



Teacher's Guide for: **Capacitors**

Note: All activities in this document should be performed with adult supervision. Likewise, common sense and care are essential to the conduct of any and all activities, whether described in this document or otherwise. Parents or guardians should supervise children. Rock-it Science assumes no responsibility for any injuries or damages arising from any activities.

NOTE: This is the transcript of a lesson that was videotaped during an actual Rock-it Science class with real students, not actors. The students' brainstorming comments are included on the video but are not transcribed here because they're not part of the lesson presentation.

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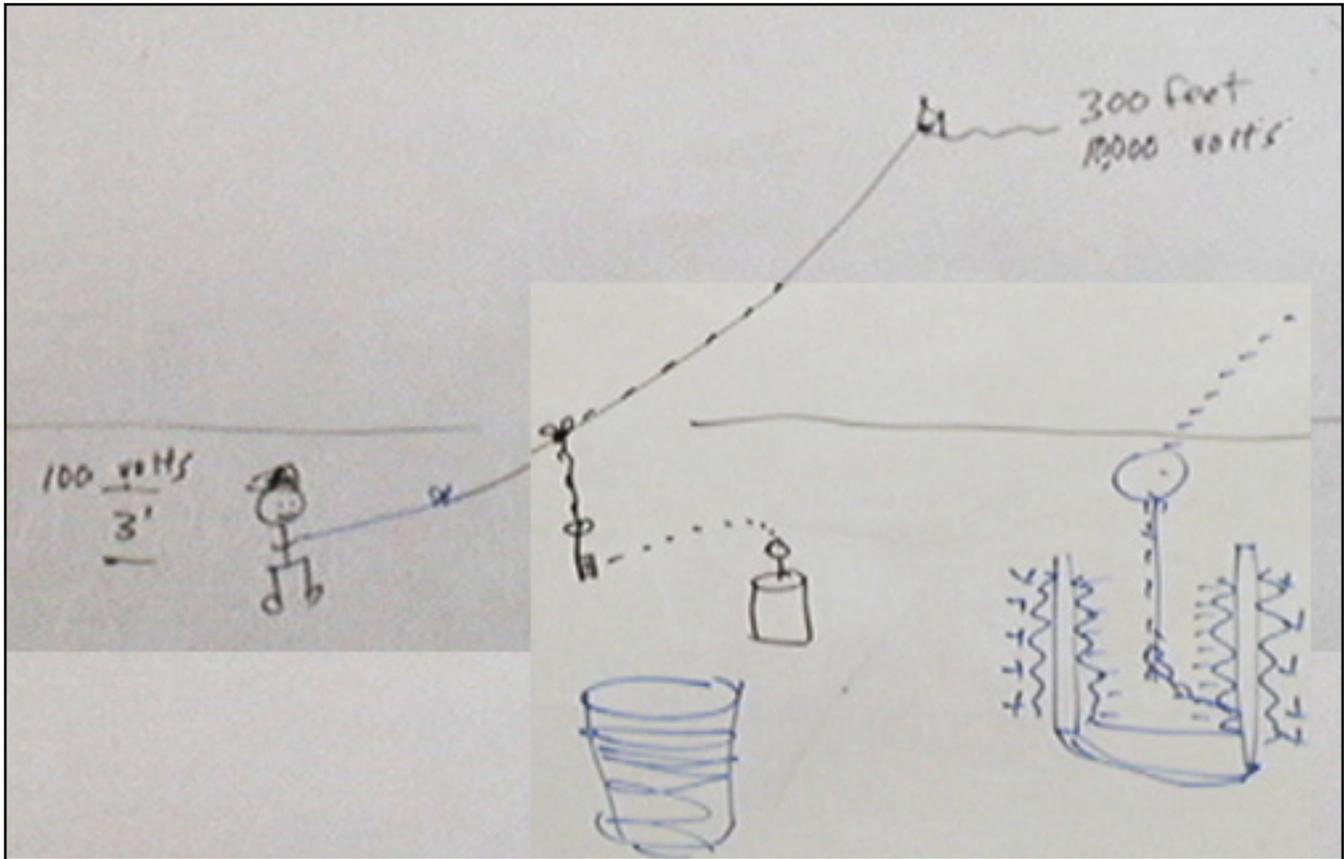
Title Page of Video

Capacitors
A Rock-it Science Lesson
Filmed November, 2009

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Intro Quick Recap:



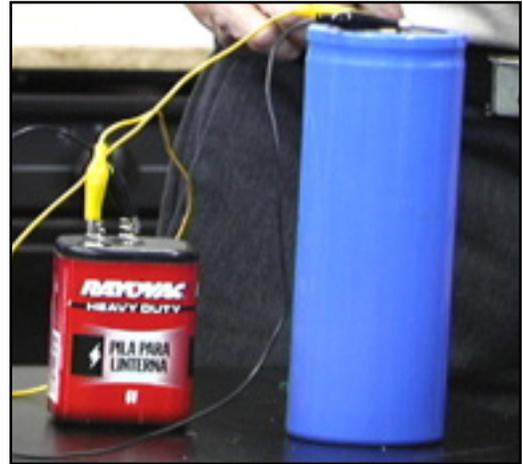
- There's a static electrical field all around the Earth. It amounts to about 100 volts for every 3 feet of elevation.
- Picture of Benjamin Franklin flying his kite in a clear blue sky. A key is hanging off on a non-conductive silk thread, hovering near a leyden jar.
- If your kite is up 300 feet, you get 100×100 volts, which is 10,000 volts.
- If you use a string made of cotton soaked in salt water, 10,000 volts of static electricity can come down and end up on the key. If you touch it you get a spark.
- Franklin would let the key touch the ball from the leyden jar a few times, and the voltage would get stored up in the jar.
- Then, as a joke, Franklin would hand the jar to someone, and the electricity would go through his body, making his leg muscles contract, so he'd jump up and then fall down.
- Franklin wrote about his experiments and sent them to Britain, but they wouldn't publish it because Franklin was an American.
- There's a story that, as a joke, Franklin wrote a letter to someone saying that he had done the experiment on a cloudy day, in front of an approaching storm, but the letter has been lost.

