



Teacher's Guide for:  
**Thermal Conductivity**

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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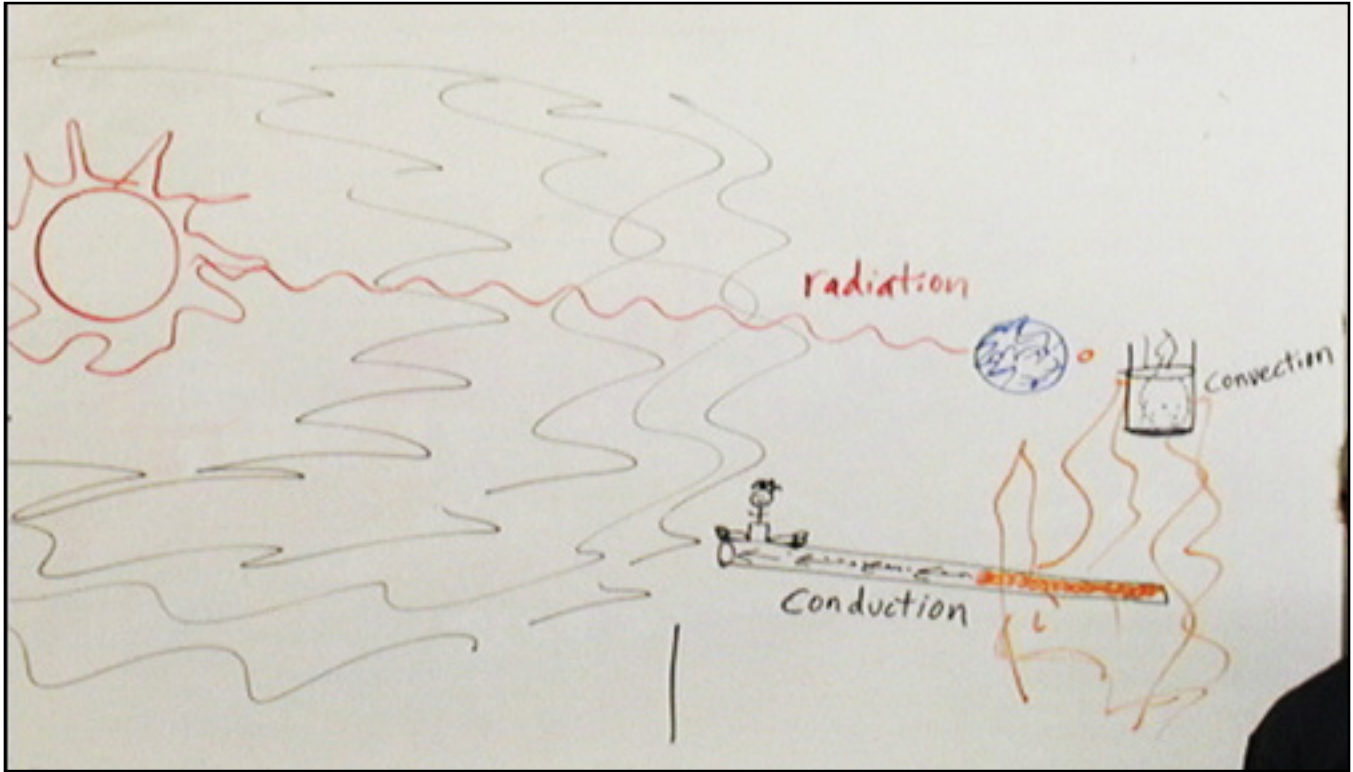
Thermal Conductivity  
A Rock-it Science Lesson  
Filmed November, 2009

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## Intro Quick Recap:



- What color is the Sun?
- Sun produces heat that gets to Earth. There's space in between. What's in space?
- Space is 99.999999999999% nothing. But heat can go through nothing and get to us. When heat goes through nothing, it's called "Radiation."
- Suppose there's a fire, with a steel bar sitting in it. If you're standing on the end of the bar and start walking toward the fire, your feet will get hot. When heat moves through a solid, it's called "Conduction."
- It's harder to do conduction with liquids because they move. If you have a cup sitting over the fire, the heat conducts through the glass to the liquid. But as the liquid at the bottom gets hot, it becomes less dense and rises to the top. Then it cools off and gets heavier and sinks to the bottom again, then repeats the cycle. They call this "Convection."
- If you're out in the desert and wanted to keep from getting hot, would you jump into a sleeping bag?
- A sleeping bag is made of material that's called an insulator, which doesn't let heat through. The heat stays in to keep you warm when it's cold, but it can also keep the heat out when it's hot.
- People who live in the desert wear long robes with linen garments underneath. When they sweat, the linen gets wet and creates evaporation. The long flowing robes make the air move around them, so they stay cool.

