# The Wonders of Physics 2018

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# The Wonders of Physics 2018

*"35th Season Celebration"*

## ***Opening*** ***(Peter, Norman, Sprott)*** **(Norman , 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}: Optional PPT intro (Emily is preparing this)***
***Lights: Change to Stage & Floods***

**Peter:** Welcome to the (298, 299, 300, 301, 302, 303, 304, 305, 306, 307) presentation of *The Wonders of Physics*... Before the show begins, I want to assure you that 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:** This year we are celebrating two anniversaries. It was *35 years ago that Professor Sprott* began **The Wonders of Physics**. Also *100 years ago Professor Earl M. Terry* of our Physics Department developed a radio transmitter and began broadcasting radio from the basement of our physics building. Today we will be producing our own live radio show with you as the studio audience.
***(ON B) - {Lectern Computer 1 - PPT Slide #2}:*** **Sprott doing the First WoP Show**
***(ON B) - {Lectern Computer 1 - PPT Slide #3}:*** **E.M. Terry**

***{Lights go down to show a video of Norman Gilliland in a radio studio}***

***(ON B) - {Lectern Computer 1 - PPT Slide #5}:: Norman Video***
**Norman (on video):** This is Norman Gilliland of Wisconsin Public Radio. This past year, we at WPR have been celebrating the first regularly scheduled radio broadcasts which took place in 1917 from the Physics building on the University of Wisconsin campus. In honor of that and to celebrate the 35th anniversary of **The Wonders of Physics**, Professor Sprott and his crew will be broadcasting their own show from the basement of the Physics building. Let's see what exciting things they have planned for us…

*{Illuminate the "ON AIR" sign and turn on lights}*

**Peter:** And now from the basement of the Physics building at the University of Wisconsin, we present the 35th Anniversary Show of The Wonders Physics. Professor Sprott is just arriving…

***Audio: Motorcycle sound***

**Peter:** And now he's opening the door!

**Peter:** And now he's walking in the building!

*{Sprott walks out casually, clad in a tuxedo and patiently waits for the theme music to end}*

***Sign Person: "Applause" sign***

***Audio: WOP Theme*** (short)

**Sprott:** Welcome to ***The Wonders of Physics*!** We are pleased to bring you this live radio broadcast using a replica of the original 9XM radio transmitter. We'll be presenting some of the best physics demonstrations from the past 35 years as well as a few new ones. Our studio audience will be voting with their applause for their favorite demonstrations.

And now a word from our sponsor...

*{This software applause meter works fine on my PC laptop using the internal microphone: https://www.grantgibson.co.uk/2014/06/free-applause-meter-pc-mac/}*

***Sponsor commercial:***

*{The guests should come on-stage during the commercials, taking their place behind a microphone stand.}*

# ***Motion*** ***(Mike Randall)***

**Peter:** ***Commercial Sponsor:*** Is your old doghouse too slow? Can't keep up with that pesky Red Baron? Well, now, the sky's the limit in the 1917 Sopwith Camel! An agile, highly maneuverable biplane, the Sopwith Camel accounted for more aerial victories than any other Allied aircraft during World War I. And, unlike your doghouse, it can actually FLY! Test drive the Sopwith Camel today!

***(ON B) - {Lectern Computer 1 - PPT Slides #7, 8, 9, &10}:***

- ***{Slide: Sopwith slides } → { Change slides on the above highlighted words}***

***Audio: { Legal disclaimer recorded at high speed }:*** The Sopwith Camel is noted for its tendency to crash. Side effects include: vicious spin characteristics; engine choking and cutting out during takeoff; crashing on takeoff due to the full fuel tank affecting the center of gravity; tail-heaviness in level flight; immediate uncontrolled spinning in a stall; and sudden right turns due to engine torque. Your results may vary.

**Sprott:** Mr. Weix, air travel has come a long way since 1917. In fact, our first show today is "Let's Fly!" with your host, **Captain R. O. Dynamic**...

- ***{Slide: "Let's Fly!" show slide - TBD}***

**Mike R:** Cheerio, everyone! Welcome to "Let's Fly!" My name is Captain R. O. Dynamic. A hundred years ago, the state of the art in motion was the airplane - or "aeroplane", as it was called back then. The most successful plane in World War 1 was the Sopwith Camel, introduced in 1917. In fact, Wisconsin's first flying ace, Rodney D. Williams, flew a Sopwith Camel!

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

- ***{Slide: Rodney D. Williams, 1st Wisconsin Flying Ace}***

**Mike R:** But how do airplanes work? We've all played with paper airplanes.

***Demo: { Paper airplane }***
***{Throw paper airplane }***

**Mike R:** They look simple enough. But what keeps them up? To understand that, we need to know more about the "ocean" we all live under - our atmosphere. I need a strong volunteer from the studio audience.

***Demo: { Magdeburg plates }***

- ***Get volunteer name***
- ***Ask them to pull suction cups apart***
- ***Release vacuum - cups separate easily***
- ***We live at the bottom of an ocean of air***
- ***Air has weight - everywhere my thumb can cover, air is pressing down with the weight of a bowling ball***
- ***Don't notice, because forces are in balance***
- ***Magdeburg plates - air removed from between plates; outside air pushes in with over 200 lbs of force***
- ***Applause for volunteers***

**Mike R:** So, a small imbalance in air pressure can generate a large force. I need two more volunteers!

***Demo: { Hovercraft }***

1. ***Get volunteers names***
2. ***Ask one to stand near middle of stage***
3. ***Other volunteer sits on hovercraft***
4. ***Forces in balance - no movement***
5. ***Turn on air blower - glide hovercraft to standing volunteer & back***
6. ***Air blower created imbalance of forces - moved hovercraft & seated volunteer up a little***
7. ***New balance point / equilibrium off the floor***
8. ***No floor contact = no friction. Easy movement***
9. ***Applause for volunteers***

**Mike R:** Consider that an airplane's lift ALSO comes from unbalanced forces. Not from air pumps or fans, but the speed of the airplane itself. Look at the shape of a wing.