Intro Quick Recap:

- Someone in France took it seriously and tried to do the experiment on a cloudy day. Lightning hit, and he died. But Franklin never did it with lightning, and he never expected anyone to actually do it that way.
 - His leyden jar was a glass jar with foil on the inside and foil on the outside. The two foils don't touch -- they're separated. But there's a gold chain that touches the foil.
 - The negative guys go into the jar, but they hate each other, so they spread out on the inside.
 - When the negative guys go inside, they attract positive guys on the outside. That's called a capacitor.
 - A capacitor is like a bucket of water. You can fill it up and dump it out really fast. A battery is different because it doesn't dump out quite as fast.
 - If you go online, you can see videos about all kinds of capacitors, and some of them hold very large charges and can melt metal or make things fly across the room.
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Experiment Quick Recap: "Capacitors"

- Students wear goggles.
- For the experiment, students will use a 6-volt battery, but it takes 40 volts to get through the skin.
- Instructor demonstrates experiment setup before giving materials to students.
- Take a Christmas light and use it to test the battery to make sure it has charge, and also to make sure the bulb isn't burned out.
- Use wires with alligator clips to connect the battery to the capacitor for several seconds. Then remove the wires. The capacitor is now charged.
- To check it, touch the lightbulb wires to the capacitor and see how long the bulb stays on. The class will use several different kinds of capacitors, so some will last longer than others.
- Students work in groups of two. After each group has had a chance to work with their capacitor for a few minutes, they pass it on to the next group. This is repeated several times, so each group has a chance to work with several different size capacitors.
- Then they charge up the capacitor and short it out by placing the blade of a screwdriver across the contacts. This creates sparks, which are harmless to the skin.
- Instructor brings out a grinding wheel and makes large sparks. The students file by and hold out their hand to feel the sparks. Warn students not to touch the wheel itself, because it will shred their fingers.
- Give students a square of aluminum foil and have them short out their capacitor with the foil. This usually creates larger sparks and burns holes through the foil.
- Students pass on their capacitors to the next group every few minutes as before.



Charging the capacitor.

Equipment List: "Capacitors"

Items needed for Instructor:

Consumables:

- Same as students

Other:

- Grinding Wheel
- Metal to make sparks with grinding wheel

Items needed for Students:

Consumables (per group of 2 students):

- Christmas light
- Foil, aluminum, about 12" square

Other (per group of 2 students):

- Battery, 6-volt lantern
- Capacitor (about 10 different sizes, to be shared among the groups)
- 24" insulated Connecting Wires with Alligator Clips. (2 wires per group)
- Screwdriver
- Goggles

Prep Work:

- Cut strings of Christmas lights into individual lights with about 2-inch wires attached.



Above: 6-volt lantern battery.



