Teacher's Guide for:

Bending Light

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

Bending Light
A Rock-it Science Lesson
Filmed October, 2009

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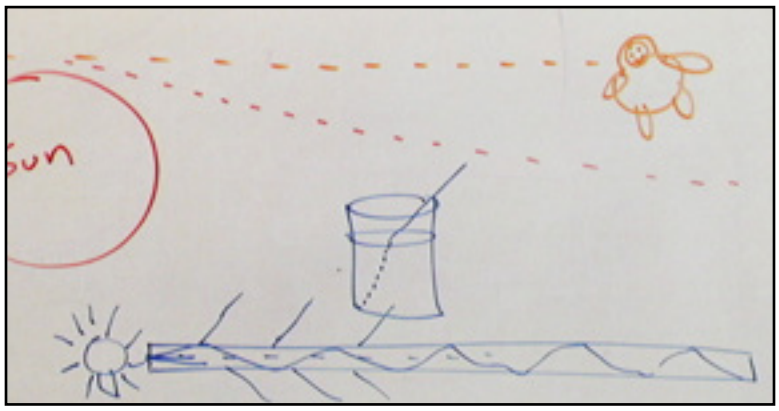
Intro Quick Recap:



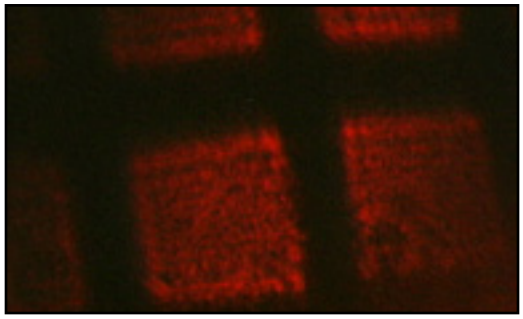
Light bounces off the insides of the fiber optic cable.

- Light usually travels straight. Light from a star will usually travel straight through space.
- Einstein said if there's a massive object near the light, like the sun, the light can get bent or shoot off in a different direction.
- It's like a trampoline with a bowling ball in the center. The surface bends a little. A smaller ball would normally roll straight across the trampoline, but with the bowling ball there, it goes a little bit crooked.
- Another way to make light bend is to shine it through water. If you put a pencil in a glass of water, it looks crooked underwater.
- Ask students where our data comes from. They may say, "computers, internet, servers," etc. Keep narrowing it down until you get to fiber optic cables.
- Data used to be pulsed through copper wires. But you can't get a lot of pulses through the same wire because they interfere with each other. You also lose a lot of signal with distance.
- If you shine light through a glass fiber, a bunch of it shoots out the walls. But if you get just the right size fiber, the light will bounce off the walls inside and it won't lose any energy. It can go for miles, and boosters can make it go even farther.
- Fiber optic cables are used for almost all the data transmission in the USA, and in most of the world.
- There's a place near the Suez Canal where a whole bunch of fiber optic cables pass through a narrow spot. A while back, somebody cut them, and a whole section of the world lost their internet connection.
- Today's experiment will make sunlight go through some fiber optic kind of material.
- Laser pens can be dangerous. The ones we're using won't permanently blind you, but you'll get a dark dot in your field of vision for awhile. So don't shine them at people's heads.
- Prison guards use laser-sighted rifles, so they don't even have to aim through a scope. They just point the red dot at the target. Hunters use these, too. So you shouldn't point a laser at someone because they might think you're pointing a gun at them.
- Don't point a laser at an airplane, because you could blind the pilot. And the police have ways of tracking you down.

Experiment Quick Recap: *"Stethoscopes"*

- We're going to use laser pens and find out if we can make the beam bend a little bit. Students work in groups of two.
- Instructor explains what students are going to do:
- First, just shine the laser around and see what it does, but don't shine it at people's heads. Point it at your finger and see if you can see anything inside your finger.
- Second, students hold a small lens in front of the laser and shine the beam through the lens. The lenses have imperfections, so try to find a spot that's not too messed up.
- Then tape the lens onto the end of the laser pen, so that the beam doesn't shine through the tape. See if the light spreads out when you shine it at the whiteboard.
- Then hold a piece of window screen in front of the lens and shine it at the whiteboard. See if you can make the image really big.
- Go up to the board and look closely at the lines on the screen image. (Don't tell them what the lines should look like yet. After they finish, draw a diagram of the shadowy diffraction lines that appear within the screen pattern.)
- Then put away the screen and place a microscope slide in front of the lens and shine the beam onto the whiteboard. See if you can get the microscopic image to enlarge. (Slides used in this lesson were things like a butterfly scale, bee antenna, fly leg, etc.)
- Then take the lens off the pen and get a clear plastic cup of water. Shine the laser through the water to see if it bends or looks crooked, but don't put the pen in the water.
- Then students shine the beam through flexible acrylic tubing to see how the light bends as it passes through the tubing.
- Instructor releases a burst of stage fog and students shine beams through the fog. If they move the beam very fast, they should be able to see turbulence in the fog.
- During the course of the experiment, the lights are on while students are assembling things or supplies are being passed out. Once they're ready, the lights are turned out so they can see the beams better.

Tape lens onto laser pen.



Diffraction pattern from screen.

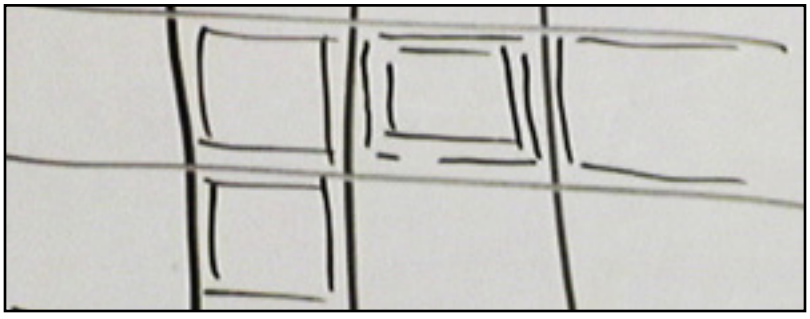


Diagram of diffraction pattern.