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

- ***{Slide: Airflow over a wing}***

**Mike R:** Notice how it's flat on the bottom, and curved on the top. The air going over the top of the wing has to travel farther. So it has to travel faster to keep up. The Bernoulli Principle says that an increase in air speed causes a decrease in air pressure.

***(ON B) - {Lectern Computer 1 - PPT Slide #15 }:***

- ***{Slide: Bernoulli principle }***

**Mike R:** Let's see what happens when we try that! I need another volunteer!

***Demo: { Bernoulli ball levitation }***

10. ***Get volunteers name***
11. ***Ask volunteer to hold beach ball steady***
12. ***Levitate ball with leaf blower***

*13. Air flowing over top of ball creates lower air pressure*
*14. Higher pressure under ball lifts it up until balanced with gravity*
*15. Same thing happens with airplane wing*

***(ON B) - {Lectern Computer 1 - PPT Slide #17 }:***
*16. {Slide: Airflow over a wing}*

*{ Applause for volunteer }*

**Mike R:** Now that we understand how the Bernoulli effect works to create lift, let's have a little fun! What do you think will happen when we blow air over the top of this roll of toilet paper? Let's find out!

***Demo: { Toilet paper gun }***

**Mike R:** Yes! The air pressure was lower on top of the toilet paper. So the higher pressure air under the paper lifted it up, and sailed it out into the room! Everyone, quickly wad up the TP and pass it down to the stage.

***(ON B) - { Lectern Computer 2 - Applause Meter ( iPad }:***
**Sprott:** And now let's vote with your applause for your favorite Motion demonstration:

1. Paper airplane
2. Magdeburg plates
3. Hovercraft
4. Bernoulli ball levitation
5. Toilet paper gun

**Mike R:** That's all for me today. Next time on "Let's Fly!", we'll talk about Robert Goddard and his controversial idea about sending rockets to the moon!

***(ON B) - {Lectern Computer 1 - PPT Slide #19}:***
- ***{Slide: Robert Goddard and rocket}***

# ***Heat** (Terry Craney)*

***(ON B) - {Lectern Computer 1 - PPT Slide #21}:***

- ***{Slide: Sular Fusion Mining Co}***

**Peter:** ***Commercial Sponsor:*** Tired of high energy bills during this long cold winter? Well look to a new company for the answer- Sular Fusion Mining Company. No, we aren't talking about harnessing the sun's infrared radiation here on earth. We are going to the sun and bringing part of it back. And with your investment we can't fail. Sure there are few technical problems, but we will be going at night when the sun is not shining. So far there has been a "massive reaction" to our IPO (SUMI). Invest now.

Legal disclaimer (recorded at high speed): Past performance of Solar Fusion Mining Company stock does not guarantee future returns.

**Sprott:** And now to get our energy going at the atomic scale and to "warm us up", we have that famous English physicist **Calvin Scale** who at times is an absolute zero....

**Terry:** What did you just call me? I'll take that as a compliment because I am Calvin Scale, I am super cool and at times I am 0 K. Anyway, thank you Professor Sprott. So let's talk about heat, heat transfer and the effects of heat and pressure on materials.

***(ON B) - {Lectern Computer 1 - PPT Slide #23}: "I'm OK"***

***Demo: { Boiling Water in a Paper Cup - setup }***

**Terry:** Let me start by putting some water in this paper cup and putting it on this Bunsen burner. I would like a cup of English tea at the end of the show*.* So let's get these molecules moving and heated up. (Joke) By the way, ***don't ever trust a molecule or atom-- they make up everything.*** ***{look surprised as the audience looks puzzled}. {Let the water start to heat up}***

***Audio: Rimshot***

***Demo: { Non-burning Handkerchief }***

***(on A ) - Camera 6: { Handkerchief }***

**Terry:** Now moving on. (sneeze into hand) Excuse me. Does anyone have a handkerchief that I could borrow for a moment? Ah yes, thank you and your name? It looks like a normal cotton handkerchief to me. (sneeze into it) So sorry! Was that a clean Handkerchief?? Let me clean it up for you. ***{put in $H_2O$ and isopropyl alcohol bath}***. I am now going to dry it over this flame before I return it . ***{Act like it "accidentally" started on fire.}***

***Audio: Response***

**Terry:** Somebody, get the fire extinguisher! ***{Put out the fire, look flustered and wipe brow with handkerchief and then have the audience member examine the handkerchief}***. So what happened? Why didn't the handkerchief ignite?

**Terry:** Well, my water solution was only 50% water but also 50% rubbing alcohol (isopropyl alcohol) like you may have in your medicine cabinet at home. The alcohol will start on fire at a lower temperature than the cotton in the handkerchief. So what you saw burning was the alcohol. But more importantly, the water in the solution has a very high heat capacity or as physicists call it "specific heat". A substance that has a high heat capacity can absorb a lot of heat energy without rising much in temperature. Further, if some of the water did reach the boiling point, the vaporization process (turning it from water to steam) also absorbs a tremendous amount of heat energy. Therefore, the heat from the burning alcohol went into heating the water and turning it into steam rather than igniting and burning the cotton cloth and the handkerchief was saved.

