The Wonders of Physics 2016

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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
- WOP sound library
- 2015 WOP script
- 2014 WOP script
- 2013 WOP script
- 2012 WOP script
- 2011 WOP script

The Wonders of Physics 2016

- *33rd Annual Presentation*

"Physics of Superheroes"

Opening

(Alex [Mic #2], Sprott [Mic #1], News Girl #1 [Mic #4], News Girl/Guy #2 [Mic #5])

Audio: Science Songs
Cue Demo: { Burner on low, 5 gl Can Crusher }

***(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

Lights: Lights Change to staged floods

Peter: Welcome to the (278,279,280,281,282,283,284,285,286,287) presentation of *The Wonders of Physics*... Before the show begins, I would like to assure you that we make all of our demonstrations as safe as possible provided you remain in your seats. (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.)

< -------------------------------Start of Intro--- >

{Show classic spinning newspaper graphic, freezing periodically on headlines with laws of physics.}

Audio: NewsFlash
(ON B) - {Lectern PPT Computer 1}: Slides 2 - 7 (Newspaper with headlines)

****Newspaper girl (Katherine):*** Extra! Extra! Read all about it! A body in motion tends to stay in motion unless acted on by an outside force! Only a $1 contribution to *The Wonders of Physics*.

Newspaper girl (Martha): Extra! Extra! Hot off the presses! The acceleration of a body is proportional to the force, and in the same direction!

Newspaper girl (Katherine): Extra! Extra! $1 a copy! Every action has an equal and opposite reaction!

Newspaper girl (Matha): Extra! Extra! Don't get caught with yesterday's news! The orbit of the planets are ellipses, with the sun at one focus!

Newspaper girl (Katherine): Extra! Extra! Red hot! Orbits sweep out equal area in equal time!

Newspaper girl (Martha): Extra! Extra! Read all about it! The square of the orbital period is proportional to the cube of the semi-major axis!

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Peter: Hey kid, here's a dollar, I'll buy one of those papers. Let's see what's in the news in Neutron City.

Newspaper girl (Katherine): It's disaster as far as the eye can see! The natural world is a chaotic calamity of exciting observations. Nobody can give us good citizens clear and rational demonstrations of the underlying phenomena!

{Peter reads newspaper upside down.}

Peter: What a world! Why I hardly know which way is up or down anymore! We need a hero. Why, when I was a kid, I used to hear of a legendary super hero..... Some called him *The Wonder*. Some called him *The Professor*. His students call him… Well, never mind what they call him… Kids, go run and get your friends; we're gonna need all the help we can get, ***{newspaper girls exit}*** but there's only one scientist who can save us now. Let's just hope he answers our call.
{Peter moves off to stage right, picks up a red phone, lights go down except spotlight on Peter who dials. Phone rings, Sprott appears on video and picks up the phone. Spot light turns off.}

(ON B) - *{Lectern Computer 1 - PPT Slide #9}:* **Intro Video** ***{Clip is 27.27 seconds}***

Intro Video: ***Sprott answering the phone*** ***(alternate avi version)***

Sprott on Video: *Hello, Department of Physics. In trouble? You need pedagogical demonstrations? I see. Outlandish hijinks? Well, okay. I'll see what I can do.* ***{ hangs up, Sprott removes glasses, speaks to himself }*** *It's a chaotic world out there. But a scientist has got to do what a scientist has got to do. Hang on, Neutron City, I'm coming to help.* ***{ rips off jacket to reveal Sheldon Cooper Superman costume }***

***Lights**: The house lights go down and a search light looks for Super Sprott.*

Intro Video: ***Superman flying overhead*** ***{Clip is 16.48 seconds}***

{ 13.55 seconds into clip theme music starts }

Peter: Hey folks!! …. Look!! …. Here he comes!! ….. Faster than a speeding neutrino!! …. Stronger than the electroweak force and gravity!! …. Able to leap tall potentials in a single bound!! …. It's a fermion!! …. It's a boson!! ….. No, it's Professor Cliiiiiiiiint Sprott! *{you currently have 13.55 sec}*

Zip-Line: ***{ Dummy sprott zips down over the head of the audience AS SOON AS the intro video ends!! } {Zipline speed ~ 7 seconds}***

***Lights**: The house lights go up*

Audio: Crash *(Sprott can provide the crash sound from behind the curtain)*

Intro Video: ***Audio: WOP Theme*** *{Re-Edit}*

{Start WOP Theme Music.}

{ Short delay, and then Sprott enters stage left and rushes to center stage while Peter sits down at Sprott's desk near stage right. }

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Sprott: Welcome to ***The Wonders of Physics*!** And a special welcome to you humanoid children. I've been asked to help save the World. But even a super genius like me needs help with that. And so I've recruited some of my aspiring colleagues to lend a hand. Let's see if I can find one now...

{ Walks over to stage right door (outhouse?) and knocks three times. }

Sprott: Isaac! Isaac! Isaac!

{The door swings open and Mike Randall emerges.}

Motion (Mike R.) **[Mic #3]**

Mike: What?

Sprott: You're not Isaac Newton!

Mike: Look, there's only room for one in here and it's me….Motion Man!

Sprott: I always thought superheroes came out of phone booths.

Mike: Have you tried finding a phone booth lately? This is the closest thing the Superheroes Guild could come up with. It's so embarrassing, I had to change my superhero name!

Sprott: Why? What was your previous name?

Mike: (head bowed sadly) Major Movement.
Audio: ***RimShot***

Sprott: Never mind. I need you to tell these people how the physics of motion allows us to do extraordinary feats and save the World.

Mike: Sure, I can do that!

{ While Mike is walking to center stage, Sprott turns to Peter: }

Sprott: You're in my spot!

{ Peter gets up and departs stage), and Sprott sits down at the desk with a laptop computer. A whiteboard with physics equations is behind him. }

Mike: If you're going to put things in motion, you're going to need ***energy***. Energy is the ability to do work. Energy is the ability to do ***anything***! The metric unit of energy is the ***joule***. It's the work done by exerting a force of one newton through a distance of one meter. The force of gravity on this stick of butter is about one Newton. So, for me to lift this butter by one meter, I expend about one Joule of energy.

{ Lift butter one meter - need "stick of butter" & meter stick }

Mike: Big deal! It doesn't take a superhero to do that! Ah, but I have some machines that can manipulate force and distance, giving YOU super-strength!

(Que) - Camera 5: { Block and tackle }

Mike: I need a superhero recruit!

{ Get child volunteer from the audience }

Mike: What is your name? ***{get volunteer name}***. OK, {name}, here we have a bunch of kilogram masses, rope and wheels called pulleys. The first pulley has a 1-kilogram mass hanging from both sides. Here, pull down on this mass.

{ Volunteer moves mass}

Demo: { Block and tackle }

(on A&C) - Camera 5: { Block and tackle }

Mike: Looks to me like they're pretty well balanced. The force of gravity is pulling equally on both. That's why they hang there, unless you push or pull on one side. It takes an UNBALANCED force to create motion!

