

# The Wonders of Physics 2020

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## Characters:

Cast	Characters
Clint Sprott	Himself
Pete Weix	Story Teller
Kimberly Palladino	The Tortoise
Michael Winokur	Justin
Robert Moskowa	Tim
Mike Randall	The Hare
Akire Trestrail	Frank Ein Stein
Terry Craney	Igor
Shimon Kolkowitz	Alphonse Einstein

## **Premise**

Sprott wants to find a way to slow down time so that we can work more leisurely on solving the great problems facing society. He falls asleep and dreams about time, eventually meeting Einstein's cousin who explains how to slow time, but it's too little and too late.

# Demo List

## Sprott (Opening)

- Rope to swing in on

## Kimberly (Motion)

- Faster than gravity stick
- High Track, Low Track
- Monkey and Hunter
- Drop and Shot balls
- Metronomes Synchronicity
- Pendulum wave demonstrator
- Bowling Ball vs Softball Pendulums ??

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- Liquid N<sub>2</sub> and balloon
- Existence of Absolute Zero
- Schlieren images
- Methane Bubbles
- Coffee Creamer

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## Terry & Akire (Electromagnetism)

- Ball with Copper tube
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- Guillotine\*
- Marx's Generator\*
- Can Crusher/Launcher \*
- EM waves (Tesla Coil) \*

## Shimon (Modern physics / relativity)

- Speed of Light
- Ballistic cart
- pair of alarm clocks
- muon scintillation

## Sprott (Closing)

- Liquid Nitrogen Cloud

# The Wonders of Physics 2020

“Physics of Time”

## **Opening** (Peter [Mic #2], Sprott [Mic #1])

**Lights:** Main Lights only

**Audio:** Science Songs

**(ON A&C) - Cameras 5 & 6:** {Crowd Shots on A & C }

**(ON B) - RGB {T1 Computer 1}:** PPT intro (Who will prepare this?)

**Lights:** Change to Stage & Floods

**Peter:** Welcome to the (318, 319, 320, 321, 322, 323, 324, 325, 326, 327) presentation of *The Wonders of Physics*... Before the show begins, I want to assure you we make all our demonstrations as safe as possible provided you remain in your seats. **(Last day only: You will also notice that we are videorecording the show. If you don't want to appear on the video or want your children to appear, don't volunteer for any of the demonstrations.)**

**Peter:** Now I'm going to read you a story:

**Action:** [ **“Peter”** takes out a large book with first words printed in giant gothic script, dust on text that must be blown off before we start ]

**Peter:** Once upon a time in the dark and dusty basement of the Physics building at the University of Wisconsin, an intrepid scientist was hard at work in his lab. One night he dozed off and began dreaming about the many problems facing society and how the physics of time might help us solve some of these problems. Who you may ask...of course it was our very own Professor Clint Sprott...

**(ON B) - {Lectern Computer 1 - PPT Slide #2}:** Sprott asleep in his lab

**Audio:** WOP Theme (short)

**Action:** [ **“Sprott”** bursts through the curtain, swinging on a rope anchored in the ceiling.]

**Sprott:** Welcome to *The Wonders of Physics*! I have been dreaming about the many problems facing society: climate change, the environment, energy, transportation, cyber crime... and it occurred to me that physics has a lot to say about these things. Most of the laws of physics involve time. If there were just a way to slow down time, we could leisurely pursue solutions to these pressing problems. I'm sure that my crack team of physicists could make that happen.

**Lights:** Down Quickly! { as Sprott exits Stage Left } { Pause }

**Lights:** Spotlights { On Peter }

**Motion** (Kimberly [Mic #3]) (Kim should ask an audience member to retrieve the balls safely before the show)

*Lights: Spotlights { On Peter }*

**Peter:** Yes, the World is facing great problems, but many people believe that we have plenty of time, and if we do nothing, everything will be just fine. And the idea of slowing down time is simply ridiculous. Meanwhile, Professor Sprott's mind was racing, but he dreamed of going slow, at the pace of a tortoise.

**(ON B) - {Lectern Computer 1 - PPT Slide #4}: { Sprott asleep in his lab}**

**Action: [Peter moves the pendulum rope away from the stage]**

*Lights: All*

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*Audio: Intro to Happy Trails*

**Action: [ Kim walks in as a tortoise ]**

**Kim:** I'm definitely eager to help slow down time, then it can match my speed. But before we needed to measure time, we could always compare the times when things happen: what comes first, and what comes last, and when things happen at the same time. As a tortoise I'm famous from some races, so let me be in charge of a few.

**(On A & C) -- Camera 6**

**Demo: {Faster than gravity stick} {Stand beside the demo so everyone can see}**

**Kim:** For instance, this lever arm is balancing on this stick, and I put a ball on the golf tee on the tip. I'm going to remove the stick to make everything fall. If they fall together the ball will stay on the tee, if the ball goes faster it will get under the lever, and if it is slower it will land in this cup. Oh boy, to make this work, I have to go fast, that's hard for me, here I go:

*Audio: TaDa*

**Kim:** Let's see these in slow-motion...

**(ON B) - {Lectern Computer 1 - PPT Slide #6}: Slow-motion video { prerecorded }**

**(On A & C) -- Camera 6 -Move**

**Demo: {Racing balls - High track, Low track}**

**Kim:** Let's see these two balls race now across these two paths. They are going to cover the same horizontal distance, will one make it back faster?

**Action:** *[ Kim gets a volunteer ] ??*

**Kim:** The balls that drops picks up energy and goes faster for more of the distance and makes the round trip first.

**Audio:** *TaDa*

**Demo:** *{Hunter and monkey}*

**Kim:** You all know the story of the race between the tortoise and the hare. Do you remember why the hare lost? *{audience answers}* Do you want to know how I really won? Let me demonstrate. I aim a ball directly at the hare, and he will begin to race at the same time I shoot the ball. Let's see what happens: I knocked him off the course. I'm slow and steady... and I know how to use physics to win a race.