***Demo: { Boiling Water in a Paper Cup - Part 2 }***
***(on A) - Camera 6: { Paper Cup }***

**Terry:** Now let's get back to my paper cup. The water is starting to steam and boil! Again the water absorbed the heat from the burner instead of raising the temperature of the bottom of the paper cup to its ignition point. This is why water is such a great cooling agent - used in many industrial cooling processes - it can absorb a lot of heat without rising much in temperature. ***{Pour steaming water out of cup}***. Now, to show there's no trickery with my cup - it does burn. ***{Light cup on fire with burner}.***

***Demo: { Fire Tornado }***
***(on A ) - Camera 6: { Fire Tornado}***

**Terry:** So now let us look at how an actual flame burns and how the air around that flame affects it. I am going to start a fire in this canister which contains paper towels and lighter fluid. Notice how the flame rises into the air. The gases in the flame rise because as they heat up they become less dense than the surrounding cooler air- less dense gases rise in the more dense air. Cool air from the sides then flow into the flame to feed it with oxygen. So a convection current is set up around the flame. Now I am going to take this cylinder shaped screen, put it over the fire and rotate it with this platform. Watch what happens! The flame rises and swirls! The cold air from the sides is not coming straight into the fire but instead is caught in the screen and rotates as it moves toward the flame. Due to friction between all of the gas molecules, the entire system rotates including the flame. This rotating column of flame has what physicists call angular momentum. The rules of angular momentum dictate that as an object gets closer to the center of rotation, it speeds up -- similar to an ice skater pulling her arms in close to her body to spin faster. Therefore the flame spins faster and also becomes longer. This phenomenon is referred to as a "fire tornado". Fire tornados actually do occur in nature. The large wildfires that happen in the western states occasionally produce large fire tornados if the conditions are just right with strong swirling winds. (point to slide on screen)

***(ON B) -*** ***{Lectern Computer 1 - PPT Slide #25}: "Fire Tornados"***

***Demo: { Freezing by Evaporation }***

***(on A ) - Table 3 Video 1: { Freezing by Evaporation }***

**Terry:** Let's now talk about the effects air pressure (which Captain Dynamic mentioned earlier) has on the freezing and boiling points of water. We have here a flask containing distilled water - nothing else - believe me. What is the boiling temperature of water? 212℉ or 100℃ but only at standard, normal atmospheric pressure like we have in this room right now. By reducing the pressure over the water, the boiling point temperature lowers. (point to slide on screen with BP of different places) And, if we reduce the pressure enough with a vacuum pump, the boiling point lowers enough so that the water will boil at room temperature - like it is now.

**Terry:** As the water boils, it also takes heat from the water-- heat of vaporization which we mentioned with the handkerchief experiment. This heat removal actually lowers the temperature of the water down to its freezing point and it turns into a slushy mixture. So you can have water boil and freeze at basically the same time and at the same temperature by manipulating the pressure. Wow!

**Terry:** By the way, this method is used in the food industry to remove the water from regular orange juice to make frozen concentrate. The process does not affect the taste of the juice like it would if the water were boiled away at 212℉ or 100℃. Likewise, "freeze dried instant coffee" is made by a similar method.

***Demo: { Exploding Balloons }***

**Terry:** Finally, let's look at gases that have different densities as compared to air. As we mentioned earlier, a less dense gas will do what in a denser gas? Correct, it will rise. ***{Show demo}***.

**Terry:** Now, here we have two balloons filled with gas that is less dense than air, so they rise. What do you think that gas might be? Helium - maybe. What else could it be? Hydrogen - maybe. How could we tell the difference? Blow them up? Wow, there's a thought! What could ever go wrong with that idea? Maybe we should ask the designers of the Hindenburg blimp.

**Terry:** But, on the other hand, we could measure the upward force created by the balloon which is called buoyancy. There will be a slight increase in the buoyant force if it is filled with hydrogen as compared to helium since hydrogen is lighter than helium. Or we could find what is in the balloon by using a chemical analysis method called, "mass spectrometry".

We take a sample of the gas, put it into a machine, push a button, and voila, the mass spectrometer tells us what gas it is.  This method is very accurate, but it's not overly exciting, so we aren't going to use it.

**Terry:** We as physicists, on the other hand, love to set things on fire and blow things up.  So let's do that!  ***{Bring match to helium balloon.}*** What happened? ***{It pops, but no explosion, just like popping it with a pin.}*** Must be helium which doesn't burn. Now over there we have the other balloon.

Here is an example, in physics, of taking nothing for granted. We like to repeat our experiments to see if we get the same results. Even though the balloons look identical, they may be different.

So let's test the other balloon and try it again. You may want to cover your ears ***{Bring match to balloon - loud explosion}***. Must be hydrogen. Very light in density but highly explosive and containing lots of energy.

So that's all for today's demonstrations on heat. Be sure to tune in next time when we will not only be burning and blowing things up by chemical means, but also creating a small nuclear fission reaction. I can hardly wait. So in a few moments, I am going to act like an atom and split.

***(ON B) - { Lectern Computer 2 - Applause Meter ( iPad }:***

**Sprott:** And now let's vote with your applause for your favorite Heat demonstration:

1. Boiling in a Paper Cup
2. Non-burning Handkerchief
3. Fire Tornado
4. Freezing by Evaporation
5. Exploding Balloons

# ***Sound* (Emily Ehlerding)**

**Peter:** ***Commercial Sponsor:*** Do you want to take your music with you wherever you go? Well now with the Pauli Portable Player you can. Weighing in at only 30 pounds, our record player lets you be the life of any party. Pauli - a proud sponsor of "Sound Off" with Rileigh Rayleigh.

***(ON B) - {Lectern Computer 1 - PPT Slide #32}:*** Pauli Portable Player

**Sprott**: Now here to break up the talk radio with some sound waves of her own, it's "Sound Off" with Rileigh Rayleigh...

**Emily:** Well hello folks. I'm Rileigh Rayleigh and you're listening to Sound Off. Today we're bringing you the top songs of the last 50 years, and some science along with them. Now, since we're on the radio, it only makes sense to talk about sound, right? Sound travels through the air (or other things) as a wave.