## Experiment Quick Recap: "Insulators on Dry Ice"

- Dry ice is 109 degrees below zero. If you touch it for 12 seconds, you can get frostbite. But you can brush your hand across it without getting hurt.
- Walk around with a slab of dry ice and let students brush their hand over it if they want to.
- Use a hammer and a spatula to break the dry ice into pieces about 3" square, one for each pair of students. Show them how the spatula screeches when the side of the blade is placed against the dry ice.
- Give each pair of students a paper plate and put a chunk of dry ice on it.
- Pass out a small cube of copper to each student, but tell them not to put it on the dry ice yet.
- Students hold the copper in their hands and blow on it to warm it up.
- When the Instructor says "Go," they all place the copper on their slab of dry ice at the same time and hold their finger on top. When their finger gets cold, they take it off.
- This process is repeated with an assortment of materials (one at a time) so students can see how long it takes for the cold to get through the material and reach their fingers. The materials include:
  - Copper
  - Zinc (used inside pennies)
  - Aluminum (soda cans)
  - Magnesium (space ships, race cars)
  - Steel (bicycles, cars)
  - Plastic
  - Glass
  - Foam. First, have the students touch the top of the foam lightly while it sits on the dry ice. Then have them press it down hard so that it will stay squashed when they take their finger away.
  - Rubber. Keep it on the dry ice for awhile to see if it gets stiff.
  - Styrofoam. Hand out styrofoam trays and let the students tear them into pieces so they can use more than one layer if they want.
  - Fabric. Provide an assortment of fabric remnants, some thick, some thin, and let each student choose one to work with. They can fold it into as many layers as they want, to see what it takes to insulate them from the cold.
- After the experiments, pass out clear plastic cups and have the students put their chunk of dry ice in their cup. Pour some warm water into the cups and let the students fool around with it for a few minutes.
- Then add a few drops of dish soap so the dry ice makes bubbles. Let them fool around with it for a few minutes. When finished, have students dump the contents of their cups into a large bucket.



Touching metal on top of dry ice slab.

## Equipment List: "Thermal Conductivity"

### Items needed for Instructor:

- Cooler for dry ice
- Metal cake spatula
- Hammer
- Pitcher for hot water
- Bucket, 5-gal

### Items needed for Students:

#### Consumables (per group of 2 students):

- Dry ice, approx. 3" cube per 2 students
- Paper plate, 10"
- Cup, clear plastic, 16-oz.
- Dish soap (a few drops)
- Water, warm, approx. 8 oz.

#### Other (per group of 2 students):

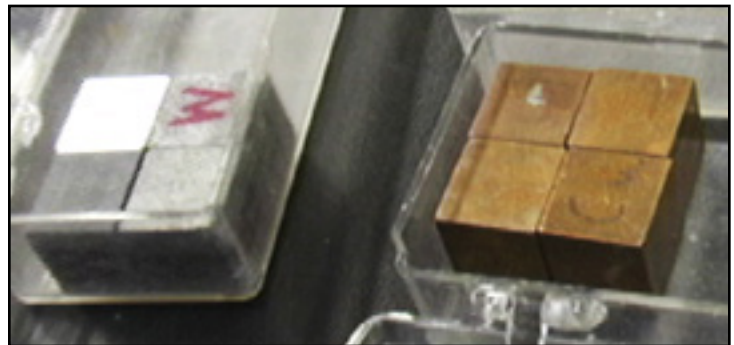
- Testing materials, 1/2" cubes:
  - Copper
  - Zinc
  - Aluminum
  - Magnesium
  - Steel
  - Wood
  - Plastic
  - Glass
  - Foam
- Testing materials, other:
  - Rubber
  - Cork
  - Styrofoam
  - Fabric
- (Not all testing materials may be used, depending on how much time you have.)

### Prep Work:

- Buy dry ice
- Prepare small samples of materials for testing. (The cubes used in this lesson were specially made by Rock-it Science.)



Breaking the dry ice into smaller chunks.