Screwdriver

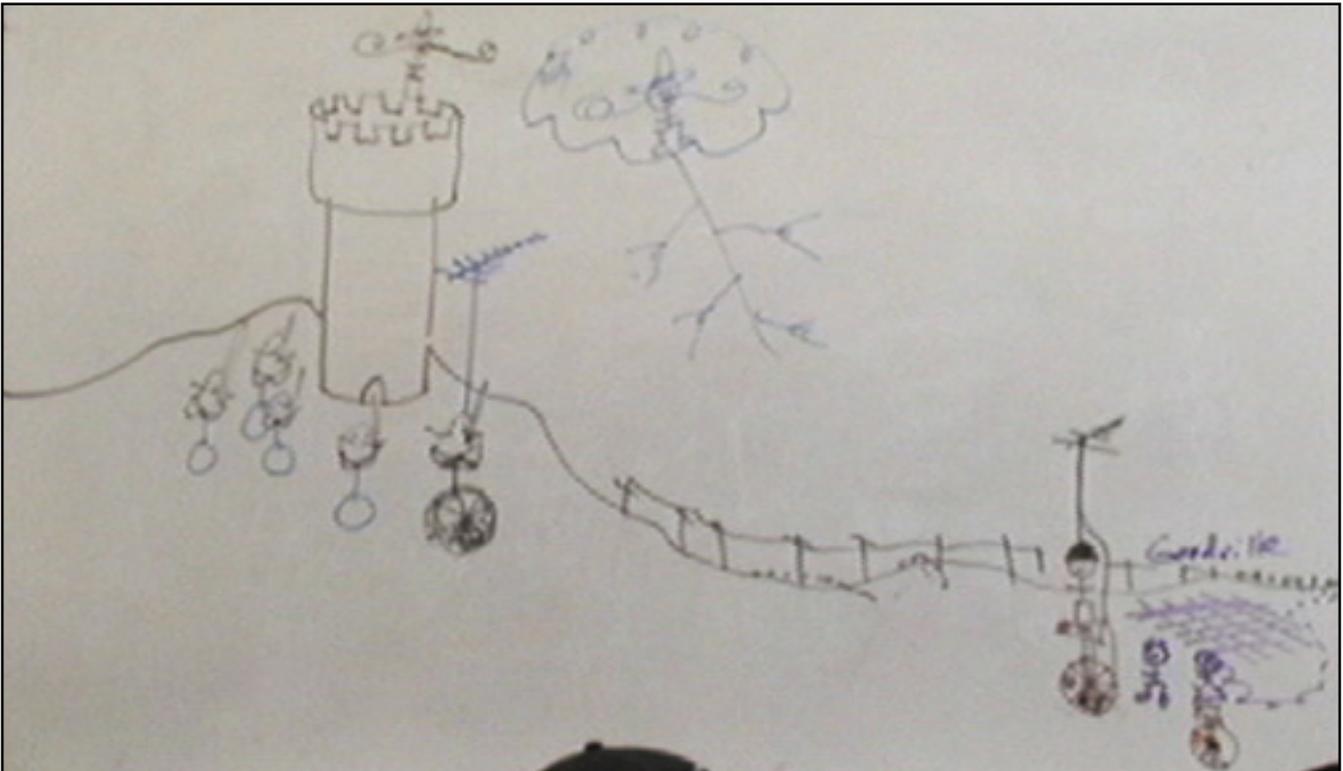


Aluminum foil sheets, pre-cut to 12" x 10 3/4", box of 500.



Assorted capacitors.

Story Recap: "Evil Mister Fred's Unicycle Attack"

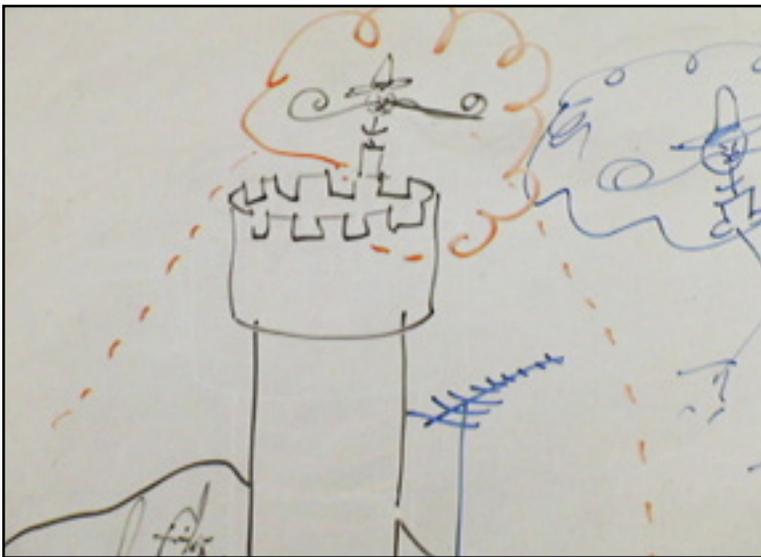


Part 1:

- Evil Mister Fred wants a new castle, and he makes the minions build it out of chewing gum wrappers. He ordered ten million pieces of gum from the Acme Store of Everything.
- The minions have to chew the gum, which keeps them quiet so they don't annoy Evil Mister Fred. And it takes a long time to build the castle, so he gets some peace and quiet.
- Jack and Jill live nearby in Goodville. They want to get people out of their houses and get some exercise, so they order a bunch of hamsters and unicycles.
- They modify the wheel on the unicycle so they can put a hamster inside. The idea is to make the hamster run so the wheel will turn, and the rider can sit on top.
- But the hamsters didn't like this, so Jack and Jill needed to motivate them. Jack discovered that his hamster liked root beer, so he suspended a glass of root beer inside the wheel so the hamster was always running toward it.
- Jill made a two-hamster model, and her hamsters liked pizza.
- Jack tried putting four hamsters together, but when you get that many, they trip over each other. But he still wanted more power.
- He noticed that whenever he rode under the power lines, the hamsters would go faster because they liked the electricity.
- So Jack put an antenna on an insulated hat, with a wire running down to the hamsters, and he'd ride under the power lines. The hamsters would get energized and go faster.

Story Recap (cont.):

- One time he got too close, and his antenna hit the power lines. This made his hamsters explode.
- Evil Mister Fred saw this through his telescope, so he ordered some unicycles for himself.
- He used minions as riders, and other minions inside the wheels. He used M&Ms to motivate the minions in the wheels. He also put antennas on the minion riders, and when the minions in the wheels got a zap of electricity, they went really fast.
- Now Evil Mister Fred is flying around on his cloud, and his cloud can shoot lightning bolts at his minions.
- With minions on unicycles with their baseball bats, he was ready to attack Goodville.