***(ON B) - {Lectern Computer 1 - PPT Slide #29}: Waveforms***

- http://www.mediacollege.com/audio/images/loudspeaker-waveform.gif

**Emily:** Basically, the air molecules are squished together ***{slide whistle up}***

***Audio: Slide Whistle Up***

**Emily:** and pulled apart ***{slide whistle down:}***

***Audio: Slide Whistle Down***

**Emily:** like you in our studio audience can see in this diagram. When those squished ***{slide whistle up}*** and pulled-apart ***{slide whistle down}*** bits of air hit our eardrums, our nerves and brains take that mechanical pressure (the squishing and pulling) and make it so that we "hear" a sound, or a song, like this top song from the 1950s by the King.

***Audio: Hound Dog (Ryan)***

- https://www.youtube.com/watch?v=-eHJ12Vhpyc (0:00 to 0:10)

***Demo: { Breathing He and SF6 }***

**Emily:** Now the speed at which sound travels depends on the thing it's traveling through. Sounds will travel faster through things that are lighter. Sound will also travel faster through lighter gases…. ***{breathe in helium}*** like helium! ***{sing something from wizard of oz munchkins?}*** A molecule of helium weighs about 7 times less than your average air molecule, meaning that sound can travel about 3 times faster in helium. And in this case when sound travels faster, it sounds higher pitched. Kind of like all the fangirls who saw our next group, the Beatles.

***Audio: Twist & Shout (Kim)***

- https://www.youtube.com/watch?v=b-VAxGJdJeQ (0:07 to 0:22)

**Emily**: If you remember, sound will travel slower through heavier things. There are also gases that are heavier than normal air…. (breathe SF6) like sulfur hexafluoride. (fe fi fo fum or something like that). SF6 has a mass about 5 times heavier than normal air… so the sound of my voice travels about threeeee… timesssss….. Slooooooower. The opposite of these guys, the Bee Gees from the 1970s.

***Audio: Night Fever (Michael)***

- https://www.youtube.com/watch?v=-ihs-vT9T3Q (0:49 to 1:03)

***Demo: { Ruben's Tube - 3D30.50 }***

**Emily**: There are some ways to see what a sound wave looks like, to see those squished ***{slide whistle up}*** and pulled apart ***{slide whistle down}*** parts. The most science-y way is using an oscilloscope. ***{can have one if we want}***.However, that's not very exciting. You know what is exciting? Lighting things on fire. ***{light flame}*** Because sound travels by squishing ***{slide whistle up}*** and pulling apart ***{slide whistle down}*** air molecules, the pressure and density at different points in this tube will change. And when the pressure goes down… ***{turn on sound}*** *the flames go up!* ***{first: single tone at resonance; second: song??: 1812 overture (start around 3:05)}***

**Emily**: You can *physically* see how the different pitches in this song make different-looking waves. Physically see them, get it? Speaking of physical, this is Olivia Newton John with Physical from 1981.

***Audio: Physical (Terry)***

- https://www.youtube.com/watch?v=vWz9VN40nCA (0:46 to 1:00)

***Demo: { Hoot Tubes }***

**Emily**: Every time someone plays an instrument like a guitar, or violin, or flute, or clarinet, they're making something called a standing wave.

***(ON B) - {Lectern Computer 1 - PPT Slide #31}: Guitar***

- (http://78.media.tumblr.com/tumblr_lh96t0EvPA1qbtjkwo1_500.png)

**Emily**: The idea behind this is that waves like to travel in the way that's easiest for them. The wave, whether it is on a string of a guitar or an air pressure wave in a flute, will create what's known as a standing wave. Now, this isn't really an instrument, but I have something here that will create a standing wave.
***{start the demo}***

**Emily**: The different parts of the sound wave, you know, the squished ***{slide whistle up}*** and pulled apart ***{slide whistle down}*** parts, have different densities. Another thing that makes air density change is heating it up, like Mr. Kelvin said, like we can do with this fire. Hot air is less dense, so it rises and will keep going through this tube, like blowing air through a straw. When it does that, we will get a standing wave which kind of sounds like this…. (demo). The speed at which that wave travels is called its resonant frequency.

**Emily**: The pitch, or how high or low a sound sounds, depends on its wavelength. When we have a long tube, our sound has a long standing wavelength and sounds deeeeeper. When we have a short tube ***{replace with shorter}***, we have a short wavelength and a hiiiigher sound. …. The Macarena from 1996.

***Audio: Macarena (Mike)***

- https://www.youtube.com/watch?v=gwWRjvwlLKg (0:42 to 0:59)

***Demo: { Breaking beaker with sound }***

**Emily**: Since sound travels as a wave, these sound waves have some power to them, like water waves or things like that. It also turns out that strings and tubes aren't the only things that can have resonant frequencies. Everyday things, like say this glass, can have resonant frequencies too. However, certain things don't really like being at their resonant frequency. For example…. (shatter glass)

By using a sound wave that was perfectly tuned to the glass's resonant frequency, we basically made a standing wave in the glass, which, because of all that power, shattered it!

***(ON B) - {Lectern Computer 1 - PPT Slide #33}: Slow Motion Video {{ TBM }}***

**Emily**: Well that's all the time we have for today, folks. Thanks again for listening to Sound Off, and come back next week, when we will be featuring more fantastically ridiculous music and fantastically fantastic science.

***(ON B) - { Lectern Computer 2 - Applause Meter ( iPad }:***

**Sprott:** And now let's vote with your applause for your favorite Sound demonstration:

1. Breathing He and SF6
2. Flame Pipe
3. Hoot Tube
4. Breaking a Beaker with Sound

## ***Electricity*** ***(Michael Winokur)***

**Sprott:** And now to get some spark out of your radio, we have our very own duo of electrifying hijinxs, Sparky and his sidekick Mr. E...