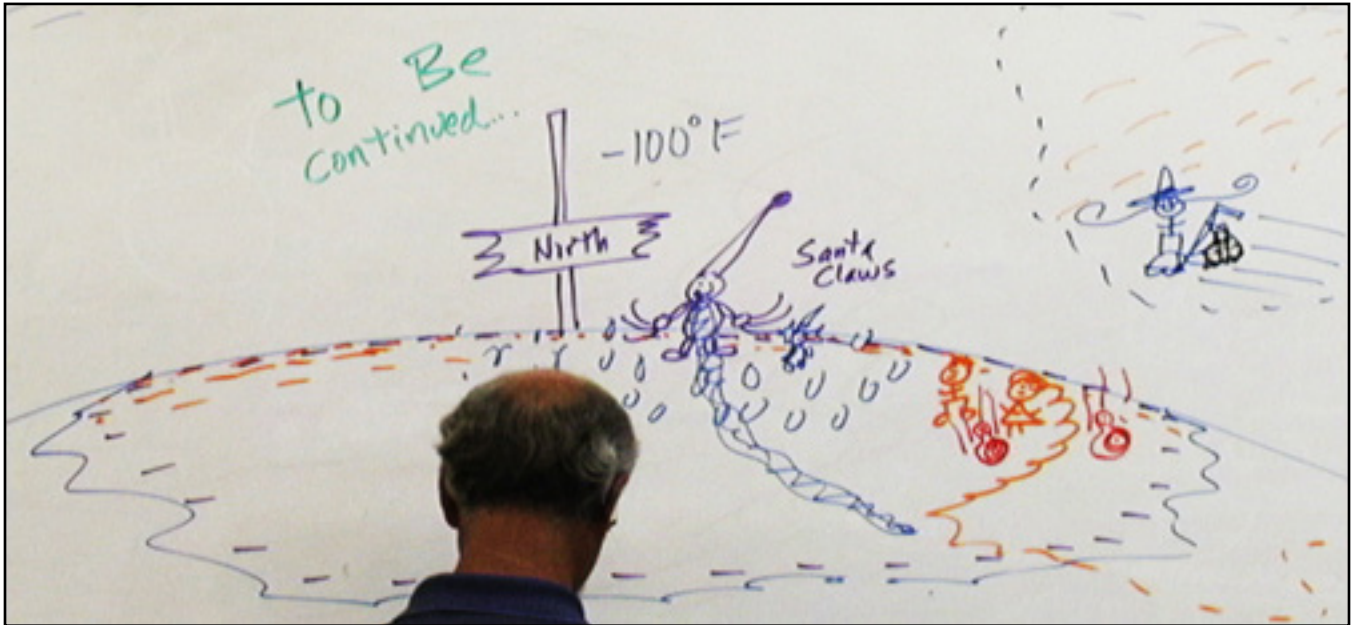


Half-inch cubes of sample materials.



Rubber washer.