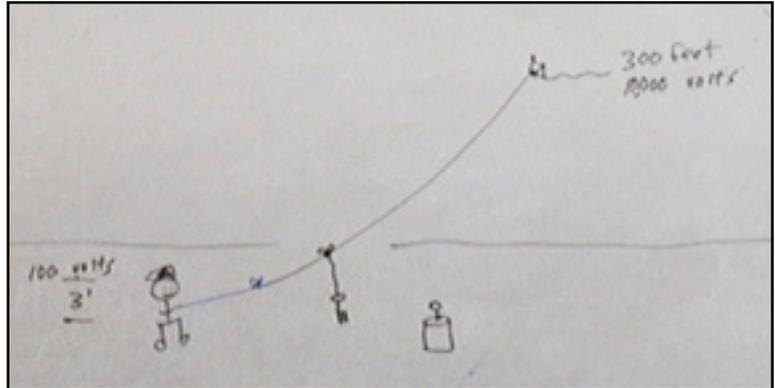


Ending:

- Evil Mister Fred's castle is made out of chewing gum wrappers made of silver foil.
- The wrappers also have a layer of waxed paper, which is an insulator.
- When you have conductors next to insulators, they make capacitors.
- Evil Mister Fred's army of minions and the army from Goodville clashed in the middle of the field on their unicycles.
- Evil Mister Fred was shooting lightning bolts from his cloud, and he hit some of the Goodville guys, which made their hamsters scream.
- Their screams were so loud and ear-piercing, the minions hated it, and they started running back toward the castle.
- Evil Mister Fred started to get off his cloud so he could make the minions regroup, and he stepped onto his castle.
- The castle was fully charged, and Evil Mister Fred was like the aluminum foil in the experiment.
- He exploded into a giant ball of fire, with little pieces of mustache drifting down.

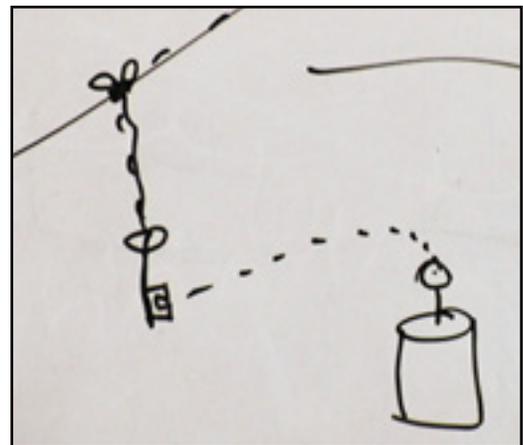
Transcript: Intro

[The drawing on the whiteboard shows a person flying a kite with a key hanging from the string. Next to the person is written "1,000 volts" and "3 feet". Nearby is a picture of a jar with a ball protruding from the top. **IMPORTANT: The number "1,000" on the video is incorrect. It should be "100."** This transcript contains the correct numbers. Use these figures, not the ones on the video.]



Ben Franklin flying his kite in a clear sky.

[NOTE: Beginning of intro is missing on the video: There's a static electrical field all around the Earth, and it amounts to about 100 volts for every 3 feet of elevation. It's just there. We never know about it, it just happens to be there. Here's Benjamin Franklin flying his kite in a clear blue sky. He's got a key hanging off a non-conductive silk thread, and it's hovering near a leyden jar.] So if your kite happens to be up 300 feet, you get one hundred times a hundred, which is **ten thousand volts**. Sweet. And if you use a string made of cotton soaked in salt water, **ten thousand volts** can come down and end up on the key. It's all static electricity.



Key on string and leyden jar.

Well, Franklin would maneuver over here and let the key touch the ball from the jar. And then he'd touch it a few times -- touch, touch, touch, touch -- and some of that voltage would go into the jar. It's called a leyden jar. It stores it all up. And then he'd find somebody out there and say, "Hey, I've got a jar here. Here you go." And the guy would grab it. And then he would go bam! He'd jump up in the air because the electricity would go through his arm, down his body, through his leg, and his leg muscles would contract, and he'd jump like this and then fall down. And Franklin thought this was a great joke, and he did this a lot of times.

And he had a problem with the British. He was an American colonial, and he wrote scientific papers, and he studied things very carefully. And he'd send his papers to people in Britain, and they'd say, "Oh, that rube, he doesn't know anything." And they wouldn't publish his papers. So once, apparently, he wrote a letter to someone that unfortunately has been lost, telling them about this experiment. But he said he did it on a cloudy day, in front of an approaching storm. And they all said, "Oh, that stupid Franklin. He doesn't know anything. He couldn't do that right. We'll show him how to do it."

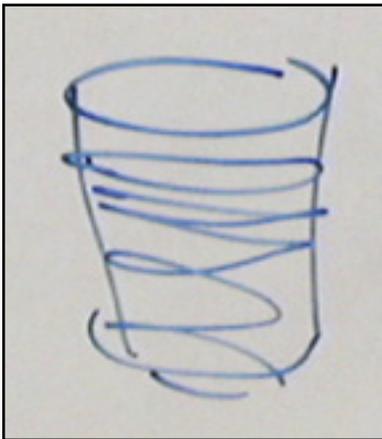
And a guy in France decided he was an expert on electricity and stuff. He reproduced the experiment to do it right. So he went out with a kite on a cloudy day. Lightning hit, and he died. So Franklin intended it to be a joke, that somebody would try it on a clear day like he did and get a big zap out of it. He didn't ever think that somebody would go and do it on a day when there'd be lightning. But somehow the word

Transcript: Intro (cont.)

got out that he did it with lightning. And I think it's Scientific American that tried to find the letter. And MythBusters also tried to find the actual letter, and there was no record of him actually doing this on a rainy day, because he wasn't that dumb.