**Mr. E:** Whoa there partner, yep it's time for another hare-raising (lift up a stuffed rabbit) adventure of "Sparky the Wonder Eel" and I'm your host, a real Mr. E ("mystery") short for Mr. Electricity, your high resistance conductor of today's show. But first, a brief announcement from our sponsor, Faraday's cages, "Shielding you from all of life's unwanted E-fields."

**Peter:** ***Commercial Sponsor:*** Yes listeners, it's true, electric fields are nearly everywhere, cell phones, microwaves, power outlets. It can really affect your potential and not always in a positive way. Well the kind folks at Faraday's have the perfect refuge. Just reserve a vacation in one of Faraday's equipotential cages and you can be field-free for as long as it takes to get your charge-balance back. Soothing, peaceful, relaxing and highly recommended by all of Sparky's closest neighbors. Now back to the show…

***(ON B) - {Lectern Computer 1 - PPT Slide #35}: Faraday's***

**Mr. E:** Well my electrified radio fans, if you'll recall from last time, Sparky rescued Timmy who'd fallen into a deep potential well. But now Timmy wants to know all about electricity, and we're here to help.

***Audio: Electrical Noise***

**Mr. E:** Yes Sparky...I'll ask

Q: Sparky wonders, does anyone knows his favorite flavor ice cream?

A: *Shock-o-lot!*

**Mr. E:** And speaking of shocks…Sparky hopes everyone knows that there are two kinds of electrical charge: positive and negative. Objects with opposite charges attract one another while things having the same or like charges repel. We can show this in a simple but classic demonstration using two identical black plastic rods, a bit of Sparky's fur and vigorous rubbing. Right now neither rod has a net electrical charge and so there should no strong electrical forces between them. We hope we can convince you of…. Rubbing with fur moves the electrons and we expect both rods to have the same electrical charge; if true they should repel one another. Let's see. Notice that they try to keep from touching; there is a repulsive force.

***Demo: { Black Plastic and holder}***

***Audio: Electrical Noise***

**Mr. E:** Yes, yes Sparky I didn't forget. Sparky also wants you to know that electrical charges can move through conductive objects and is similar to water flowing in a pipe. Except in wires the flowing electrons move right through the metal itself. It is invisible to the eye but, with high enough electric potential, we can even force electrons to flow through gases like air. This device, a Jacob's Ladder, does just that when it on. (Turn the JL on.) Do you see the light? This is because energetic electrons collide with the gas molecules exciting the atoms which you can see. Excited atoms emit a characteristic colors of light. Sparky is just green with envy.

***Demo: { Plasma Tube or Jacob's Ladder }***

**Mr. E:** The marching motion of electrons, in number of charges per second, is called a current. Oh, and by the way, Sparky's best subject in school is…."current" events.

***Audio: Electrical Noise or groans***

**Mr. E:** Sparky is really well grounded. You know...I just couldn't resist. Electrical currents can also be used to move objects. Devices that convert electrical energy to mechanical energy are called…electric motors.

***(ON B) - {Lectern Computer 1 - PPT Slide #37}: Faraday***

**Mr. E:** In 1822 a scientist, Michael Faraday, invented the first electric motor. What Sparky and I really like about this motor is that you can build one at home. All it takes is a fresh AA battery, two super strong metal magnets and a very long coil of bare wire. Just like this. We complete the electrical circuit by putting the assembly into the wire and it pulls itself along like magic.

***Demo: { Faraday Motor }***

**Mr. E:** It's just simple electric train and, as I said, I'm the conductor. And speaking of things that move, does everyone want to see Sparks fly? (Mr. E tosses Sparky up in the air.) Sorry...Sparky really doesn't like that joke. Sparky means that he **really** wants to see sparks fly. And for that we have our very own million volt Tesla coil.

**Mr. E:** Flying sparks of electricity are fun to watch as long as you don't get in their path. Then they can be quite striking. For this Sparky needs help to show how to be safe in an electrical storm by using the Faraday cage. Is there an energetic volunteer? How about you.

**Mr. E:** Sparky asks if you could tell us your name and, if you could, please sign this release form….just kidding. So this is (name) and Sparky's **new** adventure. Both you and he/she will take refuge from the coming electrical storm produced by the Tesla coil. I will operate the control panel.

***Demo: { Tesla` Coil )***

**Mr. E:** (Mr. E goes over.) Are you two ready? That wasn't tooo bad was it? Hopefully you are still alive. You've been a great sport; everyone should give (name) a little applause.

**Mr. E:** So far we have had mostly electric circuits but electric fields can move through space without a conductive path if we join them with magnetic fields. One such device that does this is an ordinary microwave oven. Now Sparky….did anyone see Sparky's tail moving up and down? No, well that is what he calls a micro wave.

**Mr. E:** Inside this oven is an ordinary light bulb just like the one we have here. Inside is a fine metal wire...which is we should never do this….put it in the oven. Let's turn it on.

***Demo: { Incandescent bulb in microwave }***

**Mr. E:** The microwave electric field, which we don't see, produces visible light from a plasma which forms around the thin metal wires inside the bulb. That is why we should never put metal objects inside a microwave.

***Audio: Electrical Noises***

**Mr. E:** Perhaps you noticed it but Sparky's getting all charged up with our electrical adventure. Sparky isn't the only thing that can get charged up. Inside this Mr. E (mysterious) box is a capacitor with alternating metal sheets of positive and negative charges. That is what will happen when I push this button. It takes a while and, at the right moment, when this meter reads 5000 Volts, I will allow the the all the electrons to flow through this piece of aluminum foil back to the positively charged plates by releasing the button. The foil will heat up like toaster coil but only a tiny fraction of second. There will be a bright flash and a very loud pop when it vaporizes. You do want to cover your ears….Is everyone ready?