Mike: Now, look at this next set of masses. These are balanced as well. BUT WAIT! What do you notice about them? Right! This one has TWICE the mass of the other! How can this be? Try moving the 1-kilogram mass.

{ Volunteer moves mass}

Mike: Does the two-kilogram mass move? Does it move the same? No! Now look at the pulleys. They're set up so that when you move the 1-kilogram mass, the two-kilogram mass only moves half as far! Remember, work equals force time distance. The pulleys let us TRADE distance for force! That means we can lift twice as much, but only half the distance. So we're still doing the same amount of work. Try moving these masses.

{ Volunteer moves other masses}

Mike: See? With the right pulley arrangement, we can lift six times as much - or more! As before, we're trading off distance for force. Let's give *{name}* a big round of applause!

Audio: Ta-Da-1

(Que) - Camera 6: { Press }

Mike: Now, there's another way to do this. I need a strong adult from the audience.

{ Get adult volunteer from the audience }

Mike: What is your name? ***{get volunteer name}***. OK, ***{name}***, will you please break this for me? Preferably not over my head!

{ Hand 4 x 4 to volunteer. Wait while volunteer makes attempt }

Mike: (whistling) No rush… (Pause) Hav ing trouble? Hmmm...you need some help. I need another superhero recruit!

{ Get child volunteer from the audience }

(on A&C) - Camera 6: { Press }

Demo: { Hydraulic Press }

Mike: What is your name? *{get volunteer name}*. OK, {child}, let's show {adult} how we can use physics to generate super strength! This is a hydraulic press. It uses ***Pascal's theory***. The pressure in a closed system is constant. Apply pressure in ONE part of the system, it increases the pressure through the WHOLE system!

ON B) - {Lectern Computer 1 - PPT Slide #11}: Blaise Pascal

Mike: This hydraulic press is a closed system, with three connected pistons. The whole thing is filled with oil. As you can see, one piston is much larger than the others.

(ON B) - {Lectern Computer 1 - PPT Slide #12}: Hydraulic press diagram

Mike: Pushing on a small piston increases the pressure on the large piston. Pressure is force per unit surface area. Multiply the pressure times the surface area of the larger piston, and you get the force exerted. OK {child}, start pumping on this lever!

{ Child volunteer climbs small stepladder and starts pumping on lever }

Mike: Kinda like the pulleys, the difference in piston size allows us to trade distance for force. AND, we're moving the piston with a lever - ANOTHER way to trade distance for force! This combination allows {child} to exert OVER 500 TIMES as much force! And this wedge on the end of the piston concentrates all that force into a small area, increasing the pressure on the wood by over 70 TIMES! An 80 pound force on the end of the lever will generate over 150 TONS PER SQUARE INCH pressure! More than enough to splinter this hefty piece of wood!

{ Child volunteer keeps pumping on lever until 4 x 4 breaks }

Audio: Ta-Da-1

(Que) - Camera 5 : { Ping pong ball cannon CANS }

Mike: Great job! Let's give {child} and {adult} a super round of applause!

Mike: Now, as Motion Man, I'd be nothing without Sir Isaac *Newton's three Laws of Motion*.

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

Sprott: I'm sure you know that the Fig Newton was named after a town in Massachusetts, and not after Sir Isaac Newton.

Mike: *Newton's Second Law* says that Force equals Mass times Acceleration. Force is how hard you push or pull on something. Mass is the measure of how much stuff, or matter, is in a thing. And acceleration is a change in speed or direction. So, if you want to make something accelerate faster, you can push harder on it, or reduce its mass. OR BOTH!

Demo: { Ping pong ball cannon }
(on A&C) - Camera 5: { Ping pong ball cannon }

Mike: ***{ Picking up a ping pong ball }*** What would happen if you applied a HUGE force to something with a TINY mass, like this ping pong ball? Let's find out! Here's my ping pong ball cannon! There's a ping pong ball inside this long tube. Both ends of the tube are sealed with thin plastic. I'm now pumping all the air out of the tube. When I push this plunger, the air will rush back in, pushing on the ball with almost 30 pounds of force! Let's see what happens! Oh, this will be LOUD! ***{ Mike puts on hearing protection }*** Cover your ears! Three! Two! One!
Audio: Ta-Da-1
(Que) - Camera 6: { Cannon }

{ Mike pushes plunger on ping pong ball cannon }
(ON B) - ***{Lectern Computer 1 - PPT Slide #14}: Sir Isaac Newton***

Mike: By *Newton's Second Law*, the ping pong ball was accelerated to almost the speed of sound! That's 340 meters per second, or 770 miles per hour! Super speed!!

{ Mike picks up the remains of the aluminum soda can }

Mike: Check this out! ***{ Mike holds up soda can }*** *Newton's First Law* says that an object at rest stays at rest. And an object in motion stays in motion, unless acted on by an outside force. Put in simple words, stuff wants to keep doing what it's already doing. The can wanted to stay put. The ping pong ball wanted to keep moving at the speed of sound. So it blew right through the pop can!

Mike: *Newton's Third Law* says that for every action, there is an equal and opposite reaction. To demonstrate, I'm going to use my super cannon!

Sprott: ***{puts on hard hat (or catcher's mask)}*** Did you know that the cannon was invented by the Chinese and was first used during the Southern Song Dynasty in 1132 AD?

Mike: I'm PRETTY sure the Chinese didn't have LIQUID NITROGEN cannons back then.

{ Mike sets up the LN2 cannon as he talks}

Mike: Yep! MY cannon is powered by liquid nitrogen - basically air that's been cooled to **minus 320 degrees Farenheit**! As the liquid nitrogen warms up, it boils into nitrogen gas. This gas takes up almost **seven hundred times** as much room as the liquid, creating tremendous pressure inside the cannon. Eventually, this rubber cork will explode out of the barrel and fly across the room. When that happens, notice what happens to the CANNON.

Mike: Everyone, cover your ears! Look out Professor Sprott!

Demo: { Large Liquid Nitrogen Cannon - Recoil }

~~(on A&C) -~~ Camera 6: { Cannon }

Audio: Ta-Da-1

Mike: Did you see that? The ACTION was the cork flying out of the barrel. The REACTION was the cannon rolling backwards. Newton's third law!

{ Mike tilts the cannon to spill out the excess LN2, which leads to the headline about a cold wave. }

{ Transition to Heat }

Newspaper girl (Katherine): Extra! Extra! Neutron City hit by cold wave! Water pipes burst all over the city! Major blanket shortage! Extra! Extra!

Audio: News Bulletin
(ON B) - RGB {Lectern Computer 1 - PPT Slide #18}: Newspaper with headline "Cold Wave Strikes Neutron City"

Mike: WHAT??? A cold wave? I have no power over that! I'm from Southern California! Oh, if only ThermoMan were here!

{{ Mike exits stage left. }}

Heat (Michael W.) **[Mic #4]**

{ Michael steps out of outhouse, shaking out a lit match, grimace on his face, waving his hand to dispel a foul odor. }

Michael: Well I've finally met my match. I'll tell you, not having running water really stinks. But I s'pose as "ThermoMan" I really should be able to cure this cold wave.