**Audio:** *TaDa*

**Kim:** Let's look at that in slow-motion.

**(ON B) -** *{Lectern Computer 1 - PPT Slide #8}: Slow-motion video { prerecorded }*

**(On A & C) -- Camera 6**

**Demo:** *{Drop and Shot Balls}*

**Kim:** Let's look at this situation in a different way. Here are two balls, that I am going to release at the same time, this one will fall straight down, and this will get shot to the side, but listen to the sound of them hitting the ground: will there be two separate clacks, or just one?

**Audio:** *TaDa*

**Kim:** and in slow-motion

**(ON B) -** *{Lectern Computer 1 - PPT Slide #10}: Slow-motion video { prerecorded }*

**Kim:** Gravity acts on the balls in the vertical direction the same, so they hit the ground at the same time. That's also what happened with the hare and the ball. Now, the middle of the lever arm also fell as fast as gravity accelerated it, but it is attached to a long arm, and at the end it has to travel further in the same time, so it fell faster vertically, which is how the cup caught the ball. *{ Someone retrieve the balls - Peter }*

**(On A & C) -- Camera 6: #1**

**Demo: {Metronome Synchronicity}**

**Kim:** What if we want to sync things up that otherwise would act at different times, These metronomes all have the same period to tick, but start offset in time with each other, by putting them on a board that can roll they can transfer momentum to each other and synchronize.

**{Talk over the metronomes as they sync up ~ 60sec.}**

When they sync up, we'll have a "shell"-abration. As long as this isn't a "turtle" disaster. This really is a fine "shell"ection of metronomes. I hope all of you will think this demonstration has "tortoise" something. In tortoise circles, I'm a minor "shell"-ebriety. Wow, maybe I have found a way to slow down time: we just need to tell bad puns, or watch metronomes get in sync. Imagine how slow it would be if we watch paint dry, or pots boil. I'm a wonderful chef, but you might call me a slow cooker. I'm also a wonderful photographer, my specialty is "shell"fies.

**{ Pause for the TaDa }**

**Audio: TaDa**

**(On A & C) -- Camera 6: #2**

**Demo: {Pendulum Wave} { Viewed on screen }**

**Kim:** Metronomes work a little like upside down pendulums, and one of the rules of pendulums is that it is only their length that determines how long it takes them to go back and forth called a period. Here is a row of pendulums with different lengths, and they start in sync, but then will come in and out of it. Let's see what this looks like: **{ ~60sec }**

**{ Pause for the TaDa }**

**Audio: TaDa**

**Kim:** You may know that 2020 is a leap year, and that's a lot like those pendulums, the period of a year for the earth to go in orbit around the sun is not a multiple of the period for the earth to rotate on its axis for a day, so we add leap days to bring them back into sync!

**Demo: {Bowling Ball vs Softball Pendulum}**

**Kim:** Let's look at another pendulum now. No matter how far I pull it back, it will have the same period. If it's short (one one thousand two one thousand etc.), or if its long (one one thousand, two one thousand.

**Audio: TaDa**

**(ON B) - {Lectern Computer 1 - PPT Slide #12}: Grandfather Clock**

**Kim:** A pendulum is useful beyond demonstrations; it makes an excellent way to measure time, used **in clocks** for a long time. I'm sorry I didn't slow time down, but at least we have a way to measure it!

**Audio:** *Intro to Happy Trails*

**Action:** [ *Kim walks out as a tortoise* ]

**Audio:** *TaDa*

## **Heat** (Michael [Mic #4] & Robert [Mic #5])

*Lights: Spotlights only { On Peter }*

**Peter:** Yes, we can measure time and use it to predict the motion of falling bodies. But it was Isaac Newton who wrote down the equations of motion that we use even today. However, there was a strange thing about his equations; they worked just as well backward in **time as forward**...

**(ON B) - {Lectern Computer 1 - PPT Slide #14}: Two-body collision -Forward**

**(ON B) - {Lectern Computer 1 - PPT Slide #14}: Two-body collision -Reverse**

**Peter:** Wouldn't it be nice if we could just turn the clock back and undo our mistakes! Alas, some things in physics suggest that **that's not possible**...

**(ON B) - {Lectern Computer 1 - PPT Slide #15&16}: Movie clip of an irreversible process - multi-body collision on the air table)**

**Peter:** And then it began, night sweats...a **nightmare**...

**(ON B) - {Lectern Computer 1 - PPT Slide #18}: Movie: Sprott Tossing & Turning with voice over  
{Sprott on video tossing and turning with perspiration on his forehead}**

*Audio: ???*

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*{Michael appears}*

**Michael:** Greetings! We are but colleagues of Lord Kelvin, Justin (M) and Tim (R), at everyone's service.

**(ON B) - {Lectern Computer 1 - PPT Slide #20}: Lord Kelvin**

**Robert:** **Lord Kelvin** is master of all things thermodynamic, hot and cold, order and disorder. Professor Sprott looks to be in a bad state, I can see we have come "Justin Tim".

**Michael:** No, no, no.....its "Just in Time"!

**Robert:** I like Tim more....and speaking of time, hot and cold, order and disorder, speeding up and slowing down, everything involves time and that includes thermodynamics.

**Michael:** Yes, and we have many ways to show that.

**Robert:** To demonstrate, we will use our favorite card game....52 pick up.

**Michael:** It is a perfect example of order and disorder.

**Robert:** Here is how it works. A deck of 52 cards in a neat and ordered state but now

**Action:** [ *Michael takes the leaf blower and shoots a stream of cards over Bob's head* ]

**Michael:** And wah-lah.....now disordered. And that only took a short time. Maybe if we wait a bit the cards will order themselves and go "Back in Tim".