***Demo: { Exploding Foil }***

**Mr. E:** At last we've finally managed to get rid of that nasty electrical charge we've been storing. Everyone should be positively ex-static!

***(ON B) - { Lectern Computer 2 - Applause Meter ( iPad }:***
**Sprott:** And now let's vote with your applause for your favorite Electricity demonstration:

1. Electrical Forces on the Black Plastic Rods
2. Jacob's Ladder
3. Faraday Train
4. Tesla Coil and Faraday Cage
5. Light Bulb in the Microwave

6. Exploding Foil

# ***Magnetism*** *(Ryan Norval)*

**Sprott:** Our next radio program will be a reading of Sherlock Ohm's by our guest and his assistant Dr. Watts-On...
***(ON B) - {Lectern Computer 1 - PPT Slide #39}: Sherlock Ohms***

**Ryan:** Welcome back folks to another episode of Sherlock Ohm's Magnetic Mysteries. Will Detective Ohms solve the crime, or has he found his polar opposite? Find out today in Sherlock Ohm's and The Brilliant Induction. But first a word from our sponsors.

**Peter**: ***Commercial Sponsor:* -** Hey amateur detectives, ever go looking for clues only to have your batteries run out? No way to turn that flashlight on, power up the camera, or call for help? Try Farad's new ultra high capacity capacitor, guaranteed to store more charge than those pesky batteries.
***(ON B) - {Lectern Computer 1 - PPT Slide #41}: Make Slide - Farad's***

**Ryan (In Watts-On hat and voice):** It was a dreary London Morning, Sherlock Ohms and I had just finished our morning tea. I was reading the newspaper and noted to the good Mr. Ohms a robbery had been committed in the London Underground, the thief, jumped in front of a train and vanished mysteriously.

**Akire (As Ohms)**
Why Watt-Son, people do not just vanish, The game is afoot.

*SFX: Footsteps*  Akire with Coconuts, or other folio sound? Even stomps?

**Ryan (Watts-On):** Detective Ohms and I found the crime seen, the subway station was near empty, we examined the tracks, I said, no way a person can dodge a train if he were to jump into the tracks.

**Akire (Sherlock Ohms):** Quite to the contrary Watt-Son, one only needs to be propelled upwards very fast to get out of the way of the train! Ah look here Watt-Son, an electromagnet attached to the railways electrified center rail. The thief must have used this to vault onto the train!

***Demo: { Ring Launcher }***
**Ryan (Watts-On):** Now listeners, you like I probably did not know how a magnetic launcher works, so I'll explain quickly as Sherlock Ohms explained to me. A magnetic launcher is a simple thing, it works like this, if you have a metal piece, in my case a ring, and in the theifs case, perhaps rings on his shoes, and you put the ring over an electromagnet, a

rapid energized magnetic field, can cause the ring to have an induced electric current in it, this current then feels a force of the magnetic field, causing it to jump upwards.

That is, by quickly turning on a magnetic field, we can make something non-magnetic, feel a magnetic force, as long as that object is able to have electrical currents in it.

***{ Jump ring, no LN2 }***

**Ryan (Watt-Son):** Detective Ohms! That ring didn't jump high enough to get over a train!

**Akire (Sherlock Ohms):** A great observation Watt-Son, but there are things we can do to make it jump higher, say the thief had a bottle of liquid nitrogen on hand. If we cool down the ring with that really cold liquid nitrogen, we change the electrical properties of the metal. It becomes less resistive allowing a larger induced current to flow, which in turn allows for a larger magnetic force to exist on the ring. (Show the nice audience would you Watts-On?)

***{ Jump ring, LN2 }***
**Add explination about iron core**
**Jump ring LN2 and Iron core**

***(on A & C ) - Camera: Table 2 Video 1: { Levitated Ball }***
***Demo: { Levitated Ball}***

**Ryan (Watts-on):** Ok, Sherlock Ohms, so the thief jumped up onto the train with a magnetic launcher, but how did he stay on once up there? Those London subways move fast!

**Akire (Sherlock Ohms):** Elementary, Watt-Son. If the thief already had metal ring on his shoes, and if he pre-planned the robbery as one would do if they were planning to jump in front of a train, he must have had some way to stay in place on, or *ABOVE*, the train. He likely levitated himself.

**Ryan (Watts-On):** Now Listeners, I know, it sounds like madness, But Sherlock Ohms is a brilliant detective, and he was right, we later found a train with magnets on the roof of a car. Now what you might not know is that you can use a set of magnets to levitate objects.

For example, here is a set of two electromagnets. And when this hollow aluminum cylinder is placed inside.

*Drop aluminum*

**Akire (Sherlock Ohms):** Watts-on, the magnets need to be turned on.

**Ryan (Watts-On):** Right you are Sherlock, now with the magnets on, we see that we can levitate the aluminum. It works then same the ring launcher did. We create a electric current in the cylinder, that feels the force of these pair of magnets. These magnets change positive to negative very fast, this is needed to make a force as only a CHANGING magnetic field can apply any work.

You see that the cylinder floats in the middle, it is being both pushed up and pulled down at the same time, the closer it gets to any one of the magnets, the more force is applied to try to recenter it.

Without the magnetic field, the cylinder drops back down.

**Akire (Sherlock Ohms):** Ok Watts-On, back to the story.

**Ryan (Watts-On):** So, after following the tracks out of the subway down to the next station Sherlock and I found the locks had been cut. Not only have they been cut, but they were right melted to slag!

**Akire (Sherlock Ohms):** As you might well have guess, the thief used magnets to melt the lock.

**Ryan (Watts-On):** You might recall that magnets lifting the cylinder were doing work on the object. Doing work means transferring energy. Transfer enough energy through the oscillating magnetic field and….

