

The Wonders of Physics 2014

“The Physics of Dimensions”

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

(ON B) - RGB {Lec Computer 2}: Intro PPT Slide Shows

Audio: Science Songs

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

{Mute all as Peter walks out}

(ON B) - RGB {T2 G1}: Optional PPT intro {on the front screen}

Peter: Welcome to the (258, 259, 260, 261, 262, 263, 264, 265, 266, 267) presentation of *The Wonders of Physics*... Before the show begins, I would like to assure you that we make all of our demonstrations as safe as possible provided you remain in your seats.

Professor Sprott is getting kind of old, and he wanted to do a show on *The Physics of Dementia*.

Audio: [Sound clip](#)

Audio: [Sound clip](#) {Voice from off-stage: "Not dementia --- dimensions! *The Physics of Dimensions!*"}

Peter: Oh! That must be why he invented this machine, to travel here from another dimension. And now here he is, arriving from the fourth dimension, that Demented Doctor, that Mysterious Magician, that Phenomenal Physicist, that Spinning Scientist, Professor Clint Sprott!...

Lights Down Low

Audio: [WOP Theme-Short](#) {Sprott enters through a centrifuge.}
{Hit switch for strobes and Lasers}

Lights up

Sprott: Welcome to *The Wonders of Physics!*

It's really quite simple to travel in different dimensions. We live in a three-dimensional world, and time is considered to be the fourth dimension. And so we are all traveling in the fourth dimension just by being here. In the theory of relativity, space and time are interchangeable so that two events that are separated in space but simultaneous for one observer may occur at the same place but at different times for another observer.

If I drop this ball, it travels in one-dimension. We know it will move straight down because it's attracted to the Earth below, but it's a bit of a mystery even to physicists how the ball knows the Earth is down there instead of somewhere else. The ball can also move in two dimensions if I throw it {throws ball to Peter}. It moves horizontally as

well as vertically -- what we call projectile motion. If I drop this piece of cardboard, it moves in three dimensions. In fact, this is an example of chaotic motion, which is my own area of research. There are other mysterious examples of three-dimensional motion. Consider this bicycle wheel...

Demo: [{Bicycle Wheel Gyroscope}](#)

Audio: [Ta-Da-1](#)

Sprott: Spinning objects do behave in mysterious ways. That's why I invented this machine. I've been experimenting to see what would happen if I were to spin myself very fast, and so let's do that after I step inside.

Peter: Professor Sprott, are you sure this is a good idea?

Sprott: Sure! What could possibly go wrong?

Lights Down - no spot

Audio: [Merry-go-Round Music](#)

Audio: [Crash](#)

Light Back up

{Lifesize 2D version of Sprott appears - Prof. Sprott is trapped in the 2nd dimension!}

Peter: Oh, No!.....

Audio: [organchord2](#)

Peter: Professor Sprott seems to have become two-dimensional. We need to figure out how this machine works so we can get him back to our three-dimensional world. Perhaps his secret laboratory notebook contains the information needed to restore him. Everyone, look around your seats to see if you can find his notebook. Oh, here it is.

[Kenny: Turns on Mic #3 and enters via stage left.]

Kenny: I'll take take that! **{Takes notebook from Peter Weix}**

{hands notebook to Peter who opens it and reads:}

Peter: Who are you?

Kenny: You don't recognize me? I am the great and villainous mad physicist, Bon Jardeen, inventor of supertransductivity and the consistor! I sabotaged Professor Sprott's machine by shorting the interdimensional variac! Now, I can take his notebook and use his physics knowledge to steal all the dimensions! Let's see, what does his notebook say...? **{Flips through notebook}** Now I have enough physics knowledge to steal all

three dimensions!

Peter: *{Dubiously}* Really? I bet you don't even know anything about motion!

Motion (Kenny Rudinger [Mic #3])

Kenny: Well, let me show you! I've never been very good at expressing my emotions, but I can tell you a thing or two about the physics of motion. Professor Sprott is trapped in another dimension, but dimensions are all about how things move. Now, the physics of motion is described by **Newton's** three laws. No, not one for every dimension. They describe how things move through the three spatial dimensions. First, I will demonstrate how an object at rest tends to stay at rest.

{Kenny sits down.}

(ON B) - RGB {Lec G1}: PPT SLIDES - Newton

(Que) - Camera 5 or 6: {ball on cut string }

Kenny: And now I will demonstrate how an object in motion tends to stay in motion in a straight line.