Equipment List: "Bending Light"

Items needed for Instructor:

- Fog machine
- Stage fog solution

Items needed for Students:

Consumables (per student):

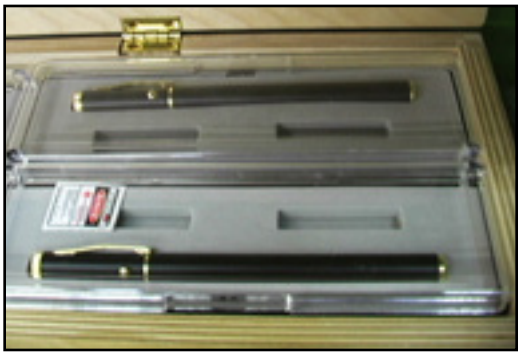
- Water, about 6 oz.
- Tape, cellophane, about 6"

Other:

- Laser pens, 0.5 milliwatt red pens
- Window screen, approx. 2" x 2"
- Acrylic rod, flexible, 1/8" diameter, from TAP plastics
- Lens, convex, with a focal length of about 1/2 to 1 inch (taken from old cheap cameras)
- Microscope slides of objects such as insect parts
- Cup, clear plastic, 16 oz.

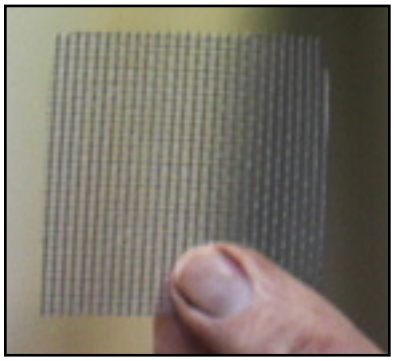
Prep Work:

- Cut screens to 2" x 2" squares.
- Check batteries in laser pens (Two AAA batteries per pen).
- Check fog machine to make sure it's working.



Laser pens.

Microscope slides.

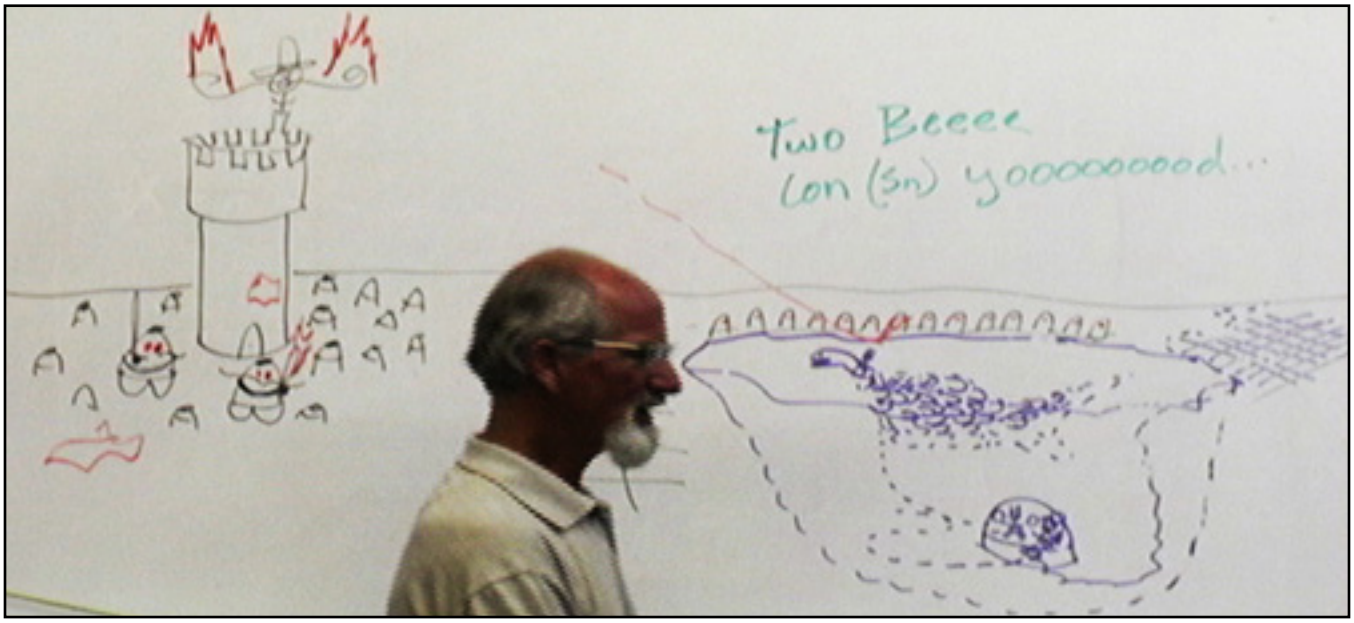


Screen.

Lens.

Flexible acrylic rods.

