



# Homeschool Teacher's Guide for: Frisbees & Curveball

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.

## Contents:

This DVD includes two lessons. The first, "Frisbees & Curveball," contains both experiments. The second, "Curveball," is a separate lesson that uses an alternate version of the curveball experiment. In the alternate version, the projectiles are small plastic balls instead of the foam disks used in the first lesson.

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## Title Page of Frisbees & Curveball Video

(Numbers in the text are **time codes**, so you can refer back to the video.)

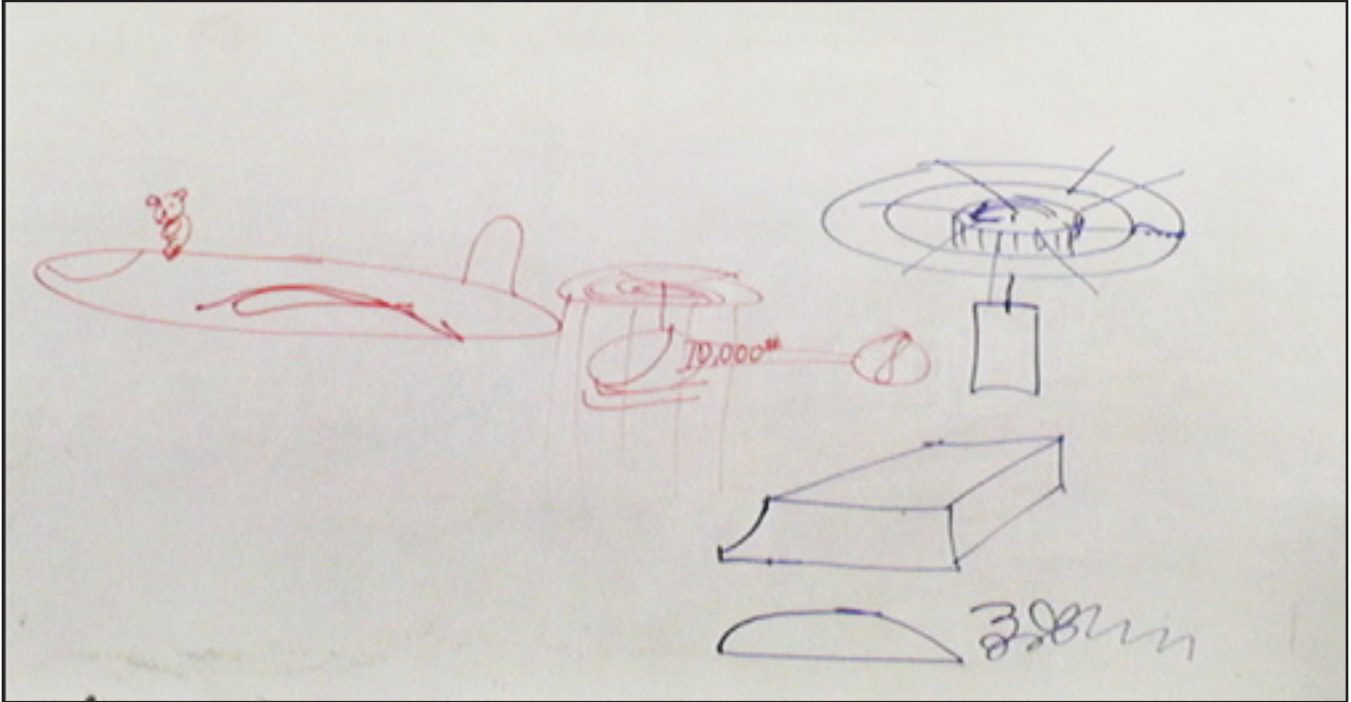
[00:03;09] Frisbees & Curveball  
filmed December, 2010

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## Intro Quick Recap "Frisbees & Curveball":



- If you want something to go up, you have to throw something downwards.
- In a helicopter, the blades blow lots of air downwards to keep the helicopter up. If it weighs ten thousand pounds, you have to have a constant ten thousand pounds of air going down just to stay where you are. To go up high, you have to push a bunch more air down.
- Airplanes have curvy wings that make the air go down so the airplane stays up.
- Somebody tried taking an airplane wing and wrapping it in a circle with a fan in the center to blow air outwards. But when they built it, the fan spun one way, which made the circular wing spin the other way, which would make people dizzy.
- We're going to make some things fly, and some will have weird shapes.
- Draw various wing shapes on board and ask students if they would fly well.

## Experiment Quick Recap: "Frisbees"



- Give each student a paper plate, a piece of plastic tubing, and a short wooden dowel.
- Have them make a closed ring from the tubing by attaching each end to the dowel.
- They use permanent markers to write or color a little bit on their plates and rings so they know which is theirs.
- Students go outside and fling the paper plates and plastic rings around to see how well they fly.
- Then they come back inside and tape their tube ring onto the back of their paper plate with duct tape.
- Then they go outside again and fling the plates around to see how well they fly with the addition of the tube.
- Then they bring their plates inside, leave them there, and go outside again.
- Instructor brings out assorted frisbees, which students fling around to see which designs work best.

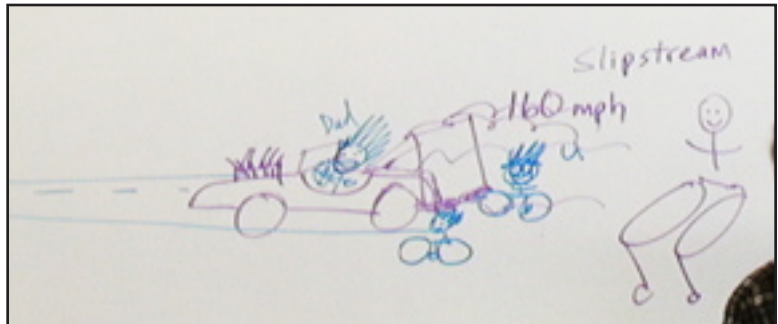
## Experiment Quick Recap: "Curveball (with foam disks)"



- Give each pair of students a launcher and an assortment of foam disks of various thicknesses.
- Have them shoot the disks to see which ones fly best.
- Have them hold one wheel still and shoot the disks with only the other wheel spinning to see where it goes.
- Have them try aiming straight up.
- Students pick out the two they think work best and the two that work worst.
- They take the best ones and shoot at a specified target (in this case, it was the camera).



## Intro Quick Recap "Curveball (with plastic balls)":



- You and your friend decide to have a bicycle race to see who can go faster.
- Your dad comes over with his race car, which can go 200 miles per hour.
- He puts a big piece of plywood on the back of the car with some supports, and a roller near the bottom.
- As your friend rides ahead down the road, you stay behind your dad's car and try to keep up with him. Can you do it?
- Somebody tried this with a forty-speed bike. They got to seventy miles per hour and the tire popped. They were wearing a harness, so they didn't get hurt.
- Then they put some super high-speed tires on and tried again. They got up to 160 miles per hour, with just a regular person on the bike.
- The secret is in the board. When you push it through the air at high speed, the air swirls around it and creates a pocket where there's no wind. There's even a little bit of suction, called a slipstream.
- If you're playing baseball and pitching against a really good hitter, and you want to prevent him from hitting the ball, you can make the ball curve. Major league pitchers can make a ball curve up to 9 inches and still hit the catcher's glove.
- The stitches on a baseball are what make the ball spin. If you know how to release it when you let go, you can make it spin one way or another.
- This lesson is about how air movement can make things change and how spin can make things change.