Demo: [*{Cut The String}*](#)

Audio: [*Ta-Da-1*](#)

(ON B) - RGB {Lec G1}: PPT SLIDES - Newton

Kenny: **Newton's** second law tells us how fast something will accelerate when I push on it, or exert a force on it, and Newton's third law says that for every force, there is another force of the same size, or magnitude, that acts in the opposite direction. Let's take this rocket for example. If I light it, hot gas will go one way, exerting a force on the jug, making it accelerate the other way!

Demo: [*{Ethanol Rocket}*](#)

Audio: [*Ta-Da-1*](#)

Audio: [*Gone Wrong*](#)

Kenny: When we have more than one dimension, we can have objects move not just in straight lines, but we can also have them rotate!

Demo: [*{Hoberman Sphere}*](#)

Opt. Audio: [*Ta-Da-1*](#)

(Que) - Camera 4 or 2: {2D Membrane }

Kenny: Professor Sprott already told us how an object that is dropped falls to the ground, but why is this? We know that objects fall to Earth because of gravity, but what is gravity? We can demonstrate it here:

Demo: {2D Membrane}

Opt. Audio: Ta-Da-1

(Que) - Camera 6: {Unmixing }

Kenny: Now, Newton's laws can be used to explain not only how solids behave, but also how liquids and gases behave as well.

Demo: {Unmixing demo}

Audio: Ta-Da-1

Peter: I was wrong, you do know something about motion! But I've been looking at Professor Spratt's machine, and the interdimensional variac works just fine! You didn't have anything to do with breaking the machine! Give that back! *{Takes notebook from Kenny}* Some mad scientist you are! Get out of here!

{Kenny glumly walks off stage}

Audio: Sad Trumpet

Peter: Bon voyage, Bon Jardeen!

Audio: TA-DA-Proud-2 {as Kenny Exits}

[Kenny, Mute Mic #3 and hand it to Narf]

Peter {transition}

(Que) - Camera 3 or 4: {Train on Bicycle Wheel }

Peter: Thanks Kenny. Newton's third law of motion states "**For every action, there is an equal and opposite reaction.**" Which can also be stated "When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction to that of the first body." Here, let me demonstrate:

Demo: {Train on Bicycle Wheel}

Audio: Train Whistle

Audio: Ta-Da-1

Peter: WELL HERE IT IS IN PROFESSOR SPOTT'S LAB BOOK: SOLIDS, LIQUIDS, GASES...Humm. You know I CAN'T SAY I UNDERSTAND WHAT HE WAS THINKING WHEN HE WROTE THIS AND THEN THERE IS THIS CRYPTIC NOTE ABOUT SOMEBODY NAMED LUDWIG. THIS IS MYSTERIOUS...

{Michael stumbles in dressed up as Ludwig Boltzmann}

Heat and Pressure (Winokur [Mic #4], Narf [Mic #3]):

Audio: [Gone Wrongly](#)

Winokur: Ludwig, Ludwig did you say? Ludwig Boltzmann at your service, well at least his ghost as he has been gone quite some time. But Ludwig Boltzmann did revolutionize our understanding of gases, liquids and solid with his ideas about the **kinetic theory** of atoms. Kinetic is just another word for motion.

(ON B) - RGB {Lec G1}: PPT SLIDES - Boltzmann

Winokur: Although we can't see single atoms with our eyes or feel them with our fingers they obey the same Newton's Laws of motion that Kenny just talked about and they are always moving.

Whether atoms move in 1, 2 or 3 dimensions is also important. I have a little exercise to demonstrate this but I require **two volunteers**.

Your names....

Now I have a little test for you; I hope you're good at tests?

Please take this sign, you will now be ATOM 1 and stand here, and you take this sign and be ATOM 2 standing opposite, here. Now we will pretend you are atoms moving in TWO dimensions (like the car the Mr. Weix mentioned) and have you exchange places. Do you think you can do that? Ready, set, go....

No problem. But what if you could only travel in just **one** dimension? I just happen to have a rope in my pocket, and if you each of you takes an end and places it on the floor I can have you "walk the line". No, its not a sobriety test but you must stay on the rope and again exchange places. Ready, set, go! Ouch.....

Audio: [I Walk the Line](#)

Maybe I'm the problem. Let me step out of the way and have you try it again. Can you do it? No...so you can see that motion in one dimension is actually very different than that in two or three dimensions (like a train on a track). That's my line and I'm sticking to it....thanks so much for your assistance.

Audio: [TA-DA-Proud-2 {as Volunteers Exits}](#)

(Que) - Camera T2V1: {Molecular Simulator }

Winokur: Now, let's talk about having lots and lots of atoms moving and crashing into things. That is what we call pressure. At the microscopic level atoms are always moving, and that motion leads to **heat** and **pressure**. To show you this I employ a "molecular simulator." It is sort of like therapy for atoms.

(Light the candle and incense!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!)

