any advanced civilization would eventually find three sources of energy. Planets, stars, and galaxies. So a type one civilization is planetary. They consume planetary energy. They control the weather. They control earthquakes, they control volcanoes. Anything planetary they control. Sort of like Buck Rogers or Flash Gordon.

A type two civilization is stellar. They control the energy output of an entire star, like Star Trek and the Federation of Planets. That's a very typical type two civilization.

Then there's type three, galactic. Like the Empire of The Empire Strikes Back.. They roam the galactic space lanes. Now, what is the energy of string theory? The energy of string theory is called the plank energy. It is

10 to the 19 billion electron volts. That's the universe I live in. I live in 11 dimensions, that's the dimensions that I work in, that's the dimensions that I dream about, and the energy scale of theory is the plank energy. 10 to the 19 billion electron volts, that's a quadrillion times more powerful than the Large Hadron Collider. That energy puts you in type three.

Once we have the power of galaxies, the power of star systems, we will have the power of the plank energy, perhaps even maybe the ability to bend space and time into a pretzel. What lies beyond that? One day I gave a lecture at the old planetarium there, and a little pesky 10-year-old boy comes up to me, and he yanks on my pants and he says, "Professor, you're wrong. There's type four." So I look down at this pesky little kid, and I said to him, "Shut up, kid. Why don't you play in traffic, there's a nice intersection over there, why don't you go there?" Oh, no, the kid didn't go, he kept yanking on my pants and he kept saying, "Professor, you're wrong, there's type four."

And I said, "Look, kid, in the universe, we have planets, stars, and galaxies, therefore any intelligent civilization will have planetary energy, stellar energy, and galactic energy. That's all there is. There's no type four."

And then the kid kept yanking on my pants again. And he kept saying, "Professor, you're wrong. There is something beyond type three, and that is the continuum." And then I said to myself, "Hmm, maybe he's on to something, the continuum, from Star Trek. On Star Trek, there's something called the Q. The Q are beyond galactic, they are on the level of gods. And in fact, they get their energy from the continuum. What is the continuum? Dark energy.

Dark Energy

We physicists in the last ten years have discovered a new energy source, larger than the galaxy itself. Dark energy. Realize in our universe today, 73% of our universe, the matter energy, 73% is in the form of dark energy. The energy of nothing. That's what's blowing the galaxies farther and farther apart. That's the energy of the Big Bang itself.

Kids ask the question, if the universe banged, then what made it bang? And the answer is dark energy. 73% of the universe's energy is dark energy. 23% is dark matter. Dark matter is invisible matter, if I held it in my hand, it would go right through my hand. It holds the galaxy together. 23% of the universe is dark matter. Stars made out of hydrogen and helium makeup 4% of the universe.

And then what about us? Where do we arrogant humans, numero uno, where do we fit into the larger scheme of things? We make 0.03% of the universe. Let me repeat that again. We, the higher elements, we, made out of oxygen, carbon, nitrogen, tungsten, iron, we make up 0.03% of the universe. In other words, we are the exception. The universe is mainly made out of dark energy. The universe is mainly made out of dark matter. Overwhelming the stars, overwhelming the galaxies, in fact, and we only make up 0.03% of the universe.

The Future of Physics is You

So in other words, for you young aspiring physicists out there in the audience, you may be saying to yourself right now, why should I go into physics? Because you guys already have a candidate for the Unified Field Theory, right? Just realize that every single physics text book is wrong. Every single physics text book on the earth says that the universe is mainly made out of atoms, right? There it is. The universe is mainly made out of atoms. Wrong.

In the last ten years, we have come to the realization that most of the universe is dark and there's a whole shelf full of Nobel Prizes for the young people who can figure out the secret of dark matter and dark energy. I should also point out that there's a morality tale. Dark matter was first predicted by a woman, Vera Reuben, but she was ignored for 40 years because it was so incredible.