**Audio:** 60-Minutes

**(ON B) - {Lectern Computer 1 - PPT Slide #22}: Newton's Laws**

**Michael:** Maybe not...(sigh). That was an example of an "irreversible process" and we can't run the clock backwards. But some things look disordered and they actually aren't. Unlike quantum physics **Newton's Laws**, as we just heard, **can** be made to go backwards.

**(On A & C) -- Camera 6: #1 - move**

**Demo:** {Reverse Mixing}

**Tim:** An example of this is our "Reverse Mixing" demonstration.

**Michael:** You can now see that Tim is just taking the time to "draw" a pair of vertical colored lines in this large liquid filled cylinder.

**Peter:** {*Peter comes with a push broom & reluctantly sweeps the cards under 1st table*}

**Action:** [ *Mix* ]

**Robert:** And I can "mix" them by slowly turning this handle while Justin and our audience counts out the number of turns...(one, two, three)...

**Michael:** They sure look mixed up now...I know I am...

**Action:** [ *UnMix* ]

**Robert:** But, let's run things slowly backwards...counting 3, 2, 1 and the line reappears.

**{ Pause for the TaDa }**

**Audio:** TaDa

**Robert:** Glycerine, which is much thicker than water, preserves the path taken. Just as bread crumbs in the old fairy tale "Justin and Tim".

**Michael:** Huh?????...Try "Hansel and Gretel". And what about hot and cold, you may ask how they relate to Tim.

**Robert:** Would you kindly leave my relatives out of this, just say "time"?

**Michael:** Fine.... things that are hot tend to move faster and expand while things that are cold move slower and shrink. And for that you need to measure the changes with time.

**Robert:** Let's not short change our audience and give them examples.

**Michael:** Sure, how about this, I bet I can get this big balloon to fit into this container.

**Robert:** Oh, that's easy.....

**Action:** [ *Bob pops the balloon with a pin....*]

**Audio:** *TaDa*

**Michael:** Hey, that's cheating Tim.

**Robert:** Fine, then you do it.

**(On A & C) -- Camera 6: #3**

**Demo:** {*Shrink Balloon w/LN2*}

**Michael:** I can and I will. Here is another balloon. By slowing down the air molecules inside using liquid nitrogen the balloon will shrink because the air pressure on the outside stays steady at 1 atm. This happens when I pour the liquid nitrogen, at a cool minus -321 Fahrenheit, on top of the balloon. (*Balloon shrinks.*)

**Audio:** *Balloon sounds???*

**Michael:** And this is a reversible process. All I have to do is warm the balloon up (*Take balloon out and let it start warming up.*) and it will return to its original shape.

**Audio:** *TaDa*

**Robert:** Shrink, shrank, shrunk....but what about time?

**Michael:** Cold things move more slowly, and so everything takes more time. In fact there is a special temperature, absolute zero in degrees Kelvin, at which all thermal motion stops, and so it will take forever to do anything.....

**Robert:** Yeah, that sounds about your speed.

**Michael:** Very funny.....and to help show this physics we need three volunteers from our

audience. *{ Robert chooses three volunteers, they come down and act out a gas molecule at high, low and at absolute zero }*

*Audio: TaDa { as volunteers leave }*

**Robert:** Those were nice moves....but can you demonstrate that absolute zero even exists?

**Michael:** Well, we actually had a demonstration for this, but to tell truth, it just took too long....

**Robert:** Well I sense a brain freeze in all this, how about speeding things up.

**Michael:** Sure, we can speed things. First, just a little by heating some air.

**Robert:** But can we actually see the hot air?

*(On A & C) -- Table 3, Video 1*

*Demo: {Schlieren Effect}*

**Michael:** Seeing is believing, it just takes a little smoke and mirrors. For this demonstration we need a light source and a camera. Then we will use this mirror to observe the Schlieren effect. This heat gun will warm the air. Hot air is less dense the surrounding air and so it both rises and causes the light beams to bend. People see this when driving in summer on the road; it is often called a mirage.

*Audio: TaDa*

**Robert:** I see the mirror but no smoke.

**Michael:** Smoke....okay....it also works with a burning match. See the smoke? Now I will put it just under the mirror and you can again see the Schlieren effect.

*Audio: TaDa*

**Robert:** And can we move air even faster?

**Michael:** Of course we can, how about some hot gas bubbles?

**Robert:** On no, I think I know where this is going. Lord Kelvin may not approve.

*(On A & C) -- Camera 6 or Camera 2: #1*

*Demo: {Methane Bubbles}*

**Michael:** Well, he can complain all he wants from his current location...which is far, far away.  
*{Michael turns on the gas}.*

**Robert:** And anyway, all the children I know love bubbles...

**Michael:** I'll just turn on the methane gas and soon we will see lots of pretty bubbles. We use methane or natural gas all the time in our homes for cooking and heating. Just a bit longer.

**Robert:** But you said something about making the air move faster.

**Michael:** Well that's what this candle is for. Hot air, faster gas molecules, and a very irreversible process. Parents, please don't let your children try this at home.

*Audio: TaDa*

**Robert:** Actually, that was fun. Do we have any other ways to make the air move quickly.

**Michael:** I do if you like creamer in your coffee.

*Demo: {Coffee Creamer}*

**Robert:** I like cream but I'm not so fond of coffee creamer

**Michael:** Oh...so that's how you feel. We can show a good way to get rid of it. There is already a mound of coffee creamer in this funnel. I'll just start the burner and then a simulated dust explosion.

