

# The Wonders of Physics 2015

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## Characters:

- mad scientist (Randall)
- weakling vigilante (Akire)
- carnival promoter (Ed)
- steampunk Tesla (Andrew)
- witness who thinks you're accusing him (guilty conscience, "I didn't see nothin'!") (Marty)
- pompous scientist ("I am the authority on the laws of physics") (Steph)
- politician (Winokur)
- absent minded professor
- snooty church lady
- <http://sprott.physics.wisc.edu/wop/sounds>

# The Wonders of Physics 2015

*32nd Annual Presentation*

*"The Laws of Physics"*

## **Opening** (Bailiff [Mic #3], Peter [Mic #2], Sprott [Mic #1])

**Audio: Science Songs**

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

**{{ Intro PPT Show Needs to be made }}**

**(ON B) - RGB {T1 Computer 1}: Optional PPT intro**

*{including posters of "WANTED For Violating the Laws Of Physics: Prof. C. Sprott" and various pictures of "The Mastermind and his Henchpersons at Work"}*  
**{WANTED POSTER ON FRONT SCREEN}**

**{Mute all MIC's as Bailiff walks out}**

**Bailiff (Marty):** Welcome to the (268, 269, 270, 271, 272, 273, 274, 275, 276, 277) presentation of *The Wonders of Physics*... Before the trial begins, I would like to assure you that we make all of our demonstrations as safe as possible provided you remain in your seats.

*{Peter enters stage right dressed in a judicial robe and takes a seat at the bench.}*

**Bailiff (Marty):** All rise. Hear ye! Hear ye! The Court of Physics is now in session, the Honorable Judge Peter J. Weix presiding...

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #2 - WANTED POSTER**

**Peter:** (You may be seated.) Professor Sprott ***has been accused OF !!!***

**{{ Pause for Audio: [DunDunDuuun](#) }}**

..Breaking the laws of physics, and we intend to put him on trial for his crimes. BRING ME PROFESSOR SPROTT!

**Lights: Spotlight Searching the stage for Sprott & Red Flashing light at Exits.....**

**Audio: WOP Theme & Siren {Re-Edit and add Crash}**

*{Combined - Theme music with siren for 35 sec.}  
 {Sprott enters stage left and runs across the stage chased by Andrew with a fish net, exiting stage right. Moments later, Sprott re-enters stage right chased by Steph with a hook on a pole, exiting stage left. Moments later Sprott re-enters stage left escorted by Andrew and Steph. Theme music ends with Sprott center stage. Lights come up, and we are back in the courtroom.}*

**Sprott:** Welcome to ***The Wonders of Physics!***

I have been accused of breaking the laws of physics, but it isn't true, and I've asked some of my trusted assistants to serve as expert witnesses, and I'd like you to be the jury and decide whether I'm guilty or innocent.

*{ Slide may need more work }*

**(ON B)** - *RGB {Lec Computer 1}: PPT SLIDE #4- Law of Gravity---?(Sprott upside down)?*

**Peter:** Professor Sprott, ***you have been accused*** of breaking Newton's Law of Gravity in several demonstrations we saw you do. How do you plead?

**Sprott:** I'm innocent Your Honor, and if it pleases the court, I'd like to call my first witness to explain why. I call to the stand Dr. Stepnicus...

*{Steph enters and takes a seat on the witness stand}*

**Audio:** [Theme Perry Mason-short](#)

**(Que )** - *Camera 6: {2 Beakers} & {Polyethylene}*

## **Motion (Steph Kubala)** [Mic #4]

**Sprott:** Please state your name and occupation.

**Steph:** I am Frauline Doctor Professor Stepheus Macmillian Augustus Winchester IV, and I am THE authority on the laws of physics

**Peter:** Now hold on, I'm the authority in this court room.

**Steph:** I think not, my good Sir. Why I understand equations, both the simple and quadratical.

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #6 -  $\{x = [-b \pm \sqrt{(b^2-4ac)}] / 2a\}$**

**Peter:** Well I know how to do that!  $x = [-b \pm \sqrt{(b^2-4ac)}] / 2a$  Huzzah!

**{Increasingly snooty}**

**Steph:** And how then are you at integral and differential calculus?

**Peter:** Well I ah, I'm a bit rusty.

**{Increasingly snooty}**

**Steph:** How do you expect to command respect if you don't know your maths? Sir, I am an expert in conics and peculiarities parabolous!

**Stenographer:** "Excuse Me!!!" ... Could the witness please spell that?

**Steph's Response:** Sure, T - H - A - T!

**Stenographer:** Thank you.

**Peter:** And I'd better hit the books! Just give your testimony!

**Sprott:** On February 21, 1988, did you or did you not on see me do a demonstration in which a liquid crawled up the side of a beaker and over the rim?

**{ Slide Needs a better photo }**

**{WOP Photos of Non-Newtonian Fluid demo -- Polyethylene Oxide.}**

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #8 -- Polyethylene Oxide Demo Photos**

**Steph:** I was not even born then!

**Peter:** And I wasn't born yesterday! Can you show us why that does not defy the Law of Gravity?

**Steph:** Sure! Let's take a look at that demo again.

**(Que) - Camera 6: {2 Beakers} & {Polyethylene}**

**Steph:** Normally, when we're dealing with a fluid we're dealing with something like water. If we pour water from one beaker to the other we need to keep the beaker tilted if we want the fluid to continue coming out of the beaker.