Winokur: In this chamber I have some steel ball bearings. Now imagine they represent atoms in the room. Please look at the camera image above. Now for a little motion. There is a speaker below which I will turn on. (Power on the speaker.) Notice the balls are hardly moving and very close together. This we would call a solid.

Demo: {Molecular Simulator}

Now to "heat" them up. At just the right amount the atoms will melt and start to exchange places. Now the atoms are moving around and are not so tightly packed. This would be a typical liquid.

(Que) - Camera T2V2: {Brownian Motion }

Now for some more heat! The atoms are now far apart and this is what we would call a gas. Notice the atoms crashing into the top baffle; that implies pressure. Squeezing the gas by pushing down on the baffle moves the atoms closer together and increases the pressure. I will return to pressure in a bit, but first I want to convince you that the atoms in the air really are in motion

Demo: {Molecular Simulator}

Audio: [Ta-Da-1](#)

Winokur: Here is a microscope, a video camera, a small chamber and a green laser. Let's take a look. Do you see any dancing atoms? NO! We can't see atoms But there is something we can do to help if you don't mind a little smoke. (Put incense in the bottle and blow.) Now parents (grandparents more likely) imagine we are back in the 1960's

{Ed goes to command center to run audio for Bed of Nails}

End Demo: {Brownian Motion}

Audio: [Ta-Da-1](#)

???? Audio: [Oooo, Wooow](#)

Winokur: The atoms in the air are colliding with the dust particles, and the motion of the dust particles can be seen by scattering of the laser light. This is "Brownian Motion" and it is these collisions that are responsible for pressure. It was first seen by Robert Brown in

pollen dust and explained by Einstein.

(ON B) - RGB {Lec G1}: PPT SLIDES - Robert Brown

Start Demo: {Bed of Nails}

Winokur: All this motion is **making** me tired. I think I'll take a nap but where? I think Professor Sprott mentioned something about a two dimensional bed. I wonder where it could be?

Narf: Prof. Boltzmann, it is right behind you...

Winokur: Fantastic! But who are you?

Narf: Well, I'm Prof. Sprott's Demonstrational assistant Steve Narf and these are my toys. Now your bed!

Winokur: (to the audience) Well, I hope you won't mind; just a little nap and my snoring shouldn't bother anyone.

{ Thud ! }

Winokur: What kind of bed is that?!!!

Narf: This is a Physicist's bed... of Nails!! Prof. Sprott and I would like you to be sharp for the show, and what could sharper than a bed from 1 3 75 aluminum nails.

Winokur: That can't really be comfortable, can it? This will hurt!!

Narf: Oh no, this will not hurt...much! Let me demonstrate with this head of cabbage.
(The cabbage drops from Narf's hands and is impaled; Narf picks up the head ruefully)

Narf: Oh dear, Too much momentum. This will go much better if we "let you down easy". See, with that many nails here, each nail will only push back with only a small fraction of you total body weight. So you will hardly feel them at all.

Winokur: Well I am tired...

Narf: Ok, but Safety first! So wear this head gear and I have this pillow for that mellon of yours. We don't wait another Cabbage Incident... Now just relax and down you go.

Audio: [Doom-March](#)

Narf: So how is it?

Winokur: Its not too bad, but it is a little chilly.

Narf: No worries, this bed comes with a cozy matching blanket....of Nails!!

Winokur: Are you sure about this?

(as I grabs a block and place in on top)

Narf: Oh don't be a baby..... a little more pressure never harmed anyone. Hey folks! Look! We have a Prof. Sandwich!!

Winokur: Oh dear, what did I get myself into...

Narf: And now for some massively parallel acupuncture, very therapeutic. Now where is my sledgehammer??

Narf: You know, I'm not a good at this {X marks the spot} any last words??

Winokur: I don't think I'm ready for this...

Narf: What could possibly go wrong!! {SMASH!!}

Audio: [Ta-Da-1](#)

Narf: So, How was that? *(Steve helps up Michael and Michael's pants rip revealing red satin underwear.)*

{Narf & Peter clean-up the Stage...Fast}

Winokur: I think I need a new tailor.

Audio: [TA-DA-Proud-1](#)

[Narf, Mute Mic #3 and hand it to Marty when off stage]

{Que } - Camera 6: {Convection Candle } move to {CO2 Through}

Winokur: Well that was, sort of refreshing, like fresh squeezed orange juice. But we were talking about pressure, heat, air and dimensions. Air doesn't just move back and forth crashing about, but it can, collectively, move along a line; in one dimension. And this can be really, really important. Here is an example.