## Experiment Quick Recap: "Curveball (with plastic balls)"



- Give each pair of students a ball launcher and some pingpong balls and small whiffle balls.
- Students use alligator clips to connect launchers to copper wires attached to a power supply.
- Have them shoot the balls different ways to see how they fly best.
- Have them hold one wheel still and shoot the balls with only the other wheel spinning to see where it goes.
- Have them sight down the trough so they can see exactly how the ball is flying.
- Have them load several balls in the trough (machine-gun mode) and shoot at the Instructor.
- Have them shoot at their partner.
- Have them shoot straight up.
- Students report what they observed about how different balls, and different shooting methods, worked.

## Equipment List: "Frisbees & Curveballs"

### Items needed for Instructor:

#### Consumables:

- (same as students)

#### Other:

- Frisbees, various types, about 20
- Scissors
- Boards extending the length of the table so that all students can reach it.
- 1/4" Copper Tubing attached to the boards.
- 24" insulated Connecting Wires, connecting the boards in series with Alligator Clips.
- 100-amp Power Supply.
- 30-amp fuse
- Battery, 6-volt lantern
- Extension cord

### Items needed for Students:

#### Consumables (per student):

- Paper Plate, 12", smooth, strong
- Plastic tubing, 1/4" inner diameter, 3 ft. long
- Wooden dowel, round, 1/4" inner diameter, 2 in. long
- Tape, duct, approx. 2 ft. per student

#### Other:

- Launchers (custom made by Rock-it Science; see next page for details)
- Foam disks, approx. 1" diameter, four different thicknesses. (At least 1 of each size per student.)
- Markers, permanent, colored
- Goggles

#### Other (alternate Curveball):

- Balls, ping-pong, 3 per student
- Balls, small whiffle, 3 per student
- Cups, clear plastic, 16-oz.
- Goggles

### Prep Work:

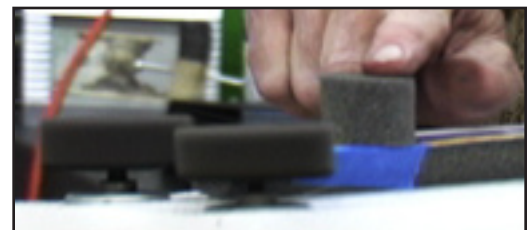
- Cut plastic tubing into 3-ft. lengths
- Cut foam cylinders into short lengths, ranging from 1/8" to 1" thick.
- Check ball launchers to make sure they work. Construct new ones if necessary.



Plastic tubing



1/4" wooden dowels, 2" long



Foam disk aimed between wheels.

## Equipment List (cont.): Launcher Components

### Components of Launcher:

- Foam, hard, approx. 12" long x 6" wide x 1.5" thick (for platform).
- Drill holes through platform the size of motors.
- Foam, hard, approx. 1" wide x 1/5 " wide x 2" tall (2 of each for back legs, glued on)
- Foam, hard, approx. 1" wide x 1/5 " wide x 1" tall (one for front leg, glued on)
- Foam disks, approx. 2" diameter, 1/2" thick (2 each for spinning wheels)
- Motors, 3-volt DC, 4000 RPM (2 each)
- Disk, plastic, with 1/8" hole, which fits onto motor shafts. Foam disks are glued onto these.
- Resister, 1 ohm, 25 watt
- Insulated cables with alligator clips, 24" (2 each)
- Tape, duct, to secure cables underneath platform
- Foam insulation tubing, split in half, approx. 2" diameter x 10" long (glued on for ball trough)

### To use Launcher with Foam Disks:

- Card stock or lightweight cardboard, approx. 2" x 8". Sits on top of trough, does NOT curve to conform to trough.
- Tape, painter's, to temporarily attach paper to trough, approx. 1" x 12"

### To use Launcher with Plastic Balls:

- Motors are pushed up so they extend further from the surface of the platform (see photo below).
- No paper on foam trough.



Launcher for plastic balls.



Launcher for foam disks (top)



Launcher for foam disks (bottom)



Closeup of launcher wheels for foam disks.



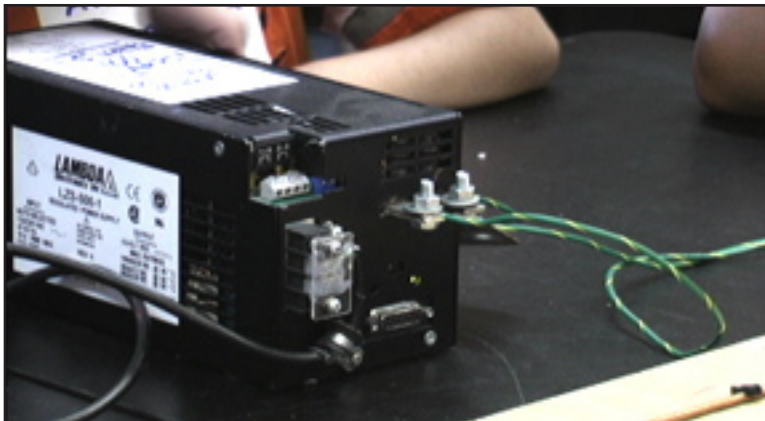
## Equipment List (cont.): Launcher Power Components

### Power components for Launcher:

- Boards extending the length of the table so that all students can reach it.
- 1/4" Copper Tubing attached to the boards.
- 24" insulated Connecting Wires, connecting the boards in series with Alligator Clips.
- 100-amp Power Supply.
- 30-amp fuse
- Extension cord



Boards with copper wires extending the length of the table, all connected to a power supply.



110-amp power supply.



Copper wires attached to wood.



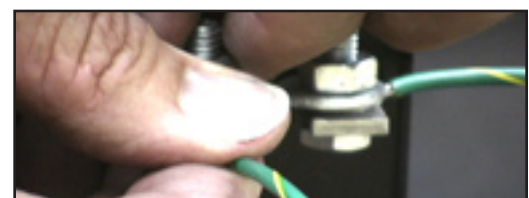
Connecting boards with alligator clips.



30-amp fuse.



Inserting fuse.



Attaching wires to power supply.

## Story Quick Recap: "Jack & Jill and the Doughnut People"



### Part 1:

- Jack & Jill went to the land of the doughnut people and pancake people, where the mountains were made of marshmallows and the clouds rained syrup.
- The doughnut people were always worried that the sky was falling; that's why their mouths are wide open, going "Ahhhh!"
- When tourists come to visit, they try to bite the doughnut and pancake people.
- The people ask Jack & Jill for help. So Jack & Jill print brochures, put up advertisements, put ads on tv, etc. to educate people about not eating the doughnut and pancake people. But it didn't help.
- This problem made worldwide news, so Evil Mister Fred found out about it and went there.
- Evil Mister Fred put up posters encouraging people to eat the doughnut and pancake people, which made it worse. His minions were also eating them, especially the ones with M&Ms on them.