Michael: So...how do you like my superhero suit? *THERMAL UNDERWEAR!* What else would ThermoMan wear. And, according to my super-spouse, it has a cute "bear" bottom! So embarrassing.

(Que) - Camera 6: { 5 gl Can Crusher }

Michael: I even made my own cape, it's electrical heater wire taped to a blanket… I wanted to use lumps of radioactive plutonium, but the safety office vetoed that idea. They said it was too hot to handle. Now what am I going to do with all this plutonium…..I know….I'll just package it into candy. I already have samples…..get your "Red Hots"....

Michael: So now it's time to deal this cold wave a blow. Not with superhero fists mind you but just with a little physics. I'll show you….

Demo: { 5 gl Can Crusher }

{Turns on infrared heater as he walks to the can demo}

- **Michael:** ***(Que) - Turn on heater for { Light the Match }***

Michael: I'm going to do a little "warm up" exercise by crushing this can. Do you think I can do it? Just look at these superhero muscles….nevermind. Let's try something different...it is what we physicist call a "phase change". We will use thermal energy to transform liquid water to a gaseous form (known as steam). You may have noticed the vent on top of this can and observed water vapor forming. The liquid water inside the can is boiling at 100 Celsius. Gaseous steam at that temperature occupies nearly 2000 times more space than liquid water and completely fills the can.

Michael: Now we will just close the valve and, on yes, ***{remember to turn off the Burner!}***. What do you think happens to the stream inside as the can cools?

Michael: Yes, it will condense back to liquid water and occupy almost 2000 times less space, leaving a vacuum. The air on the outside of the can will press down with a force of about 15 pounds for each and every square inch. Notice these red squares; each one is exactly one square inch. If I add them all up this gives a total force of over 6000 pounds.

Why that is just about the weight of two passenger cars! We “can” speed things up with this ice bath.

{What until can Crushes - takes up to one minute }

(on A&C) - Camera 6: { 5 gl Can Crusher }

Audio: Ta-Da-1

Michael: See, I hardly had to lift a finger. But that won’t break this cold snap. What we really need is some more heat, radiant heat and I have just the superhero thing. The dreaded infra ray.   I’m sure you’ve noticed the orange glow coming from this heater coil. Actually most of the radiated energy is a type of light which you can’t see but you can feel. It’s not just the thermal energy radiated that matters but the ability to move it around at will.   And I know how to send radiant heat over large distances and then focus it so things get really hot. I will show its effect by igniting an ordinary cotton ball. I don’t even have to touch it. The first curved mirror aims the thermal energy this way and then the second curved mirror focuses the radiant heat onto the cotton ball. Just a few seconds…..

(on A&C) - Camera 6: { Light the Cotton Ball }

Demo: { Parabolic mirrors (Light the Cotton Ball)}

Audio: Ta-Da-1b

Michael: That was easy. I can even send this radiant energy your way with this movable focussing mirror. Now, is there any parent in the audience that have a “small fry” they would like to volunteer see if the infraray works on them? I mean, what is life without a little spontaneous combustion?

Michael: But I have another “hot” idea.   (Don’t say I didn’t “warm” ya…). So does everyone see that white pipe coming out of the outhouse? Can someone guess what it is there for?

Audience: *….gas exhaust….*

(Que) - Camera 6: { Methane Bubbles }

Michael: Very good. Being an Informed citizen of Neutron City is important. Even superheroes need to take renewable energy seriously. That pipe takes a very special gas from the outhouse and passes it through my little bubble machine. Ohhh, I just love bubbles. I need to open the valve to let the gas out and get some beautiful bubbles.   My “powers” tell me the that this gas is less dense than air and so these bubbles will float. The gas isn’t helium or hydrogen, but this gas can be used to warm Neutron City. All it needs is a light.

Demo: { Methane Bubbles }

(on A&C) - Camera 6: { Methane Bubbles }

Lights: The house lights go down for some of the bubbles

Audio: Ta-Da-1

Michael: Did you feel that? Should we try it again? These bubbles are filled with methane (or natural gas) which is used in many human homes for heating and cooking. Almost everyone has thermal powers at their fingertips. And, as for those children who want to become their own methane source I happen to have an extra can of "Superhero Kiddy Beans" available…..just make sure you ask your parents for permission…

Michael: Now floating bubbles are nice; but wouldn't it be better if I could "fire" that gas like a cannon ball? Yes indeed, we have "powers" that allow us to do that. Here I have a "vertex generator".

Sprott: I think you mean "vortex." A vertex is a point where two or more curves, lines, or edges meet. A vortex is a whirling fluid.

Michael: Okay, okay not even superheroes are perfect. You can even make one of these at home with an oatmeal can, a plastic sheet and a few big rubber band. Is there a young superhero with burning desire to assist me? (Ad lib)

Michael: But I want to see if I can't send out a vortex ring of an another special gas with this slightly larger version. Aiming the vortex at the flame is a little tricky.

(Que) - Camera 6: { Flaming vortex rings } - Burner or candle
Demo: { Flaming vortex rings }
Audio: ***(Play "Ring of Fire" from J. Cash???)***

Audio: Ta-Da-1
(Que) - Camera 6: { Fire Tornado }

Audio: Ringing Bells

Michael: Now that "rings a bell" ***{bell rings}***. So we have vortex rings and a flammable gas but I want more. I'm thinking I want show off my superpowers with a big swirls of flames. And here I have just the thing. It works by using a process called thermal convection in which hot air rises and, then with a twist, it creates a much bigger vortex. They seem to happen all the time in Kansas and Oklahoma. And with this demonstration I can bring a tornado to life…..

Michael: A little lighter fluid soaked towel and a match. Ahh, I can feel the heat rising. Now the safety screen and a twist for some some swirling convection…a fire tornado.

(on A&C) - Camera 6: { Fire Tornado }
Demo: { Fire Tornado }
Audio: Mary-go-round
Audio: Ta-Da-1

Michael: Now things are really getting hot in Neutron City…

Sprott: How hot is it?

Michael:
- Well, in Wisconsin, the cows are giving evaporated milk.
  - ***Audio: Rim-Shot***
- The chickens are laying hard-boiled eggs.
  - ***Audio: Oh-Dear***
- I saw a roasted turkey fly by.
  - ***Audio: Crickets***
- And the poor song birds, we they have to use potholders to pull worms out of the ground.
  - ***Audio: Crickets***

Michael: And since I'm on a hot roll and I don't want to blow it…..or maybe I do !! Look at these lovely balloons. Let's see which one will generate more heat. That one's a dud, as it is contained helium but I think this one has hydrogen...and you may want to cover your ears.

{ Michael sets off hydrogen balloon }

Demo: { Exploding Balloon }

Audio: Ta-Da-1

{ Transition to Sound }

Audio: Many dogs barking

Newspaper girl (Katherine): Extra! Extra! Canine chaos! Dogs barking frantically across Neutron City for no reason! Cats even more annoyed than usual! Extra! Extra!