Do you see this candle? It needs three things. Fuel, oxygen and air flow. Notice what happens if we put this glass tube around it? It is open at both ends. As I lower it, the flame increases. That is because the hot air rises and oxygen rich air flows in from the bottom. Eventually the flame will extinguish because now I have stopped the air flow, and so the candle will use up all the oxygen nearby.

Demo: *{Convection Candle}*

Winokur: Let's try the same thing again but with a little twist. I will put in a metal divider into the glass. Watch carefully. The candle now burns brighter because the divider creates one dimensional air flow in which hot air goes up one side and fresh air down the other.

Scientists call that convection.

Audio: [Ta-Da-1](#)

Winokur: Now does anyone have a birthday coming up? No cake but I do have some candles. I hope you are just four years old because I only have four candles forming a one-dimensional line. Sadly, we can't even sing Happy Birthday because we didn't pay the copyright fees but I think it will be okay to hum a few lines.

Audio: ~~Happy Birthday~~

Demo: {Butane / CO2 Trough}

Audio: [Ta-Da-1](#)

Enough of that. Now make a wish and I'll blow out the candles by pouring a special gas contained in this beaker. Oops....wrong beaker....that was the gas butane which is heavier than air. Let's try this one. Ahh...that's better. So what do think was in this beaker?

Carbon dioxide which is also denser than air and sinks. That is the same gas they use in soda pop so best be careful with it.

Winokur: And air's motion is important for sound. I just really need a good flame. (Light the burner.) I can feel the air rising, and here is another tube. That was interesting. I wonder what will happen if I use a longer tube. So, do you think the pitch will be higher or lower?

Demo: {Hoots Tube}

Audio: [Ta-Da-1](#)

Winokur: Well I think dementia is setting in because I keep hearing sounds...(maybe Phantom of the Opera???)

Audio: [Phantom of the Opera](#)

Audio: [TA-DA-Proud-2](#)

[Winokur, Mute Mic #4 and hand it to Mike R.]

Peter {transition}

{Marty enters, on tiptoe and very sneakily, and Peter does not notice him as he says goodbye to Ludwig Boltzmann.}

Peter: Well so long Prof. Boltzmann. You sure do know how to make an entropy. If I'm hallucinating ghosts, maybe I need some rest.

{Peter sits down and begins to snooze in a chair.}

Sound (Marty Lichtman [Mic #3])

{Marty enters, dressed as The Cat in the Hat Burgler trying to be very sneaky, but whispering very loudly to the audience.}

Marty: *{Speaking aside to the audience.}* I'm the Cat Burgler, and I nab knowledge,
I get 4 pawed discount, on what people learn in college,

I have an M.O. in science, and to give specifics,
I stole Maxwell's Laws, and I stole quantum physics

I want to pilfer 4-dimensions, so I'll grab Clint Spott's notes,
Then I'll know where to find them, those are my hopes

Marty: Professor Sprott? Where did you go? Where did you go? Professor?

Audio: Phone { Play it two or three times }

{Telephone rings. Startling Marty, who was trying to be quiet. He bobbles the receiver, and picks it up.}

Marty: Helloooooooooooooooooooooooooooooooooooooo?

Audio: Sound clip. *{Sprott over PA: Hello. You've reached Professor Sprott. I can't take your call right now, so please leave a message, and I'll get back to you.}*

{The ringing telephone wakes up Peter. Marty finds and excuse for being there.}

Marty: *{Speaking aside to the audience.}* Well Sprott isn't here, that's a relief,
But I'll need to dupe this guy, the lab safety chief.

Marty: *{Speaking to Peter.}* Well Sprott isn't here. That's too bad!

PETER: IF HE DOESN'T COME BACK, I WILL BE SAD!

Marty: I know some physics, but I had hoped to learn more.

PETER: HERE, SEE WHAT THE LAB NOTEBOOK SAYS ON PAGE FOUR.

(Que) - Camera 6: {Transverse Wave Boards }

{Marty takes lab notebook with an excited gesture to the side.}

Marty: It says that Spratt mastered the physics of sound.
Let me see what demos are around.

There are 2 kinds of waves. And the difference is clear.
It depends on the dimension of motion, it says here.

There are 2 kinds of waves. The first is transverse.
That means the waves vibrate sideways, in girth.

Perpendicular vibration to the direction of motion.
Radio waves, or a tsunami on the ocean.

I have an example, a demo with rods.
I'll shake these beams, and your confusion will become nods.

Lights Down - No spot

The wave travels along, from your left to your right,
But the rods move up and down, as they glow in the light.

Demo: {Transverse Wave Boards}

Audio: [Ta-Da-1](#)

Lights up

Marty: We get transverse waves on an instrument with strings
The string doesn't travel, and yet the guitar sings

I can show you this, with a long piece of coil.
I need a **volunteer** from the audience, one who doesn't mind a bit of toil?