## Story Recap: "Evil Mister Fred and Santa Claws"

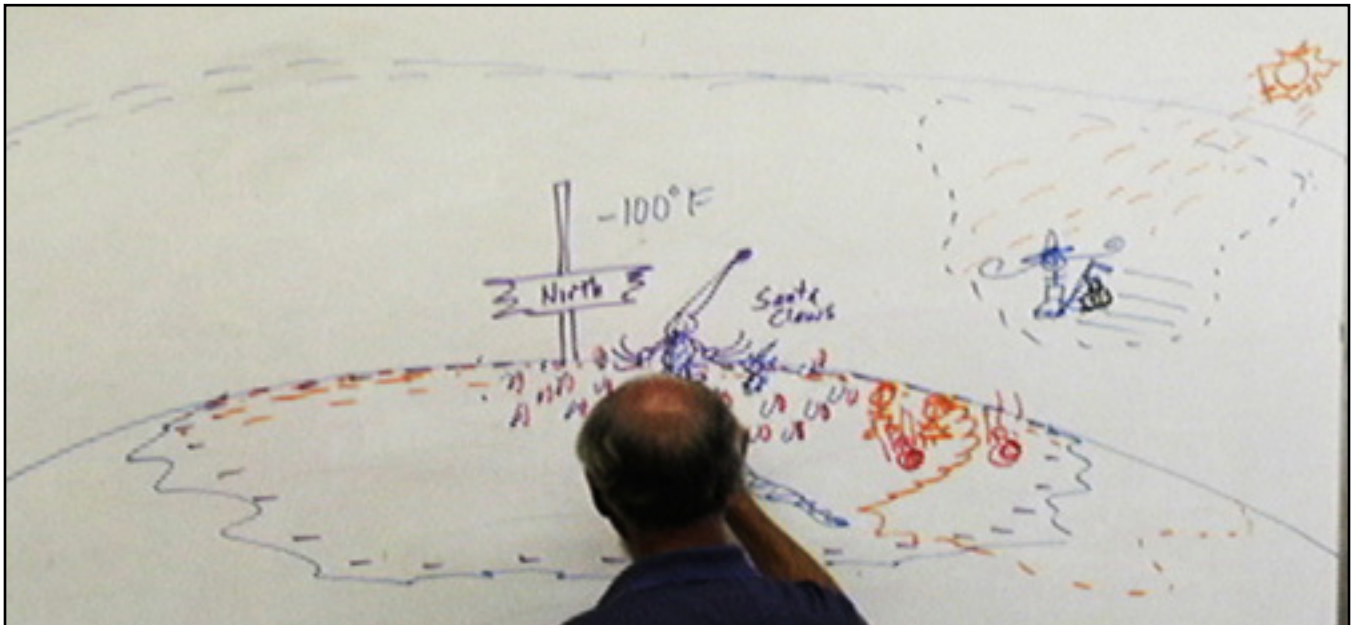


### Part 1:

- Evil Mister Fred discovered how to suck air into his vacuum cleaner and not have it come out.
- He created an invisible hole in the atmosphere, so there's less air to absorb the Sun's heat. He realized this could give people sunburns in a very short time.
- It takes a lot of work to create a hole in the atmosphere, so Evil Mister Fred wants to use this technique as effectively as possible, to make children cry.
- He flies to the North Pole, where there's a guy with long claws on his hands, called Santa Claws. No one wants to be around him because of his claws, so they sent him up there.
- Evil Mister Fred told Santa Claws he'd arrange for him to make gifts for kids so he'd become famous and everybody would love him.
- He called the Acme Store of Everything and ordered a bunch of elves who made the gifts. Santa Claws gave the gifts away and became famous.
- The minions didn't understand why Evil Mister Fred was making kids happy, but he told them to be patient.
- Jack and Jill heard about Santa Claws and went to visit him. He told them he was concerned because the North Pole doesn't have any land underneath it. It's just ice floating on the ocean. If the ice ever melted, everything would be destroyed.
- Jack and Jill had brought some Kick-Mes with them. Kick-Mes are always warm, so they were always melting holes in the ice, so they had to be careful.
- After a couple of years, all the kids in the world came to expect Santa's gifts every year, so Evil Mister Fred decided it was time to use his plan. He started flying around on his vacuum cleaner, sucking up the air above the North Pole, so the ice started melting.

## Story Recap (cont.): "Evil Mister Fred and Santa Claws"

- Jack and Jill ordered a gazillion mirrors from the Acme Store of Everything and placed them all over, so they reflected the sunlight and the ice got frozen again.
- Then Evil Mister Fred sucked up more air from other places and started piling it all on top of the North Pole, so the temperature dropped to -100 degrees and the elves started to freeze.



### Ending:

- Jack and Jill duct-taped a Kick-Me to the back of each elf, like a backpack, so the elves were kept warm and they could work again.
- Then Evil Mister Fred lowered the temperature to -200 degrees.
- Jack and Jill started wrapping the elves in any kind of insulating material they could find.
- Evil Mister Fred kept making it colder and colder.
- Jack and Jill started pretending it was really warm down there instead of cold, so Evil Mister Fred flew closer to investigate.
- As he flew over, Jack and Jill threw a bunch of Kick-Mes into the air, and they got sucked up into the vacuum cleaner.
- Kick-Mes love being chewed up, so when they saw the vacuum cleaner's motor, they jumped into it, got chewed up into Kick-Me juice, and wrecked the motor. Then the juice came back together and re-formed the Kick-Mes.
- Evil Mister Fred's vacuum cleaner crashed onto the ice at -200 degrees and got frozen solid.
- When the air that had been piled up started to even out again, the temperature was restored to normal.



Let's see, I've got a question for you. If it's really, really hot out, and you wanted to keep from getting so hot, would you jump into a sleeping bag to stay cooler? How many people would not jump into a sleeping bag?

Well, a sleeping bag is made out of a material that's called an insulator, and it doesn't let heat go through it, which is a good thing. So the heat stays in to keep you warm on a cold night. But if it's really hot out, it also keeps the heat out! Isn't that weird? Yeah.

*[Student: But if there's any black on it, it'll attract the heat.]* If there's radiation, yes. Black absorbs radiation. That's very good.