Audio: News Bulletin

(ON B) - RGB {Lectern Computer 1 - PPT Slide 18}: Newspaper with headline "Dogs Are Barking Mad"

Michael: Barking dogs! My thermal powers have no effect on dogs...other than to make their tongues hang out. Oh, if only Acousto Man were here!

Audio: Who Let the Dogs Out

{{ Michael exits stage left }}

Sound (Akire) [Mic #5]

{ The door swings open and Akire emerges, blowing a dog whistle, and looking around }

Akire: Well, he's not in there! Isaac! Isaac! Isaac! SIRRRRRR ISSAAAACCCCCCC!!!!!!!

Sprott: Hey, that's my line!

Akire: You stay out of this! How will I ever solve the dog barking mystery without my crime fighting dog SIR Isaac? Someone accidentally left the door open- and I'm trying to find who let my dog out!!!!!!

Demo: { Dog Whistle }
Audio: Dog Barking-1 *{ AS -- Stuffed dog pops out from behind a curtain. }*

Akire: There you are! You naughty puppy! We have work to do!
{ Akire listens }

Akire: Hey! The barking has stopped! Wait a minute….I wonder if my super crime-fighting dog whistle was upsetting all the dogs in Neutron City?
{ Akire blows on dog whistle }

Demo: { Dog Whistle }
Audio: Many dogs barking

Akire: Yep! Mystery solved! I know it was my crime fighting whistle that was making all of the dogs bark-but I still don't know who let my dog out!!!!

Akire: Hello? Oh really? Okay I'm on my way…..yes, I'll remember to pick up the Milk!!!!

Akire: Hey did anyone else hear what I just heard? No? Really? Hahaha Of course you didn't!! You don't have super hearing like I do!!

{ Rubens' Tube }
{Show image of sound wave with high and low pressure regions

Demo: { Rubens' Tube }

(ON B) - {Lectern PPT Computer 1}: Sound waves

{Hit tuning fork}

Akire: So sound is a wave right? Well a wave of what? The answer is that what we call a sound wave is just a fluctuation of high and low air pressures. As you see from the picture, when the air bunches up, that's a high pressure region, and when the air is sparse or spread out, the pressure is low. Now consider this tube. If we produce a sound wave in the tube at just the right frequency, we can set up what called a standing wave. All that means is that the high and low pressure regions stay in the same place.

Akire: Well if instead of air, we use a flammable gas, then the high pressure regions of the sound wave will push the gas out of tube very strongly whereas the low pressure regions don't push the gas all that much.

Akire: Okay do you wanna see something hot? haha Let's ignite the gas ...

Akire: The distance from one high pressure region to the next is determined by the frequency of the wave. By changing the frequency, we can make the tallest parts of the flame appear at different locations. The frequency is shown on that display in the front of the table.

Audio: ***Ta-Da-1***
{ Doppler effect}
Audio: ***Doppler Horn***

Akire: Now there is another superpower I'd like to share with you. We just saw that sound waves have what's called a frequency? Well what if I told you that I could change the frequency that you hear without changing the frequency at the source? Would you believe me? Haha Well that's why I'm the super"hear"o!! haha

Akire: Okay let me turn on this sound and you'll hear its frequency or pitch. Now without me touching the source, tell me if you now hear a different frequency or pitch…

Akire: And now you hear the original frequency again right? Hahaha So now do you believe that I have superpowers? Ok, good, well as you now know, all my so-called superpowers are just me following the laws of physics. How does this one work?

Demo: { Doppler effect - Ball }
Audio: ***Ta-Da-1***

{Show image of sound waves with source moving towards and away from receiver/ear }

(ON B) - {Lectern PPT Computer 1}: Doppler Effect

Akire: Well from that picture, when the ball is moving towards you, your ear will be on the right of the picture and as you see all the high pressure regions are all bunched up together. So your ear detects a higher frequency and you hear a higher pitch. But when the ball is moving away from you, your ear is now on the left. And the high pressure regions are further apart so your ear detects that the frequency has gone down and you therefore hear a lower pitch.

Akire: Pretty cool huh? This explains why a car passing by sounds like ...

{Play car driving by if possible}
Audio: ***Car Horn***

Akire: This is called the Doppler effect!

(ON B) - {Lectern PPT Computer 1}: Christian Doppler
(ON B) - {Lectern PPT Computer 1}: (Christophorus Bollot)

Sprott: Did you know that the Doppler effect was tested by a Dutch meteorologist (Christophorus Bollot) in 1842 with trumpeters on a train sounding a note while musicians with perfect pitch recorded the note as the train passed?

(ON B) - {Lectern PPT Computer 1}: (Big Bang slide)

Akire: It's also what Hubble used when he realized that every galaxy is racing away from every other galaxy. This was the first piece of evidence that lead to the Big Bang Theory.

Sprott: The Big Bang? I never heard of that!

{ Driven Chladni Plate }

Demo: { Driven Chladni Plate }

Akire: Okay well we don't have to stick to only pushing and pulling on gases. What would happen if we similarly pushed and pulled on a solid? That would make the solid start to vibrate.

(ON B) - {Lectern PPT Computer 1}: (Plate modes)

Akire: Take a look at the following image. It shows a simplified version of a slice through a Chladni vibrating plate. When the plate vibrates at certain special frequencies, notice there are some parts that don't move. These are called nodes. If we push and pull with those special frequencies, we can get the solid to also vibrate at the same frequency. This is called resonance!

Akire: Well if we throw some sand on there, then we'll get the sand to start bouncing around as the plate vibrates. Every time sand gets to a node, it will stop bouncing around since the plate isn't moving at the node. After some time, most of the sand ends up at these nodes.

Akire: Let's try this out now. Again you can take a look at the frequency on the display. When not at resonance, there aren't any nodes and thus the sand bounces around chaotically everywhere. But when we find a resonance frequency, we get a really cool pattern.

Akire: Let's try for another pattern.

Audio: Ta-Da-1

(Que) - Camera 5: { Breaking glass with sound }

Akire: Okay, well let's see what else I can do with resonance. I learned this superpower from the evil super villain that all children despise named "Queen bee quiet." If I recall most children like loud noises and in this "case" there will be. Hahaha

Akire: Now if instead of pushing and pulling on the plate with sand on it, we push and pull on this beaker. The atoms that make up the beaker are now what vibrates. If like the plate, we push and pull with just the right frequency, we can get those vibrations to become really intense. If I use this strobe light, I can show those vibrations…

Akire: Now get ready…

Demo: { Breaking glass with sound }
Audio: Ta-Da-1

Akire: I use acoustic resonance to break through walls and doors that bad guys try to hide behind!!

Newspaper girl (Katherine): Extra! Extra! Widespread brownout hits Neutron City. Electrical grid is in complete disarray.
Audio: News Bulletin
(ON B) - RGB {T1 Computer 1 - PPT Slide 30}: Newspaper with brownouts"

Akire: What a shocking turn of events! My sound skills will attenuate to nothing without electric power to energize them. Oh woe is me….the spark has gone out of my life.

