# The Scientific Method

## Project Guidebook



*By Aurora Lipper, Supercharged Science and Science Jim, Bite-Sized Physics*

# Table of Contents

## Welcome to the world of Supercharged Science! 

In just a moment, you'll be building an ultra-cool science project, taking data, and transforming your great ideas into an outstanding science experiment using the scientific method! Whether you're looking to blow away the competition at a science fair or simply expose your students to how real scientists do their work, you've got the keys to using the scientific method in your hands right now.

We're going to walk step-by-step through every aspect of the scientific method from start to finish, and we'll have fun doing it. All you need to do is follow these instructions, watch the video, and do the steps we've outlined here. We've taken care of the tricky parts and handed you a recipe for success.

## Why Use the Scientific Method?

One of the problems kids have is how to experiment with their great ideas without getting lost in the jumble of results. So often students will not have any clear ideas about what change caused which effect in their results! Students often have trouble communicating their ideas in ways that not only make sense but are also acceptable by science fairs or other technical competitions designed to get kids thinking like a real scientist. Another problem they face is struggling to apply the scientific method to their science project in school, for scout badges, or any other type of report where it's important that other folks know and understand their work.

The scientific method is widely used by formal science academia as well as scientific researchers. For most people, it's a real jump to figure out not only how to do a decent project, but also how to go about formulating a scientific question and investigate answers methodically like a real scientist. Presenting the results in a meaningful way via "exhibit board"… well, that's just more of a stretch that most kids just aren't ready for. There isn't a whole lot of useful information available on how to do it by the people who really know how.

This workbook is designed to show you how to do several cool projects (and one really nifty one at the end), walk you through the steps of theorizing, hypothesizing, experimentation, and iterating toward a conclusion the way a real engineer or scientist does. And we'll also cover communicating your ideas to your audience using a display board *and* the oral presentation using top tips and tricks from real scientists.

For years, Supercharged Science has served as the bridge between the scientific community and the rest of the world. This is yet another step we have taken on to help serve as many families as possible. Thank you for your support and interest… and let's get started!

## What is the Scientific Method?

The scientific method is a series of 5 steps that scientists use to do research. But, honestly, you use it every day too! The five steps are Observation, Hypothesis, Test, Collect Data, and Report Results. That sounds pretty complicated but don't worry, they are just big words. Let me tell you what these words mean and then we'll play with them.

**Observation** means what do you see, or hear, or smell, or feel. What is it that you're looking at? Is that what it usually does? Is that what it did last time? What would happen if you tried something different with it? Observation is the beginning of scientific research. You have to see or touch or hear something before you can start to do stuff with it right?

Once you observe something, you can then form a **hypothesis**. All hypothesis really means is "guess". Hypothesis is an educated guess. Tonight at dinner, when someone asks you "Do you want peas or carrots?" Say, "I hypothesize that I would like the carrots." Everyone will think you're a genius! Basically you're saying "I guess that I would like the carrots". Hypotheses aren't right or wrong they are just your best guess.

To see if your guess is correct, you need to do the next step in the scientific method, **test**. The test is just what it sounds like; running experiments to see whether or not your hypothesis is correct.

As you do your tests, you need to **collect data**. That means collecting the numbers, the measurements, the times, the data of the experiment. Once you collect your data, you can take a look at it, or in other words analyze it.

Once you analyze your data you can report your **results**. That basically means tell someone about it. You can put your data in a chart or a graph or just shout it from the rooftops!

Here's a great way to remember the 5 steps. Remember the sentence "Orange Hippos Take Classes Regularly". The first letter in each word of that goofy sentence is the same as the first letter in each step of the scientific method. That's called a mnemonic device. Make up your own to remember all sorts of stuff.

"Ok, so that's what the words mean. How do I use that everyday?"

Well, I'm glad you asked that question. If you had cereal for breakfast this morning, you did the scientific method. On the table you had a bowl of cereal with no milk in it. As you looked at your dry cereal, you made an observation, "I need milk!" At that point, you made a hypothesis, "There's milk in the fridge." You can't be sure there's milk in the fridge. Someone might have used it up. It might have gone bad. Aliens may have used it to gas up their milk powered spaceship. You just don't know! So you have to do a test.

What would be a good test to see if there is milk in the fridge? Open the fridge! Now once you move the week old spaghetti and the green Jell-O (at least you hope it's Jell-O) out of the way, you can see if there is milk or not. So you collect your data. There is milk or there isn't milk. Now you can finally report your results. If there is milk you can happily pour it on your cereal. If there isn't any milk you report your results by shouting, "Hey Mom...We need milk!" Scientific method, not so hard is it?

Let's get familiar with the scientific method by doing some simple experiments you'll find on the next several pages. The first one focuses on working through the five steps.