If you're in Arabia and you're riding your camel across the hot deserts, and the temperature's 130 degrees. They wear these long robes. And then underneath the robes they wear like linen and stuff. Well, when they sweat, the linen gets wet. And the linen creates evaporation. The long robes are always going *[indicates robes blowing around]*, pumping air by them. So the air goes by and makes their sweat evaporate, and they stay cool. That's really clever.

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## Story: "Evil Mister Fred and Santa Claws"

Okay, we need a crazy story. Let's see, we're going to have . . . Evil Mister Fred has been studying the planets. He's flying around on his vacuum cleaner. So Evil Mister Fred's flying by on his vacuum cleaner, and he's discovered a way to suck up air and not let it come back.



Evil Mister Fred makes a hole in the atmosphere by sucking out the air.

So as he's flying around, the atmosphere -- which is usually way, way up here like this -- starts developing a hole in it, because he's flown around and sucked away the air. And he's created this invisible hole. And the Sun, which is way out there in space, shines through the hole. And there's less air to absorb any of the Sun's heat or bounce it off. And now it starts getting warmer wherever he sucked away the stuff.



Evil Mister Fred flying on his vacuum cleaner.

And he says, "Oh, I like this! I could fly over New York City and suck away most of the air. And the people would go outside, and they'd be enjoying the nice sunny day, and next thing you know -- sunburned people! Oh, I could create torture. They're usually out there for an hour or two before they get sunburn. I can burn them up in ten minutes."

And he thought, "Yeah, this'll be fun." But it takes a lot of work. He has to fly around and around in circles, and he's really busy doing this. So he doesn't want to do this too long. He says, "Now, what would be the most effective way to use this new power?" And he thought, "If only I could make all the children in the world cry. It would make me so happy!" How would you make them cry? *[Students offer ideas, including giving the children something they like and then taking it back.]*

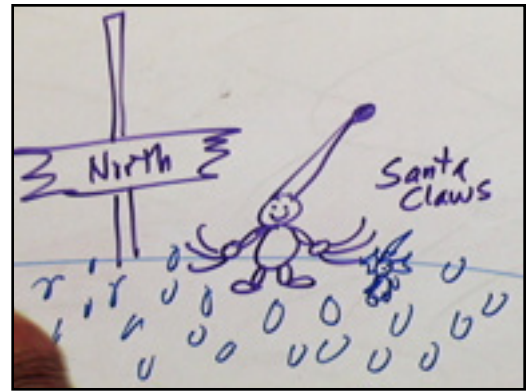
I like the idea of giving them something and taking it back. So let's suppose Evil Mister Fred flew up to the North Pole. And he was visiting with a guy there. This guy has arms and feet and legs, and on his hands he has these long claws. So they call him Santa Claws. And Evil Mister Fred said, "Hey, Santa Claws! I've got this neat plan. And you'll be famous. Everybody will love you!" And Santa Claws said, "Aw, I would like that. They sent me up here because whenever I shake hands, I cut them open. Whatever I'm doing, I make a big mess of it because of these claws. And I try to cut them off, but they always grow back."

And Evil Mister Fred said, "I've got just the thing for you. You're going to get some helpers, and you're going to make gifts. And you're going to give them to all the children in the world. And then you'll be famous! And everybody will love you." Santa Claws said, "Oh, great idea! I love this idea!"

So Evil Mister Fred called the Acme Store of Everything and ordered a whole bunch of elves, like that. And they all sat around at the North Pole, and they made gifts and gave them to all the children in the world. And Santa Claws became famous. And Evil Mister Fred said, "Oh, my plan is working." And the minions, who were hanging around inside the vacuum cleaner bag, said, "Hey, boss! You're supposed

to be evil. This is terrible. You're making the kids happy. We don't like this." And Evil Mister Fred said, "Don't worry. We'll get them. Just be patient. Good evil takes time."

So Jack and Jill heard about this, and they said, "We've got to go visit that Santa Claws guy and see if he needs any help." So Jack and Jill showed up, up there. And there they were, all these elves working like crazy, Santa Claws helping packaging gifts, putting them all on stuff to be delivered throughout the world. And they said, "Hey, Santa! This is really great! You're a nice guy." And Santa said, "Thank you very much. I'm trying to do as well as I can here." And Santa said, "We do have a problem. The North Pole has no dirt under it. It's just ice floating on the ocean. If anything should happen, we could just float away and the ice would all melt, and all my work would be for nothing."