You right there, now come on down.
What is your name? How does it sound?

Take the coil over that way.
Now hold on tight and don't let it sway.

I will shake the coil once, and send a wave packet.
The pulse travels along, but doesn't make a racket.

To make a sound we'll need continuous vibration,
I'll shake it up and down, now hold to your station!

Demo: {Wave on rope}

Audio: [TA-DA-Proud-2](#) {as Volunteers Exits}

(Que) - Camera 6: {Slinky }

Marty: Thank you scientist, now go sit down,
We'll continue to learn about the wave of sound.

Marty: But sound travels through air in a slightly different way.
It's a longitudinal wave, with compression and hey,

Also expansion, in the direction of motion.
The same dimension, that's the notion.

There's a common toy that behaves like this
You know it as a slinky, it shimmies and shifts

Demo: {Hand-held Slinky}

Marty: It compresses and expands, and if we hang it up,
It mimics a sound wave, when I give it a bump

Demo: {Longitudinal wave hanging slinky}

Audio: [Ta-Da-1](#)

Marty: As a sound wave travels across the land
The air compresses and then it expands

Vibrations created when I speak with my voice
Then vibrate the air, it has no choice

The vibrating air then enters your ear
It shakes your eardrums, and that's how you hear

(ON B) - RGB {T3G1}: Oscilloscope

Demo: {oscilloscope + microphone + flute}

We can see those vibrations on my oscilloscope
I've attached a mic, and my flute is in tune, I hope

Different pitches change the frequency
Low pitches vibrate slowly, as you can see

Low pitches arise when the wavelength is long
So the longer the wavelength, the deeper the song

When the wavelength is short, we get a toot,
High pitch, and high frequencies, like the tweet of this flute.

Audio: [Ta-Da-1](#)

(Que) - Camera 6: {Ruben's Tube}

Marty: Now let's visualize a sound wave with a Ruben's tube
It's a long hollow cylinder, no not a cube.

Lights Down - spot only

We'll put in methane gas, and light a fire.
Higher pressure will make the flames go higher.

We can modulate the pressure with the speaker at this end
I'll turn up the noise, and the flame height depends

On the pitch of the sound, the tone of the song
With low tuba pitches the wavelength is long

Then turn up the pitch, play a high tone
You get a short wavelength, from your sax-a-ma-phone

Lights Up

{Ruben's Tube}

Audio: [Ta-Da-1](#)

(Que) - Camera 6: {Brass Target}

Marty: But we can do something that will leave you even more impressed
We'll make a shock wave, where air is compressed

A shock wave forms when waves build up in one place
From faster than sound motion, a speedy pace

A ping pong ball canon is the device I have there,
A vacuum pump will remove all the air

Then I puncture this diaphragm with a sharp pawl
and the atmosphere will rush in and propel the ping pong ball

I will cover my ears, because this will be quite loud,
And I suggest you do the same out there in the crowd

If it's a big bang noise, that you desire
Count with me 3 2 1 0, and then I will fire!

Three, two, one, ZERO!

{Sleeping Peter is awoken by big noise.}

PETER: Hey, wait, you're no student, you're a thief in a hat.

Give me that notebook, now run off you cat!

Marty: And I almost got away with all my sneaking around,

Next time I'll be quiet, and make not a sound.

(Que) - "SNORING" Audio

Demo: {ping pong ball cannon}

Audio: [Ta-Da-1](#)

Audio: [Snoring sound clip](#) {Clint speaks through PA again}

Marty: What's that sound reverberation?

That's shaking my station.

Hmm, there might be another way to steal some dimensions,

For a curious cat, with scientific intentions.

I'd better investigate that noise, and see what it's not

I'll use my audio knowledge to find Professor Sprott,

{Marty exits}

Audio: [TA-DA-Proud-2](#)

[Marty, Mute Mic #3 and hand it to Ed]

Peter {transition}

Peter: WELL, THE SCIENCE WAS SOUND, BUT WE DIDN'T SOLVE THE MYSTERY. WHAT'S NEXT IN PROFESSOR SPROTT'S LAB BOOK? IT LOOKS LIKE A SKETCH OF A FAT JEDI KNIGHT...WAIVING A LIGHT SABER...WITH LIGHTNING COMING OFF HIS FINGERS? AND DANCING? I KNOW SPROTT IS AN AVID DANCER, BUT HE NEEDS TO BACK OFF THOSE STAR WARS MARATHONS.

{Mike R. walks in, wearing chain mail, waving a fluorescent tube like a light saber, making light saber sounds}

Electricity (Mike Randall [Mic #4])

Audio: [Gone Wrong](#)

Audio:

Audio: [Light Saber](#)

Mike R: *(looking at Peter)* Chewbacca?