Dark matter, invisible matter, holding the galaxies apart? And that's a very sad story in my field, theoretical physics, because women often times are slighted and not given credit. The most famous example of this, by the way, was the case of Jocelyn Bell. She was a young PhD student in astronomy and she looked up in the heavens and a star was blinking at her. Stars don't blink. They twinkle because of imperfections in the atmosphere, but they don't blink like that. I mean, they don't blink regularly.

She catalogued this day after day, week after week, month after month. And then she made the biggest mistake of her life, she told her thesis adviser. Well, when it was time to write the paper, whose name came first? His name came first. He was the big shot, she was a lowly female grad student. When it was time to give talks around the world, who gave the talks? He did. And when it was time to win the Nobel Prize in Physics for the discovery of the pulsar, who won the Nobel Prize in Physics? He did. Not her.

What's the lesson here? The lesson is, if you in the audience ever discover something important—tell me first. I mean, I'm a generous man. I can find enough money for a subway token for you, I'll be the big shot physicist, I'll put my name first and hey, a subway token isn't so bad as a consolation prize.

The point I'm raising is, there's a whole shelf full of Nobel Prizes for those people who can discover what is making up 73% of the universe, dark energy. And what is dark matter, which makes up 23% of the universe? No one knows. String theory gives us a clue, but there's no definitive answer.

The thing about physics, or even science, that really intrigues me the most, is to find the most fundamental basis for everything. Rather than trying to massage a theory or make a theory prettier, why not find out why it works, what makes it tick? For example, let me give you something from the area of medicine.

I was reading an article once about breast cancer recently in the New York Times, and it mentioned a figure which I found absolutely startling. And that is, that 95% of the money going to breast cancer research does not go to curing breast cancer at all. It simply goes to massaging breast cancer, maintaining the established quo, polishing up existing therapies rather than curing it at the fundamental level. You know, when I was a kid, I still remember, people were talking about iron lungs. Polio was this horrible disease and there were people saying that one day we will have thousands of iron lungs over the United States. Whole villages of iron lungs, because we have to manage polio. But you know something? Jonas Salk went out there and cured the damn thing. Today we have no iron lungs, but we have something very similar. We have a cancer establishment that puts so much money in massaging cancer and only 5% of that money is earmarked to actually curing it. So that's the analogy in biology.

In physics, what we want is the fundamental theory that drives all these subatomic particles. It's hard to believe that nature could be so malicious to create a universe at the fundamental level based on thousands of subatomic particles and even the standard model is ugly. 36 quarks, 19 free parameters that you can adjust, 3 generations, Xerox copies of each other, 3 redundant copies of quarks. Why should nature be so redundant to create a fundamental theory that is not elegant, not beautiful, not simple, but horrible, but it works.

Being a physicist, we also have some insight into the energy picture of the future. First of all, solar power is very nice, but it's twice as expensive as fossil fuel technology on average. Therefore, if you bet the store on solar power, you're going to go bankrupt.

However, solar, wind, renewable technologies are going down in price every year. Fossil fuels are rising in price on average every year and the two curves should cross in about 10 years time. We don't know for sure, but when that happens, there's going to be a sea change. It means that it will be economically advantageous to go with solar, hydrogen, renewable technology.

For example, in Europe today, investors are buying up rights to the Sahara Desert. Not because they want to put solar panels in the desert, it's too soon for that. But in 10 years time, when solar does become cheaper, more efficient, with tax credits and mass production, in 10 years time, it's too late. Everyone will have rights to desert areas and put solar panels there. So the time to invest in solar is sometime between now, when it's still too expensive, and 10 years from now when it's too late. You want to get your foot in the door.

And then beyond that, fusion power becomes a possibility. The Europeans are bidding the store on the ITER fusion reactor based in southern France, 10 billion Euros from the European Union, also Russia, the United States, Japan, and Korea, to create the first fusion reactor in southern France and in 10 more years, by 2030, we hope to make it commercial.