Santa Claws and his elves.

And Jack and Jill said, "Yeah, that is kind of a problem. But somehow you're figuring it out." And Jack and Jill brought along with them a bunch of their Kick-Mes. And the Kick-Mes are always sad, but Jack and Jill kick them around and kick them into the ocean. Killer whales come along and eat them and play with them, and Kick-Mes love that. The problem with the Kick-Mes, though -- Kick-Mes are always hot. So the Kick-Mes are always melting holes in the ice. And Santa said, "Hey, you'd better watch out with those Kick-Mes. Those guys are too warm, and they're melting holes wherever they go." Jack and Jill said, "Okay, we'll figure out something to do for that."



Jack and Jill's warm Kick-Mes.

Now, a couple of years went by. Santa became totally famous. All the kids every year expected new gifts from Santa. [*Student: And he grew a beard.*] Okay, he grew a beard, like that. And Evil Mister Fred said, "Now's the time to play my ace, the final card. Oh boy, this'll be good." And he flew over the North Pole and started sucking up more and more air from the North Pole. As he did, the Sun came through hotter and hotter, and the ice started to melt away. And Santa said, "Oh, oh! This is bad! The ice is melting. This is not good at all." And the little elf guys were having a hard time working.

And Jack and Jill said, "Never fear! We'll solve this problem." So Jack and Jill called the Acme Store of Everything and ordered a gazillion mirrors. They put mirrors all over the North Pole. And the sunlight reflected back into the sky, and it got all nice and frozen again. And Evil Mister Fred said, "No! My plan! It's not working! Arrrgghhh! I've done this good. I've got to undo something to reverse this trend." So he said, "I know what I'll do." And he went and he sucked up air from all over the place that he could get it, and he started piling more and more over the North Pole. So now the air was really thick. And instead of being regularly freezing cold, the temperature at the North Pole got to be minus 100 degrees F. It was so frozen, the ice became hundreds and hundreds of feet thick. And the elves who were helping Santa Claws were all going chatter, chatter, chatter, chatter, chatter. They were freezing. If you were Jack and Jill, and you saw that the elves couldn't make gifts for the kids because Evil Mister Fred was freezing them, what would you do?

## 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: “Insulators on Dry Ice”

For our experiment, we need something that’s really cold, and then we want to test ways to keep the cold from getting through to our finger. The stuff that’s really cold is in here. Dry ice is 109 degrees below zero. Whatever you do, don’t put your hand on dry ice, or your hand will explode! *[Puts hand on dry ice for a moment, then makes a sound like an explosion.]* Oh, darn, it didn’t explode. It didn’t even get stuck. Is it cold? *[Touches a student’s arm with the hand that touched the dry ice.]* *[Student: Yeah, it’s cold!]*

Dry ice is made out of pure carbon dioxide, and it changes from a solid directly into a gas. It never gets to a liquid. That’s why they say it’s “dry” ice. It doesn’t drip. And any moisture that’s in the air, like moisture in your breath, *[blows onto the dry ice, making fog]* turns into fog on the dry ice.

If you put your hand on it for twelve seconds, you get something called frost bite. It actually freezes your skin, and it kills the cells in your skin, so that you have to wait for new ones to grow. It takes a long time for new ones to grow. So if you want to touch dry ice, you can kind of brush it like that, just to see what it’s like. But you don’t want to be leaving your hand directly on it. So I’m going to bring it by. If you want to pet it, you can pet it. *[Brings around dry ice slab so students can brush their hand across the surface if they want to.]*

Now, since it’s so cold, we can use it in our experiment. We need to make it smaller. It’s too big right now. *[Brings out a cake spatula and a hammer.]* Oh, by the way, this is a singing spatula. *[Places side of spatula against the slab, and it makes a screeching sound.]* Pretend like you’re sitting in the chair in the dentist’s office, and something happens inside your head.

This is a handy way to break it *[places edge of spatula against slab and taps it with the hammer, breaking the dry ice into smaller pieces]*. We just need smaller chunks for the experiment that we’re doing. *[Student: Where can you buy it?]* Oh, at some grocery stores.

We’re going to put some of this on paper plates. We’ll put it on a paper plate and



Breaking up the dry ice into approx. 3" x 3" squares.

there'll be one sitting by you. We're going to test various things on there to see how long it takes the coldness from the dry ice to get through whatever it is to our finger. So if I put a hammer on there and put my finger on the hammer and see how long it takes for my finger to get cold, well, it's going to take awhile. So our samples are a lot smaller than a hammer. Samples are over here. We have a bunch of different kinds.