**Robert:** And so with one good blow.

*Audio: TaDa*

**Michael:** Let's see what that looks like **if we slow down** Tim, er... I mean time.

**(ON B) - {Lectern Computer 1 - PPT Slide #24}: Slow-motion video of creamer explosion { prerecorded }**

**Michael:** Maybe a good hot cup of coffee, without creamer, will calm Professor Sprott when he finally wakes up.

## **Sound** (Mike R. [Mic #6])

**Lights: Spotlights only { On Peter }**

**Peter:** Another day and another story. So having dreamed of the tortoise, Professor Sprott began to dream of a hare...

**(ON B) - {Lectern Computer 1 - PPT Slide #?}: {Slide of Sprott asleep in his lab}**

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**Mike R:** *(voice offstage)* I'm late! I'm late!

**Audio: William Tell Overture (short)**

**Lights: All**

**Mike R:** *(runs in, out of breath, dressed as the White Rabbit)* Whew! I don't think I'll EVER catch up! Did you notice it go by?

**Mike R:** *(interacting with audience)* What went by? Why, my voice, of course! It's been outrunning me all day. Do you know how fast sound goes? No? Let's find out!

**Mike R:** As we've already learned, anything involving speed involves time. Speed is how far something travels divided by how long it takes to get there.

**(On A & C) -- Table 2, Computer 1 - O-Scope**

**Demo: {Speed of Sound}**

**Mike R:** Hear that clicking sound? Those clicks are coming from that speaker *(pointing)*. And they show up on my oscilloscope as a yellow spike *(pointing to projector screen)*. On the other side of the room *(pointing)* is my Lightning McQueen umbrella! For today, it's not an umbrella, but a collector. It's focusing the sound clicks onto a microphone *(pointing)*. Sound picked up by the microphone shows up on my oscilloscope as a blue squiggle *(pointing to projector screen)*. Notice that the yellow spike and the blue squiggle show up at different places on the screen. That difference is **TIME** - the time it takes for sound to go from the speaker to the microphone.

**Mike R:** The distance between the speaker and microphone is about 15 meters. So to get the speed of sound, we divide that distance by the **TIME** it takes for the sound to cross that distance. Looking at the oscilloscope, the time is 44 milliseconds, or 44 thousandths of a second. *(Picking up a calculator)* So 15 meters divided by 44 thousandths of a second means the speed of sound is about <340> meters per second, or <767> miles per hour.

*Audio: TaDa ??*

**Mike R:** That's more than the length of **THREE** football fields in one second! Including the end zones! Do you think you can run that fast?

*Demo: { Barsoom }*

*{{(time, frequency, and the speed of sound in different gases)}}*

**Mike R:** For my next demonstration, I need a helper from the audience. I have a wood whistle, and four balloons, each with a different gas.

**Mike R:** The particular note we hear from this whistle depends on **TIME**. How much time does it take for sound waves to bounce back and forth inside the whistle? That determines how many sound waves come out of the whistle in a second. Scientists call that **FREQUENCY**, and measure it in waves per second, or Hertz.

**Mike R:** So why the four balloons? The speed of sound depends on a lot of things, including what the sound wave is traveling through. Here's what the whistle sounds like with air going through it *(Open up the valve for the air balloon)*.

**Mike R:** Hear that? OK, my next balloon is filled with helium. It's a very light gas. What do you think will happen? *(Open up the valve for the helium balloon)*.

**Mike R:** The pitch, or **FREQUENCY**, is **HIGHER!** Because helium atoms are lighter, they move much faster than air molecules at a given temperature. Faster atoms means they can move back and forth faster in the whistle, making more sound waves per second - a higher frequency!

**Mike R:** This balloon is filled with carbon dioxide. Do you think it's lighter or heavier than air? Let's listen *(Open up the valve for the CO2 balloon)*.

**Mike R:** The pitch sounded a little **LOWER** than for air, so the carbon dioxide molecules must be a little **HEAVIER** than air. Speaking of, let's try this balloon, filled with really heavy sulfur hexafluoride *(Open up the valve for the SF6 balloon)*.

**Mike R:** Those molecules are REALLY heavy compared to air! So the speed of sound is much slower, and we get fewer waves per second.

*Audio: TaDa*

**Mike R:** Do you like races? What do you think will take less time? A sound wave? Or *(holding up a ping pong ball)* a ping pong ball? Here is our famous ping pong ball cannon. *(turning on the vacuum pump)* See the ball inside? Both ends are sealed with plastic,

and we're pumping out the air. When I pop the plastic on this end, the air will rush in, pushing on the ball.

**(ON B) - {Lectern Computer 1 - PPT Slide #?}: Sir Isaac Newton**

**Mike R:** By Sir Isaac Newton's Second Law of Motion, when you apply a force to a mass, the mass will accelerate, which means to change its speed or direction. Air rushing in will push on the mass of the ping pong ball, causing the ball to speed up RAPIDLY, crashing into the aluminum can at the other end.

**Demo: {Ping Pong Ball Bazooka } {w/sound trigger video system}**

**(On A or C) -- Table 2, Video 1**

**(On A or C) -- Camera 6: #3**

**Mike R:** Our race will have a photo finish. A special microphone here will pick up the sound of the plastic popping, and a moment later will set off a camera flash. Let's see what happens! We're going to turn the lights off now. **(Bring house lights down)** This will be loud, so cover your ears. 5-4-3-2-1! **(trigger camera shutter, then quickly push the plunger. Bring house lights back up )**

**Audio: TaDa**

**Mike R:** Let's see what happened! **(Examine the remains of the aluminum can)** Look! We blew a hole clear through the can! And the ping pong ball was completely destroyed! Let's see the photo finish! **(Set camera to Play mode)**

**(On A or C) -- Table 2, Video 1**

**Action: [ Replay photo from camera ]**

**Mike R:** Our camera flash was triggered by sound. But we had to add a delay. The sound wave only took about 11 thousandths of a second to arrive. From a standing start, the ping pong ball took about 18 thousandths of a second to get here. **That's REALLY fast, but sound is the winner in this race!**

**Audio: Woman's voice -- {Hey! Where are you? You know I can't start dinner until you bring those carrots home! Quit dawdling! I'm hungry!}**

**Mike R:** Oh my gosh! I'm late...for DINNER! **{Grabbing carrots from guillotine demo}** Coming my little snuggle bunny! Coming!!!