{ Static electricity gets charged for loitering. Static electricity causes bad hair day in Neutron city. City council offers solution for no charge. Charge of the light

brigade. }

{{ Akire exits stage left }}

Electricity (Moriah) **[Mic #]**

Moriah: Is everyone charged up? I doubt it. As a superhero, that's my job! I hope you're ready for an electrifying performance. Let's see if we can stabilize the electricity in Neutron City.
(Que) - Camera 6: { VDG }

Moriah: Electricity may be something you are most familiar with as a source of power but electricity is actually much more interesting than just batteries. You probably have already noticed my first example, this levitating wand in my hand!

Moriah: You see electricity is the movement of charges (of which there are two kinds), and like charges push each other away, while opposite charges pull each other closer together. With this wand I have filled this floating ball with one type of charge, and the wand, having lots of this same charge pushes it away with enough strength to counter gravity - Wingardium Levioso! (but no magic required!)

Moriah: Now I also have another item with me that moves charge: *The Van De Graaff generator* here. And if you watch carefully you will see that it allows my minions to take flight in a very organized way - they are very well trained!

(ON B) - RGB {T1 Computer 1 - PPT Slide 30}: Van de Graaff

(on A&C) - Camera 6: { Kid on VDG }

Demo: { Van de Graaff generator }
Audio: Ta-Da-1
(Que) - Camera 6: { Marx }

Moriah: For this next demonstration I will need a volunteer, who is not afraid of a little shock!

Moriah: Greetings! What is your name? Thank you for your brave volunteer work - brave volunteers are what superhoroes grow out of ^.^ Ah, now, if you carefully follow my instructions you won't feel a shock at all….

Moriah: ….Lets all thank _____ for their wonderful work! The same electric push was at work here to push each hair apart as they were filled with more and more of the same charges, pushing harder and harder until each hair was lifted as far away from each other as the charges could push them.

Moriah: Now for something a bit more dramatic! Hopefully you are all familiar with the sight of lightning? My next demonstration will show off electricity at it's most shocking! ~~We will be charging up __ times as much charge as we were using in the Van de Graaff generator,~~ This demonstration will be releasing a very large amount of charge all at once through the air, so there will be a bright arc-ing show for you all. The machine that I use to accomplish this is called a Marx Generator.

(ON B) - RGB {Lectern PPT Computer 1}: Erwin Marx

Sprott: That's not Karl Marx, the German philosopher, and it's certainly not one of the Marx Brothers. It was invented in 1924 by the German electrical engineer, Erwin Otto Marx.

Moriah: Thank you Professor, that's quite right!

Moriah: This will be a two step process -because I want to make sure you all have as much fun as possible. First I'm going to give you an introduction to the Marx Generator's lighting arc. All of the cylinders you see on the Marx Generator are capacitors which act as batteries, storing charge in the first phase of the process. Then to make the stunning lighting arc, I will be releasing the charge from all of the capacitors at once.

Moriah: This will be quite loud for those in the first couple of rows from the generator, so if you have sensitive ears like Acoustoman or Sir Isaac, I recommend you plug your ears.

~~(on A&C) -~~ Camera 6: { Marx }

Demo: { Marx Generator }
Audio: Ta-Da-1

Moriah: Wonderful! Now I'm coming back to the Marx Generator to clear out the residual charge. The Capacitors work by piling up the charge on one side of the cylinder, so by using this device to touch the two sides at once, I'm letting the excess charges get released. Now we're ready for round two.

Moriah: ~~In order to make sure that the charges go where I would like them to go I have this handy~~ For the next discharge, I will be using this lightning rod to collect the charges. You see, charges don't move at the same speed in all materials, and charges love to go just as fast as they possibly can, so if possible they choose to move through whatever material lets them go the fastest. Metals just happen to allow charges to move very fast, so the charges will come to the metal if it's close enough since that lets them speed by much quicker than the air does, and thus my lightning rod is made of metal.

Moriah: I place the rod here, and now I would like a volunteer who likes explosions!

Moriah: Ah, yes, you! Hello! And what is your name? I would like you to call down the great arc from the Marx generator by pushing this button for me in just a minute, but first, I need you to put on this earmuff, since we'll be rather close and it will be quite loud. Even superheroes need to ensure that we don't needlessly put ourselves in danger! After the earmuff is on, I'll count to three and you will press the button on 3, alright? Great. Here we go, 1, 2, 3.

Demo: { Marx Generator w/wood }
Audio: Ta-Da-1

Moriah: Wow! That was magnificent, lets all thank ____ for thier explosive expertise!

Moriah: Now I'll discharge the capacitors one last time to ensure that we don't have a shocking turn of events later in the show.
{transition to Magnetism}

Newspaper girl (Katherine): Extra! Extra! Metallic object floats spontaneously. Unregulated magnetism is suspect.

Audio: News Bulletin
(ON B) - RGB {Lectern PPT Computer 1}: Newspaper with headline "..Metallic Object Floats Spontaneously..."
(Que) - Camera 6: { Magnet & materials }

Moriah: Hmmm...although MagnetoMan and I are close friends, we tend to act in different directions, so I best exit quickly, before we leave my dimension entirely. The two of us together can be blinding!

{{ Moriah exits stage left }}

Magnetism (Narf in for Peter) **[Mic #3]**

Narf: I'm MagnetoMan here and ready to help save Neutron City!.....
I'm here to talk about magnets and magnetism.(turns c back to crowd so they can see the chick on his cape) Does anyone know what a magnet can do? …..(Turns back around to face crowd) That's correct, it will attract other magnets with like poles or it repel magnets with opposite poles.(Turns again to display chick) It will also attract ferrous metals, such as Iron, cobalt and nickle.(turns to face crowd)

Narf: And now I need a young superhero in training to come down? Any volunteers? Yes you!
What is your name young hero? …….
(Here is where the participant will most likely point out to NARF that there is a chick on the back of his cape) Oh, that!!!! Occupational hazard! I have such a magnetic personality, I just become a "Chick magnet" (RIMSHOT, GROAN)

(on A&C) - Camera 6: { Magnet & materials }
Demo: { Magnet & Metals }

Narf: My nemesis mixed up my supplies and left them in this Plastic bin. [I'll get you yet Captain Chaos….] Ok, I need your help to sort the ferrous materials from the Non-ferrous materials by using this magnet…. help me spate them!… Remember the ferrous materials are attracted to our magnetic superpowers.

- Farrous: Iron and alloys that contain iron are attracted to magnets.
- Non-ferrous: aluminum, brass and copper do not have iron so a magnet will not be attracted to them.

Narf: Thank you my friend!
Audio: Ta-Da-1

(Que) - Table 2 Video 1: { Ferrofluid }

Narf: So, there is this invisible force field that allows us to pick up other ferrous materials. And opposite poles attract well the same poles repelling. Therefor this invisible force surrounds this whole magnet.
Narf: Even Einstein was fascinated by a compass as a child, perhaps musing on how the needle felt a force without direct physical contact.