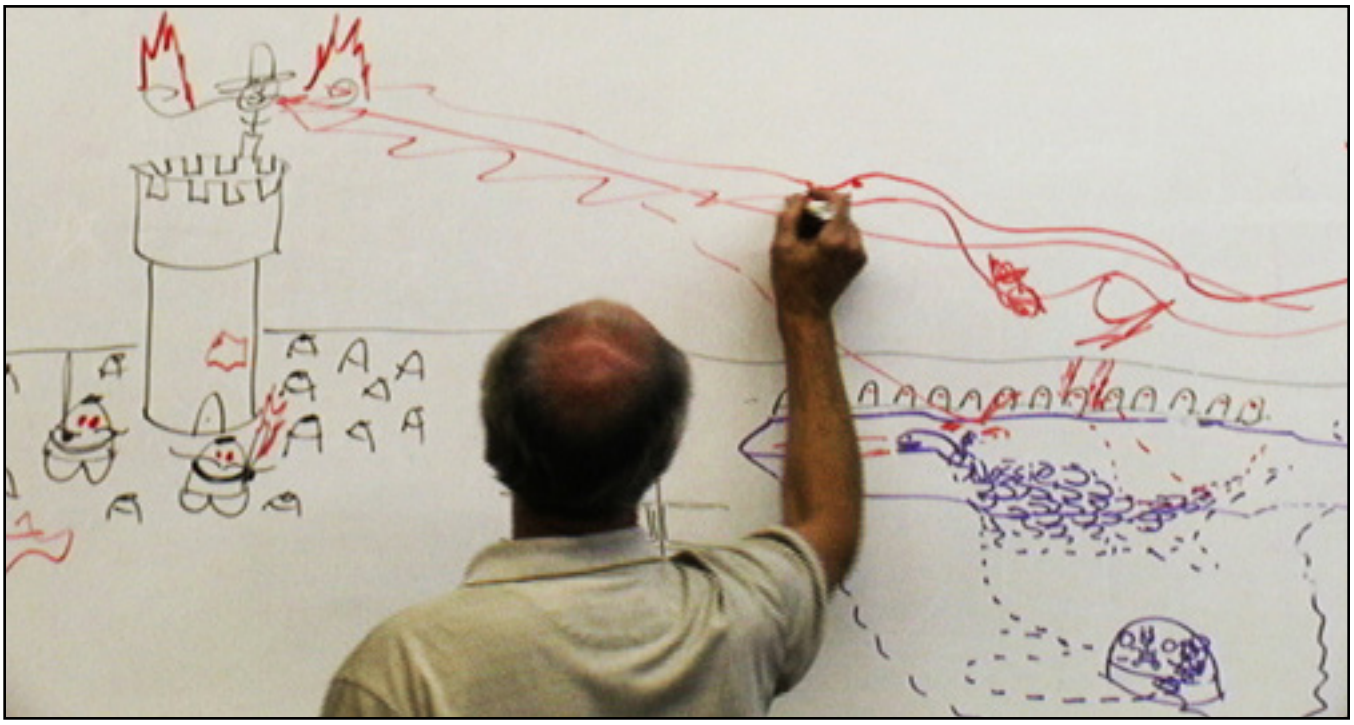
Story Recap: "*Minions with Laser Beam Eyes*"



Part 1:

- Evil Mister Fred wanted to improve his army of minions, so he found an old magic book and used an incantation on one of them: "Eeny-meeny-chili-beany-hear-the-spirits-speak." It gave the minion red eyes.
- He used the incantation on all the minions and gave them all red eyes so they'd scare people.
- One day he got mad at a minion and started hitting his foot with a baseball bat. The minion got mad and laser beams shot out of his eyes and set Evil Mister Fred's mustache on fire.
- Evil Mister Fred put electric dog collars on the minions, which would deliver a shock to them when he wanted them to get mad and shoot lasers.
- In order to get them to all shoot the same way, he embedded compasses in their heads, and the shocks only stopped when they all pointed the same way.
- Nearby was a lake where Nessie, the Lock Ness Monster, lived. Jack and Jill lived in a big steel chamber at the bottom of the lake. They were breathing oxygen and helium so they wouldn't get nitrogen narcosis. Breathing it made their voices high.
- Jack and Jill were there to take care of Nessie. No one had ever found her except for Jack and Jill. Nessie is like an amphibious dinosaur with fins and shiny scales.
- Evil Mister Fred saw Nessie and wanted to capture her. But first he had to get rid of Jack and Jill.
- The minions lined up around the lake and waited for Jack and Jill to come to the surface. When Jack came up, he saw the minions goofing around, and one of them shot another one with laser beams.
- Jack went down to tell Jill, but she didn't believe him. So she went up to the surface and Evil Mister Fred saw her. He made the minions shoot beams at her, and her hair caught fire. She swam back down. Now Jack and Jill are trapped in the lake.

Story Recap (cont.): "*Minions with Laser Beam Eyes*"

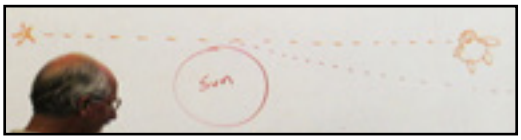


Ending:

- Nessie is a fire-breathing monster, and her scales are as shiny as mirrors, and her tail is like a fiber-optic cable that can have light go in one place and come out somewhere else.
- Jack and Jill told Nessie to go and talk to the minions on the shore. When Evil Mister Fred saw him, he didn't want to kill the monster.
- But when Jack came up, Evil Mister Fred pushed the button for the shock collars, and the minions started shooting laser beams.
- But it was hard for them to aim because they were jumping around screaming from the shock. So laser beams were going all over the place.
- Nessie absorbed some of them with her tail and shot them back, setting some minions' mustaches on fire. Some of the beams bounced off her scales into the air, and she was also shooting some flames just to keep the minions jumping up and down.
- Then Nessie jumped out of the water. She concentrated a whole bunch of the laser beams through her tail and shot them at Evil Mister Fred. She set his mustache on fire and made the castle red-hot, and Evil Mister Fred went running and jumping over the horizon.

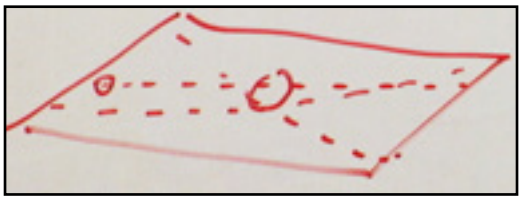
Transcript: Intro

Today we're going to be doing something with light. Light usually goes pretty much straight. If you have a star out there, and light is coming from the star through space, and if you're floating there in a spacesuit, you can pretty much depend on the light being straight. However, a guy named Einstein said that's not always the case. Einstein said if there's a big massive object near that light, like the sun, that the light can actually get bent as it goes by. And it can shoot off in a different direction.