**Demo: {Two Beakers of Water}  
{ No TaDa }**

**Steph:** We call water a Newtonian fluid, but here we have a non-Newtonian fluid. Non-newtonian fluids behave differently from Newtonian fluids.

**Note: {Ours isn't working. Maynard is making another batch. Most likely will NOT be ready for the 1st weekend's shows ;-( }**

**Demo: Non-Newtonian fluid - {Polyethylene Oxide} {Polyacrylamide Glycerol}**

**Steph:** This gel consists of long chains of molecules called a polymers. The polymer here is polyethylene oxide. This polymer is really long and stretches so even if we stop tilting the top beaker, the fluid will stretch and keep pulling itself out of the higher beaker into the lower one once we start pouring it.

**Steph:** So the force of gravity is still there, but the polymer also exerts a force on itself through the chemical bonds that keep the molecules in the polymer bound together so that it keeps pulling itself out of the beaker even after I've stopped tilting it as much.

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

**Steph:** A similar thing happens in this next demo.

**(Que) - Camera 6: {Bead Chain}  
Demo: {Siphon, Bead chain}**

**Steph:** We see the beads look like they're climbing out of the beaker. Let's break think about what's happening. Why do the beads keep falling out of the jar? This side of the chain (the side of the chain outside of the jar) feels a lot heavier than the loose bit of chain inside the jar. So there's a force pulling the bit inside the jar out. But to get out of the jar it needs to change direction and fall. But that can't happen instantaneously because that would require infinite force so it has to bend a little bit which is what we saw in the demo and answers the question of why it looks like the chain is jumping out of the jar.

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

**Demo:** {Stack of cards}  
**(Que ) - Camera 6:** {on Cards}

**Steph:** Here's another demonstration that seems to defy the law of gravity. If we move this stack of cards out over the edge it looks like they should fall but they don't! Let's look at one card. As we slide it out of the edge gravity will exert a force on the side over the edge and the side on the table. Now objects that have more mass have more gravitational force pulling on them. As long as there is more mass on the table side of the card, the gravitational force there will be stronger than the force pulling the card down toward the ground. We can extend this idea to the stack of cards. As long as there is enough mass on the supported side, the cards won't collapse. The **Saint Louis Arch** was designed & built in this way.

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #12 -- Saint Louis Arch**

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

**(Que ) - Camera 6:** {on Ball & Cup}  
**Demo:** {Faster the "g" Stick}  
**Audio:** [Ta-Da-1](#)

**Steph:** For this exhibit's set-up we have this plank with a cup and a ball balanced on top of a golf tee. If I knock out the stick who thinks... Ok so let's take out the stick and see what happens \*Do demo\*

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

**Steph:** The ball landed in the cup even though the cup had to travel faster than the ball for the ball to land inside the cup. This once again, this does not violate Newton's laws because the hinge also exerts a force on the stick. Only one part of the stick, about here \*point to where center of percussion is\* falls at the same rate as the ball, and, because the stick is rigid any point beyond this point must travel faster than the ball.

{transition}

**Steph:** Now for my last exhibit we will once again see something fall counterintuitively. When jack and jill fell, did they go up or down the hill? So if I put this double cone shape at the middle of this ramp, will it roll up or down? Let's see what happens... \*do demo\*

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

**Steph:** \*explain about rails and that the center of the double cone is still moving

7

downward\*

**Peter:** Thank you Dr. Stepicus

**Audio:** *TaDa Proud*  
{EXIT}

## Peter {transition}

**Peter:** Professor Sprott, you have been accused of *making water boil by cooling* it in obvious violation of the Laws of Thermodynamics in a demonstration we saw you do. How do you plead?

**(ON B) - RGB {Lec Computer 1}: PPT SLIDES 14 & 15 -- [Photos of Boiling with Ice](#)**

**Sprott:** I'm innocent Your Honor, and I'd like to call my second witness, Ed Leonard, to explain why...

*{Ed enters.}*

**Audio:** [Theme Perry Mason-short](#)

## Heat (Ed Leonard) [Mic #4]

**Ed:** Step right up, step right up! See the amazing Wonders of Physics. See marvels beyond belief! Here for one night only! Amazing fantastical demonstrations beyond compare!

**Peter:** Please just state your name and occupation.

*{Ed turns on gas source with water on it and lights a fire.}*

*{Ed also turns on the hot supply for the ice-water-boiling demo}*

**Ed:** Ed Leonard's the name, but the lion tamers and the snake charmers all call me Rex. That's right Rex, 'cause I'm the king o' the carnival! I've got wonders galore. Feats unheard of. I'll make the dubious believe. Don't hesitate, bring your kids! Bring the family! Physics will astound you under the big top tent!

**Stenographer:** "Excuse Me!!!" ... Would the witness please stop being so annoying?

**Ed:** Sure! I'll be quiet as a mouse! Meek as a lamb! Sleepy as a kitty!

**Stenographer:** Thank goodness!!!!!!

**Peter:** Well, Ed, you've been called here to give testimony about some of Professor Sprott's thermodynamics demonstrations.

**Ed:** The Amazing Professor Sprott! Wonder of Wonders! The Man in the Hat! The Tiger in the Tuxedo! Bringing you science with a smile, and a dance if you're lucky. Step right up folks, and see the greatest show on Earth!

**Sprott:** Ed, that's very nice of you to say, but on February 19th, 2006, did you see me do a demonstration in which I boiled water using ice?