Demo: { Ferrofluid }
(on A&C) - Table 2 Video 1: { Ferrofluid }

Narf: Here on the screen it looks just like a plain black liquid in a beaker but this is my super special superhero fluid, which can show us this invisible magnetic field of force. We call the black liquid a ferrofluid. It is a finely ground compound containing iron suspended in a solution. Now let me bring a magnet near it you'll see that I can move this fluid. This fluid loves to flow along the magnetic field lines of a magnet.

Narf: Ferrofluids like this are used in high tech industrial applications as a sort of motor oil especially in the aerospace industry and are even used in high fidelity speakers as a cooling agent. These speakers are sometimes call liquid cooled speakers. Just like the one used to break the beaker.

Audio: Ta-Da-1
(on A&C) - Camera 5: { Magnet - Coil - Meter }

Narf: Now we call these types of magnets - permanent magnets. We can use this permanent magnet to induce a current within a coil of wire. Did you know that? Well, here I have a coil of wire that is attached to a meter and watch the meter as I insert the magnet.
(on A&C) - Camera 5: { Magnet - Coil - Meter }
Demo: { Magnet - Coil - Meter }

Narf: The needle move to the right! Watch as I remove it. Now it moves to the left. Did you notice that the needle returned to Zero before I removed the magnetic? This shows both **Faraday's law of induction and Lenz's Law**. A moving magnetic field will induce a current in a loop of wire. That induced electric current will flow within the coil such that it opposes changing magnetic field.. So as long as the magnet moves we can produce a current. Also the faster the magnetic field move the larger the induced current within that loop. Lets try! … See!

(ON B) - RGB {Lectern PPT Computer 1}: Faraday Law
(ON B) - RGB {Lectern PPT Computer 1}: Lenz's Law

Narf: To put another way, the faster the magnet moves through a coil of wire the more force is induced by the magnetic field on to those electrons within the wires of the coil. Hummmm! I have an Idea..

Demo: { Magnet - Flashbulb }

Narf: I have this big magnet here and this coil that is attracted a flashbulb. So, I bet you I can make the flashbulb go off using this principle… What do you think? Here I go! -- O Ya This could be very bright!!! …… Hummm Nothing! What did I do wrong?? That's right, I went toooo slow. Ok One more time!! This could be very bright!!!
{slap the two together really fast}
Audio: Ta-Da-1

Narf: Wow! That was bright!! Magnets are so much fun...

(on A&C) - Camera 6: { on then LN2 }

Narf: There is another way to make a strong magnetic field by using an electric current. This is call an electromagnet. It's only magnetic when you have an electrical current.

Narf: What we have here iron core that is surrounded by several hundred turns of copper wire and its plugged into an outlet. Now here I have an aluminum ring and you know aluminum is not normally a magnetic material as we showed earlier. {Show again} see attracted to the magnet. However when I lower this ring down over the electromagnet and turn it on, that will induce an electric current in this aluminum ring making it momentarily magnetic. But since they are now both magnet and in opposit direction. The ring will be repelled by the electromagnet. So let's try it and see what happens…. {{Ok, that was pretty fast so let's see it again}}

Demo: {Jumping Ring } - [without LN2]

Narf: Well that was cool! Would you like to see it go higher?
We can do that by taking this iron pipe and place it on top of the electromagnet. The iron will then concentrates the magnetic field and makes it go up higher. So let's try!!

Demo: {Jumping Ring } - [without LN2 - Pipe]

Audio: Ta-Da-1

Narf: Now would you like to see it go even higher?
Well it turns out there is a way to do that. If I take this ring and cool it down it turns out it will become a better conductor of electricity. I do that by pouring liquid nitrogen over it and the temperature of liquid nitrogen is 321 degrees below zero fahrenheit. Now the reason it is boiling is because the dish and the ring are much warmer than the liquid nitrogen. Most materials become better electrical conductors when you cool them down. and in fact aluminum becomes a 7 times better conductor of electricity when it is at the temperature of liquid nitrogen then it is at room temperature. As a result, the electric current that is induced in it is much larger and therefore it is a more powerful magnet. So I'm going to lower it down over the iron core and energize it again, we would expect, perhaps for it to go even higher. so let's try that.

Demo: {Jumping Ring } - [LN2 & pipe]

Narf: Well that was high, would you like to see it again.

Audio: Charge [as I look to the ceiling]

Narf: OK, we'll I'll try just about anything for science. We'll see how high we can make it go by using the iron pipe and cooling it down to this very low temperature.

Audio: <u>Ta-Da-1</u>
(Que) - Table 2 Video 2: { Levitating Ball }

<u>Narf:</u> Electro-magnets have many different purposes, like to hold open a fire door. Here we have two very large identical coils, one on top of the other. That will make a very strong magnetic field when we apply an electric current to them. However they are moment and wired in a way where the electric current flows in opposed directions which will make a very strong magnetic field between them.

(on A&C) - Table 2 Video 2: { Levitating Ball }
Demo: {Levitating Ball }

<u>Narf:</u> I can take this hollow aluminum cylinder, about the size of a softball. Now I remind you aluminum is not a magnetic material. Aluminum is not normally a magnetic material, but when I place it inside this magnetic field, it becomes sort of temporarily magnetized, due to the induced current within the cylinder. Since the magnetic field is symmetric, we can do the same thing neat with this cylinder. { give it a spin } You see how it spins around but you see how it stays in there suspended by these magnetic forces.
Audio: <u>Ta-Da-1</u>{

<u>Narf:</u> (standing by maglev track) So, does this remind you of anything? (AUDIO< TRAIN WHISTLE)Tracks, perhaps ?Train Tracks, Maybe?

<u>Sprott:</u> Trains? ***{Jumps up and puts on train hat.}*** I love trains!

(Que) - Camera 6: { Maglev }
<u>Narf:</u> Well you are in luck. I may just have something for you Proof. Sprott
Demo: {Maglev }

<u>Narf:</u> Earlier when I cold that aluminum ring with LN2, I told you that it was a 7 times better conductor of electricity. Well there are some materials that when cooled to LN2 (-321F) that all electrical resistance is removed and it becomes a perfect conductor or what we can a superconductor. I have such an item cooling here in this dish. This is a a YBCO superconductor that is inside this container that hold some LN2. Let see what happens!...

(on A&C) - Camera 6: { MagLev }
{ ooo's and haaa's }

<u>Narf:</u> What's going on! Let me remove this cover...A Ha! Magnets!! … lots of magnets!! We have two circles of magnets here the inner circle is all one magnet pole (lets call that North) and the outer circle is all South poles. Since there is a symmetric magnetic field across the magnets and superconductors try to repel all magnetic fields it must hover.

{{ Stage lights go off - house light flicker on/off }}

__Newspaper girl (Katherine):__ Extra! Extra! Night has fallen on Neutron City, citizens running into each other in the dark. We need someone to illuminate the city.