**Audio: William Tell Overture (short)**

**{Runs offstage}**

## Electromagnetism (Akire [Mic #4] and Terry [Mic #5])

**Lights: Spotlights only { On Peter }**

**Peter:** Yes, sound travels very fast, but some things seem to happen immediately. When I flip this switch, *{light switch demo}* the light comes on right away *{demonstrate}*. But even electricity takes time to act... **And in his sleep**, Professor Sprott was dreaming about the speed of electricity and it's many consequences.

**(ON B) - {Lectern Computer 1 - PPT Slide #?}: {Slide of Sprott asleep in his lab}**

**Lights: All**

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*{Akire and Terry walk on stage. Terry turns on Marx generator. Akire dressed in an old 19th century outfit and Terry dressed as a mad scientist, "Igor," holding a bubbling beaker of warm H2O and dry ice. He drinks the water (will need dry ice pellets)}*

**Akire:** I'm Professor Stein - first name Frank. *{Akire turns to audience and asks}* What do you think my middle initial is? *(Audience yells "N"!)* No not N but EIN!- Frank EIN. Stein. My father is Frank N. Stein! And You? *(turning to Terry)*

**Terry:** I am Professor Sprott's worst nightmare, Igor.

**Akire:** Whoa, snap out of it, Igor!! This isn't the nightmare dream sequence, it's the dream sequence exploring the physics of time!!

**Terry:** Wow, that was weird. I think I'm back now. I still may prefer the nightmare dream sequence!! Oh well there's always tomorrow night!! *{Terry turns to audience} (Terry chuckles menacingly)*

**Akire:** Oh Igor!! I can't wait to see what you have in store!! But for this dream, *(toggle switch on and off)* let's consider what Peter just pointed out!! The lightbulb certainly does turn on very quickly when the flip is switched. But as it turns out, it's not instantaneous!!

**Akire:** Well let's explore this phenomenon of the lightbulb appearing to turn on instantly, when it is in fact not instant; to better help Professor Sprott with the idea of slowing time down. The light bulb turns on because charged particles in the wires convert their electrical energy into light energy.

**(ON B) - {Lectern Computer 1 - PPT Slide #?}: {Slide of charges/current flowing in circuit}**

**Akire:** Why do the charged particles do that? Well because they do whatever electric and magnetic fields tell them to!!

**(ON B) - {Lectern Computer 1 - PPT Slide #?}: {Slide of electric and magnetic fields}**

**Akire:** These fields can travel extremely fast!! So fast that they can circle the entire Earth seven and a half times in a second!! So when the flip is switched, (*toggle switch on and off*) these fields travel from the power plant (the energy source) to the lightbulb so quickly, that to us, the lightbulb seems to turn on in an instant!!

**EM wave simulation:**

<https://phet.colorado.edu/en/simulation/legacy/radio-waves>

**Akire:** Now that we have some insight into how the speed of these fields can affect our perception of time, shall we explore some more exciting features of what these fields can do to charged particles?

**Akire:** Oh I love the enthusiasm - but first, did you hear about the woman who fell into the infinity pool at the local hotel? It took her forever to get out.

**Audio: Rim Shot**

**Akire:** Oh, that reminds me, I heard two atoms talking the other day!! One said, "I think I lost an electron. The second said, "Are you sure?" The first said, "Yes, I'm positive."

**(ON B) - {Lectern Computer 1 - PPT Slide #?}: {Slide showing atom, ion and liberated electron}**

**Audio: Rim Shot**

**Demo: {Copper Tube & Ball}**  
**(On A & C) -- Camera 6 -Move**

**Terry:** Ah I like that joke!! But before we start our demonstrations and speaking of time, did you hear about the three people, the past, the present, and the future who walked into a bar? It was a little tense.

**ON B) - {Lectern Computer 1 - PPT Slide #?}: {Slide showing words past tense, present tense and future tense}**

**Audio: Crickets**

**Terry:** Ah, tough/great room!! So now let's look at this copper tube and a steel ball as I drop it through the tube - pretty much free falls, right. But now I am going to slow down time! I am going to replace the ball with another ball, a different ball. Watch what happens – (ball drops through much slower, takes a longer period of time.)

**Audio: TaDa**

**(ON B) - {Lectern Computer 1 - PPT Slide #?}: Slide of Faraday's Law**

**(ON B) - {Lectern Computer 1 - PPT Slide #?}: Slides of Lenz's Law**

**Terry:** What happened? Is gravity different now? No, I replaced the metal ball with a magnetic ball. A basic law of electricity and magnetism, called **Faraday's Law**, says that a moving magnet, the ball, creates a current in the conductor- we say it induces a flow of electrons- in the tube. This is how most household electrical current is produced. Now copper is not normally magnetic but another electromagnetic law, called **Ampere's Law** says that the induced current creates a magnet in the copper tube. And finally a third law, called **Lenz's Law**, states that the new magnet acts in opposition to the original magnet and slows down the ball – like two bar magnets opposing one another. Wow, a moving magnet can create an electric current and an electric current can create a magnet. Isn't physics fun! The magnetic ball falls much slower – takes a much longer time to fall.