***Demo: { Induction heating }***
***(on A & C ) - Camera 6: { Heating & Guillotine }***

**Akire (Sherlock Ohms):** You heat up metal enough that it can melt!

**Ryan (Watts-On):** Our attempts to catch the thief, were coiled again. Because we are changing the magnetic field back and forth many times per second, the electrical energy used to power our electromagnet, is being turned into a magnetic field, that field, as it changes polarity back and form then induces a current in the metal, and much like your toasters at home, enough current in metal objects cause them to heat up melt eventually.

But now Sherlock Ohms, what kind of criminal has enough magnetic know how to pull off this crime?!

**Akire (Sherlock Ohms):** Only the vile Prof. Magnetsen could possibly do this, using physics to rob people.
***Demo: { Magnetic Guillotine }***

**Ryan (Watts-On):** Detective Ohms? How could Magnetsen have been the thief, he was executed after you caught him last week?!

**Akire (Sherlock Ohms)*:*** Elementary my dear Watts-On, he must have faked his death in the Guillotine last week! Here lets see how that's possible! We just happen to have a Guillotine right here.

**Ryan (Watts-On):** A guillotine works by lifting up a heavy blade, usually metal, and dropping it on someone or something below as such.

*carrot* into Guillotine

**Ryan (Watts-On):** However we know that magnets can affect objects, in this case if we place a set of magnets at the bottom of the Guillotine, You'll see a basic physics principle at work, nature abhors change.

*Slowed Guillotine*

As the metal blade enters the magnetic field, an eddy current was created. This current produces a magnetic field that wants to oppose the existing field, that is, it want to keep it from moving.

**Ryan:** That's all for this week folks. Will Sherlock Ohms and Watts-On, catch the Ne-ferrious Prof. Magnetsen? Tune in next week for the shocking conclusion of Sherlock Ohms: A Brilliant Induction!

***(ON B) - { Lectern Computer 2 - Applause Meter ( iPad }:***
**Sprott:** And now let's vote with your applause for your favorite Magnetism demonstration:

1. Ring Launcher
2. Levitated Ball
3. Induction Heating
4. Magnetic Guillotine

## ***Light*** ***(Kimberly Palladino)***

Google slides
https://docs.google.com/presentation/d/1ItVZrkHPb4K2bO4uzNH9rOCrY4GZFnnXT4nuhBZ0uso/edit#slide=id.g2d1943cbd7_0_6

**Peter:** ***Commercial Sponsor:*** Hi folks, is that gravitational force getting you down. Well then, make a motion over to Newton's for some of the best rings in the universe. Don't confuse them with someone else's dark and tasteless corpuscular theories. These rings are light, light as can be. ***{show a slide of Newton's rings}***. Remember it well listeners, Newton's rings run circles around the competition.
***(ON B) - {Lectern Computer 1 - PPT Slide #44}: Newton's Rings***
***Audio:*** Overall theme: Late Night radio program

**Kimberly:** Hello Prof. Sprott. I'm in a few minutes early for my program. Can I tell you about my new passion for painting? It's too bad I can't share it over the radio-waves.

**Sprott:** Actually, we're already on the air… And now it's Late Night Lights With Dr. Sunshine Maxwell. For those of you still awake, she'll help you see in the dark...

**Kimberly:** Hello my late night nightlights. We have lots to learn about light tonight. Light is energy that travels in a vibrating pattern of electricity and magnetism. (Show slide) Is there an energetic volunteer to help me? Different amounts of energy have different wavelengths: shorter wavelengths have more energy (my volunteer will jump up and down quickly) and shorter wavelengths have less energy. (jumping slowly) Which took more energy? Only some of these wavelengths are the visible light we usually think about. Red is less energy and blue and violet have more energy. The individual units of light energy are sometime called photons.
***(ON B) - {Lectern Computer 1 - PPT Slide #45}: Visible Light***
***Demo: { Prism }***

**Kimberly:** White light, like from the sun and many lightbulbs is actually made up of multiple wavelengths, and we can separate them with a prism *(turn on prism to light, make sure microphone isn't in the way, then turn off)* or a diffraction grating like a CD. *(turn on document camera and light, hit menu button to get rid of the menu, show CDs)*

***Demo: { CD Diffraction }***

**Kimberly:** Do my listeners know what happens to a photon when it goes bad? It gets sent to prism.
***Audio: Rim Shot***

***Demo: { 3D holograms }***

We can also look at holograms, which reproduce the 3D vision  we get in the real world as we observe objects with our two eyes.  Here's a white-light hologram  on the document viewer so everyone in the room can see it too.

***Demo: { Fluorescence }***

**Kimberly:** Many of the interesting features of light come from how it interacts with different materials. Some materials will absorb light in wavelengths we can't see, and then re-emit light that is visible. This is called fluorescence. The light absorbed usually needs to have a shorter wavelength, and higher energy than the light emitted, and UV light has a shorter, bluer wavelength than visible light. A blacklight has a lot of UV light, so let's turn on one and see what things look like. If things emit the visible light long after they've absorbed the UV, they glow in the dark!

**Kimberly:** Here are some beads that actually change color in when exposed to UV light. And when a UV absorber is in front of them, they stay white. But what's behind me: it's my masterpiece. I call it Sunshine's Sunflowers.

***Demo: { Fluorescent Screen}***

**Kimberly:** Now, here is a screen, which can get be excited to glow if we shine energetic enough light on it. Will the red laser work? Will the green laser work? What about the violet?

**Kimberly:** For those who've made it through  Late Night Lights, we'll try to keep you awake. Certain materials only absorb some wavelengths .

***Demo: { Laser Popping Balloons }***

**Kimberly:** Clear or transparent materials don't absorb much visible light at all, that's why we can see through them. So here is a powerful blue laser, and I can aim it at this colored balloon and make it pop. Oh that got some listener's attention.