And the jar that he used, this thing called a leyden jar, is something that we're going to use today. In it there was a glass jar. And there was foil on the outside and foil on the inside. The two foils don't touch -- they're separated. And if you let electricity go in, and there's a gold chain that touches the foil . . . Suppose it's all negative guys. The negative guys go in there, and they hate each other. They all spread out on the inside. And when negative guys go on the inside, it attracts positive guys on the outside. And they call that thing a capacitor. Anytime you can get one charge to attract another, you have a sort of a capacitor.

A really good example of a capacitor is just a bucket of water. If you have a bucket of water, it's like a capacitor full of electrons. You can fill it up, and you can dump it out really fast. A battery is a little bit different, because with a battery you can't dump things out quite as fast. Today we're going to be doing some experiments with capacitors and see what happens.

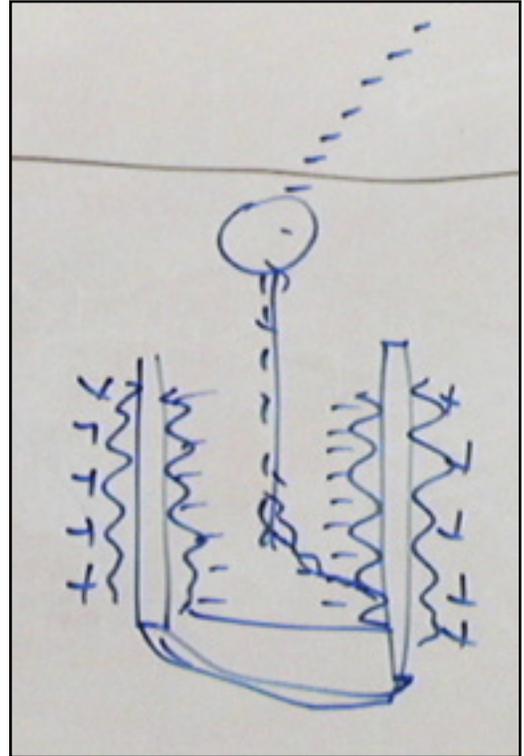


Bucket of water.

Do you guys ever go online and look at videos? *[Students: Yes.]* Oh, okay. They have

some really good videos about capacitors, super-capacitors, and ultra-capacitors. And some of them are just fantastic. If you get a capacitor that is like that size *[holds up a small capacitor]*, it's not too large. But these guys are using capacitors that are like this size *[large]*. And they put three thousand volts, ten thousand volts in them and see what happens. Maybe sometime later we'll get some of those videos and show you, because you can melt metal with them, you can make things fly across the room, get destroyed.

But first, we need a crazy story.



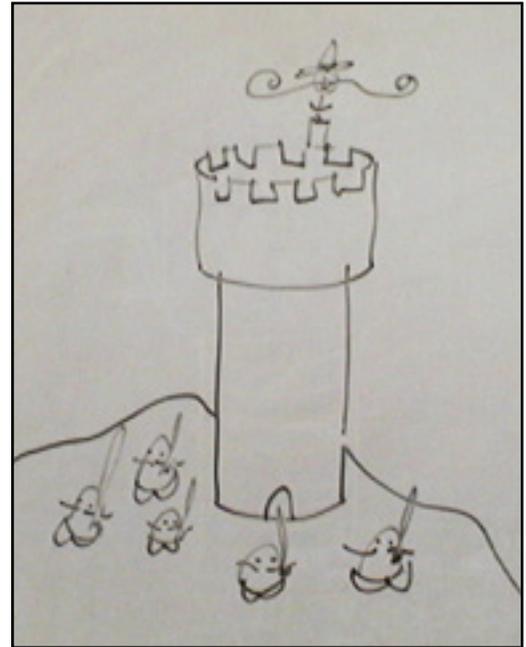
Cross-section of leyden jar.

Story: "Evil Mister Fred's Unicycle Attack"

Let's suppose that Evil Mister Fred wants a new castle. And usually he lets the minions build the castle out of stone. They're pretty good with that. They use their baseball bats and break the stone. But they've been really obnoxious lately, and he wants them to take some time to build the castle. Plus the minions are all running around making minion sounds and bothering him. He wants to focus on doing whatever bad he's going to do, so he says, "Minions, you've got to build me a new castle, and you've got to make it out of gum wrappers." And the minions said, "Gum wrappers? Oh, boy! Who gets to chew the gum?" He says, "You chew the gum."

So he called the Acme Store of Everything and ordered ten million pieces of gum. And the minions would take the gum out, chew the gum, and they'd have the wrapper left over. And then they had to stick the wrappers together to make a castle for Evil Mister Fred. And he ended up with a regular castle, but it was made out of gum wrappers. They did a good job. And Evil Mister Fred could stand on it and it didn't fall down. He was kind of surprised. It probably didn't fall down because they'd left gum all over it.

And it kept the minions busy. They were chewing the gum and working, and they couldn't make noise because they were chewing the gum. And minions can't multi-task too well. When they're chewing gum, they can't do other things. But they can stick wrappers together. It's hard for a minion to chew gum and walk at the same time. And when he got his castle all done, Evil Mister Fred was looking around for evil things to do.