**Ed:** Now that you mention it, ol' chap, I do believe that I've some recollection of you doing such a thing. It's nothing compared to a trapeze artist boiling in mid-air, though!

**(Que) - Camera 6: {Boiling w/ice}**

**Peter:** Forget the trapeze!  
**{transition}**

**Demo: {Boiling Water with Ice}**

**Ed:** Fine fine fine. **{Moves over to demo}** Here we have a bottle of water sitting upon a hot fire. **{To jury}** What will happen if I let this bottle of water stay on the hot plate for a longer time? **"It will boil!"** And at what temperature does water boil? **"100 Celsius!"** Good! So while we're waiting for this water to start boiling, let's talk about the phases of water.

**Ed:** Water, like many elements and molecules, can be found in three different phases of matter. **{Graph a}** Who can tell me one of the phases? And another? And the last one for water? Good!

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #17a -- Graph a**  
**{Slide: <http://i.imgur.com/2tAYOaK.jpg> }**

**Ed:** As you can see, whether or not we see ice, water, or steam depends on the temperature and pressure of the water. If you look carefully at the curve, **{Graph b}**

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #17b -- Graph b**  
**{Slide: <http://i.imgur.com/qJ50U4A.jpg> }**

**Ed:** you'll notice that it's possible to reduce the pressure below our lovely single atmosphere to a place where the water will prefer to be vapor at a temperature that is below 100 degrees Celsius, and that's just what we're going to do now that this water is already at 100 degrees.

**{Ed turns off the heat and waits a few seconds as the boiling stops before capping the system.}**

**Ed:** Now that we have a nice hot water bottle, we're bored! This isn't doing anything but being

hot! What do you think will happen if I put some ice on top of the glass? *{Wait for responses.}* Well, let's find out!

*{Ed places ice on beaker, waits in anticipation until finally the water starts to boil.}*

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

**Ed:** By reducing the temperature of the water vapor in the bottle, we've caused the steam to condense. This brings the pressure inside the bottle down enough to keep the water boiling even after our heat has been removed! We could even go to more extreme points *{Graph c}* and make even room temperature water freeze!

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #17c -- Graph c**

*{Slide: <http://i.imgur.com/hmQqAVf.jpg> }*

*{transition}*

**(Que) - Camera 6: {Freezing by Evaporation}**

**Demo: {Freezing by Evaporation}**

**Peter:** Freezing water at room temperature? That doesn't sound right!

**Ed:** Your honor, I'm telling the truth I swear it! I've got some water in this bulb and the bulb is attached to this vacuum pump! Ladies and gentlemen, girls and boys, please pay close attention to this water as I turn on the suction!

*{Ed turns on the vacuum and waits for the water to boil and freeze.}*

**Ed:** The pressure is falling and falling and falling and....!!!!!!

*{The water freezes.}*

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

**Ed:** The water pressure fell low enough to bring this water to a freezing point so now all we have is a big block of ice!

**(Que) - Camera T1V1: {Leidenfrost}**

**Demo: {Leidenfrost Effect}**

**Peter:** Well that's all fine and dandy, but I have another document here saying that Prof. Sprott was able to move liquid without friction along a smooth surface! What say you about that!?

**Ed:** Boy that does sound pretty tough, but not as tough as balancing an elephant on a small

chair!

*{Ed moves to hotplate}*

**Ed:** But I'm glad you asked! I've got my handy hot plate and water dropper here and if you watch carefully, the water drops don't do exactly what you would expect.

*{Ed drops some water onto the hotplate and wow amaze it skids away}*

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #19**

*{Slide: <http://goo.gl/EU9zjw> }*

**Ed:** As you can see, as I drop room temperature water on the hotplate, it simply skids away!

*{Slide 19}* This happens because the plate is so hot compared to the water that it boils the water closer to the surface quickly enough to keep a bed of water vapor (steam!) between the water and the surface. This only happens when the temperature difference between the liquid and the surface is very large.

*{Ed grabs the dewar of LN2 on the table and moves out in front of the tables to directly face the audience}*

**Ed:** The same thing happens when we use liquid nitrogen! Does anyone know the boiling temperature of liquid nitrogen? *{Waits for answers.}* That's right: -321F. What about the skin on my hand? Probably about 80F right now, which is 400F warmer than the liquid. I'm sure that it's quite safe for me to pour this liquid onto my hand! Remember, members of the jury, I'm what they call an "Expert Witness," and this shouldn't be tried at home!

*{Ed pours LN2 onto his hand, and it's totally fine.}*

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

*{transition}*

**Ed:** My hand is safe now because of the Leidenfrost effect; there's a small layer of gas between the skin of my hand and the extremely cold liquid nitrogen!

**Demo: {Handheld LN2 Cannon}**

**Peter:** Now this reminds me of another charge against the defendant! He's been accused of making a cannon without any explosives! What say you to that?

**Ed:** You certainly don't need an explosion to make a cannon! In fact, it's safer to use other methods such as steam or electromagnetic energy. Can any members of the jury tell me how much a liquid expands when it boils into a gas? *{Audience replies.}* That's right! About 1000 times more volume is taken up by boiled liquid nitrogen. So, if I take some liquid nitrogen and put it into a small container....

*{Ed puts LN2 into the cannon and hammers the cork on IN RITHM WITH AUDIO,*

*aiming it at the back of the lecture hall until it fires.}*

**Audio:** [NitrogenCannon.wav](#)

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

**Ed:** The gas expands to such a large volume that it forced the cork off of the tube just like a cannon! I haven't had this much fun since I fired myself out of a cannon back in '05.