Peter: Very funny. Are you one of Prof. Sprott's lab assistants?

Mike R: Yes! My name is Mike Randall, and I've been experimenting with electricity.

Mike R: Electricity is AMAZING! We use it for lights, television, computers, video games - almost everything! But what IS electricity? Raise your hand if you KNOW what electricity is. *(Audience interaction)*.

Mike R: Isn't it fascinating? Look how few hands are up. We use electricity all the time, but we don't know what it is! What is electricity? *(Points to audience member with hand up. Audience member either gives the correct answer, or Mike R. keeps asking other audience members until correct answer is given)*.

Mike R: That's it! All the stuff around us is made of teeny, tiny things called atoms. Atoms are made of even TINIER things, and some of the TINIEST things in there are called ELECTRONS. Now there's a dead giveaway! Think electrons have something to do with electricity? Of course! Electricity is the MOVEMENT energy, or KINETIC energy, of those little electrons as they move around! Now there are different ways to get them moving.

Mike R: Most of our electricity is made this way

Demo: {Hand generator}

Mike R: This is called a generator. All a generator is is a coil of wire near a magnet. As the magnet moves, the magnetic field pushes on the electrons, gets them moving, giving them enough energy to do something useful. Like lighting this light bulb.

Optional Audio: [Ta-Da-1](#)

Mike R: Here's another way to get electrons moving. This is called a **Tesla** coil. This makes high voltage, high frequency electricity. Which is a fancy way of saying that it takes the electrons and SHAKES them back and forth really hard and really fast!

(ON B) - [RGB {Lec G1}](#): PPT SLIDES - Nikola Tesla

Demo: {Hand held Tesla coil}

Audio: [Ta-Da-1](#)

Mike R: Have any of you ever rubbed your feet on the carpet on a cold winter day? What happens? *(Audience interaction)* That's right! You get a spark! What's this kind of electricity called? *(Audience interaction)* Static electricity! When you rub your feet on the carpet, you're scraping electrons off the carpet and onto your body!

(Que) - Camera 6: {on the grounding ball - Van de Graaff}

Mike R: Now I know none of you wants to watch an old fat guy rubbing his feet on the floor. Good news! I have a machine that does this for me. This is called a **Van de Graaff** generator. I'm not going to tell you HOW this works - I encourage all of you to look into this. Here's what it does.

(ON B) - RGB {Lec G1}: PPT SLIDES - Van de Graaff

Demo: {Van de Graaff Generator}

Audio: [Ta-Da-1](#)

Mike R: I need a helper. *(Audience interaction)*. This is called a **Jacob's** Ladder. Let's see if we can figure out how this works. Flip on that switch!

Demo: {Jacobs Ladder}

Audio: [Frankenstein](#)

(ON B) - RGB {Lec G1}: PPT SLIDES - Nikola Tesla

Mike R: Remember that **Tesla** coil from earlier? I have a much larger one, that does something very special!

Lights Down - spot only

Demo: {Musical Tesla coil}

Audio: [TA-DA-Proud-2](#)

Mike R: The hydrogen balloon has NOTHING to do with electricity. It's just REALLY FUN!

Audio: [Ta-Da-1](#)

Lights up

Audio: [TA-DA-Proud-2](#) {as Mike R Exits}

[Mike R, Mutes Mic #4 and hands it to Bethany]

Peter {transition}

Peter: Well that was certainly a SHOCKING lesson about electricity! It's time, though, to move on to the next page of Professor Sprott's notebook:

THE TOP OF THIS PAGE WARNS: "BE CAREFUL, OR YOU MIGHT FIND YOURSELF ATTRACTED TO LARGE PIECES OF METAL." HOPEFULLY, WE CAN FURTHER ALIGN OUR INVESTIGATION ON THE RIGHT PATH IN FINDING OUT HOW TO RESTORE PROFESSOR SPROTT WITH HIS NEXT LAB ASSISTANT, ED!

{Ed enters stage left.}

Ed: Thanks, Peter; I sure hope that I can help!

(Que) - Camera 4, 5 or 6: {Eddy Current Pendulum}

Magnetism (Ed Leonard [Mic #3])

Audio: [Gone Wrong](#)

Ed: Well I'd sure be glad to help with this investigation of what happened to our dear Professor Sprott! He and I were working together on how magnetism and motion work together to generate power; perhaps this will help us find a way to bring him back to three dimensions -- though I will say the look is quite slimming on him!