## Story Quick Recap (cont.):

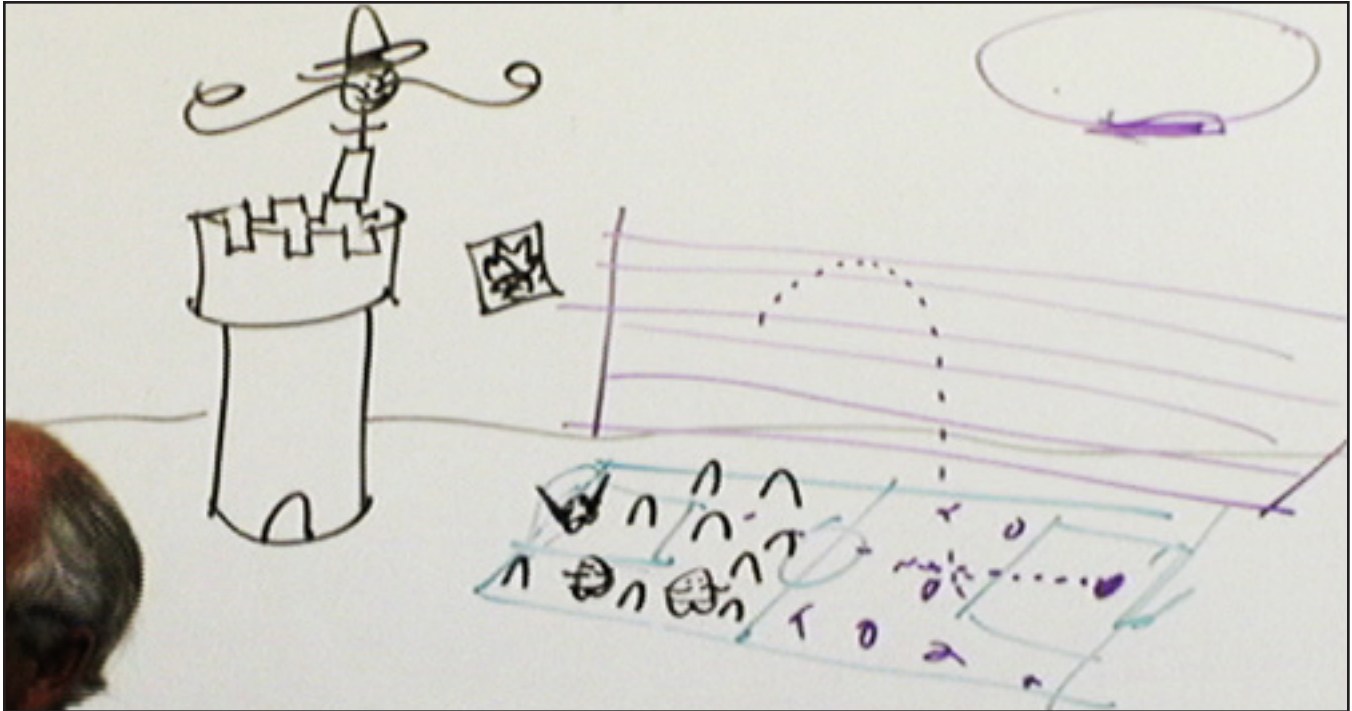


### Ending:

- Jack and Jill called the Acme Store of Everything and ordered their friend George, who has one arm that's a lot longer than the other.
- Jack told the doughnuts to partner up with a pancake.
- Then George picked them up and threw them.
- When the tourists came around and tried to bite them, George would throw them to safety.
- George could throw them clear around the planet and have them come back again from the other side.
- The first one that came back hit Evil Mister Fred's mustache and knocked off part of it. The next one came by and knocked off the other half. The third one knocked the cherry off his hat.
- Then twenty of them came around at once, and Evil Mister Fred jumped into the air and landed in the syrup cloud. He got all sticky, and the bees ate him.



## Story Quick Recap (cont.): "Jack & Jill and the Soccer Minions"



### Part 1 (This part was not recorded, but it probably went something like this):

- Evil Mister Fred wanted to conquer the world, so he challenged all the countries to play soccer against his minions. Whoever won would get to be the ruler.
- Evil Mister Fred mutated his minions so they grew really powerful feet, and they could kick the ball harder than anyone else, so they were winning all the games.

### Ending:

- Jack and Jill trained their Kick-Mes to play against Evil Mister Fred's minions.
- Kick-Mes can turn themselves into soccer balls. If another Kick-Me hits it sideways and puts spin on it, it can go crooked through the air.
- The minions won the first goal, but then the Kick-Mes kicked one of their Kick-Me balls forward, and they ran into the minions.
- The minions tried to eat the Kick-Mes, which the Kick-Mes loved, and the minions weren't watching the ball.
- The ball went bouncing down the field and made itself a goal.
- Evil Mister Fred ran down near the net and yelled at the minions to get the ball. They started chasing after it.
- Another Kick-Me put spin on the ball so it curved away from the net and hit Evil Mister Fred.
- The minions were so busy trying to kick the ball, they swarmed all over Evil Mister Fred and kicked him over the horizon.



## Transcript: Intro to "Frisbees & Curveball"

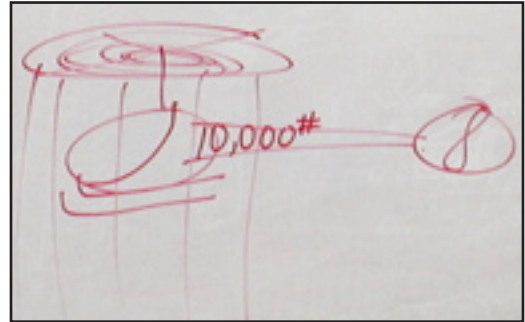
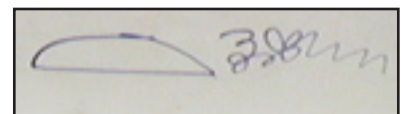
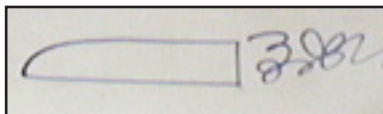
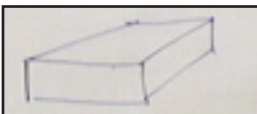
[01:00:11;02] Usually if you want something to go up, you have to throw something downwards. So in a helicopter, they've got all these blades going round and round and round and round really fast, and they're blowing air downwards, and it keeps the helicopter either where it is or it lets it go up. And you have to throw lots of air down. If your helicopter weighs ten thousand pounds, you have to have a constant ten thousand pounds of air going downwards just to stay where you are. If you want to go up high, you have to push a whole bunch more air down.

In an airplane, they have these funny shaped wings that are curved like that, stuck on the side of an airplane. And there's King Kong up there flying. It's King Kong with bear ears. And you need a curvy wing. And the curvy wing makes the air go down so the airplane stays up in the air.

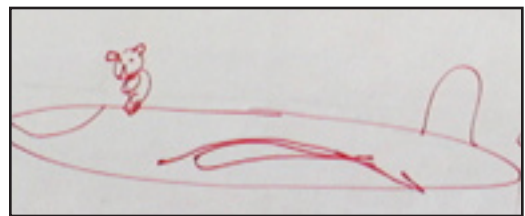
And you can do weird things, too. Somebody said, "Well, I have a better idea. Why should you have spinning propellers on a helicopter? Let's just take an airplane wing, wrap it in a circle, and blow air over it." And they're saying, "What?" He says, "Yeah. You take an airplane wing, wrap it in a circle so it has this wing shape to it. And then put a fan that blows air outwards over all the surfaces." Looks like a squirrel cage kind of fan. And it spins, and then the air goes over the wing, which is supposed to make it rise. And they actually made some of those. And they kind of get up off the ground, but there's a problem to it. If you've got a big motor hanging here, and you're spinning this fan, if the fan is spinning this way, the wing spins the other way. And if you're on it, you get dizzy really, really fast.

Well, today, we're going to try to make some stuff fly, and it's going to have some weird wing shapes. Like, if you made a wing shaped like that, do you think it would fly very good? [Students: No.] Well, it looks like a rectangular prism. It probably wouldn't fly very good. What if you changed your wing and made it look like that? Would that fly very good? [Students: No.] If you made it look like this. [Students: No.] It would be better, but you get a lot of turbulence out here, which slows it down. It's only when you round off the corners that it starts to fly good. Well, there's some genius out there that made things in a weird shape, and they still fly good. We have to find out why. But first, we need a crazy story.