**Ed:** Now if it pleases the court, I'm sure many are interested in hearing about my newest take on Cirque du So-

**"Peter Interrupts"**

Nothing about you pleases the court. Fold up your circus tent and take your tap dancing elephants with you! The witness is dismissed!

**Ed:** Your loss; everyone else will see an elephant walking on a rope wearing a party hat! Tap dancing! The very idea!

*{Ed leaves with a flourish of some sort.}*

**Audio:** [TaDa Proud](#)

**{EXIT}**

## Peter {transition}

**Peter:** Professor Sprott, you have been accused of claiming that you can make sounds that cannot be heard. How do you plead?

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #21 -- [Photo of Dog Whistle](#)**

**Sprott:** I'm innocent Your Honor, and I'd like to call my third witness to explain why. I call to the stand Akire Trestrail.

*{Akire enters, as the Weakling Vigilante and takes the witness stand.}*

**Audio:** [Theme Perry Mason-short](#)

## Sound (Akire Trestrail) [Mic #4]

**Sprott:** Please state your name and occupation.

**Akire:** I'm Akire Trestrail, and I keep these streets safe for physics.

**Peter:** Is that your occupation?

**Audio:** [Dog Barking](#)

**Akire:** Well, it's more of a hobby. Me and my crime fighting dog Sir Isaac **{RUFF!}** make sure that no one is breaking the laws. The laws of physics.

**Peter:** And how do you do that?

**Akire:** Well, I've got my trusty utility belt. Ultrasonic cleaner. Transimpedance amplifier. Sonic screwdriver. And of course Issac helps out with his magneto-optical trap!

**Stenographer:** "Excuse Me!!!" ... Would the witness repeat that"?

**Akire:** Sure, That That That That THAT THAT THAT **THAT THAT!!!!**

**Stenographer:** Thank you, thank you!

**Peter:** And have you saved any physicists from certain doom?

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #23 -- Doppler**

**Akire:** Recently I heard my **Doppler**-warning sirens activate. Isaac and I suited up, I readied my boson-mobile, sure that the evil Doctor **Schrödinger** was on a terrible crime spree.

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #24 -- Schrodinger**

**Peter:** And was he?

**Akire:** Well, it turned out just to be a cat in a box. Isaac was very helpful though. Where is Isaac?

*{Blows dog whistle. Isaac appears}*

**{{ Dog Pops UP somehow }}**

**Audio:** [Dog Barking](#)

**Demo:** *{Dog Whistle} -- on O-scope*

**Demo:** *{Tuning Fork - 440Hz} -- on O-scope*

**(ON B) - RGB {T1 PC1}: Oscilloscope #1**

**\*\*{Que) - Camera T1V2: { For Sound Only } {Turn down speakers}**

**Akire:** Now I bet many of you are wondering how I called Sir Isaac without making a sound. Well the truth is, I did make a sound, except it was inaudible to most humans. To understand what I mean, you have to know what sound is. Sound is just a fluctuation of high and low air pressures. How quickly they fluctuate is called frequency. We can use a device called an "oscilloscope" to see what a sound wave looks like. You may not be able to hear this dog whistle like Isaac can, but with the aid of this oscilloscope you can see what it looks like. To prove to you that this isn't just noise, here is a tuning fork that produces sounds you can hear. Lets see what that looks like. ... The peaks of the wave show where the pressure is high, and the valleys show where the pressure is low.

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

*{transition}*

**(ON B) - RGB {Lec Computer 1}: PPT Show ---- BLACK - ready for Slide 26**

**{Que) - Camera T1V2: { For Sound Only } {Turn down speakers}**

**Demo:** *{Range of Hearing}*

**Akire:** Now if you look at the Range of Hearing chart, you'd notice that dogs and humans have different hearing ranges. Dogs can hear faster fluctuations than can humans. Let me show you what I mean. That display over there shows the frequency of the sound. Raise your hand if you can hear anything. I will now gradually raise the frequency. Put

your hand down when you no longer hear anything.

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #26 - Range of Hearing Chart**

**Akire:** It's interesting to note that the younger members of the jury kept their hands up longer. As it turns out, the range of human hearing decreases with age.

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

**(Que ) - Camera #6: {Ultrasonic Levitation}**

**Demo:** {Ultrasonic Levitation}

**{Needs to be cleaned up & wind/camera screen made}**

**Akire:** So now that you're familiar with ultrasound, would you like to see something really cool? Ok, we'll generate another ultrasonic beam, then reflect the beam using this reflector. When the beam reflects, it sets up a standing wave. Recall that sound is just a fluctuation of high and low pressures. So the high pressure regions are going to push these styrofoam balls towards the low pressure regions where they become trapped. Let's see how many we can fit. Isn't that cool?

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #28 - Ultrasonic Levitation**

**Audio:** [Dog Barking](#)  
{Isaac barks}

**Akire:** Uh oh, sounds like trouble. I better go see what it is. Last time Sir Isaac found Timmy stuck in a gravity well...