Demo: {Eddy Current Pendulum}

(Que) - Camera 5: {Galvanometer }

Ed: For my first experiment, I'm going to use a pendulum made of copper and swing it between the two sides of an electromagnet while it's off and on and observe the difference of what happens. Here, the pendulum swings freely while the magnet is not on; it looks fairly free and unimpeded in motion. However, once I turn the electromagnet on, the copper pendulum's motion is drastically slowed, and it even comes to a complete stop. This effect is so strong, if I start with the magnet on and try to start the pendulum swinging, it doesn't swing past the bottom at all! This is because good conductors, like copper, react to a change in magnetic field by moving electrons around to make magnetic fields of their own. These currents are called "ED-dy currents" and are a result of nature not liking it when things change.

Audio: [Ta-Da-1](#)

Demo: {Solenoid-Galvanometer Demo}

Ed: Keeping to the idea of how magnets and motion can do things together, my next experiment takes a moving magnet and runs it through the center of a coil of wires called a solenoid. The two ends of the solenoid are connected to this large current sensor which is called a galvanometer. Now a magnet has two distinct sides: the north pole and the south pole.

(ON B) - RGB {Lec G1}: PPT SLIDES - [Magnetic Field - Magnet]

Ed: The magnetic field is emitted from the north side of the magnet and then curves around the magnet into it's south pole, very similar to Earth's own magnetic field.

(ON B) - RGB {Lec G1}: PPT SLIDES - [Earth's B Field]

(Que) - Camera 6: {CRT }

Ed: The experiment we're going to do now is to move the magnetic field through the solenoid by moving this magnet through the center of it. As I do this, you can see that the

galvanometer needle is bouncing around. If I move the magnet more slowly, the needle doesn't measure as high a value. From this, it's apparent that the speed of the movement of the magnet matters! This is because of a simple fact that is true in a variety of different ways, and that is that nature doesn't like to change. While I hold the magnet outside of the solenoid and move it around, the galvanometer reads zero. However, as soon as I change the field inside the coil, a current runs through the wire because nature is trying to negate the new field with one of its own.

Audio: [Ta-Da-1](#)

Demo: {Magnet w/CRT Demo}

Ed: For my final experiment, I have here an old CRT. Can anyone tell me what "C-R-T" stands for? *[Poll the audience; someone probably knows it.]* That's right! It's a "cathode ray tube!" Inside this tube, electrons are fired at very high speeds from the back of the tube to the screen where you see the bright white dot; that's where the electrons are hitting! The cool part about this setup is that if I bring a magnet near the screen, I can steer the direction of the electrons as they approach the magnet. This is because electrons are charged particles, and charged particles take curved paths in magnetic fields.

Audio: [Ta-Da-1](#)

Ed: I have to get back to my lab now, Mr. Weix, but I do hope that you're able to use some of this information to bring Prof. Sprott back from the second dimension; he just looks so hungry!

Audio: [TA-DA-Proud-2](#) *{as Ed Exits}*
[Ed, Mutes & Hands back to Kenny after show]

Peter {transition}

Peter: Hmm, look at these flashing lights from Prof Sprott's machine...

Light (Bethany Reilly [Mic #4])

Bethany: Did someone say light? Light is my favorite! Let's link it to dimensions! Hi kids, I'm Bethany [or a historical physicist?] and I'm a particle astrophysicist. This means I study things like particles and light from all over our universe! Let's think about how light travels. This is a laser. It travels in a straight line, or one dimension. A regular light bulb (hold one up) on the other hand, sends light out in three dimensions.

Demo(ish): {laser vs lightbulb}

Bethany: Here's glow in the dark fabric. What do you have to do to make things glow in the dark? (shine light on them) Okay, let's maybe use something really bright and see if we can get this to glow really bright too with the lights off. How about these lasers here? [Laser safety talk] Okay, let's use the bright red one! [nothing happens] Huh. It's so bright. Well, maybe this nice bright green one. [nothing] Well, I guess let's try this wimpy purple one. [it works] Whoa! Well, this is because purple light has more energy! It's not intensity, but the energy that matters. Light is made up of many little pieces of light, called photons. In order to make the sheet glow, we need photons that each have a lot of energy. Lots of photons with a little energy won't work, but even just a few photons with high energy will make it glow. And what we see as color is telling us what energy the light has. **Albert Einstein** won the Nobel Prize for explaining this experiment, which is called the Photoelectric Effect.

(ON B) - RGB {Lec G1}: PPT SLIDES - Albert Einstein

[Lights Down]

Demo: {Photoelectric Effect with phosphorescent surface}

Audio: [Ta-Da-1](#)

[Lights Up]

(Que) - Camera 6: {Fluorescent Cylinders }

Bethany: Now, Professor Sprott has these cool colored cylinders here. I wonder what would happen if we shine these lasers through. Oh look, this red one just goes right through all the cylinders. Whoa, look at that! When I use a laser with more energy, instead of just passing through the cylinder, the light makes the cylinder glow. This is because the light from the laser is being absorbed, and then the cylinder glows with its own color.