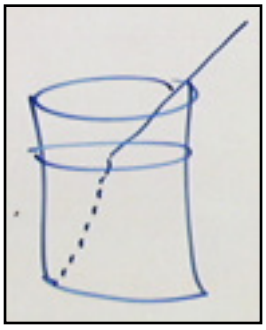


Light from a star can bend as it passes the sun.

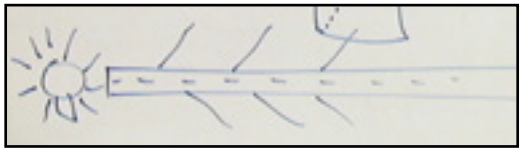
And some people say it's kind of like if you have a trampoline and you put a bowling ball on the trampoline, you kind of bend it down a little bit. And if you roll a ball across it without the bowling ball in there, the ball would roll straight. But when you put the bowling ball in there and you roll the little ball by it, it makes it go crooked.


Trampoline and bowling ball.

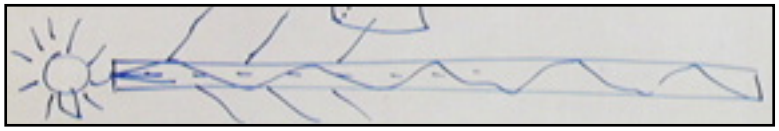
Well, it turns out there's another way to make light bend. And you've all done it before. If you look at somebody through a glass of water, they'll look weird. When light goes through a glass, it bends. If you stick a pencil in there, the pencil looks crooked under the water. It looks like it got suddenly bent at the surface.


Pencil in glass of water.

There's other ways to make light bend, too. Nowadays all of our data comes through . . . what? *[Student: Computers.]* Computers. How does a computer get it? *[Student: Internet.]* Internet. How does the internet transfer it from one place to another? *[Student: Servers.]* Servers. And servers are connected to other servers. Through what? Is it transmitted by hamsters that run from place to place? *[Student: Satellite.]* Oh, yeah. It could go by satellite. Does it go through telephone wires? *[Student: Waves.]* Waves? Yeah, light waves. What does the light travel in? What's under the ground? Well, they used to transmit all data through copper wires. And it was pulses -- pulse, pulse, pulse, pulse, pulse -- really fast through the copper wire. And it's kind of hard to get a lot of pulses through the same wire because they interfere with each other, and you lose a lot of the signal with distance.


Light shoots out through walls of fiber.

Well, somebody else had a better idea. They said, "Let's put the light through glass fibers." So if you have a glass fiber and you shine light through it, the light can go through the fiber. But a bunch of it shoots out the walls of the fiber. And so for a fiber ten feet long, you'd have little bit of light at the end, but not very much. Then somebody else said, "Well, you've got to get just the right size of fiber. If it's too big, it might not work; if it's too little, it might not work. If you get one that's just the right size, the light, instead of shooting through the edges, will bounce inside -- boing, boing, boing, boing, boing -- and it won't lose any energy as it hits the walls." It turns out, it worked. So we have fiber optic cables that can


Light bounces inside the walls of the fiber, if it's the right size.

transmit light for miles. And then they have boosters that can make it go further and further. And almost all of the United States now sends data through fiber optic cables. And almost all the world does, too.

If somebody cuts the cables, like at a place where they go all together to cover a whole big area, like the Suez Canal . . . This happened last year, I think. There's a place here *[points to the Suez Canal on a globe]* between Egypt and Saudi Arabia where a whole bunch of the fiber optic cables all go together through that little spot. Somebody went and cut them. That's not cool. And a whole bunch of this section of the world lost their internet connection. And we're going to make sunlight go through some fiber optic kind of stuff today. We're lucky that we got some new laser pens to use for this.


The Suez Canal, where cables were cut.

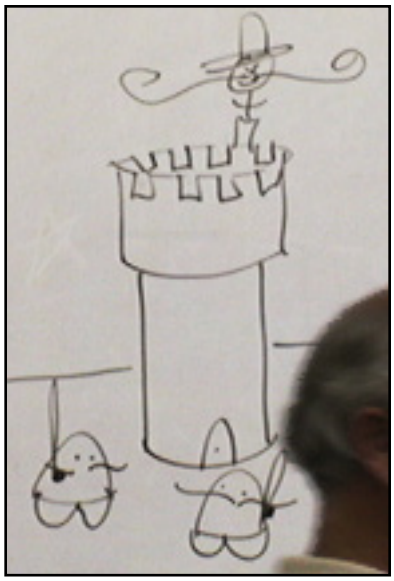
Laser pens can be dangerous. If you shine a laser pen at somebody's face and they turn around and look at you and they get it in their eye, it can temporarily leave a blind spot on their eye. *[Student: Can it blind you?]* It's hard to get a permanent blind spot. A clerk at one of the stores said, "Oh, they're not dangerous. See?" And he shot it right in his own eye. And he said, "Oh, well, maybe they are." Have you ever had a flash camera go poof! right in your face? And then for awhile you see this dot? Wherever you look, there's the dot. Well, that's what happens with a laser pen. And it's usually not permanent damage, but you don't want to do it. So during the experiment, when we're using laser pens, don't be shining them on other people's heads or faces. If you happen to bounce it off on someone, it isn't going to hurt them at all, but they just don't like it.