So in 10 years, we could be entering the solar age, in 20 years, we'll enter the solar fusion age, when sea water, sea water is the basic ingredient for a fusion plant. Now, what about fission power? Fission power is the power of uranium. Fusion power is the power of the stars, the power of hydrogen. Uranium has a problem. When you split uranium, you create nuclear waste, tons of nuclear waste. That nuclear waste is hot. That heat is what's causing the meltdown in Japan even as we speak. In fact, it may take 30 years, according to the Hitachi Corporation, to bring that raging accident finally under control. 30 years is one of our best projections as to when we can finally put that reactor accident to rest.

Fission power has problems. First, meltdowns. Second, nuclear waste. Where do we put it? President Barack Obama has decided to cancel the Yucca Mountains Nuclear Waste Repository. So at the present time, the United States is suffering from a massive case of nuclear constipation. Nuclear waste is banking up at every single nuclear site. 104 of them in the United States with nowhere to put the nuclear waste.

Now, my attitude is, it takes about 10 years to get a new nuclear power plant to completion. In that 10 years time, solar becomes very competitive. So the economic climate changes. Now it may seem to be economical to build a nuclear power plant, but in 10 years time, solar becomes very competitive with fossil fuels, in which case, nuclear energy may be an idea whose time has come and gone.

Some people ask the question, "Professor, if you're finding the theory of everything, then what's in it for me? Everything is gone, right?" Wrong. There's several ways you can look at this question. Think of looking at a chess game for the first time in your life and you watch the two players move the chess pieces. If you've never played chess all your life, you can figure out the rules just by looking at the game. How pawns move, how kings move, and so after a while, you figure out all the moves. But does that make you a grand master? No. Finding out the rules of chess is like finding the Unified Field Theory.

We now know how particles move, we now know how every object in the universe moves. We know all the moves of matter and energy. That's the Unified Field Theory. So it's like figuring out the rules of chess, but does that make you a grandmaster? Does that make you a master of gravity? A master of electricity and magnetism? A master of the nuclear forces? No.

There's another way to look at this. Dark matter, dark energy, have been discovered in the last ten years, which have forced a revision in every single physics on the planet earth. This is embarrassing. Because we now realize the most of the universe is dark and we're clueless as to what they really are. Now, we have some hints, string theory says that dark matter may be a higher vibration of the string called sparticle. A sparticle is a super particle, but is not proven. Dark energy, even string theory, has a hard time explaining the magnitude of dark energy.

So once we understand dark energy and dark matter, we'll understand the Big Bang. Because what is driving the Big Bang, but dark energy. So once we understand dark matter, dark energy, we'll understand the birth of the universe and the death of the universe.

I'm a theoretical physicist. Being a theoretical physicist, my laboratory is my pencil. I can carry it on the bus, on the airplane, the train. My laboratory is my pencil.

And on one final note, let me say the following. That ever since I was a child, my role model was Albert Einstein and I had the rare privilege of speaking at the Einstein Centennial several years ago. And my favorite Einstein story is this:

When Einstein was an old man, he was tired of giving the same talk over and over and over again. So one day his chauffeur came up to him and he said, "Professor, I'm really a part time actor. I've heard your speech so many times, I've memorized it. So why don't we switch places? I will put on a mustache, I will put on a beard, I mean, I will put on a wig. I'll be the great Einstein, and you can be my chauffeur." Well, Einstein loved the joke, so they switched places and this worked famously until one day, a mathematician in the back asked a very difficult question.

And then Einstein thought, “Oh, the game is up.” But then the chauffeur said, “That question is so elementary that even my chauffeur here can answer it for you.”

Let me give some advice to you, if you are a young physicist, perhaps just getting out of high school, you have dreams of being Einstein, of dreams of working on string theory and stuff like that. And then you hit freshman physics. Let me be blunt. We physicists flunk most students taking elementary physics and we’re more or less encouraged to do so by the engineering department. We don’t want to train engineers who make bridges that fall down. We don’t want to create engineers that create skyscrapers that fall over. There’s a bottom line. You have to know the laws of mechanics. So before you can work with the laws of Einstein, you have to work with the laws of friction, levers, pulleys and gears.

So if you’re a young physicist, graduating from high school with stars in your eyes and you encounter freshman physics for the first time, take heart, if you have a rough time, that’s the way it is.

Thank you very much.

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