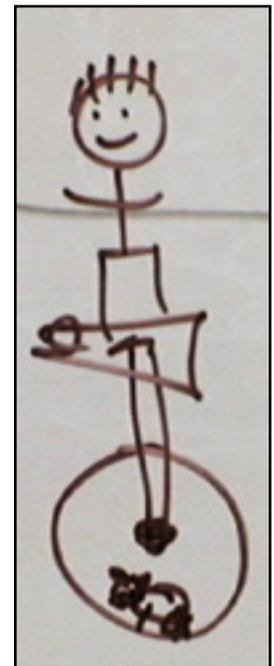


Evil Mister Fred on his castle, with minions carrying baseball bats.



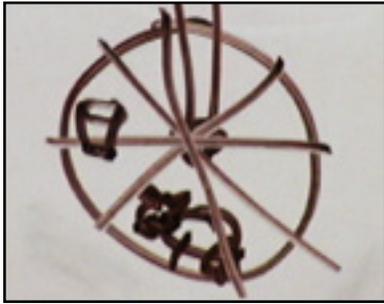
Jack and Jill live in Goodville.

And of course, nearby is Goodville. And Jack and Jill are there. And Jack and Jill want to get the people out of their houses, have them do a little bit of exercise, have some fun. So they ordered a bunch of hamsters and unicycles. And they modified the wheel on the unicycle so that you could put a hamster inside. It would be a one-hamster-powered unicycle. And you'd sit on top, or you could stand on top. And you'd tell the hamster to go, and you'd balance yourself up there and ride on this unicycle.



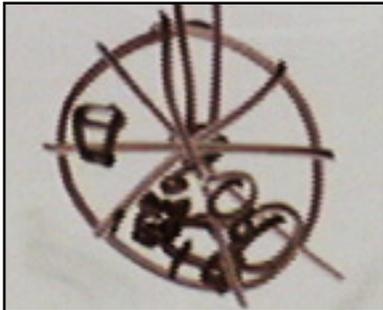
Jack's hamster-powered unicycle.

Well, the hamsters didn't like this. They don't want to go. So you need some motivation for the hamsters. At first they thought, "Well, we could play some inspi-



Glass of root beer in the wheel.

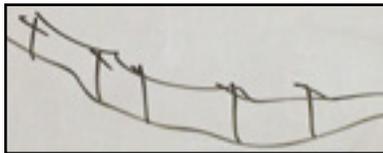
rational music.” But the hamsters didn’t like their inspirational music. Then they thought, “Food! We’ll give them the food that they like. And so Jack was experimenting with his hamster and discovered the hamster loved root beer. He put a glass of root beer suspended like that inside the wheel, so the hamster was always running, trying to get the root beer. And as he’d run to get the root beer, the wheel would turn, and Jack could ride all around the countryside on this thing.



Four hamsters -- too many.

And Jill thought that was pretty good, so she made one for herself. But she made hers a two-hamster-powered model. And her hamsters liked pizza. And she could go twice as fast as Jack.

And Jack said, “Well, that’s no good. I want more hamsters.” So he tried putting four hamsters in his, but when you put four hamsters in there, they trip over each other. Next thing you know, there’s root beer covered hamsters, and it’s going thunk-a, thunk-a, thunk-a, like that. And Jack said, “Well, I need more power. Got to get these hamsters to work harder.”



Power lines.

So he noticed that not too far away there were some telephone poles and power lines, like that.

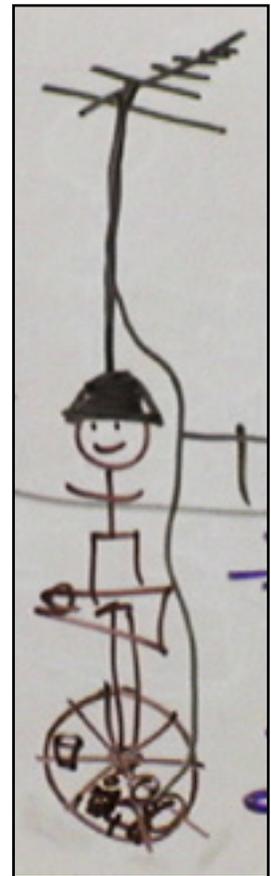
And he noticed that early in the morning the power lines would hiss and humm -- ssszzzzz, like that. And he took his hamsters out early one morning, and he was riding under the power lines, and he’d go faster when they were going by the power lines. So he said, “Oh, that’s pretty cool! They like the electricity. I wonder how much is good and how much is bad.”

So he put an antenna on his head, like that. And he put on a hat that was insulated. And he took a wire from the antenna and put it down on the hamsters. Then he’d ride under the power lines. The antenna would pick up some of the electricity from the power lines, and the hamsters would get energized and go faster. And he could beat Jill in races with his hamsters going that way. And Jill said, “Wow, that’s really good!”

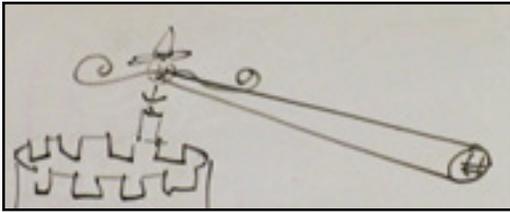
Well, one time Jack was riding under the power lines over the hill here, and he came up over a rise, and his antenna hit the power lines. And his hamsters exploded. He says, “Oh, man! Too close. Bad.” So he had to make his antenna lower. And he realized too much electricity was bad.