If you go to prison for some reason, and you're out in the exercise yard, just being cool, trying to keep the other guys from beating you up, and you notice a red dot on your chest, the guards have rifles with laser sights on them. They don't have to look through the little beads anymore. They just point the dot. A red dot on your chest means there's a rifle pointed at you. And if you're out in the woods and you see a red dot somewhere, tell the guy, "I'm not a deer!!" So it's not good to point lasers at somebody because they might think it's a gun pointed at them.

If you point a laser in the sky at an airplane and say, "Oh, lookit there! I can hold it on the airplane!" A guy in Campbell did this. It took ten minutes, and the police were at his door. And they won't tell how they found out. Somehow they can track you down. So it's not a good idea to point lasers at airplanes.

Well, we need a crazy story. Then we'll do some experiments. *[Student: How high up does the plane have to be?]* You've got to be able to see it. You'll find out later how hard it is to hold a laser in your hand and aim it at something. *[Student: How is it dangerous to point a laser at a plane?]* If the pilot looks down at it, and it happens to be one of the powerful green ones, you'll blind the pilot. Now you have this plane going *[moves hand in a chaotic swerving motion]*.

Story: *"Minions with Laser Beam Eyes"*

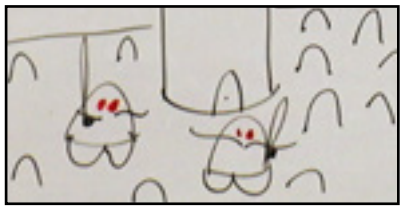

Evil Mister Fred and minions.

Once upon a time, Evil Mister Fred was on a mission to improve his army. The minions, of course, aren't very good soldiers. They don't want to obey orders, they're not very smart, and they have no arms. Kind of hard to make good soldiers with no arms. And Evil Mister Fred had given them baseball bats, and they could bang each other on the head with their baseball bats with their mustaches because they have very strong mustaches. But he still wasn't satisfied with that.

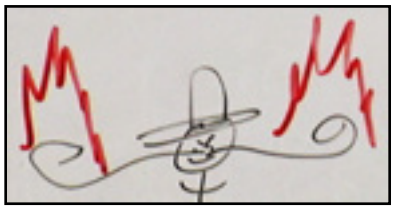
So he called the Acme Store of Everything and he said, "What have you got to make my minions stronger and more powerful?" And they said, "Oh, is this the Evil Mister Fred speaking?" And he said, "Yeah, the very one and only." And they said, "Nothing. " He said, "Awww, that's not good." And they said, "Why don't you go look in the library?" So Evil Mister Fred went to the library.

And up there in the lowest depths of the library, he found some dusty old books. He opened up one of the books, and there was all these incantations and stuff. And he said, "Aw, this is what I need. Yeah!" And he was turning the pages. He turned one of the pages and a big hand came out and started to choke him. And he said, "Yeah, I love this book!" So he checked it out.

He took it home to his castle, and he was sitting there looking through the pages, and one of the minions was watching him. And he said, "Oh, here's a good one. It's all written in latin or something like that: Eeny-meeny-chili-beany-hear-the-spirits-speak." And he pointed at the minion and he said, "Poof!" And the minion's hair just went psssshhhh *[hair stands on end],* and his hair sat back down. And then the minion looked at him and he looked different than he did before. He had red eyes. And Evil Mister Fred said, "Whoa, that's a nice touch. I like that."


Army of red-eyed minions.

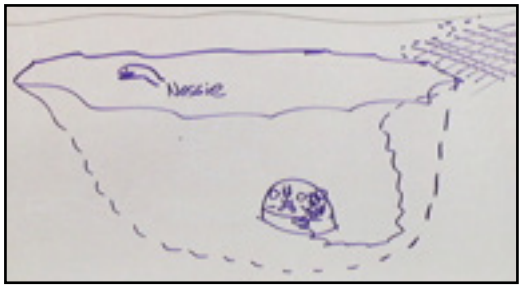
So he got a whole bunch of minions together and he did the eeny-meeny-chili-beany thing. And now he's got a whole bunch of minions with red eyes. And he said, "Well, at least they look cool. Maybe they'll scare everybody away, and we can steal their money that way."


Mustache on fire.

Well, he was out there goofing around with the minions, and they were being their usual bad selves. He got really mad at one of them. And he grabbed the minion's baseball bat and started hitting him on the foot -- whack! whack! whack! And that made the minion really mad. The minion was trying to run away. And the minion looked at Evil Mister Fred and went,"Arrrrrgggghhh!" Like that. Laser beams shot out of his eyes and caught Evil Mister Fred's mustache on fire. And Evil Mister Fred, of course, did the ooh-ah-ooh-ah dance and put his mustache out. And then he said, "Now we've got something! This is great. If I can get the minions mad, they'll use their laser eyes and shoot whatever I tell them to shoot. Ho, ho, ho!"

Minions with dog collars and compasses.

So he tried some practice things. He ended up with holes in his castle, in the ground, minions with all kinds of flaming baseball bats and burned parts. So he had to find a way to control them. So what he did was he put on the minions the kind of dog collars that giver you a shock. You know, if a dog barks or does the wrong thing, it gives him an electric shock. And he says, "Okay, I've got it all worked out now. When all the minions are pointed in the right direction, I'll just push the button and pzzzhoom! -- laser beams will shoot out of their eyes, and I'll defeat my enemy." And he had to just get them to point all the right way. So he embedded a compass in their heads, and they would always get shocks until the compasses pointed the same way, whatever way he told them to point. Now he had this thing worked out. He had the invincible army. There's no way it could fail.

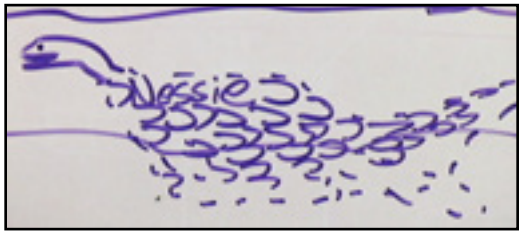


Nessie swimming in the lake.