[Lights Down]

Demo: {Fluorescent Cylinders}

Optional Audio: [Ta-Da-1](#)

[Lights UP]

Bethany: Well that was pretty cool to think about. I see one more thing here that I think you'll like to see. Here I have a piece of plastic, not too exciting right? But if I shine a laser through it, it splits the laser beam into this cool pattern. The reason this happens is that this clear part of this disc actually has thousands of little slits in it. When the light passes through these slits, it interferes with itself, and spreads out to make this pattern. This is called diffraction. See how the dots look like a line? A line is one dimension. This other diffraction grating is a little different. This one makes a two-dimensional pattern. Check it out!

Demo: {diffraction}

Optional Audio: [Ta-Da-1](#)

Bethany: Cause physics! Oh, look here in Prof Sprott's lab notebook! It says here that a physicist named Jenny Rosenthal Bramley discovered a lot of things about light. She actually holds the patent on the color TV tube. [reaches] Oh dear, they're having a light emergency in my other lab. I'd better check it out. Thanks for thinking about light with me everyone!

(ON B) - RGB {Lec G1}: PPT SLIDES - Jenny Rosenthal Bramley

(http://photos.aip.org/history/Thumbnails/bramley_jenny_a1.jpg + text "Jenny Rosenthal Bramley")

Audio: [TA-DA-Proud-2](#) {as Bethany Exits}

Closing (Sprott, Cast)

Peter: AH, THE FINAL PAGE OF PROF. SPROTT'S LAB BOOK HAS A CLUE. IT SAYS, "AT THE MICROSCOPIC LEVEL, THE LAWS OF PHYSICS ARE TIME-REVERSIBLE." MAYBE IF WE PUT THE 2-D PROF. SPROTT BACK IN THIS MACHINE HE INVENTED AND RUN IT BACKWARDS, WE CAN BRING HIM BACK TO HIS 3-DIMENSIONAL SELF...

{Peter puts the cardboard cutout in the machine and turns it on.}

Audio: [Merry-go-Round Music](#) - *{Sprott rushes in stage left.}*

Sprott: Oh, I'm sorry! I fell asleep. I guess I missed the whole show. When I spun around, I got really dizzy and went into the back room to lie down, and I fell asleep. I hope my snoring didn't bother you. That cardboard cutout is just something left over from my last book signing tour. But I did travel forward nearly an hour in the fourth dimension.

String theory proposes that there may be 10 or more space dimensions plus time, with seven of the dimensions rolled up into tiny tubes much as two of the three ordinary dimensions are rolled up in this piece of string. However, there is no technology to travel to those other dimensions and probably never will be.

Something you may not know is that objects can have a non-integer dimension. This string is one-dimensional and this sheet of paper is two-dimensional. It has a width and a height, but very little thickness. If I wad up the paper, I can make it into a three-dimensional ball, but at what point does it stop being two-dimensional and become three-dimensional? Perhaps it does so gradually.

(ON B) - RGB {Lec G1}: PPT SLIDES -

[Here's](#) an object with a dimension of about 1.3, and

(ON B) - RGB {Lec G1}: PPT SLIDES -

[here's](#) one with a dimension of exactly 1.5.

(ON B) - RGB {Lec G1}: PPT SLIDES -

[Here's](#) one with a dimension of about 1.9, and

(ON B) - RGB {Lec G1}: PPT SLIDES -

[here's](#) one with a dimension of about 2.7 *{holds up a Menger sponge and/or a Sierpinski tetrahedron}*. It's a sponge with zero volume and infinite area. These are called "fractals," and they are very common in nature.

{If Shakhashiri comes, he could make his appearance here - probably only for the last show.}

It's been a pleasure to share with you some of the mysteries of the dimensions in which we live. And now I'd like to end with the demonstration we have used to end all 200+ presentations of The Wonders of Physics over the past 30 years by making for you a cloud. The surface of a cloud is a fractal with a dimension of about 2.35 ([slide](#)) ...

Demo: {LN2 Cloud}

[SLIDE OF CLOUD (FROM PAST YEARS PPT ENDING)], ...

(ON A & C) - RGB {Lec G1}: PPT SLIDES - Thank you

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

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

{The show concludes with Sprott disappearing in the Liquid Nitrogen Cloud. [Theme music video](#) plays. Cast enters stage right and bows in unison.}

Miscellaneous Notes

See [list of demos](#) we have done in previous years for other ideas.