Jill's two hamsters with pizza.



Jack's antenna hat.



Evil Mister Fred's Telescope.

Now, while this was going on, Evil Mister Fred happened to notice, being that he had a telescope. And he saw what Jack did. And he said, "That fool! That idiot! Look what he did. He just blew up his hamsters! That's great!"

So Evil Mister Fred got himself some unicycles for his minions. But he didn't put hamsters in there. Know what he put

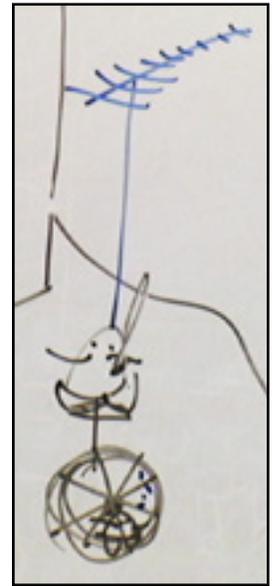
in there? Minions. So now there's minions riding on top, there's minions on the inside, and minions like M&Ms. So he put M&Ms in there. And he put antennas on his minions, and he tried it out. And sure enough, if you give a minion motivation with M&Ms, give him a little bit of a zap of electricity -- zzzoom! He goes really fast.



Evil Mister Fred on his cloud.

Now, Evil Mister Fred bought himself . . . what's a good way to use electricity? He's flying around on his cloud, and he's made it so his cloud can shoot lightning bolts down at his minions. He says, "Now we've got it. We've got the electricity. We've got the minions on wheels, they've got their baseball bats. I'm ready to attack."

So Jack and Jill see that Evil Mister Fred has copied their foolish design, and he's going to attack the city with minions on unicycles. If you were Jack and Jill, what would you do?



Minion unicycle.

Imagination and Brainstorming Time

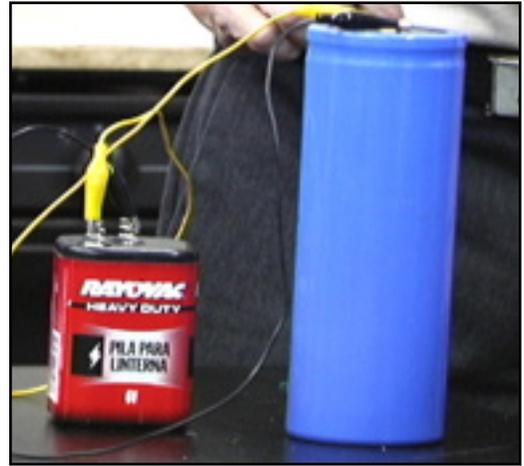
[Students make suggestions] (THERE ARE NO WRONG ANSWERS! Whatever they say, you should reply: "That's a good idea," "They might do that," etc. After brainstorming, proceed with the experiments, then finish the story.)

We'll leave this "To be Continued . . ."

Experiment: "Capacitors"

Now, electricity is pretty good stuff. Luckily, you guys have skin. If you didn't have skin, we'd have a problem with this experiment. You're going to use a 6-volt battery. It takes 40 volts to get through your fingers. And we're going to hook them up to some of the capacitors and see what they do. Usually, if you put a battery like this on a light, the light will light up. *[Takes out a bag of Christmas lights.]* You're going to have to find a light that works. These were tested by other kids yesterday, so they may have gotten burnt out.

So you have a light and a battery and one of these things *[holds up a capacitor]*. So if you want to charge one up, you need to get some voltage on the two screws that are on the top. And these guys have a little plus sign on them, and a minus sign. The battery has a plus sign and a minus sign. If you get close to the rated voltage of it, it makes a difference, but for us it probably doesn't. This guy says it's made for fifteen volts, and we're only using six.



6-volt lantern battery hooked up to a capacitor with alligator clips.



Checking the capacitor's charge with a Christmas light.

And we'll hook our wires onto it. You can just touch them with your fingers. Negative goes to negative, and the positive goes to positive *[connects battery to capacitor with wires and alligator clips for several seconds]*. And now you can take the wires off *[disconnects wires from capacitor]*. The electricity went into the capacitor. And you can touch the lightbulb to it and see *[bulb lights up]* that it lights up. So this capacitor can make the light go . . . *[bulb goes out]* that long.

If you use a different capacitor *[brings out a small one]*, we'll see how it goes. *[Charges capacitor, then tests light. The bulb only lasts a few seconds.]* And it goes that long. Now, the things have written on the side numbers. This one *[reads info on side of large capacitor]* says "Sprague Pow-

erlitic 36DX. 300,000-15 DC. 8621L1901. Made in USA. 85 degrees C." Well, that's a lot of information that means nothing to us. The only thing I recognize is the 15 DC. Fifteen volts DC. Before that there's a big number, 300,000. This one *[reads from small capacitor]* has a number 24,000. But it says "MFDs". Hmm. Miniature Flower Developers. No. Or, MicroFarads. It's supposed to be microfarads. A farad is a measure of how much charge it will hold. This one's got three hundred thousand, this one's got twenty-four thousand. And if you look in the box, there are various kinds. This one's got one hundred and forty thousand. This one is sixty thousand. This guy is forty-seven thousand. They all have their own values. The previous class may have left some electricity in them still, so when you first get them, touch your lights on there and see if they light up.