**Kimberly:** Now I am going to use this setup to change the color of this balloon, I'll put it in place, and turn on the laser, and now we have a different color balloon. Let's do it one more time, now we have a clear balloon!

***Demo: { IR Camera )***

**Kimberly:** A photon checked into a hotel and was asked if he needed help with his bags. He said no, I'm traveling light. ***{sound effect for a bad joke}***

***Audio: Crickets***

**Kimberly:** I've got a letter from a listener, asking how to determine when a glass is half full. Well I hope my listeners are all optimists, but for a scientific answer, it all comes down to infrared radiation. Infrared wavelengths correspond to the thermal energies of things around room temperature: and warmer, like living things. (panning across audience) as you can see. Some materials, are transparent to infrared wavelengths, so we can actually see through them, when we can't in the visible spectrum with our eyes. Can I get a volunteer to look at these cups: can you tell which is half full? Now I will look at them with the IR camera. One is empty, one is half full of cold water, and the third is full of warm water. Now if my volunteer can slowly and carefully pour the warm water into the cold water, we can watch it mix. Isn't that lovely. Thank you to my volunteer.

**Kimberly:** I also use my IR camera to check myself in the mirror everyday. But it isn't a regular mirror, it's just this dull stainless steel. ***{Look at self}*** Yup a head and two arms, I look great! This works because the IR wavelength is long enough that the rough surface that interferes with visible light doesn't affect them!

**Kimberly:** Can I get 2 volunteers. ***{Volunteers comes down}***, Now, they are going to stand behind this black sheet of plastic. What are they up to, we'll see with the IR Camera. Now we'll lift the black plastic and put down this screen. And we can't see our volunteers anymore. But if they touch the screen, or use the pieces of metal I've given them, we can see some other artistic endeavours. Oh no, perhaps I need to give up on my dream of being an artist. Thank you to our volunteers. (Pan across audience again)

So join me next time for our next light wave adventure.

***(ON B) - { Lectern Computer 2 - Applause Meter ( iPad }:***

**Sprott:** And now let's vote with your applause for your favorite Light demonstration:

1. Fluorescence
2. Laser Popping Balloons
3. IR Camera

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

**Sprott:** Now, Peter, which demonstration got the greatest applause from the entire show?

**Peter:** And the winner is… (your choice)

**Sprott:** Some of you may be thinking that we're just pretending to broadcast this show, but if you have a portable radio, tune it to 550 kHz at the bottom of the AM dial, and you should be able to hear us. ***{Hand portable radio to Peter and pick up telephone}*** … Can you hear me now? Mr. Weix, come here, I want to see you. This is radio station 9XM broadcasting from the basement of the Physics building on the University of Wisconsin campus 100 years after the first radio broadcasts were made from here.

**Sprott:** When I started **The Wonders of Physics** 1984, I had no idea how popular it would become or that I'd still be doing it 35 years later. Our audiences have been extraordinary, and we thank you for listening over the years. We look forward to many more years of presentations, but we need your help. Please go to **wonders.physics.wisc.edu** and click on **Donate** for your tax-deductible contributions.

***(ON B) - RGB {Lec Computer 1}: PPT SLIDE # 47 - Donate***

***Display the link on the screen (https://wonders.physics.wisc.edu/donate/) along with a QR code (see http://sprott.physics.wisc.edu/wop/donate.pptx).***

**Sprott:** (the usual ending) And now I'd like to end the program as we do every year by making for you a cloud...

***(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.***

***{Turn off the "ON AIR" sign}***

***{Cast enters from right and left doors, and all bow in unison.}***

# ***Resources:***

- 2015 PowerPoint Slide Show (This link is broken; please replace it with the 2017 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
- WOP sound library
- 2017 WOP script
- 2016 WOP script
- 2015 WOP script
- 2014 WOP script
- 2013 WOP script
- 2012 WOP script
- 2011 WOP script
- WHA 9XM History - Wikipedia
- Old time radio commercials
- More old time radio commercials
- 1920's radio advertising history
- Free Sound Effects Archive

# ***NOTES:***

***This is good and useful information, but we are not trying to replicate any particular time period or style of show; rather we are producing our own unique show:***

***{NOTE: make sure our timeline coincides with the WPR websites:***
***https://www.wpr.org/wprs-tradition-innovation***
***http://wprcentennial.org/***

***Here's a timeline of events in WPR's history:***

***1914 - University of Wisconsin electrical engineering Professor Edward Bennett sets up a personal wireless transmitter set on campus and applies to the Commerce Department for a license; He is assigned call letters 9XM.***

*1915 - The license for 9XM is transferred to the University of Wisconsin for use with a new transmitter being built by Professor Earle Terry and his physics students.*

*1916 - On Dec. 4, station 9XM carries the first regular "broadcast" of Wisconsin state weather forecast by Morse Code from UW's Science Hall.*

*1917 - 9XM experiments with music transmissions from phonograph records. 9XM is allowed to remain on the air during World War I for experiments with the U.S. Army and Navy.*

*1918 - 9XM moves from Science Hall to Sterling Hall. Experimental voice transmissions are made with the Army.*

*1919 - On Feb. 17, the first documented clear transmission of human speech occurs on 9XM.}*

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*https://isthmus.com/arts/stage/university-theatre-its-a-wonderful-life/*

*Transition idea: faux commercials to lead into each of the six areas of physics. Peter Weix as announcer.*

*e.g. Curie's Radium Tonics (radiation)*
*Steam-driven exercise belt (motion)*
*Light bulbs (light)*
*Rheumatism treatment (magnetism)*
*RCA Victrola (sound)*
*Chicken incubator (heat)*
*75 lb "portable" radio (electricity)*
*Cavendish's Fire and Brimstone*
*Farm Report*

*Props: build old-fashioned applause meter, using analog meter}*