**Audio:** [TaDa Proud](#)  
{EXIT}

## Peter {transition}

**Peter:** Professor Sprott, you have been accused of breaking Ohm's Law. How do you plead?

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #30 -- [Photo of Plasma Discharge](#)**

**Sprott:** Innocent! You can't break a law that's not really a law.

**Peter:** NOT A LAW? You sir, are flirting with contempt of court!

**Sprott:** Not at all, your Honor. Let me call my next witness to explain why. I call to the stand Mike Randall.

*{Mike enters.}*

**Audio:** [Theme PeopleCrt-short.](#)

## Electricity (Mike Randall) [Mic #?]

**Sprott:** Please state your name and occupation.  
*{laughing maniacally}*

**Mike:** I'm Mad Mike Randall! I teach *mad* science to...children!  
*{swearing Mike into the court --- use a E&M book ??? lines }*

**Peter:** You want HIM as a WITNESS? Why are you wearing a cage on your head?  
*{Mike leaps at Peter, snapping and growling}*

**Stenographer:** "Excuse Me!!!" ... Is that one "r" or five?

**Mike:** Rrrrrr!

**Stenographer:** OK, that sounds like five.

**Sprott:** Mr. Randall, stop fooling around and explain why Ohm's Law is not really a law.

**Mike:** Well! You can't explain Ohm's Law without understanding a few things first! The world is made of stuff. Scientists like me call stuff *matter*. If you take any piece of matter, and start breaking it into smaller and smaller pieces, you'll eventually end up with some *teeny, tiny* things that sound like a boy's name. Those are called...

{jury response.}

**Mike:** Atoms! But atoms are made of even *tinier* things. Some of the *tiniest* things you'll find are called...

{jury response.}

{ Setup New Camera }

{Que } - Camera T3V1: {Ohm's Law Board}

**Mike:** Yes, *electrons*! So, what we *typically* call electricity is *REALLY* the movement energy of these little electrons!

**Demo:** {Ohm's Law Board}

{ON B} - RGB {Lec Computer 1}: PPT SLIDE #32 - Ohm's Law Slide

**Mike:** **Ohm's Law** tells us about the relationship between how hard the electrons are being pushed (that's called *voltage*, or V), how many electrons go by in a certain time (that's called *current*, or I), and how much the material that the electrons are moving through resists their movement (that's called...uh...*resistance*, or R). Resistance is is kinda like friction. (Resistance is futile!)

{No TaDa}

{Fast Transition to Pickle}

{Que } - Camera #6: {Move to Pickle}

**Mike:** Now, by it's *definition*, Ohm's Law *DEMANDS* that the relationship between voltage and current is *LINEAR*. For example, if I double the voltage, the current *MUST* also double! *EXCEPT*...it doesn't always work that way! Like when you electrocute a pickle!

**Demo:** {Electric Pickle}

**Lights:** DIM --- then back up {House lights dim}

{Mike laughs maniacally as the house lights come up}

**Audio:** Ta-Da-1

**Mike:** I *LOVE* electrocuting pickles! Did you see it light up? Weird, huh! But that's not the *weirdest* part! Electricity flowing through the pickle does *NOT* follow Ohm's Law! Did you notice how the light from the pickle flickered? If the

electricity in the pickle had been following Ohm's Law, the light would have been constant and even. So why wasn't it? In a pickle, the electric current is NOT carried by electrons! Salt in the pickle juice creates sodium and chlorine *ions*. Ions are atoms either missing electrons, or with extra electrons. It's the *ions* that are carrying the current. Turns out that currents in *ionic solutions* are *often* not linearly proportional to the voltage.

{transition}

**Mike:** I want to tell you about another case where Ohm's Law fails. But to do that, I'll need a helper from the jury.

{Select jury Helper}

**Mike:** Hi! What's your name? Well, \_\_\_\_, we talked earlier about what matter is. Do you know the states of matter?

{Kid and / or jury response.}

*Demo: {States of Matter}*

*Audio: [TaDa Proud](#)*

{transition}

**(Que)** - *Camera #6: {Plasma Ball}*

**Mike:** Wait! There's one state of matter missing! What's that called?

*Demo: {Plasma Ball}*

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

**Mike:** Yes! *Plasma!* If you take ordinary matter, and hit it with extreme heat or high voltage, you can rip the electrons off the atoms. That's what plasma is: an even mix of free electrons and atoms missing electrons - ions, remember?

**Mike:** Plasmas don't follow Ohm's Law either! In a plasma, the current is carried by electrons AND ions. AND, these moving electrons and ions make magnetic fields that affect how they move. The bottom line is, all this extra stuff going on means that the current in a plasma is **not** proportional to voltage.

{transition}

{Mike laughs maniacally}

**Mike:** Would you like to see what I can do with a plasma?

*Demo: {Musical Tesla Coil } - "Thunderstruck"*

*Lights: OFF --- then back up after song*

**Audio:** Ta-Da-1

*{Mike laughs maniacally}*

**(ON B)** - **RGB** {Lec Computer 1}: **PPT SLIDE # 34 - Tesla**

**Mike:** This is a musical Tesla coil! Named after famous inventor **Nikola Tesla**, it makes plasma using high voltage electricity. Would you like to hear another?

**Demo:** *{Musical Tesla Coil } - “Imperial March”, with H2 Balloon ending*

**Lights:** *OFF --- then back up after balloon*

**Audio:** Ta-Da-1

*{Mike laughs maniacally}*

**Mike:** Clearly, the plasma is very hot! The sound is made by turning the electricity on & off hundreds of times a second. This causes the air to heat up and expand hundreds of times a second, making sound waves we can hear! The frequency, or pitch, of the note is determined by how often we turn the electricity on and off.