Different types of wings. The fourth one works best.



Helicopter



Airplane wing



Experimental circular wing with motor.

## Story: "Jack and Jill and the Doughnut People"

[01:03:36;26] Once upon a time, Jack and Jill were off in the land of the pancake people and the doughnut people. They had mountains made out of marshmallows, and it rained syrup. So high fructose corn syrup rain. So here's the syrup clouds. Then we need -- what flavor of doughnuts should they be? [Students: Choc-vanilla.]

Choc-vanilla. Choc-illa, there you go. Choc-illa doughnut people.

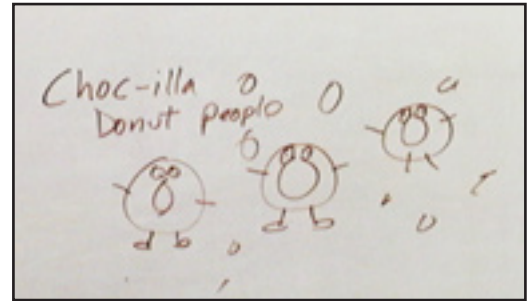
So there's choc-illa people, and the choc-illa people were always worried because they thought the sky was falling. That's why their mouth looks like that. They went, "Aaaaaaa!" They think the sky's falling, and they're kind of crazy. If they're jelly-filled, they go splat. [Student: Are they plain, or powdered, or chocolate?] Oh, it depends on what they want to wear that day.

Now for the pancake people. Okay, are they blueberry pancakes? [Student: No, chocolate chip.] We've already got chocolate. They've got to be pancakes. What flavor pancakes? [Student: Banana.] Banana flavored. Sour cream banana? Brussels sprout flavored pancakes? Uhhnnn. There.

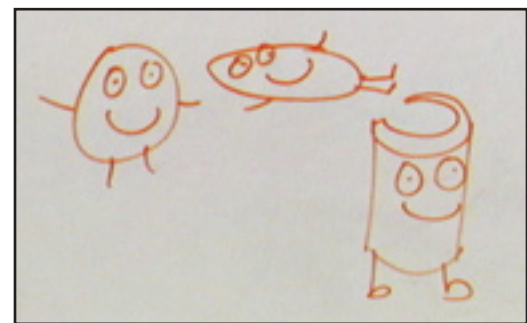
And you can imagine that when people come to this place, and they visit, they get hungry. And they want to eat the people that live there. And actually, the people don't like others to come in, especially tourists from America, coming in and chomping them. We need some people. Tourists usually wear shorts with pictures of flowers on them, t-shirts, hawaiian t-shirts with pictures of palm trees on them, and they're dragging around a bunch of little kids. And they've got a camera that they're carrying around on their neck, like that.

And as soon as the kids see the doughnut people, they run right over and bite them. And the doughnut people don't like to be bitten by little kids, because it hurts.

And so the doughnut people and the pancake people called Jack and Jill and they said, "Jack and Jill, we need some help here. We've got tourists. We need the tourist industry because it provides lots of money, but they try to bite us. It's worse than having a bunch of mad dogs around." And Jack and Jill were trying to convince the people that it wasn't right to eat the natives. And they printed up brochures, they put up advertisements on tv, they put posters in the buses, on the airplanes, they tried to educate all the tourists not to eat the natives. And the tourists just didn't get the message.



Choc-illa Doughnut People.



Pancake People.

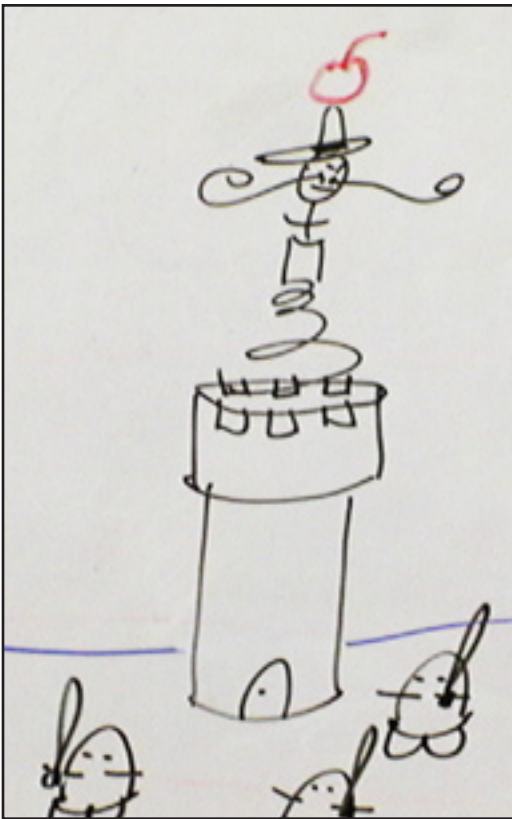


Tourists.

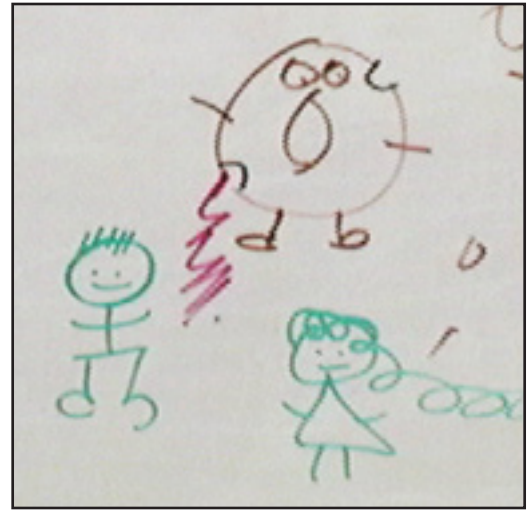
Well, this made worldwide news because the poor natives were running around with bite marks on themselves. And they could be bleeding jelly. They've got bite marks all over the place. And then there's some jelly coming out.

Well, Evil Mister Fred heard about this. He says, "You've got to be kidding! There's a place where there's pancake people and doughnut people, and it rains syrup? This is just really weird. I've got to go there."

So Evil Mister Fred went there, and he built a castle out of -- what? [*Student: Whipped cream!*] Whipped cream, okay. Licorice flavored whipped cream. We'll put Evil Mister Fred on top, with a cherry on his hat. And of course Evil Mister Fred bought a couple thousand minions with him. And the minions like doughnuts, especially doughnuts that have M&Ms on



Evil Mister Fred and his minions.



Jack & Jill with Doughnut Person, who has bite marks and jelly coming out.

them. So now, instead of it being just a little problem, it's a big problem because Evil Mister Fred put up his own posters. His posters said, "Come one, come all, have a feast. Come to the land of the doughnuts and the pancakes and eat as many as you like. They like being chewed on."

And now people came from all over the world, and the doughnuts were running everywhere. And the pancakes were bouncing all over the place. And they were all saying, "Help! Jack and Jill! It's terrible! Everybody's trying to eat us!" If you're Jack and Jill, and you want to stop everybody from eating the doughnuts, or at least protect the doughnuts, what would you do?

### Imagination and Brainstorming Time

[01:11:05;15] [*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.)

Okay, we'll leave this "To be Continued . . ."