Now, over here we've got a lake, and there's a creature that lives in the lake. It's name is Nessie. And there's people living near the lake in a city, like that. And down at the bottom of the lake, there's a big steel chamber with a hole in the bottom. And there's some water in it. And Jack and Jill are living in this thing. They want to see how long they can survive underwater, with the pressure down there. They don't get to breathe regular air, because if you breathe regular air, the nitrogen gets in your blood, and pretty soon you start acting drunk. They call it nitrogen narcosis. And so Jack and Jill are breathing a combination of oxygen and helium gas. You know what happens to your voice when you breathe helium gas? You get a real high-pitched voice.

Jack and Jill's underwater chamber.

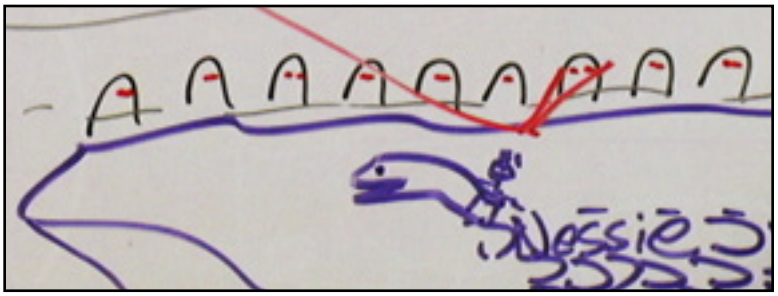
So Jack and Jill are down there talking in a really high voice to each other and looking out the windows. And they can jump through the hole in the bottom and swim around in this big lake. And there's Nessie down there. They take care of Nessie. *[Student: Doesn't Nessie have a body in the water?]* Yeah, Nessie has a big body in the water. Nessie's a huge dinosaur-looking thing, and he's got fins. *[Student: Like the Loch Ness monster.]* Yeah, the Loch Ness monster. And Nessie is kind of like an amphibian, like a frog or a newt, but Nessie has scales, like a salmon or other kind of fish that has scales. And the scales are really shiny. And everybody has heard about Nessie, but nobody's found him, except Jack and Jill.



Nessie has shiny scales.

Now, Evil Mister Fred, being kind of clever, had sent minions over to this lake, and they discovered Jack and Jill's secret: The Lock Ness monster was in this lake. And he wanted to capture the Loch Ness monster. But first, he had to get rid of Jack and Jill. So he had his minions march over there early one

morning and all line up around the edge of the lake. And he was going to wait for Jack and Jill to come to the surface. He was going to have his minions just look at them and pzzzhoom! -- burst into flames with their laser bolt eyes.



Jack riding on Nessie's neck, while minion's laser beam bounces.

Now, Jack was out swimming there, and he swam up and got on Nessie's neck, and he was riding Nessie around. And the minions were all there. And Jack noticed the minions. Can't miss those guys. And he said, "Whoa! Red eyes!" And the minions as usual were goofing around. Luckily for Jack, one minion was hitting another minion with a baseball bat, and laser beams shot out of his eyes -- pzzzhooom! -- and hit the water, bounced off, and into the air, like that. Jack said, "Whoa!" and dove into the water and went back down.

He said, "Jill, there's minions out there. They've got red eyes, and they can shoot laser beams out of their eyes!" And Jill said, "Right, Jack. What have you been eating?" And Jack said, "Nothing. You go look." And Jill swam to the surface. And Evil Mister Fred spotted Jill, and he said, "Ready, get set, fire!" And pzzzhooom! -- they caught Jill's hair on fire. It just exploded. And Jill said, "Whoa!" and swam back down. Now Jack and Jill are trapped in the lake. If you were Jack and Jill, what would you do?

Imagination and Brainstorming Time

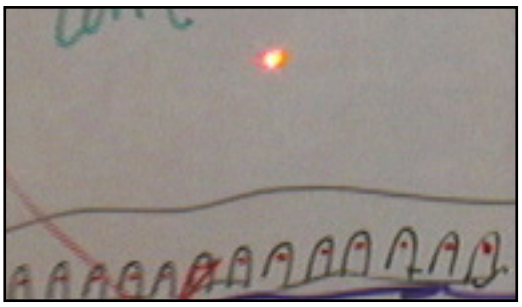
[Students make suggestions] (THERE ARE NO WRONG ANSWERS! Whatever they say, you should reply: "That's a good idea," "They might do that," etc. After brainstorming, proceed with the experiments, then finish the story.)

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

Experiment: "*Bending Light*"

Well, we need to do some experiments, and we've got new laser pens that actually work. They're not really powerful, but as I said, you have to protect your eyes from them. Don't shine them on other people's faces. We want to find out if we can make the laser beam bend a little bit. And we also want to create a microscope out of the laser beam. And that would be kind of odd. A laser beam, when it goes through air, stays relatively small. When it's close to the board, it's that size *[shines beam on whiteboard from a few inches away]*. As you get further and further and further away, it doesn't get much bigger in size *[backs away from board, keeping beam shining at the same spot]*, but you can see that it slowly grows larger. We want it to get big fast. If you shine the laser through a lens, it'll bend the light. That's called refraction *[shines beam through a small lens toward the board, creating a larger area of light]*. And any imperfections that are in the lens will show up on the board. *[Student: Would a fingerprint show up?]* Let's see *[puts his finger on the lens to leave a fingerprint, then shines the beam through it]*. It kind of fuzzes it out a little, but that's it pretty much through a fingerprint.

Close up, the beam is small.



Shining the beam on the whiteboard from a distance, it's only slightly larger.