Chunk of dry ice on paper plate.

First sample we're going to try is a piece of copper. It's pure copper metal. When I say, "Go," you're going to put it on the dry ice and put your finger gently on top, and sit there and go dum-de-dum-de-dum-de-dum. And then eventually your finger will get cold, and you'll go, "Aaaaah, it's cold!" And then you'll take it off and set the cube on a plate. We just want to get some idea of how long it takes for the coldness to get through copper.

And we're going to try all these various things. We'll be trying a sample of steel -- bicycles are made out of steel. We'll be trying a sample of wood, a sample of magnesium -- rockets and race cars and jet aircraft are made out of magnesium. We'll be trying a sample of zinc -- pennies are zinc on the inside nowadays because it's cheaper than copper. We'll try some aluminum -- soda cans are made out of aluminum, and aluminum foil is made out of aluminum. We'll try a sample of glass -- looks like ice. There's a sample of clear plastic, too, that's there. We'll try a sample of foam -- we'll see how that works. We'll try a sample of rubber. And we'll look around and see what other samples we can find. There's a bunch of different kinds. There are corks here, you can try cork. There's a bunch of cloth down there. We'll see how much time we have. There's some blue foamy things, styrofoam pans. We just want to see what works.

*[Students work in groups of two. Instructor passes out a paper plate to each group, then places a chunk of dry ice on each plate.]* First we're going to give each person a copper cube, and then you're going to warm it up in your fingers, because it works better if it's warm. When you get the copper cube, do not put it on the dry ice. Hold it in your hands and blow on it until it's warm. And then when I say, "Ready, get set, go," then everybody will put theirs on the dry ice all at the same time.



Blowing on the sample to warm it up.

*[Instructor passes out a copper cube to each student, and they hold them in their hands and blow on them for several seconds.]* Okay, ready? Get set. Go! *[Students place cubes on the dry ice, and the cubes make vibrating sounds. It only takes a few seconds for students to feel the cold reach their fingers.]* Okay, take them off.

Next one, warm up this one, don't put it on the dry ice until we all get them. This one is zinc. This is the inside of pennies. *[Instructor passes out a zinc cube to each student, and they repeat the experiment. It takes a little longer this time.]* When your finger gets frozen, take it off.

*[Experiment is repeated with each of the following materials.]*

Next one is soda cans. What are they made out of? Aluminum.

Next one is magnesium -- space ships, race cars. They almost feel hollow, they're so light. Light, but it's strong.

Next one is steel -- bicycles, cars, all kinds of things are made out of steel.

Next one is plastic. *[After several seconds]* Is your finger frozen yet? *[Students: No.]* Is it vibrating? *[Students: No.]* Is it doing nothing? *[Students: Yes.]* They call that a good insulator because an insulator protects your finger from the cold. Take it off and feel the bottom of it and see if the bottom feels cold. *[Student: The bottom is freezing.]* Yeah, the bottom should be really cold.

Next one is glass. *[After a few seconds]* Is glass doing anything? *[Students: No. A little -- it made a little sound. Mine is just sitting there.]* Is your finger getting cold yet? *[Students: No.]* Is this a good insulator or a bad insulator? *[Students: Good.]* Let's feel the bottom. *[Students: Cold.]* Yeah, it's really cold.

Next one's a piece of foam. When you do the foam, you don't need to warm it up because it's hard to warm up. Set it on your ice and just barely put your finger on it so you don't crush it. And when you get bored with that, smoosh it flat. Smoosh it really good, and see if you can keep it smooshed hard enough so that when you let go it stays smooshed. So try to make it stay smooshed.

Next sample is rubber. *[After a few seconds]* This is not a good insulator. *[Student: It's cold.]* Keep letting it get cold and see if it gets stiff.

When you get tired of that, then you guys can tear up pieces of that *[passes out pieces of styrofoam trays]* and see if styrofoam works any good. Rip off some pieces and see if this stuff works. *[Student: Horrible insulator.]* Try doing two layers of it. *[Some students try multiple layers.]*

Come over here and get a piece of cloth, any cloth you like, and try it and see how many layers it takes for it to not feel cold. *[Instructor provides a wide assortment of fabrics, some thick, some thin, and students choose whichever one they want. While students are experimenting with the fabric, Instructor collects the cubes.]*



Sample is placed on dry ice chunk. Students keep a finger on it to feel the cold.