**Peter:** OK, OK, I think we get the point. Now, will somebody PLEASE put this guy back in his cage?

*{Mike exits while continuing to leap and growl at Peter}*

**Audio:** TaDa Proud

*{EXIT}*

## Peter {transition}

**Peter:** Professor Sprott, you have been **accused** of using magnets to push on electrons and accused of transferring electrical power without wires. How do you plead?

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE # 36 -- [Photo of small Tesla Coil](#)**

**Sprott:** I'm innocent Your Honor. There's no law of physics prevents that, and I'd like to call my next witness to explain why. I call to the stand Andrew Seltzman...  
*{Andrew enters and pours liquid nitrogen over superconductor.}*

**Audio:** [Theme Perry Mason-short.](#)

## Magnetism / E&M (Andrew Seltzman) [Mic #?]

**Sprott:** Andrew, please stop fooling around over there and take the stand... Please state your name and occupation.

**Andrew:** I'm Andrew Seltzman, master of electromagnetic waves, inventor of this and that.

**Stenographer:** "Excuse Me!!!" ... Would the witness say that more slowly?

**Andrew:** Thhhhhhhhhhaaaaaaaaaaaaaaat

**Stenographer:** Thhhhaaaannnnnnank yooooouuuuuuu

**Andrew:** You're welllllccooooooommmmmmeee

**Peter:** Professor Sprott, you have been accused of bending the path of moving electrons without pushing on them thus violating Newtons first law. How do you plead?

**Sprott:** Innocent! There is a force. It's called the Lorentz force. Andrew, please explain.

**(Que ) - Camera #6: {e/m demo}**

**Andrew:** Quite right, anything in motion stays in motion in a straight line until acted on by an external force, but although you are not touching the electrons directly, a magnetic field applies force on moving charge, such as electrons, thus bending the beam.

**Demo: {e/m Demo} -- {bending a beam of electrons in a B field}**

**Andrew:** By increasing the magnetic field even further, the electron beam can be bent into a circle.

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #38 -- Lorentz**

**Andrew:** The **Lorentz force** pushes on the beam perpendicular to the direction of motion. As the beam changes direction, so does the force, making the electrons circle in the magnetic field like the moon circles the earth.

**Audio: Ta-Da  
{transition}**

**(Que ) - Camera T3V2: {Superconductor}**

**Demo: {Simple Eddy Current} -- {Superconductor}**

**{ Need camera screen & Light }**

**Andrew:** A superconductor has no resistance, so once currents start flowing, they never stop. Since a changing magnetic field can drive currents, when a magnet is brought near a superconductor, the increasing field drives current in the superconducting disk. These currents generate a magnetic field that traps the magnet in place.

**Audio: Ta-Da-1  
{transition}**

**(Que ) - Camera #6: {Induction Heating}**

**Demo: {Induction Heating}**

**{paul nonn's huge transformer inductively heating a wire loop}**

**Andrew:** A strong changing magnetic field from this electromagnet can drive current in this metal ring. So much current flows, that the ring glows like the filament in a lightbulb.

**Andrew:** Ah, but there is a voltage; a changing magnetic field produces an electric field that encircles it. When the ring is placed in this electric field, current is driven around the loop. Since the loop has resistance, the flowing current heats it up.

**Audio:** Ta-Da  
{transition}

**(Que ) - Camera #6: {Microwave}**  
**Demo: {Fluorescent light in microwave}**

**Andrew:** When a fluorescent bulb is plugged in, the voltage from the light socket drives a current through the tube exciting the gas into a plasma, thus causing the bulb to fluoresce. Electromagnetic waves including light and radio waves, such as those found in a microwave oven, carry energy. The radio waves within the microwave oven have a very rapidly changing electric field that excites the gas in the fluorescent bulb, causing it to glow.

**Audio:** Ding {Bell sound "Ding" on Microwave  
**Audio:** Ta-Da

**Peter:** Thank you Andrew. I will take your evidence into consideration.

**Audio:** TaDa Proud  
{EXIT}

## Peter {transition}

**Peter:** Professor Sprott, you have been accused of using magnets to attract and repel aluminum and copper, which everyone knows are not magnetic materials. How do you plead?

**{{ More Photos are Needed }}**

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #40 -- [Photo of Levitated Ball](#)**

**Sprott:** I'm innocent Your Honor, and I'd like to call my next witness to explain why. I call to the stand Michael Winokur...

**{Michael enters and takes a seat in the witness stand.}**

**Audio:** [Theme Perry Mason-short.](#)

## Magnetism (Michael Winokur) [Mic #?]

**Sprott:** Please state your name and occupation.

**Michael:** Michael Winokur, scientist by day, but, because of my magnetic personality, Physics Party candidate by night.

**Sprott:** In your capacity as a scientist, have you ever seen me do a demonstration in which I levitate an aluminum using an electromagnet?

**Michael:** Yes, of course I have; an excellent demonstration.

**Sprott:** Does that demonstration violate any laws of physics?

**Michael:** Laws, laws you ask? Did you know that a vote for me is a vote for Ampere's **Law** and magnetic **order**.

**Sprott:** That's a great platform, but we'd really like to know more about the physics.

**Michael:** Nothing better! I love babies, I love Ampere's Law and I love physics !

**Stenographer:** **"Excuse Me!!!"** ... Could you say that a little LOUDER?

**Michael (shouting):** THAT!!!!!!!

**Stenographer:** Thank you

**Sprott:** You have my vote.

**Peter:** Professor Sprott, I don't allow electoral shenanigans in my courtroom, please refrain yourself.

**(Que ) - Camera #2: {Oersted Effect}**

**Michael:** No problem, like I said I've got a **magnetic** personality. **Ampere's Law** relates electric currents to magnetic fields. Here I'll demonstrate.