## Experiment One: "Frisbees"

[01:13:57;03] Well, the first part of the experiment is very simple. You need one of those *[holds up a paper plate]*. Ta-da, that part's done. And you need a stick. Here's a stick -- see the stick? *[Holds up a small piece of a dowel.]* And a piece of tubing. The tubing has to eat the stick. See? It only eats half of it with that end. *[Inserts half of dowel into one end of tube.]* Then it eats the other half of it with this end. *[Inserts other half of dowel into other end of tube, making a closed ring.]* There. Now you're done. But yours is going to look like everybody else's, so you need to draw on it or put your name on it, or write the declaration of independence on it, both of these, so you know which one is yours. Then we're going to take them outside. When you get outside, throw them straight up. You're going to throw them sideways this way, you're going to throw them sideways that way. You're going to throw them under your leg, going to throw them behind you, going to throw them every direction and see how they fly. Okay?

*[Instructor passes out tubing, dowels, paper plates, and permanent markers. After a couple of minutes of drawing time, they go outside and throw around the plates and tube rings. After a few minutes, they go back inside.]*

Now, you're going to take one piece of tape and then put it on your plate to hold the tube to the plate. And then you're going to come back and get another piece of tape. We'll give pieces of tape this big. You put it on, wrap it around the edge because it's strong that way, and then you come back and get another one. And put four of them around the edge. The reason we don't want you to take more than one at a time is they get all stuck together. *[Instructor cuts pieces of duct tape and students line up to get them and tape their tubes to their plates.]*

Okay, everybody go outside. And you're going to throw them straight up, straight back, sideways, under your leg, behind you, anywhere. *[Students go outside and throw their plates around. After a couple of minutes, they go back inside.]*

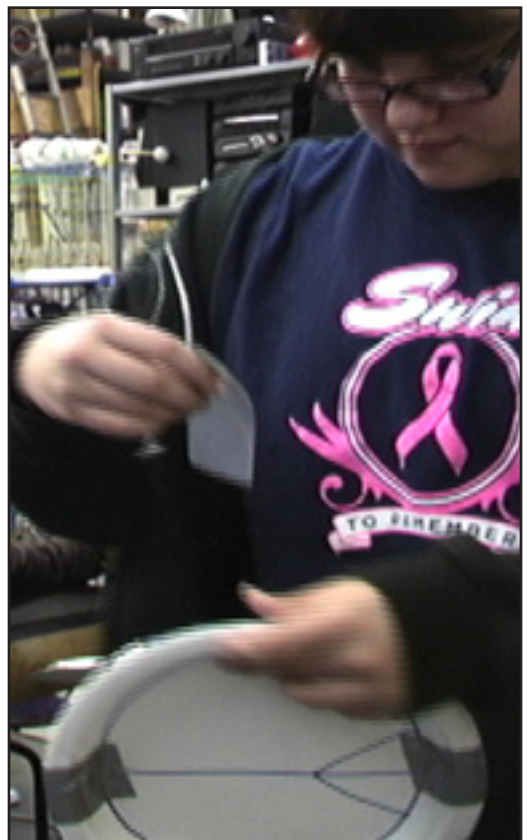
Put yours down and go back outside. *[Students leave their plates in the classroom and go outside. Instructor is carrying commercial frisbees.]* Now, there's not enough for everybody. There's always going to be someone that doesn't have one. Some of them have weird front edges. Should that fly? I don't



Plastic tube ring & paper plate.



Making frisbees.



Taping ring onto back of plate.





Different styles of frisbees.



Students wait while Instructor tosses the frisbees in various directions so they're scattered around the parking lot. When he gives the word, students each pick one up and start throwing.

think so. Some of them have roundy edges. There's one with another weird edge. Here's one with a hole in it. Here's one with a big hole in it. Don't let them go on the roof. They get lonely if they're on the roof. They cry a lot and keep people awake at night. I'm going to throw them out. Don't go get them until I say go. That means stay where you are.

*[Instructor tosses frisbees in different directions, then lets the students retrieve them.]* When you get one, throw it. *[Students toss various frisbees. After a few minutes, they go back inside.]*



Students toss different styles of frisbees. Once a frisbee is thrown, whoever is nearby when it lands can pick it up and throw it.

## Experiment Two: "Curveball (with foam disks)"

[01:31:20;23] You and your partner are going to have a face from Easter Island. See? He's got eyes, and his eyes can spin. And there are motors, of course, on his eyes. If you put the alligators on the coppers, his eyes should spin fast. There. So his eyes can spin. And that ought to be good for something.

Now, if we put a foamy marshmallow shape between his eyes . . . oh, it went the wrong way. What shall we do? *[Student: Switch the wires.] [Instructor reverses the wires.]* Here goes the marshmallow. If we put a less foamy marshmallow on there *[shoots foam disk]*. If we put a purple pancake on there *[shoots it]*. If we put a papery-foamy thing on there *[shoots it]*. There are lots of different shapes. You guys are going to be shooting stuff in here, but you're only going to shoot them at that wall because you have to pick them all up later.

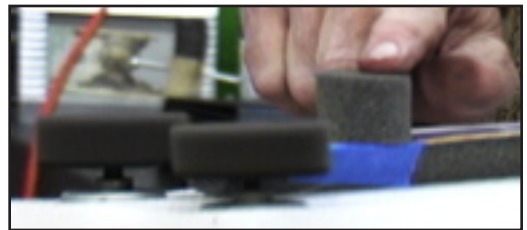
So send one person from your group to grab maybe one or two of each kind out of this bucket. Send the other person from your group to get one of these *[shooters]*. Certain ones work better than others. Try to hook it up and see if you can make them fly. If you're worried about your eyes, put on goggles.

*[Students hook up their launchers to the wires and start shooting the foam disks.]* Try to figure out which ones fly the best. Try shooting them straight up. Make one *[wheel]* be still and see which way it shoots. Don't stop both *[wheels]* -- it burns out the motor.

Pick out two of the ones that you think work the best, and two of the ones that you think work the worst. And then take yours over to that side. *[Students move to one side of the table, facing the whiteboard.]* We're going to set them up all over on this side. You're going to pick the ones that you think are best, and you're going to try to hit the glass lens on the camera. Okay, fire! Take turns. Okay, go get more ammo and reload.



Launcher



Pushing a foam disk between the wheels.



Shooting foam disks toward the camera.

Now it's your job to scurry around and find all of the little circles and put them into the container.

Fifty years ago, this was the only kind of frisbee you could get, with a rounded edge. And then somebody came out with this, that they call an aerobie. An aerobie has a flat edge on it. If you made it big, it would look like a gummy thing. They call these squidgies. Squidgies were so cool, but look at the edge. Who would have thought that that would fly? Somebody should try to make an airplane wing with a squidgy edge on it. And it flies perfectly. That's just so bizarre. So hopefully, they're going to come up with some wing designs based on squidgies, because that's a great idea.



Original frisbee shape.



Aerobie.



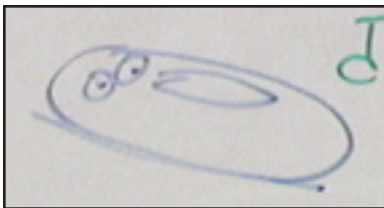
Squidgie.