We want to be able to expand it so that it's big. It would show up better if I turned out the lights. I'm going to switch off the lights *[lights off]*. Now you can see the imperfections in the glass. You try to find a spot where it's not too messed up, and you're going to tape the lens onto the pen at the spot where it's best for you. If you have a big lens like this, trying to tape it onto the laser beam is a challenge. We're going to give you some scotch tape and a laser pen. We'll give one laser pen to each group of two, and one lens to each group of two.

Shining the beam through a lens bends the light, making the beam wider . . .

. . . like this.

First you're going to shine it around and see what the laser does on various things in the room when I turn off the lights. Then, when you get that out of your system, you're going to put the lens on the end of it, and then we're going to give you some stuff. And you're going to put stuff in the light beam and see what happens.


Laser pens

Some of the stuff that we have is a piece of screen door screen. And we have a box of old microscope slides, some of which have become dropped by students so that there's some razor-sharp edges. This is always good. In the center, there's a little panel with something on it. Like one has a locust wing, one has a bee antenna, one has a butterfly scale, and you're going to try to make them big enough so that you can see them. *[Student: I didn't know butterflies had scales.]* Yeah, butterflies have scales on their wings. And there are guys in Japan who make pictures, elaborate beautiful pictures, by taking the scales off one at a time and sticking them onto rice paper. The problem is, you can only see the pictures under a microscope. *[Student: They take it off a live butterfly?]* A dead butterfly.

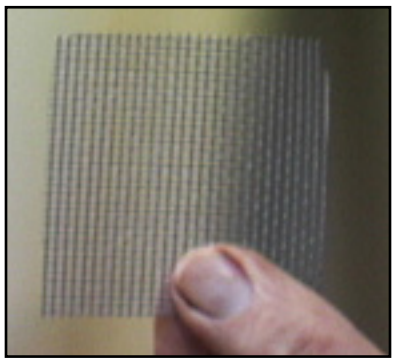
So first we'll hand out the laser pens. So you guys choose a partner *[hands out pens to each group of two students]*. And we'll turn off the lights *[lights off]*. *[Students shine lasers on various objects in the room.]* And if you're holding it in your hand, now hand it to your partner.

[After a few minutes] Try pointing it at your finger and see if you can see anything inside your finger.

[Lights on. Instructor passes out lenses, one for each pen.] Here's the lens. These have a fairly large radius on them so they spread the light well. Now, just hold the lens up and take turns shining the light through the lens and see what it does. *[Lights out.]*

Now we need to tape the lenses onto the pens. *[Lights on. Instructor passes out cellophane tape.]* Try to tape it on in some way so the laser light doesn't have to go through the tape. It would diffuse the light.

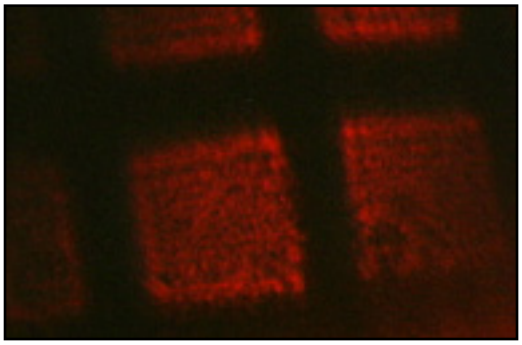

Taping lens onto pen.


Piece of window screen.

Now we have a piece of screen door screen. *[Instructor passes out pieces of screen.]* Has everybody got a lens on their pen? *[Students: Yes.]* I'll make it easier for you. *[Lights off.]* Try to make the screen big. *[Students shine the laser through the lens with the screen in front of it.]* Now send your partner up to the board to look at yours and see if the screen looks sharp that way. If you look closely at the lines, there's a pattern between the lines that we want you to see. And then trade places. The one who went up to the board to look at it, go hold it, and let the other person go up and look at it.

[After a few minutes.] Okay, everybody sit down. We're going to trade you a microscope slide. *[Lights on.]* By the way, when you were looking at the squares, you probably didn't see perfectly black lines. If you looked carefully, you would have seen shadows like waves bouncing off of walls inside the lines.

[Draws diagram of lines.] These extra waves are called diffraction. Diffraction is when something else happens weird.



Diffraction patterns from screen.

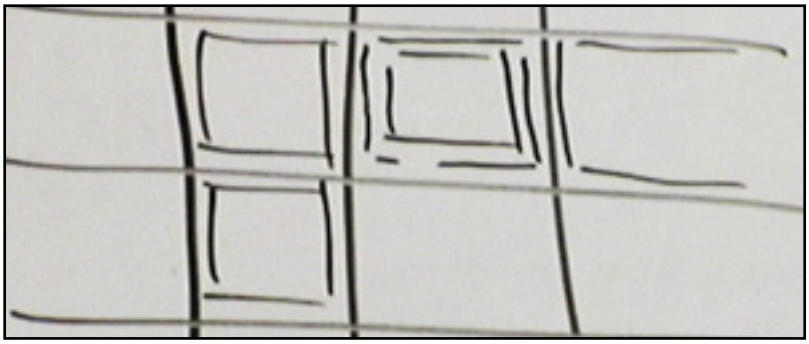
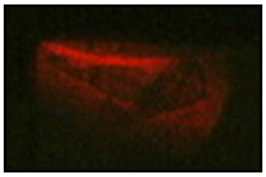


Diagram of diffraction patterns.

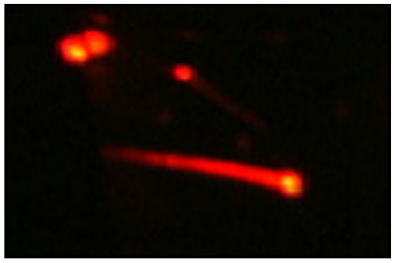
[Instructor passes out microscope slides, which include a leg of a honeybee, the antenna of a butterfly, a bee abdomen, a locust wing, a bee antenna, a butterfly wing, a praying mantis leg, a butterfly scale, a butterfly leg, etc.] If you drop it on the floor, it will break into small pieces, and then it will be hard to find. If you have to drop it, drop it on the table. Now, the objective is to make whatever's on the slide look really big. *[Lights off. Students shine laser through lens and microscope slide, projecting image on whiteboard.]*

Microscope slides.