**{{ Need camera screen }}**

**Demo: {Oersted Effect - (but Vertically Mounted) }**

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #42 -- Ampere**

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #43 -- Orsred**

**Michael:** In this, Exhibit A, I have a compass which as the member of the jury will know, usually points to magnetic north. But over here we have a wire with 20 amperes of dc current flowing. Notice that my magnet now points out a circle of magnetic field around the wire. That is **Ampere's Law** in action.

**.Audio: Ta-Da-1**  
**{transition}**

**Michael:** In Exhibit B we can see the entire magnetic field of magnet using these iron filings.  
Ad lib....

**Demo: {Mag. with Iron Filings }**

**(Que ) - Camera T2 PC1: {Document Camera}**

**Audio: Ta-Da-1**  
**{transition}**

**Sprott:** Well I do see a circle but how does this relate to my demos?

**Michael:** Ah, that's the easy part. The magnet's poles line up with the **invisible** magnetic field.

**(Que ) - Camera T2V1: {Ferrofluid}**

**Demo: {Ferrofluid}**

**Michael:** Magnetic Fluid Demo. If you are following my campaign then you know that many materials can be made to follow magnetic field lines. Among the most visually interesting are "magnetic fluids". Exhibit C, In this beaker, is a magnetic fluid consisting

even finer magnetic particles suspended in oil . Let's set what a very strong magnet does. Ad lib....

**Audio:** [Ta-Da-1](#) or Ooh and ahh.  
{transition}

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #45 -- Faraday**

**Michael:** But that's only half the story. Not everything is what or who it seems to be (Just look at me...) Just because something isn't a magnet does mean it can't have a magnetic attraction. There's yet another law, **Faraday's Law** of induction (and, just for the record, I am against the military draft!), which says a moving magnet will "induce" an electrical current in any metallic object. This current itself creates a magnetic field which then induces a force on the first object. This is called "**Lenz' Law**".

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #46 -- Lenz**

**Michael:** In fact we can demonstrate Lenz' Law by running a race, a "two party" magnetic race. But the exhibit requires a juror....ad lib.  
{Select jury helper}

**(Que) - Camera #6: {Helper}**

**Demo: {Simple Eddy Current} -- (Magnet falling in a metal tube)**

**Audio:** [Jeopardy Jeopardy](#)  
**Audio:** [TaDa Proud](#)  
{transition}

**(On A) - Camera #4: {Can Crusher} -- ON CAN**

**(On C) - Camera #6: {Can Crusher} -- ON Meter**

**Michael:** I'm planning to use this effect to prevent my polls from falling further (and I don't mean magnetic poles).

**Demo: {Can Crusher}**  
{Now force i.e. action at a distance}.

**Michael:** The magnetic forces can be quite strong. This exhibit uses a device that stores a large amount of electric charge. When the charge is released and flow through this wire it creates a really strong magnetic field with which will **crush** my political opponents....like this aluminum can. Ab lib.

**Audio:** [Ta-Da-1](#)  
**Audio:** [Ball Game](#)  
**Audio:** [TaDa Proud](#)

{transition}

**(Que ) - Camera T2V2: {Levulator}**

**Demo: {Levulator }**

**(( Need a Camera Screen ))**

**Michael:** If we put all the elements of these laws together we can even appear magical! In this exhibit, the one Professor Sprott is accused of performing use back and forth electric currents to get attractive and repulsive forces, all politics aside, and suspend a solid metal object in mid air. Ad lib.

**Peter:** Thank you Professor Winokur. I will take your evidence into consideration.

**Audio: TaDa Proud**

**{EXIT}**

## Peter {transition}

**Peter:** As the next witness I would like to call one of Prof. Sprott's **co-conspirators**, who has been caught bending light with Prof. Sprott.

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #48 -- [Photo of water light guide](#)**

## Light (Marty Lichtman) [Mic #?]

**Audio:** [Doom March](#)

**Marty:** I didn't see nothin'.

**Peter:** I haven't asked you any questions yet.

**Marty:** Good, 'cause I ain't answerin' nothin'.

**Peter:** You will use proper grammar in this courtroom!

**Marty:** For what? This ain't the Wonders of English.

**Peter:** I will hold you in contempt!

**Marty:** Never been to Contempt. Is it nice this time of year?

**Peter:** Now I'm angry.

**Marty:** Hello Angry. Pleased to meet you.

**Peter:** If you're not careful you'll go to jail for the rest of the year!

**Marty:** Well seeing as 2015 here is the International Year of Light, that'll be a pretty light sentence. A light-year, if you will.

**Peter:** Now look here. We have evidence that you conspired to violate the laws of physics. If you don't cooperate, you'll find yourself in jail.

**Marty:** I've been trying to find myself. I've tried Hari Krishna.

**Peter:** On the 15th of February, 1992, you were seen to bend light. As we all know, light travels in straight lines.

**Marty:** But wait'a minute, I can bend light using a fiber optic tube!

**Peter:** AHA! So you admit your guilt!

**Marty:** Nah, it ain't guilt, it's physics! Let me show you!

**{transition}**

**(Que) - Camera #6: {Spiral Light Pipe}**

**Demo: {Spiral Light Pipe}**

**Lights: OFF --- then back up**

**Marty:** And we don't need no fancy fiber optic plastic neither. We can bend light with just regular old water. Lemme show ya'.