Audio: News Bulletin

(ON B) - RGB {Lectern PPT Computer 1}: Newspaper with headline "*Night has fallen on Neutron City*...."

__Narf:__ I can't see a thing, my magnetic personality is of no use in illuminating the city, but perhaps my good friend Raymond can help.

{{ Andrew comes out of outhouse with head lamp}}

Light (Andrew) **[Mic #5]**

- *Infrared camera*
  - *People radiate infrared light, night vision*
  - *Looking through a garbage bag*
  - *Looking at footprints*
- *Visible light*
  - *prism causes rainbow*
  - *Polarizer filters*
- *Lasers*
  - *scattering light in a fog*
  - *Diffraction through a double slit*
- *Ultraviolet light*
  - *UV laser/black light causes fluorescence*
- *X-rays*
  - *X-ray machine looks through something*

Andrew: Don't tell them my alter ego, pay no attention to him, my name is Ray Man, and let me see if I can cast some light on the subject.

{{ Stage lights turn on}}

Andrew: There seems to be a problem with light in neutron city, but what is light exactly? To understand how to solve the problem, we need to understand light itself. Light is an electromagnetic wave, a traveling combination of oscillating electric and magnetic fields.

{{ show slide}}

(ON B) - {Lectern PPT Computer 1}: (EM-Wave)

Andrew: This electromagnetic wave has a wavelength, or distance between peaks of the electric field. In a certain range of wavelengths, we are able to see electromagnetic waves, and call them light. In this range, we commonly call the wavelength of light its color. Light, however, extends into wavelengths past the visible spectrum. For wavelengths longer than we can see, we say the light is infrared, for wavelengths shorter than we can see, we say the light is ultraviolet.

{{ show slide}}

(ON B) - {Lectern PPT Computer 1}: (Spectrum)

Andrew: Let's start by examining light in the infrared by using this thermal camera. A thermal camera is a camera that can see light in the far infrared, such as heat. This could be useful to solve neutron city's light problem by allowing people to see in the dark.

{{ stage lights off}}

Andrew: Even though the lights in the visible spectrum are off, we can still use this thermal camera to see the heat given off by various objects and people as we can see here. Your bodies are warmer than the surrounding environment and thus radiate off more heat. We can even see subtle differences in the temperature of surrounding objects. This should keep people from running into each other in the dark.

{{ stage lights on}}

Andrew: Lets see what else we can see in the infrared. For this next demo I'll need a volunteer who doesn't mind taking off their shoes.

{{ child comes onto stage}}

Andrew: Excellent, let's have you sit behind this black plastic screen while you take off your shoes. Now you may not be able to see through this screen because it absorbs visible light, but let's take a look at it with the thermal camera. Why it doesn't appear to be there, we can see right through it. This is because while it absorbs visible light, it is transparent to infrared.

{{ child has shoes off}}

Andrew: Ok, now that you have your shoes off, let's have you walk around on the carpet. Why look at that, you seem to be leaving footprints. Heat is transferred from your body to the carpet making it warmer and allowing us to see where you have walked. Lets give him a hand.

(Que) - Table 3 Video 2: { Thermal imaging camera }
(on A&C) - Table 3 Video 2 { Thermal imaging camera }
Demo: { Thermal imaging camera }
Audio: Ta-Da-1

Andrew: Let's now look at visible light. the light in this room may look white, but did you know it is infact a mixture of colors? Not just red, green, and blue either. Visible light is a continuous spectrum of wavelengths from red to violet which I will demonstrate. Here we have a source of white light and a prism. This prism is made of a material that will bend different wavelengths of light at different angles. The result is that the light is spread out into its component wavelengths and forms a rainbow.

{{ show slide}}

prism causes rainbow
(ON B) - {Lectern_PPT Computer 1}: (Spectrum dispersion)

Andrew: But wavelength is not the only property of light that matters. The direction the electric field is pointing, or polarization of the light, also leads to some interesting properties. This lamp is producing light of many different polarizations, so let's place a polarizing filter in front of it. This absorbs all light not polarized in a given direction. By placing another polarizing filter in front of the first one, but oriented in the same direction, we see that the light is still transmitted, but if we rotate it 90 degrees we see that the light is no longer visible. The polarized light that is passed through the first filter is now absorbed by the second.

{{ show slide}}
(ON B) - {Lectern_PPT Computer 1}: (Spectrum)

Polarizer filters

(ON B) - {Lectern_PPT Computer 1}: (CrossPolarizer)

Andrew: Here is something even more amazing, let's place a third polarizing filter between the other 2 rotated 45 degrees between the two, and now we can see the light again. This is because the middle filter only absorbs the component of the wave not oriented with its axis, effectively rotating the wave's polarization, and the next filter does the same thing a second time. Sure there is some loss in intensity, but pretty impressive nevertheless.

(ON B) - {Lectern_PPT Computer 1}: (3-Polarizers)

Andrew: As previously stated, light is a wave, so let's examine some of the amazing things we can do with waves. Here we have a laser, we can see that it travels in a parallel beam to the screen scattering off this canned fog. You see that the beam hits the screen at a single point. Now let's' see what happens when we shine a laser beam through a pair of very narrow slits. Since light is a wave, the beam passes through both slits and interferes with itself on the other side, generating an interference pattern on the screen instead of a single point..

{{ show slide}}

Diffraction through a double slit
(ON B) - {Lectern_PPT Computer 1}: (Waves - 2 slit)

Andrew: Moving to even shorter wavelengths, we arrive at ultraviolet light. While you may only be able to see a very small amount of light coming from this flashlight, most of it is beyond the visible range, but we can see it's effects through fluorescence. Very short wavelengths of light, such as ultraviolet, can excite various molecules causing them to re-emit light at different visible wavelengths, such as what is happening when the UV light hits this screen causing it, or your underwear to glow.

{{x-ray camera on screen}}

Andrew: Now let's get to one of the most impressive uses of light: x-ray vision. X-rays are just really short wavelength light. So short that they can pass through your body and allow a doctor or dentist to see inside you, or allow airport security to see inside bags and boxes. Here we have an x-ray generator and an detector. We'll place this mystery box between it and have a look inside. Very interesting. We can now see(explanation of what is inside)

(Que) - Table 3 Video 2: { X-Ray }
(on A&C) - Table 3 Video 2: { X-Ray }
Demo: { X- Ray}
Audio: Ta-Da-1

Andrew: That seems to have covered the range of light we were interested in so it looks like my work here is done.

{{ Andrew exits stage left }}

Closing (Sprott, Cast)

Audio: Phone {phone rings}

<u>**Sprott:**</u> Hello… Yes, my team has taken care of it. Neutron City can relax… I'm glad we could help… Goodbye…

{Sprott stands up and walks to center stage}

<u>**Sprott:**</u> Even superheroes can't violate the laws of physics, but those same laws allow us to do extraordinary things. The World is facing many problems including climate change, terrorism, cyber crime, political instability, economic inequities, and much more. I believe that a knowledge of physics is useful and even essential for solving many of these problems. Things may get worse before they get better, but I'm optimistic that most of these problems will eventually be solved. Perhaps one of you will find a way to apply the laws of physics to one of these problems and be the superhero who saves the World!