**Terry:** And oh by the way, did you hear about the hungry time traveler? She went back four (for) seconds.

**Audio: Crickets**

**(On A & C) -- Camera 6**

**Demo: {Jumping Ring} Part I**

**Akire:** Thank you Igor, your demo was better than your joke though!! I have another demonstration using that same principle of **Faraday's Law**!! I have an aluminium ring here which certainly isn't magnetic, yet if I place it over this coil with several hundred turns of wire, connected to the wall socket. If I turn it on, and energize the coil, it will induce an opposing current in the ring. Both will then act like magnets, and we'll see what happens. **{demonstrate}** Oh that was fast!! Shall we try it again?! **{demonstrate}**

**(ON B)** - *{Lectern Computer 1 - PPT Slide #?}: { Slide Faraday's Law }*

*{Ring jumps up.}*

**Demo: {Jumping Ring} Part II**

**Akire:** Would you like to see it go even higher?? Awesome!! Well if I place this iron cylinder over the coil, the iron concentrates the magnetic field causing the ring to jump higher!! So let's try it with the iron!! *{demonstrate}* Well that certainly went higher!!

**Demo: {Jumping Ring} Part III**

**Akire:** Would you like to see it go higher yet again? Well if we cool the ring down to liquid nitrogen temperatures, that allows the ring to become a better conductor of electricity!! Most materials become better conductors of electricity when they are cooled down. With more current, the ring becomes a stronger magnet, *{demonstrate}* causing it to jump higher!!

*{Ring jumps to medium height}*

**Audio: TaDa**

**Demo: {Jumping Ring} Part IV**

**Akire:** Shall we try that again? What's that? WITH the iron cylinder this time? *{as I look to the ceiling}* I hadn't thought of that - well anything for science!! Let's see what happens!! - *{demonstrate}* Wow, we almost hit the ceiling!!

*{Ring jumps to ceiling}*

**Audio: Charge [ as I look to the ceiling ]**

**Audio: TaDa**

**Terry:** Well that was an OK demonstration, right? (Thumbs up) But do you think we can do better than just OK. Let's see these two laws applied on another apparatus –

**Demo: { Guillotine } -Start**

**Terry:** What is this machine called? A guillotine?? Is that what you call it? Well here in the UW Physics Department's it's known as a vegetable chopper. And if you order in the next 30

minutes free shipping is included. Demo by cutting carrots (warn large noise). (Hold up cut carrot end.) Viva la carotte! Long live the carrot!

*{Blade drops in free fall and cuts the carrots}*

*(On A & C) -- Camera 6*

*Demo: {Guillotine} Part I*

**Terry:** Watch what happens when I add a few magnets toward the bottom of the frame. Again the copper blade is not normally magnetic, but the magnets cause a current in the moving blade, which in turn causes an opposite magnet and slows down the blade so that it hardly dents the carrot.

*{Blade slowly drops}*

*(On A & C) -- Camera 6*

*Demo: {Guillotine} Part II*

*Audio: TaDa*

**Terry:** During the French Revolution if someone was condemned to the guillotine, just make sure they have huge magnets on the back of their shoulders. Physics saves lives!

*Demo: {Marx Generator} Part I*

*(On A & C) -- Camera 6 or 5*

**Akire:** That's pretty cool!! I guess they could have used you during the French Revolution!! Well, let's turn our attention now to what happens if we take some time to let charge build up but then release all of the charge in a mere fraction of a second!!

**Akire:** With this particular capacitor, each of these individual capacitors can store up to 50 thousand volts, and there are 10 of them for a total of half a million volts!! That's a lot of charge that we will be releasing at once!! In fact when all this charge is released at once it creates one of the most powerful forces in nature!! Focus your attention where Igor is pointing to observe where the effect will be the most drastic!!

**Akire:** We'll take about 10 seconds to build up the charge before releasing them all at once!! Are we all ready? ***Please cover your ears for this one as it will be really loud!!***

**Akire:** Let's all count down together: 10, 9, 8, remember to cover your ears, 5, 4, 3, 2, fire in the hole!!! *{turn off switch}*  
*{POP!}*

*Audio: TaDa*

**Akire:** Wasn't that neat!! We just created lightning indoors!! Who said physics wasn't amazing?! Where else will you be able to safely see a lightning bolt this close up?!

## Demo: {Marx Generator} Part II

**Akire:** But let's not forget, we're in a dream!! So let's repeat the demo, but try to be more explosive this time!! Let's put a piece of wood in the path of the charged particles!! Unlike metals, wood does not let charges flow through it readily. But remember, we have half a million volts of charge trying to flow through the wood!! What will happen??

**Akire:** *Again, cover your ears for this will be loud!!* Let's count down together again... 10, 9, 8, remember to cover your ears, 5, 4, 3, 2, fire in the hole!!! {turn off switch}  
{POP!}

Audio: TaDa

**Akire:** Now, I think, more than ever, we can appreciate the advice of not sheltering beneath a tree during a thunderstorm!! Being under a tree that gets hit by lightning will not be pleasant!!

(ON B) - {Lectern Computer 1 - PPT Slide #?}: Tree/

Demo: {Can crusher/launcher}

**Terry:** Well, making a lightning bolt inside this room is fine, but let's talk sports now and have some audience participation in just a few moments. Let's start by looking at another type of capacitor that can store electrons up to 5000 volts. I have a soda can in this copper coil. It takes a few seconds to build up the charge in the capacitor. I will then release the stored electrons into the copper coil. That current will cause a magnetic effect in the coil and create a current in the can and an opposing magnet. Let's watch!-- (Do 1st demo- can crusher) Wow it crushed the can, we made an electronic can crusher. And again we will be selling these machines for home use in the lobby after the show! Not really just kidding. But as you can see-- "We can crush a Crush can with this can crusher". Whew, say that fast three times.

Shall we do it again? OK, now let's do a second demo with a baseball variation. Before the show started, I asked for an assistant to help me. (Name) is in the third row with a baseball glove. (Do 2nd demo- can launcher)

Audio: Ball game

Audio: TaDa

**Terry:** Ask temperature of the can? (person who catches can)-- This is the basic principle behind an induction stove top burner-- the pan heats up without the stove top getting hot.