{transition}

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

**(Que ) - Camera #6: {Water Gide}**

**Demo:** {Water Light Guide}

**Lights:** OFF --- then back up

**Marty:** .....???

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

{transition}

**Peter:** That's just not right. An abomination to nature!

**Marty:** Nature? Nah, Nature don't mind none. Ain't you never seen a rainbow?

**Peter:** I don't get out much.

**Marty:** Ah, well that's a shame. Lemme show you one!

**Lights:** OFF --- then back up

**Demo:** {Rainbow }

**Marty:** Here I have a nice triangular piece of glass. I got it on sale special, downtown. You know, five finger discount. Same type of triangular prism that old Ike Newton had. I put in white light into one end. The light bends through the crystal, but each color of light refracts a different amount, causing it to spread out into all the colors of the rainbow. The visible spectrum, right there on the screen.

**Audio:** [Over the Rainbow](#)

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

{transition}

**Peter:** Okay, so you can use some material to bend light. But it must violate the laws of physics to do so just in air.

**Marty:** You like the stars Mister?

**Peter:** Sure, I'm a big fan of **George Clooney**. He's dreamy.

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE #50 -- George Clooney**

**(Que ) - Camera #4: {Twinkling Stars}**

**Marty:** Jeez, you've got wax between your ears and nothin' else. Not the movie stars, the stars in the night sky! We see their light bending all the time.

**{{ Need White Screen for laser }}**

**Demo:** {Twinkling Stars } - {Candle or meker burner}

**Audio:** [Twinkling Stars](#)

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

**Peter:** Alright, so light can bend, and that's perfectly allowed by the laws of physics. But you have also been caught changing the speed of light, and that is a horrendous crime!

**Marty:** Well then you're in on the heist, buddy. We've already changed the speed of light three times in the last five minutes.

**Peter:** How dare you accuse me!

**Marty:** Hey, I'm not gonna judge ya.

**Peter:** That's my job.

**Marty:** We'd'a gone an' changed the speed of light in every demo so far. But I'll let you in on a little secret. Let's just say it fell off the back of a truck. The speed of light is always the same in a vacuum, but when light goes through some material, it interacts with the atoms in the material, and that slows it down.

**(ON B) - RGB {T1 PC1}: Oscilloscope #2**

**Demo:** {Speed of Light}

**Marty:** Let's see if we can measure that. I'm gonna need a volunteer from the jury to help me out here.

**(ON B) - RGB {Lec Computer 1}: PPT Show ---- BLACK - ready for Slide 52**

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

**Marty:** Wowza. 300 million meters per second. I sure wish I could get away from a heist that fast. Speaking of which, this courtroom is makin' me nervous, I better make like a light beam and propagate!

**Audio:** [TaDa Proud](#)  
 {EXIT}

## **Closing (Sprott, Peter, Cast)**

**Sprott:** I hope that I've convinced you that I have not broken the laws of physics. In fact, it's impossible to break the laws of physics. Unlike the laws that our legislators pass and that lawyers and juries debate, the laws of physics are true everywhere in the Universe and for all time. But every law has a regime in which it applies, and we must be careful not to try to use it where it doesn't apply. Occasionally we're able to modify a law so that it applies for a wider range of conditions, but the laws of physics cannot be broken. I hope that you the jury will agree that I'm innocent of these charges and that I can continue to make presentations of The Wonders of Physics for many years to come.

**Peter:** Does the jury have a verdict? All those who think Professor Sprott is innocent of these crimes, respond by saying "aye." All those who think he is guilty, respond by saying "no"... I'm pleased to report that the eyes are above the nose! Court is dismissed.  
(bangs gavel)

**Audio:** [Rimshot.wav](#)

**Sprott:** Thanks for that anatomy lesson. I'm delighted that you've found me innocent, except for those who think I'm guilty and shouldn't bother coming back next year. But with your generous contributions to The Wonders of Physics Fund, I certainly intend to continue doing these presentations for many years to come.

**Sprott:** And now I'd like to make my triumphant exit with the demonstration we've used to end every presentation of The Wonders of Physics for the past 32 years by making for you a cloud...

**Demo:** {LN2 Cloud}

**(ON B) - RGB {Lec Computer 1}: PPT SLIDE # 52 - Clouds / 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 from right and left doors and bows in unison.}***

## Notes:

### Here are some laws we should try to work in:

- General Laws
  - Conservation of mass/energy
  - Murphy's law!
- Motion
  - Newton's laws of motion
  - Law of gravity
  - Conservation of linear and angular momentum
  - Hooke's law (?)
  - Kepler's laws (?)
- Heat
  - Ideal gas law
  - Laws of thermodynamics
- Sound
  - Acoustic levitation
  - Breaking glass with sound
- Electricity
  - Ohm's Law
- Magnetism
  - Ampere's law
  - Faraday's law
  - Biot-Savart Law
- Light
  - Snell's law
  - Invariance of speed of light

## Resources

- [2015 PowerPoint Slide Show](#)
- [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](#)
- [2014 WOP script](#)
- [2013 WOP script](#)
- [2012 WOP script](#)

- [2011 WOP script](#)