## End of Story

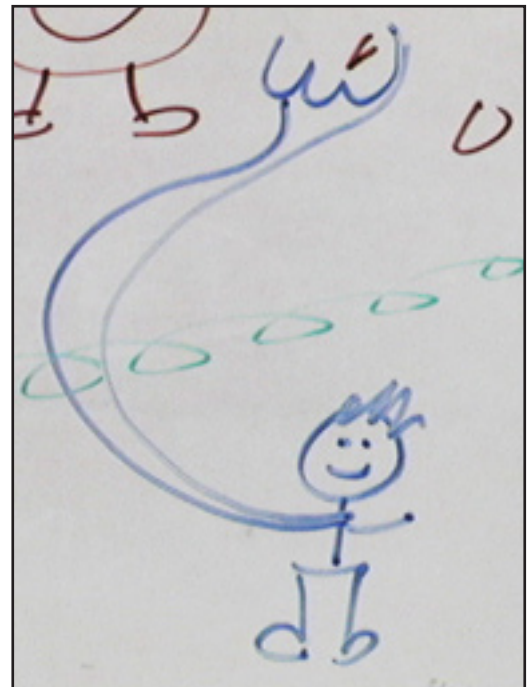
**\* DO NOT \* present this part of the lesson until after you have done the experiments!**

[01:50:59;03] So the tourists have come to the land of the pancakes and the doughnuts. And their kids are running around eating the population there. And everybody's saying, "Jack and Jill, you've got to stop them from doing this." And of course Evil Mister Fred is encouraging the tourists to eat the pancakes and the doughnuts. And Jack and Jill said, "We've got to do something."

So they called the Acme Store of Everything and they ordered their friend George to come. George looks like an ordinary person pretty much, but he's got one arm that's a lot longer than the other, like that. And Jack and Jill said, "George! We need your help!" He said, "All you doughnut folks, I want you to go partner up with a pancake person." The doughnut guys said, "Yay, we're going to go visit our pancake friends." And the pancakes and the doughnut guys got together to make doughnut pancake things.



Doughnut-pancake thing.



George has a really long arm.

And they said, "George! Pick them up and throw them!" And George says, "All right!" When the tourists come around, if the tourists want to take a bite out of one of the pan-



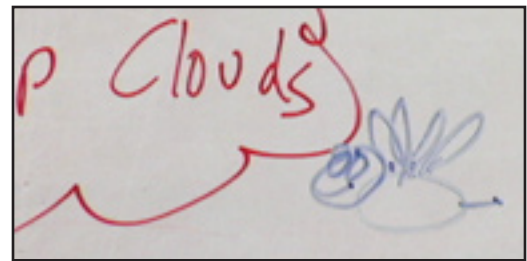
cake doughnut things, George would come along and go whoosh! And George could throw them really good. George could throw a pancake doughnut thing clear over the horizon. It would go clear around the planet and come back again from the other side.

And the first one that came back hit Evil Mister Fred's mustache and chomped off part of it and flew by. And Evil Mister Fred said, "Nooooo!" And then another one came by and ate the cherry off the top of his hat. And Evil Mister Fred said, "Nooooo!" And of course, another one came by and ate the other side of his mustache off. "Nooooo!" So Evil Mister Fred tried to escape. He turned around and saw twenty of them flying at him all at once. And he jumped into the air and landed in the syrup cloud. And he got all sticky and the bees ate him -- the sugar plum bees ate him. And they all lived happily ever after, except Evil Mister Fred.

### **End of Main Lesson**



One pancake-doughnut chomped off half of Evil Mister Fred's mustache. Another knocked the cherry off his hat.



Evil Mister Fred fell into the syrup cloud and the bees ate him.



## Transcript: Intro to "Curveball (with plastic balls)"

The next segment is an alternate version of the "Curveball" lesson, using pingpong balls and small plastic whiffleballs instead of foam disks. The first part of the story, as well as the brainstorming session, were not recorded. The very end of the story also was not recorded, but it is included in this Teacher Guide transcript.

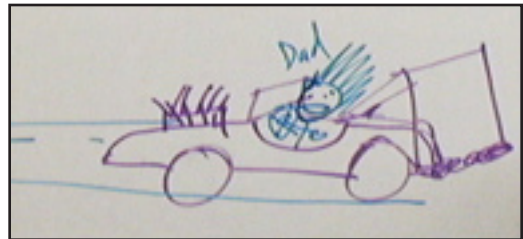
[01:48:10;18] Let's suppose that your friend tells you that he can ride his bicycle faster than you. And you say, "No, you can't." He says, "Yes, I can." And you say, "No, you can't." He says, "Yes, I can." And then you say, "Okay, we'll have a race." So you call your dad on the phone. "Dad, I'm having a bicycle race with my friend. Can you come over?" And dad says, "Okay."

So dad shows up, and he's got a race care with the engine sticking out in front. And his race car can go two hundred miles an hour. And your dad put a big piece of plywood on the back with some supports, and he put a roller near the bottom, like this. There. There's your dad. And you're going to race your friend down the road, and you say, "Is it okay if I ride behind my dad? He's very protective." And your friend says, "I don't care where you ride. Just ride anywhere. I'm going to beat you no matter where you ride."

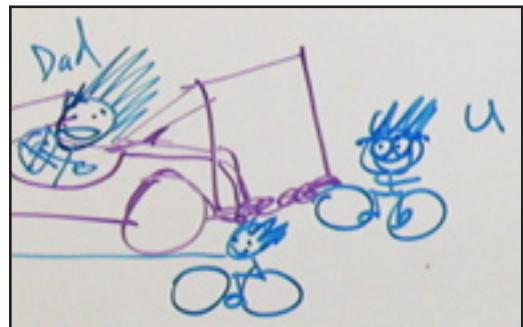
So your friend is out here on his bicycle, and you're over here behind your dad on your bicycle. And we need you in here. You're on your bicycle, they're on their bicycle, and you take off. And immediately, he starts going like crazy and he's way ahead of you. And your dad slowly starts going faster and faster and faster and faster. And you're trying to keep up with your dad. Are you going to be able to keep up with him or not? [Students: No.] No.

Well, somebody tried this. Instead of a ten speed bike or a twenty speed bike, they got something like a forty speed bike. And they could get into really high gears. And they got right behind a race car and they started riding -- vroom, vroom, vroom, vroom, vroom. And they didn't get too fast. They got to like seventy miles an hour and the tire popped. Luckily, they had rigged up a harness thing so they didn't fall on the ground and get all ground up to bits. So then they put on some super high speed tires on the bike and tried it again. And they were able to stay behind the car until they got up to one hundred sixty miles per hour. On a bicycle, pedaling by themselves.

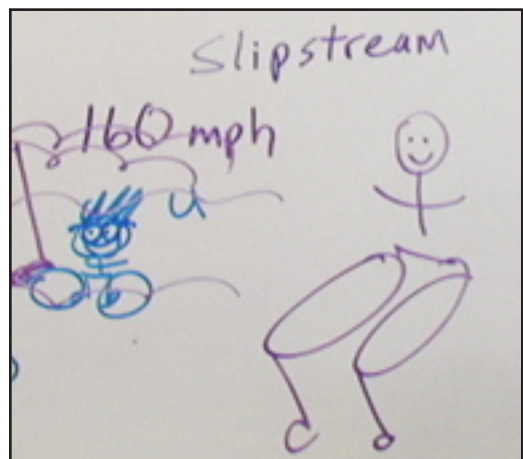
And you've got to wonder: Did the guy have legs that look like big monster legs? No, he looked like a regular guy. And they tried it with other people, and other people could do it, too. So the secret is in the board. As you take a big wide board and push it through the air at a hundred and sixty miles an hour, the air swirls all



Dad's race car with plywood on back.



You ride your bike directly behind Dad's car, while your friend is off to the side.



The guy who went 160 mph didn't have monster legs like this.

around it, and it creates a pocket where there's no wind. In fact, there's a little bit of suction there. They call it a slipstream. And if you can keep your bicycle in the slipstream, it'll actually pull you along. So all you have to do is keep your legs going so that you can stay up at a hundred sixty miles an hour. So this slipstream is very useful.

Now suppose you're playing baseball and this is you. You're the pitcher. And you're batting against a huge guy who's declared that he's going to hit that ball so hard he's going to knock it right down your



You pitching against a huge guy.

throat and out the back of your head. Well, you know a trick that he doesn't know. Even though you're a lot smaller than him, and he probably could hit the ball that hard, if you can keep him from hitting it, you'll win.