Before we do our last demonstration, do you want to hear another atom joke? OK, did you hear about the neutron that walked into the bar , ordered a drink and asked how much it was. The bartender said " for you no charge"!

**(ON B)** - *{Lectern Computer 1 - PPT Slide #?}: Slide Tesla*

**Akire:** Finally, let's look at this large cage-called a Faraday Cage- and this apparatus called a **Tesla coil**. I need a brave volunteer from the audience, who hasn't been up here yet.

*(Volunteer)*

**Akire:** And your name is? Well (state name), don't worry about how intimidating our electric chair looks. It's completely safe, if you don't put your fingers through the holes.

**Audio: Doom march**

**Akire:** (state name), go ahead and follow Igor into the electric chair, uhh I mean completely safe Faraday Cage!! *{turn to audience mischievously}*

**Akire:** Now to really make this demo pop, let's turn down the house lights...

**Lights: ??**

**Audio: Charge**

**Audio: TaDa**

*{Tesla coil}*

**Akire:** Thank you (insert name) for being so brave!!

*(Thank volunteer)*

**Akire:** Now isn't it interesting that the Tesla Coil has twice the voltage as the Marx generator, yet (insert name) was safe in the Tesla Coil, whereas the piece of wood in the Marx generator was blown to pieces?? Why would that be?? Well it's because charges prefer to stay on the outside of metals, and so (insert name) being on the interior of the cage, meant that none of the charges were interested in going to (insert name). This is why being inside a car or even an airplane is quite safe during lightning storms

**Akire:** So as you can see, time is a very important factor in electricity and magnetism. We can't just slow it down. It would be difficult, if not impossible, to change time.

**Terry:** And remember, "Time is what keeps everything from happening at once."

## **Modern Physics** (Shimon [Mic #3], Sprott [Mic #1])

**Lights: *Spotlights only { On Peter }***

**Peter:** Electricity and magnetism move at the speed of light, and nothing can move faster than that, but why? And how can it be that two people, one moving very fast and the other at rest, could measure the same speed for a beam of **light passing them by?** Grappling with these puzzles, Professor Sprott dreamed of Albert Einstein and awoke with a start.

**(ON B) - {Lectern Computer 1 - PPT Slide #?}: (Video of Sprott waking up and bolting to his feet)**

**Lights: *All***

**Action: [ *Sprott rushes in, a bit disheveled and still groggy from having just awoken. ]***

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**Sprott:** Oh, I was working in my lab and fell asleep, and I had these really weird dreams about the physics of time. And just as I was waking up, I thought I saw Albert Einstein ride by on a bicycle! But I must have been dreaming because he's been dead for a really long time.

**Action: [ *Shimon rides in on a bicycle, dressed as Einstein. ]***

**Sprott:** Oh, it wasn't a dream! You look like Albert Einstein. But didn't you die in 1955?

**(ON B) - {Lectern Computer 1 - PPT Slide #?}: Slide Albert Einstein**

**Shimon:** You're thinking of dear old Albert. You know, people say we look alike, but I don't really see the resemblance. I'm his American cousin, Alphonse Einstein. But you can call me Al.

**Audio: *Call Me Al***

**Sprott:** Didn't Albert Einstein marry his cousin?

**Shimon:** Yes, but not me, that was our mutual cousin Elsa.

**(ON B) - {Lectern Computer 1 - PPT Slide #?}: Slide Albert Einstein with Elsa Einstein.**

**Shimon:** And I'll tell you, it sure made the family reunions interesting.

**Sprott:** Well Al, I suppose you'll have to do. I'm really desperate to find a way to slow down time, and these other scientists haven't given us much hope. You're our last resort. Can you help us solve this problem?

*{Sprott recedes into the background and disappears.}*

**Shimon:** Of course! In fact, it's as easy as riding a bicycle! You see, what my dear cousin Albert realized is that time, much like his second wife Elsa, is relative. His revolutionary theory of relativity taught us that how fast time passes for you compared to for someone else depends on your relative speed, or velocity. And to prove it you only need two basic principles. The first is that the speed of light is always the same no matter how fast you're going. We've already heard about the speed of light from Professor Frank E. Stein and Igor, but we haven't actually seen how to measure it. Here, let me show you.

*Demo: {Curly light pipe with green laser pointer}*

*Demo: {Speed of light}*

*(On A & C) -- Table 1 Computer 1*

*(On A & C) -- Camera 1*

**Shimon:** So even though light moves very fast, it still has a finite velocity. The strange thing is that it doesn't matter how fast I'm moving or in what direction, if I do this experiment I'll always get the same answer. In fact, the Earth is currently whizzing around the sun at about 67,000 mph, and the sun is currently whizzing around the center of the galaxy at ~450,000 mph, but it doesn't matter which direction I measure in, the speed of light will still be the same. This brings us to **Albert Einstein's** second principle, which is actually very simple and easy to understand, and to explain it I'd like to do an experiment with you all. Imagine you're on a train, and the train is stopped at the station. Now suppose you toss a ball straight up in the air like this:

*(ON B) - {Lectern Computer 1 - PPT Slide #?}: Slide Albert Einstein ??*

*Demo: { Ballistic Cart } -start*

*(On B) -- Apple TV - Lec. Computer 2*

*(On A & C) -- Camera 5*

*{First Shimon sets off the cart without it moving, and the ball falls straight back down.}*

**Shimon:** The ball came right back down and landed on the launcher, and on a stopped train it would land right back in your hand. Not too surprising. But now imagine that the train leaves the station, and is moving at a constant speed, and you're facing forward towards the train's engine. Suppose you toss the ball straight up in the air again. How many of you think the ball will land in front of you? How many think it will land behind you? And how many of you think it will land right back in your hand again?