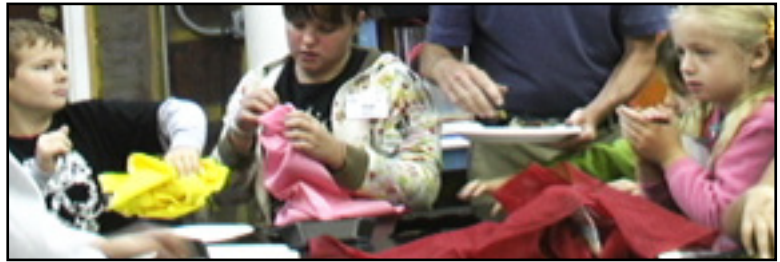
Squishing the foam cube.



Pieces of styrofoam.

*[When they finish with the fabric, Instructor passes out a clear plastic cup to each group, and students put away their fabric samples.] Put your dry ice in the cup. Try blowing in the cup. [Student: Put water in it!] Okay, I'll pour water in it.*

*[Instructor pours warm water into each cup, so the dry ice generates fog. Students fool around with it for a few minutes. Then the Instructor adds a few drops of dish soap to each cup so it makes bubbles. After fooling around with it for a couple of minutes, the Instructor has the students dump the contents of the cups into a large bucket, then return to their seats.]*



Experimenting with various fabrics.



Playing with the dry ice.

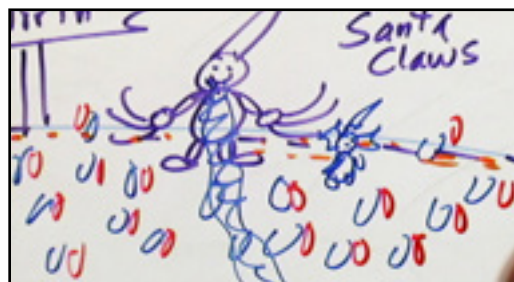


A few drops of dish soap makes lots of suds.

## End of Story

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

Evil Mister Fred had changed the temperature of the North Pole by piling a ton of air over it so it's a hundred degrees below zero, just like the dry ice. And the little elves are all getting frozen. And Jack and Jill said, "Never fear! We've got heat sources. We'll put our Kick-Mes on the back of them." So they duct-taped the Kick-Mes onto the elves. So now the elves are walking around with Kick-Mes backpacks. [Student: *Where'd they get the duct tape?*] From the Acme Store of Everything. Or from a bunch of ducks. Like that. And now the elves could work again.



The elves had warm Kick-Mes on their backs.

And Evil Mister Fred said, "Never fear!" And he changed the temperature to two hundred degrees below zero. And Jack and Jill said, "Oh, no! That's too cold!" They started wrapping the Kick-Mes and the elves in insulation material, anything they could find -- jackets, foam trays. Wrapped them all up to keep the heat inside. But Evil Mister Fred kept making it colder and colder and colder. And Jack and Jill said, "We've got to stop that Evil Mister Fred some way."

And they looked up in the sky and there he was, singing his song, "Yeah, just piling on the air, yessir, piling on the air." And Jack and Jill said, "Hey, Evil Mister Fred, it's really nice down here. It's getting kind of hot. Can you kind of cool it down for us a little?" And he's going, "What?? It's supposed to be freezing down there." And Jack and Jill said, "Oh, we're going to go swimming, it's so hot. It's just way too warm down here."

And Evil Mister Fred said, "What?" And he swooped down on his vacuum cleaner to see what they were talking about. And Jack and Jill said, "Hi!" And they grabbed a bunch of Kick-Mes and went [*pantomimes throwing them into the air*] -- threw them into the air, and they got sucked into Evil Mister Fred's vacuum cleaner. Well, the Kick-Mes love being all chewed up. And while they're in the vacuum cleaner, one of them looked at the other one and said, "Hey! There's something whirring in there. Sounds dangerous!" And the other one said, "Yeah, let's see what it is." So they dug through the filter and they saw the spinning motor of the suction thing. They said, "Whoo-hoo!" And they jumped into it.

As soon as they did, it turned them into Kick-Me juice, which spewed out all over and wrecked his vacuum cleaner. And of course the Kick-Me juice came back together and they formed as Kick-Mes and went boing, boing, boing. And Evil Mister Fred was not zooming along and crashed. Two hundred degrees below zero. And Evil Mister Fred froze solid. And then the air that had been piled up started to even out again, and it got to a nice temperature. And they all lived happily ever, 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.***