What you've discovered is through practice and cleverness, that if you hold the ball a certain way and you release it a certain way, the ball doesn't fly straight. It could go this way, or that way, or like this, or like that [indicates the path of four different curve balls]. And so you throw

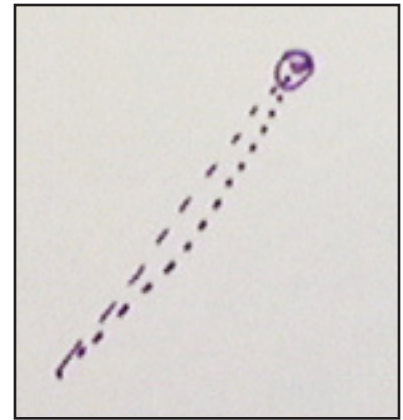
the ball in a curve and it goes right by him. And he whiffs the ball. And actual major league pitchers can do this really well. If you put a camera behind a major league pitcher and you draw a dotted line towards the catcher's glove, the ball should follow that dotted line. Well, these guys can do something to it so it goes off course by up to nine inches and still hits the glove.



Stitches on a baseball.

If you look at a baseball, it doesn't work if it's perfectly smooth. They can't do it very well. A baseball has these red stitches on it. Ever looked at one? Turns out those stitches are really important. If you can make the ball spin while it's going through the air, it won't fly straight. And these guys know how to release it so that when they let go, they can put a little spin on the ball. They can put a spin one way, they can spin it the other way, and make it

go weird directions. So today we're going to try to find out a little bit about how air movement can make things change and how spin can make things change. But first we need a crazy story.



A curveball can curve 9 inches.

The story opening was not recorded, but an outline of it appears on page 12 of this transcript.  
The brainstorming session was also not recorded.

## Experiment Three: "Curveball (with plastic balls)"

[01:55:15;24] If you have a ball like this [*holds up a small whiffleball*] -- it's a tiny whiffleball. If you put your finger on it and let it slide [*propels ball across table*] -- did you see it was spinning as it went? It's hard to catch because it's spinning. I'll do it a little softer so you can see the spinningness. There, you see how it spins?

So, this one just has friction against the table. If I spin it a little bit on one side by flipping my finger this way, you can make it act funny because of the friction against the table. If it's spinning through the air, will it do anything weird as it spins through the air? Well, that's what we want to find out.

We have a whole bunch of balls. Some of them are pingpong balls, some of them are white whiffleballs, and some of them are yellow whiffleballs. And some of them are white pingpong balls. But there's really only two kinds here. We want them to be able to fly through the air, but not fly in a regular pattern. Usually when you throw something, it goes up and comes down and flies in a path that's called a parabola. We don't want them to fly that way. We want them to fly weird.



Make the ball spin with your finger.

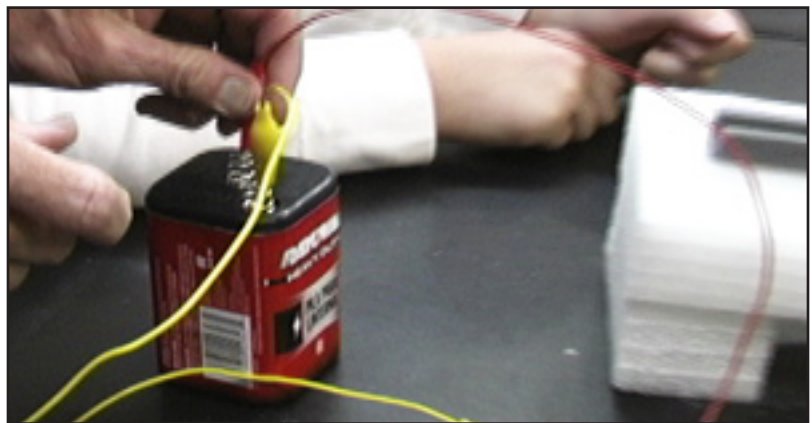


Ping pong balls and small whiffleballs.



Ball shooter.

And it's best if you can actually throw it and watch how it travels with one eye closed and see if it really goes straight or not. But throwing them and watching is hard. So we have created a handy-dandy ball thrower. And the handy-dandy ball thrower lets you -- it's leftover motors and some foam. So his eyes can spin, and he's got a long nose. He ought to be good for something. If we hook him onto a battery, now his eyes spin. And it's kind of a neat thing about these



Ball shooter hooked up to 6-volt battery for demo.





If you hold one wheel, the other still spins.

*disks.]* So it's a ball shooter. So this way, just being that it's foam, you can hold it up like this and aim it right at the top of *[student's]* head. *[Shoots a couple of balls.]* And you can sight right down it and see whether the ball's going straight or crooked.

However, there's a problem. El cheapo batteries last about ten minutes and you're saying, "Come on, spin, spin," and it doesn't spin. So we have luckily a black box that provides a whole lot more power. This box is much better than the batteries. It's not as much voltage, but it doesn't run down. So we can hook it up. This one has a fan inside, so when I turn it on, you'll hear the fan running to keep it cool.



Power supply won't run down like a battery.

squeeze their head the secret way, they open their mouth? *[Hooks up a ball shooter to the wires with alligator clips.]* So you can make it a ball shooter that way. You're not supposed to aim it at other people. I'm going to just let it go -- here goes. Ready? *[Ball rolls down to the spinning disks and just stays there, doesn't get pulled through.]* Aw, what's wrong? *[Student: It's spinning the wrong way.]* It's spinning the wrong way? *[Student: You have to switch the wires.]* Okay, you can switch them. *[This time the ball shoots through the spinning disks.]*

motors -- they're cheap enough that if you rub your finger on one, the other keeps spinning. But if you stop that one, then this one spins really fast. You can hear the batteries running down. And they're just foam, so you can rub your fingers against them and change one spin or the other spin. Or you can let them both spin.

So now they're sitting there spinning away. *[Instructor drops a ball into the chute and it shoots out between the spinning*



You can sight down the trough to see if the ball goes straight.

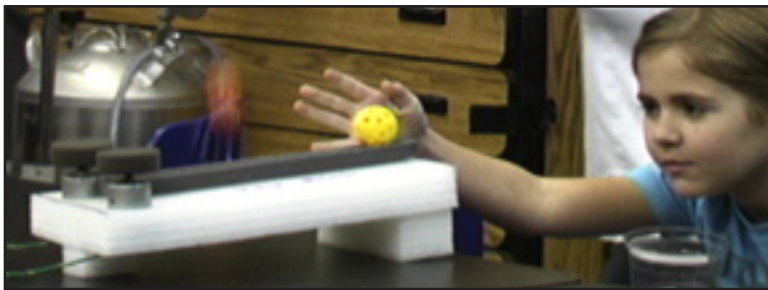
Now there's electricity in those wires. I'm going to touch them and see if I turn into a monster. *[Touches one finger of each hand to the wires.]* Aw, darn, I didn't die. There, see if you die. *[Students touch wires.]* Is anybody dead yet? Did you feel anything? *[Students: It was cold.]* Yeah, you felt cold. Well, five volts can't get into your hands. The door is too strong. Your skin can hold forty volts and you don't feel anything. So you won't get anything out of five volts. We can put our alligators on there. You remember these guys? If you

We're going to have one of these ball throwers for each group of two. Then you're going to come and choose balls. Each person will get three pingpong and three whiffleballs. Send someone from your group over here and get one cup for each person. After you have a cup, come over here and pick out three whiffles and three pingpongs for each person.