<u>**Sprott:**</u> And now I'd like to end with a demonstration we have used to end every one of the presentations of **The Wonders of Physics** for the past 33 years by making for you a cloud. Some clouds warm the Earth, but others cool the Earth, and perhaps making them on a large scale in the right places at the right time could solve the global warming problem …

{Explains cloud demo}

<u>**Sprott:**</u> And with that I thank you all for coming. Oh, and I should thank my mother for the monogrammed shirt -- S for Sprott!

Demo: {LN2 Cloud}

(ON B) - RGB {<u>Lec Computer 1</u>}: PPT SLIDE # 52 - Clouds / Thank You

(ON B) - DVD Video: <u>Theme music video</u>

Audio: <u>WOP Theme-long-3m22s.wav</u>

{The show concludes with Sprott disappearing in the Liquid Nitrogen Cloud. <u>Theme music video</u> plays. Cast enters from right and left doors and bows in unison.}

Peter: I'm Magneto Man here and ready to help save Neutron City!.....Today I am going to talk about magnets and magnetism. I will show you how a magnet affects different metals and how they can be used to generate electricity. Let's first start our discussion with a simple bar magnet.

(on A&C) - Camera 6: { Nails }
Demo: { Magnet & Nails }
Audio: Ta-Da-1
(Que) - Camera 6: { Ferrofluid }

Peter: Does anyone know what a magnet can do? That's correct, it will attract other magnets with like poles or it will repel magnets with opposite poles. It will also attract ferrous metals. Ferrous metals and alloys contain iron which allow a magnet to be attracted to them; and non-ferrous materials like aluminum, brass and copper do not have iron so a magnet will not be attracted to them. Now I have some nails here in this small plastic bin, what's going to happen when I place this magnet close to the nails? Well it depends, are my nails made out of iron? Let's try the experiment, well the magnet didn't pick up my nails, this means they are made of a non-ferrous metal. In fact these nails are made out of aluminum. Let's try these nails, the magnet picks up these nails because they are made of iron.

(on A&C) - Camera 6: { Magnet - Coil - Meter}
Demo: { Magnet - Coil - Meter }
Audio: Ta-Da-1
(ON B) - RGB {Lectern PPT Computer 1}: Lenz & or Faraday

Peter: Let's investigate a little bit more about this magnet. There is an invisible force that surrounds this magnet. Einstein is said to have been fascinated by a compass as a child, perhaps musing on how the needle felt a force without direct physical contact. What is this invisible force? We can feel it but we can't see it. The invisible force around this bar magnet is magnetic field lines.

(on A&C) - Camera 6: { Ferrofluid }
Demo: { Ferrofluid }
Audio: Ta-Da-1

Peter: Scientists have been experimenting with fluids that react to magnetic fields and we call them ferrofluids from the latin word ferrum which means iron. I have here an example of a ferrofluid which is just a bunch of small iron filings that have been emulsified in a liquid. You can see up here on the screen it looks just like a plain liquid in a beaker but as I bring a magnet near it you'll see the fluid will try to flow along the magnetic field lines. Now ferrofluids like this are used in high tech industrial applications as a sort of motor oil especially in the aerospace industry.

(on A&C) - Camera 6: { on then LN2 }
Demo: {Jumping Ring } - [without LN2 & with LN2]
Audio: Ta-Da-1

Peter: One way to make a strong magnetic field is with an electric current. Here I have a bar of iron surrounded by several hundred turns of copper wire and its plugged into the wall back here. In a moment I'm going to turn it on. Now here I have an aluminum ring and you know aluminum is not normally a magnetic material and here I have a magnet and it's not at all attracted to the magnet. To prove it's a magnet it easily picks up these nails. However when I lower this ring down over the electromagnet and turn it on, that will induce an electric current in this aluminum ring making it momentarily magnetic. and then this magnet will be repelled by this magnet. So let's try it and see what happens.

Audio: Ta-Da-1

That was pretty fast so let's see it again.

Would you like to see it go higher? Turns out there is a way to do that. We take an iron pipe and place it on top of the electromagnet. The iron concentrates the magnetic field and makes it go up higher. So let's try it with the iron pipe.

Audio: Ta-Da-1

Now would you like to see it go even higher? Well it turns out there is a way to do that. If I take this ring and cool it down it turns out it will become a better conductor of electricity. I do that by pouring liquid nitrogen over it and the temperature of liquid nitrogen is 321 degrees below fahrenheit. Now the reason it is boiling is because the dish and the ring are much warmer than the liquid nitrogen. Most materials become better electrical conductors when you cool them down. and in fact aluminum becomes a 7 times better conductor of electricity when it is at the temperature of liquid nitrogen then it is at room temperature. As a result, the electric current that is induced in it is much larger and therefore it is a more powerful magnet. So I'm going to lower it down over the iron core and energize it again, we would expect, perhaps for it to go even higher. so let's try that.

Audio: Ta-Da-1

Well that was pretty high, would you like to see it again. OK, we'll do anything for science. We'll see how high we can make it go by using the iron pipe and cooling it down to this very low temperature.

Audio: Ta-Da-1

(Que) - Camera 6: { Levitating Ball }
(on A&C) - Camera 6: { Levitating Ball }
Demo: {Levitating Ball }
Audio: Ta-Da-1

Peter: there is another thing people have found some uses for, this is a very large electro-magnet. now a lot of people confuse electricity and magnetism and with good reason because they are closely related. In fact one way to make a very strong magnet is with an electric current. Here I have two coils an in a moment I will turn them on and there will be an electric current flowing in them and that will make a very strong magnetic field here. Then I'll take this aluminum ball, about the size of a softball. Now I remind you aluminum is not a magnetic material. Here's a magnet, and the aluminum is not at all attracted to the magnet, just so you know it is really a magnet, here are some nails. but aluminum is not normally a magnetic material, but when I put it inside this magnetic field, it becomes sort of temporarily magnetized. and that's because electric currents flow in it and those electric currents make it magnetic. We can do the same thing with this cylinder, these are both hollow on the inside. and you see how it spins around but you see how it stays in there suspended by these magnetic forces. now this is very important technologically because the ability to levitate some things magnetically could be very important.

Sprott: Trains? ***{Jumps up and puts on train hat.}*** I love trains!

(Que) - Camera 6: { Maglev }
(on A&C) - Camera 6: { MagLev }
Demo: {Maglev }
Audio: Ta-Da-1

Peter: ….

{{ Stage lights go off - house light flicker on/off }}

Newspaper girl (Katherine): Extra! Extra! Night has fallen on Neutron City, citizens running into each other in the dark. We need someone to illuminate the city.
Audio: News Bulletin
(ON B) - RGB {Lectern PPT Computer 1}: Newspaper with headline "….."

Peter: I can't see a thing, my magnetic personality is of no use in illuminating the city, but perhaps my good friend Raymond can help.
{{ Andrew comes out of outhouse with head lamp}}