Projection from microscope slide.

[Lights on.] Okay, now you can take the lens off. Here's a cup. Have one person in your group come over to one of these buckets and put water in the cup. Don't put your laser pens in the water. They don't work if they're all wet. *[Lights off. Students shine lasers into the water.]* Now, you should be able to see the beam in the water. Try it from different directions and see if you can get it to bend or to curve. While one person shines, have the other person look, because sometimes the light looks curved. Depends on which direction you look from.



Laser beam in water.

[Lights on. Instructor hands out fiber optic tubing.] Don't break them into pieces. They work better if they're the same size as when I hand them to you. They're fragile. They're not glass; they're plastic. *[Students shine lasers through the tubing. Then they direct the light from the tubing through the glass of water.]*

Flexible acrylic tubing.

[Instructor turns on fog machine.] If the fog machine shoots out fog, don't stand directly in front of it because it's hot. Okay, you can go over there and shine your laser beam in the fog. *[Students shine lasers through the fog.]* If you wiggle your beam really fast, you should see turbulence in the fog.

[Lights on.] Okay, you can put the laser pens back in the box. *[Instructor collects pens and tubing and has a student collect slides and tape dispensers.]* Take your water and dump it back into the water bucket.

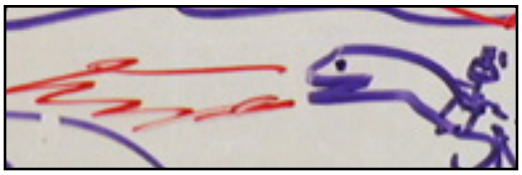
So you saw a little bit about how fiber optics work and saw the lights travel inside of yours. Yours looked bright because a lot of the light was going out through the walls. Regular fiber optics don't let light go out through the walls. You saw that it can magnify something by putting a lens on it and holding it close to the lens. You saw how light can bend when you put it through water like that, and how it can light up the fog.

Laser beam showing turbulence in fog.

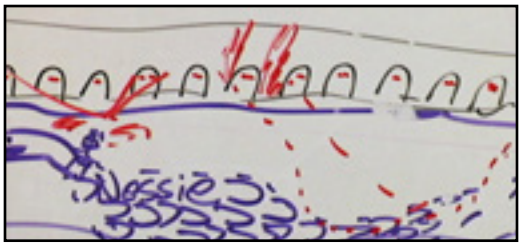
Laser beam shining through flexible tubing.

End of Story

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



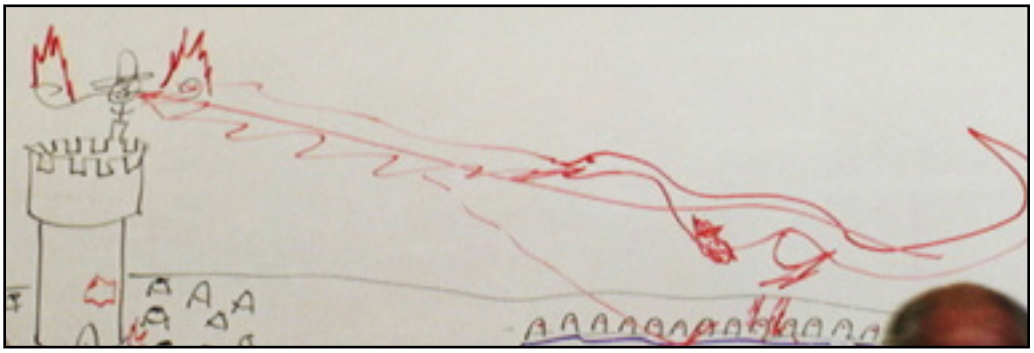
Nessie breathes fire.



Beams bounce off Nessie's scales and set minions' mustaches on fire.

Now we need a crazy ending for our story. It turns out, the Loch Ness Monster is a fire-breathing monster. And he's got scales that are like mirrors, and his tail is like a fiber optic fiber that can have light go in one place and come out somewhere else. So Jack and Jill said, "Hey, Nessie, we've got a job for you. See those guys on the shore with laser beam eyes? They'd like you to come and talk with them, or maybe play games with them." And Nessie said, "Oh, boy, let's see what happens."

So Nessie swam up and said, "Hi, guys, how ya doing?" And Evil Mister Fred said, "Ah, the monster. Well, I really shouldn't shoot the monster." And then Jack popped up above the surface and he said, "Hey, what's up?" He was waving his hand around. And Evil Mister Fred said, "Get the guy!" And he pushed their collars, and all the minions went, "Aaaahhhh!" and got shocked like this. They were trying to shoot laser beams at Jack. Well, it's hard to point your eyes straight when you're screaming, like that. And laser beams are going all over the place, and Nessie absorbed some of them with her tail and shot them back at the minions. She had minions with mustaches on fire. She let some of them bounce off of her scales into the air, and she was shooting some flames out just to keep them jumping up and down, just to see what they would do.



Nessie jumps out of the water and shoots laser beams at Evil Mister Fred.

So now the minions are really unhappy because there are flames on them. And she was going whoooommmm! And they weren't paying attention to where they were looking, and she just jumped up out of the water. So now you have a giant Nessie out of the water. She's got a long tail. She has fins like a walrus. And the laser beams were shooting all over her, and she concentrated a whole bunch of them through her tail and shot them out straight forward at Evil Mister Fred. And then she warmed up Evil Mister Fred with some flames just because he's such a nice guy. And the castle became red-hot, and the last thing they saw was Evil Mister Fred running and jumping and hopping over the horizon. And they all 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.