Now, suppose you launch the balls and you say, "Woo-hoo!" and you run to pick them up, and you hear this sound as you walk by -- scrunchy, scrunchy scrunchy. And you pick up your balls -- scrunchy, scrunchy, scrunchy, and you run back. Then you look back and you say, "Oops! Sorry," because you stepped on other people's pingpong balls and made them into flat balls. So in order to preserve the pingpong balls, when you're going to pick up some, shuffle your feet. Shuffle, shuffle, shuffle, shuffle, so you don't smoosh them all. And also, don't be too attached to the balls that are in your cup. After you shoot yours, go pick up any six that you find and come back. Somebody will end up with an empty cup, saying, "Ohhh, I don't have any balls." By the Evil Mister Mac's rules of unfairness, they've got to go find some. There are certain directions that you could shoot the balls where you'll never find them again. If you shoot them over towards those yellow boxes, they'll slip into the boxes and be lost forever. But if you shoot them that way, you have at least a moderate chance of finding them again. And if you shoot them that way, chances are you could find them again.



Each student gets three ping pong balls and three whiffleballs in a plastic cup.



Sighting down the trough.

The first job is to just try shooting it different ways and see which way it works the best. You can roll it down the trough and have it shoot out, or you can turn it around backwards and scoot it and have it go up the trough. Whatever you feel like. So set it up, I'll turn on the power, and you give it a try. If the wires smoke, that means something's wrong. *[Students experiment*

*with shooters for a few minutes.]* Now divide them up so everybody has close to six of them. This time you're going to pick up the ball shooter and hold it really close so you can sight right down the trough, roll balls down it, and see whether they go straight, to the right, to the left, or jump up or down. The idea is to see if they go straight without you doing anything to the motors, so don't be dragging on the motors. Just let them roll down and go the way they feel like by themselves. So I'm going to turn on the power. Pick some direction to shoot them, take turns. Let one shoot whatever they have, and then you shoot what you have. You're supposed to be looking down the trough, sighting down, that's the way. *[Students shoot until each one has shot their six balls.]*

This time you're going to drag your finger on one wheel, roll it down, and see which way it goes. *[Student shoot their balls this way.]*



Loading up in machine gun mode (six balls at once).

Now, you're going to be shooting at Mister Mac. You need to load them up for machine gun mode. *[Students put all six balls in the trough and shoot them at the Instructor.]* Now you're going to aim at your partner. Try to shoot them up into the sky.

*[After putting the ball shooters away.]*

Hopefully, during this time you saw that sometimes the balls don't go straight. I

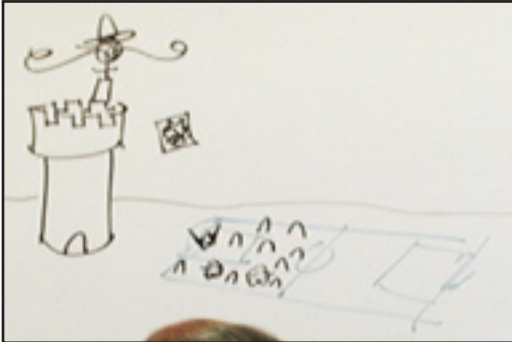
heard one person say that when they rubbed this side and that one stopped, the ball went that way. Then I heard somebody else say, "When I stopped this one, the ball went that way *[indicates the opposite way]*." And then we have one who says that the pingpong ball goes one way and the whiffleball goes the other way. *[Student: I think the difference is the whiffleball has holes and the pingpong ball doesn't.]*

Have you ever looked at a golf ball? It's got dimples. And if a golf ball's spinning while it goes through the air, it really goes crooked a long ways.



## End of Story

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



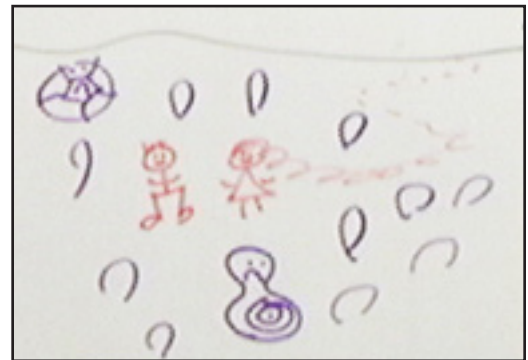
Evil Mister Fred's minions on the soccer field.

[02:10:46;25] So the great soccer tournament is about to be continued. Evil Mister Fred has trained his minions to be awesome soccer-playing machines that could beat just about anybody. And they were taking over all the countries of the world. Jack and Jill were the only ones able to stop them. And they were training their Kick-Mes to play against Evil Mister Fred's soccer-playing guys.

And the Kick-Mes could turn themselves into soccer balls. And they practiced and practiced and they discovered that if they were to bounce along -- boing, boing -- and then hit their

buddy with a little bit of spin on it by making their head go [swings head in a sideways arc] like that, their soccer buddy ball would spin and go crooked through the air. And they said, "Oh, this is great!"

So they all went out to the tournament. All the Kick-Mes were out here. People from all over the world were in the bleachers. They were watching on tv and on their computers. They had a blimp up there and they were watching from the sky. Everybody wanted to find out the outcome of the tournament. Could anybody stop Evil Mister Fred and his machine?



Kick-Mes can turn into a soccer ball.

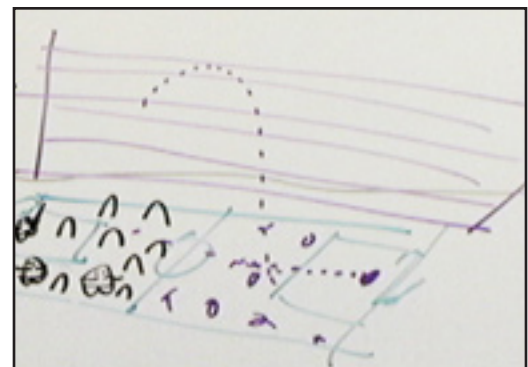


A full stadium with a blimp overhead.

And they started the game, and the minions ran forward with their super-duper feet, and they weren't kicking just the ball. They were kicking the Kick-Mes. And the Kick-Mes are going, "Woo-hoo!" They love being kicked, and they're flying all over the place. And Evil Mister Fred's team scored the first goal, and everybody said, "Uh-oh, this looks bad." And then they had another kickoff, and the Kick-Mes started kicking their guy forward. They kicked him way up into the air -- fwooo -- there's a Kick-Me ball. And

they all ran forward shouting and everything, and they ran into the minions. And the minions tried to eat them. The Kick-Mes said, "Oh, that was cool, do it again!"

Now the minions are chasing around, trying to eat the Kick-Mes, and Evil Mister Fred said, "Stop that, stop that! Get the ball, get the ball!" Well, the ball is alive. And the ball just went boingy-boingy-boingy [Tape ran out here.] down the field, right into the net and scored a goal. And the crowd cheered,



The Kick-me ball went way up in the air.

but the minions didn't even notice, because they were so busy chasing the other Kick-Mes and trying to eat them.

Well, Evil Mister Fred was so angry, he ran down to the field to try to get the minions' attention. He stood next to the net and yelled, "Get that ball!!" And the minions started chasing after the Kick-Me soccer ball again. This time, one of the other Kick-Mes hit the ball and put some spin on it, so instead of going straight toward the net, it swerved and hit Evil Mister Fred. And the minions swarmed all over him, trying to kick the ball, and they kicked so hard that Evil Mister Fred went flying over the horizon. And everybody lived happily ever after, except Evil Mister Fred.

***End of Alternate Lesson***

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