Small capacitor.

And after you figure out how to make the lights light up and see how long they go, we're going to do something you're not supposed to do. The thing you're not supposed to do is short out a capacitor by putting something conductive between the two screws. And you can touch them to do that. I'll make it so I can turn out the lights. It's more fun that way.

What I'll do is charge it up and turn off the lights and short it out. I have to first release the battery so it'll go off. So when you get yours, you'll charge up your capacitor. Give it about ten seconds for the big ones. And then you choose a weapon of your choice, either a fat one or a skinny one [*picks up a screwdriver*]. You can go sideways across it. [*Turns off lights and places screwdriver across the screws to create sparks.*] And just kind of use the screwdriver until it stops. See how long it goes.

[*Student: What happens if the spark makes contact with your skin?*] Then you would explode into flames, do the ooh-ah-ooh-ah dance, and die. No, they don't do anything. They just bounce off. Have you ever used a grinder to grind metal and seen sparks go flying off? [*Some of the students say no.*]

So you need a partner, and you'll need a battery and alligator clips. So choose someone to work with. Send one of your partners to go get a battery. Send the other one to get wires. And when you take the wires, try not to create an incredible tangled mess. Then send somebody over here to pick either a fat screwdriver or a skinny screwdriver. [*Student: Do we take a capacitor?*] Not yet.



Charging the capacitor.

[*After students have their other materials, the Instructor passes out a capacitor to each group so there are several different sizes being used.*] If you have one that has a metal plate on the top, there is a thin piece of plastic between the two sides. You want to short between those.

Now you need a lightbulb [*passes out bulbs*]. Test one on your battery and see if it works. If it doesn't work, I'll toss you another one. Does everyone have a lightbulb that works?

Okay, now charge up your capacitor. When it's charged, then you take the wires off. Everybody be sure to put on goggles.

Did everybody's capacitor light up the lightbulb? [*Students: Yes.*] Okay, now that you know how to charge it and discharge it with a lightbulb, then you charge it back up again and try it

with a screwdriver. [*Instructor turns out lights to make the sparks easier to see.*]

[*After students have worked with their capacitors for a few minutes, Instructor turns on lights.*] Okay, now everyone's going to move their capacitor one group to your left. [*Students pass on their capacitors and repeat the experiment. After a few minutes, they pass them on again. They do this five or six times so everyone has a chance to work with several different sizes of capacitors.*]



Using screwdriver to short out capacitor.



Above: Grinder wheel. Below: Sparks.

[After turning on the lights again, Instructor brings out a grinding wheel and points to the outer edge of the wheel.] This part of the wheel you don't want to touch. It's a grinder. It will give you hamburger fingers. What we're going to do is, I'm going to touch this to make sparks. If you want to, you can come by to feel the sparks with your fingers to show you what sparks feel like. [Instructor turns off lights, then holds a piece of metal against the grinding wheel to make sparks. Students file by and hold out their hand to feel the sparks.]



[Lights on.] Now we're not going to use screw drivers. What we're going to do is, you're going to charge up your capacitor and put aluminum foil between them and see what it does to the aluminum foil. It's better if you leave it thin than make it thick, but you can try it either way. [Instructor hands out a square about 12" x 12" of aluminum foil to each team, then turns out the lights. Students try shorting out the capacitors with the foil and pass them on every few minutes as before.]



At Left and Above: Shorting out the capacitor with foil.

End of Story

**** DO NOT * present this part of the lesson until after the experiments!***

So now we need an ending for our story. Have you ever eaten gum? Have you ever had the gum that when you take the cover off the gum it's like a silver foil? Well, Evil Mister Fred's castle was made out of pieces of silver foil. And the gum has, inside the silver foil, a little bit of waxed paper, which is an insulator. So when you have conductors next to insulators, they make capacitors. Now, Evil Mister Fred's up in his cloud, and he's been busy zapping his minions, trying to get them to go over and attack Goodville. Jack and Jill are coming out with everybody in Goodville and their hamster-powered uni-cycles, trying to fight off the minions. And when the two armies clashed in the middle of the field, Evil Mister Fred is shooting lightning bolts everywhere. And he accidentally shot some of the good guys. And hamsters turn out to have super powers when you hit them with just that kind of electricity. And the hamsters don't just run fast, they scream. Have you ever heard a hamster scream? Oh, it's a really loud ear-piercing sound. The minions hate it. The minions went, "Aaaaaaahh!" and they turned around and ran.



Evil Mister Fred in a ball of fire.

Evil Mister Fred said, "No, no, stop! Turn around, you cowards!" The minions kept running. And Evil Mister Fred said, "Arrrgh! We'll regroup and we'll attack." So he got off his cloud. He was going to step from his cloud onto his castle. The castle was fully charged. Evil Mister Fred was like the aluminum foil. He just kind of exploded into a giant ball of fire and flame. And little pieces of mustache fell this way and fell that way. And everybody lived happily ever after, except Evil Mister Fred.

End of Lesson

If you have questions about this lesson, please ask them through the online [Teacher Support Forum](#) on our web site.