*(On B) -- Apple TV - Lec. Computer 2*

*(On A & C) -- Camera 5*

*Demo: { Ballistic Cart }*

*Audio: TaDa*

**Shimon:** The ball landed right back on the launcher again. And in the train, the ball would land right back in your hand again. That's because before you throw it, your hand and the ball are already moving with you at the same velocity as the train. **As you can see in this video**, if you're moving with the train, it's as if the train isn't moving at all. This is the second key principle of Einstein's theory of relativity. If you're moving at a constant velocity, the laws of physics will be exactly the same as if you're not moving at all, no matter how fast you're going! And believe it or not, those two principles, that the speed of light is a constant and that the laws of physics are the same no matter how fast you are going, are all that it takes to prove that the faster you go relative to someone else, the slower time will pass for you compared to them. That might seem crazy, but it's true, and has important consequences! Here, I'll show you!

**(ON B) - {Lectern Computer 1 - PPT Slide #?}: Slow-motion video { prerecorded }**

*Tada ??*

*Demo: { Muons } -start*

*(On A & C) -- Table 3, Video 2*

**Shimon:** Right now, about 10 km up in the atmosphere cosmic rays from outer-space are constantly creating unstable particles called muons, which only live for 2 millionths of a second. Even though they travel close to the speed of light, that's only long enough for them to go about 600 meters, so none of them should make it down here to us. But with this **scintillation detector** here, we can see the tracks of individual muons that are whizzing through the detector, and us, all the time. How is this possible? Well, because these muons are traveling at over 99.8% the speed of light, time goes 15 times slower for them than for us, which means to us they live 15 times longer, and that's just long enough for them to reach us and our detectors.

**{ Pause for some tracks }**

*Audio: TaDa*

**Shimon:** All this stuff about cosmic rays and unstable particles with weird names might seem very abstract, but the exact same thing is true for me and you. If I run with this alarm clock here, it will actually tick slightly slower than this alarm clock I leave on the desk, and over time it will fall behind the stationary one. While it might not make me all that late for my next meeting, this is actually an effect we can measure. Physicists can build clocks called atomic clocks that are so precise, they have measured time slowing down from being on a moving airplane. In fact, there's an atomic clock here in this building that is so

precise it can measure time slowing down from moving at the speed of a bicycle. And if we didn't account for these weird relativistic effects in the clocks on the satellites that make up the GPS network, your iPhone wouldn't have been able to give you accurate directions to this show because it would have had no idea where you were!

**Shimon:** So to slow down time, all you need to do is move fast! Why do you think I'm so much livelier than my dear cousin Albert? The secret to eternal youth is to spend your whole life biking around at close to the speed of light. Just don't let any cops catch you doing that down University Avenue, or you'll get one heck of a ticket! Speaking of which, I've been standing still for too long. I'm off, but I'm sure I've solved all your problems!

*{Shimon rides out on the bicycle to call me AI.}*

*Audio: Call Me AI*

## **Closing** (Sprott [Mic #1])

**Peter:** So now we know that it is possible to slow down time, just as Professor Sprott wanted us to do! All our problems are solved! Physics has saved the World! [{THE END slide}](#)

**Audio:** [story-ending music](#)

*{The lights go down and come back up with only Sprott on stage.}*

**Sprott:** Yes, it is possible to slow down time, but only by traveling at over 500 million miles per hour or by living near a black hole. Since that's not very practical, we'd better look for other ways to solve the great problems facing society. Those problems will require us to use the laws of physics and especially the physics of time, and I dream of a better World in the future. But we had better get about finding solutions since **time is of the essence**.

**Sprott:** And now, I'd like to end the show the same way we have ended every one of the 300+ shows for the past 37 years by making for you a cloud. It may be that making more clouds will help us combat climate change, one of our more pressing problems.

**Sprott:** Actually, clouds have both a cooling and a warming effect. During the day they block the warming rays of the sun, while at night they act like a blanket that keeps the Earth warm.

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE # 48 - Clouds / Thank You**

**(ON B) - DVD Video: [Theme music video](#)**

**Audio:** [WOP Theme-long-3m22s.wav](#)

[Theme music video](#) plays.

*{Cast enter and bow in unison.}*

## Resources:

- [2018 PowerPoint Slide Show](#) (where is the 2019 version?)
- [Physics Lecture Demonstrations](#)
- [+An old Physics 103 Demo List](#)
- [An old Physics 104 Demo List](#)
- [WoP Demos from Previous Years](#)
- [85 Video Clips from Physics Demonstrations Book](#)
- [WOP sound library](#)
- [2019 WOP script](#)
- [2018 WOP script](#)
- [2017 WOP script](#)
- [2016 WOP script](#)
- [2015 WOP script](#)
- [2014 WOP script](#)
- [2013 WOP script](#)
- [2012 WOP script](#)
- [2011 WOP script](#)
- [Free Sound Effects Archive](#)

<http://sprott.physics.wisc.edu/demobook/chapter3.htm>

<https://science.howstuffworks.com/how-to-measure-sound-travel-air.htm>

<https://demonstrations.wolfram.com/SpeedOfSound/>

[https://phys.libretexts.org/Bookshelves/University\\_Physics/Book%3A\\_University\\_Physics\\_\(Open Stax\)/Map%3A\\_University\\_Physics\\_I\\_-\\_Mechanics%2C\\_Sound%2C\\_Oscillations%2C\\_and\\_Waves\\_\(OpenStax\)/17%3A\\_Sound/17.03%3A\\_Speed\\_of\\_Sound](https://phys.libretexts.org/Bookshelves/University_Physics/Book%3A_University_Physics_(Open_Stax)/Map%3A_University_Physics_I_-_Mechanics%2C_Sound%2C_Oscillations%2C_and_Waves_(OpenStax)/17%3A_Sound/17.03%3A_Speed_of_Sound)

<https://spark.iop.org/nodes/Speed%20of%20Sound>