## Experiment: Underwater Presidents

**How many drops of water can a penny hold?**

*What you need:*

- Pennies
- Eye or medicine dropper
- Water

1. Make your observations of the penny; the size, the cleanliness, heads or tails etc. Next look at the water dropper? How big is the opening? How big are the drops that come out, etc?

2. Make your hypothesis. Make a scientific guess as to how many drops you can get on that penny before the water drips off the penny. Unless you've done this before, you will almost certainly have a hypothesis that is not very close to your results. Don't worry about it.

3. Do your test. Slowly but surely put drop after drop on that penny. Eventually you will see a surprisingly large mound of water on the penny that will burst and overflow.

4. Collect your data. Keep a careful count of how many drops are sitting on that penny. For accuracy's sake, you may want to do this several times (besides, it's fun) and average your results. (To get an average, add up all your results and then divide by the number of results you got. For example, if you did the experiment three times and got the results 14, 16, and 30 you would add those numbers together (60) and then divide that by 3 (the number of results). So your average would be 20 drops.)

5. Report your results. Once the water spills over the edge, construct an interplanetary telecommunications device to broadcast your results across the universe....or you could just tell your kid brother. It's up to you. I've seen folks get more then 70 drops on a penny! Pretty amazing really. The average seems to be between 30 and 40. The reason the water mounds up like that is because water really likes to stick to itself. It takes a good amount of weight before the water breaks apart.

Would you like to do more with this experiment? What would happen if you used different coins? Is there a mathematical relationship between the number of drops and the size of the coin? Is there a difference between the head side and the tail side of the coin?

The next time you're about to do something around the house apply the scientific method to it. For example, if you're about to write something you could apply the scientific method by saying, "I observe that I need a pencil. I hypothesize that there is a pencil in my drawer. I will test this by opening my drawer. I will collect data by looking in the drawer. I will report my data by writing with my pencil or by asking mom where the pencils are." How could you apply the scientific method to making a peanut butter and jelly sandwich, or walking into a dark room, or buying an ice cream cone? Can you think of others?

## The Scientific Method: Variables

Now let's use the scientific method to discover a couple of things about pendulums. Before we start, I need to tell you two new terms. One is constant variable and the other is changing variable. A variable is a part of your experiment, like the coin in the Underwater Presidents experiment. If it is a constant variable, it stays the same for every trial of that experiment.

For example, we always used the same penny in the Underwater Presidents. Those variables never changed. A changing variable is what you change for each trial. It is often what you are testing for; "If I change this, what happens to that?"

For example, in the Underwater Presidents experiment, if we tried water in the dropper, then we tried vegetable oil, then corn syrup; the changing variable would be the liquid we are using in the droppers. When you do an experiment you have to try very hard to keep all variables constant except for the one you are testing for. If you don't keep all but one variable constant, you won't know why you are getting the results you're getting. If you change the size of the coin, and the type of liquid with the Underwater Presidents experiment, you will have a hard time knowing if it's the change of coin or the type of liquid that's causing more or fewer drops on the coin. Let's try the following experiment and see if this becomes clearer.

## Experiment: The Size of the Swing

*What you need:*

- String
- Weight of some sort
- Tape
- Timer (or a watch with a second hand)

First of all, you have to make your pendulum. A pendulum is really nothing more than a weight at the end of something that can swing back and forth. The easiest way to make one is to get a string and tape it to the edge of a table. The string should be long enough so that it swings fairly close to the ground. Tie a weight of some sort (a washer, a watch, your dog (just kidding, live things make poor pendulums)) to the bottom of your string and you've got a pendulum. Now, for this experiment the changing variable is going to be the length of string. In each trial you will be changing the length of the string. The rest of the variables will be constant. The weight at the end of the string, the string itself, the time you will be letting it swing will be the same for every trial. Getting the hang of constant and changing variables now? Okay so here's what you want to do:

1. Make an observation. Play with the pendulum a bit and see how it behaves.

2. Make a hypothesis. How will the length of string effect the number of swings in 10 seconds? Will there be more, less, or no change in the number of swings as the string gets shorter.

3. Set a timer for 10 seconds or get someone who has a watch with a second hand to tell you when 10 seconds are up.

4. Now for the test. Pull the pendulum back as far as you'd like (the pendulum swings smoother if you don't lift the weight higher than the top of the string).

5. Start the timer and let go of the weight at the same time.

6. Count the swings the pendulum makes in 10 seconds.

7. Write down what you found (collect the data). This works well if you make a chart with two columns, one for length of the string, and one for number of swings.

8. Do two more trials with the string at that same length.

9. Now change the changing variable. In other words, shorten the string. I would recommend shortening it at least an inch.

10. Redo steps 3 through 9.

11. Continue shortening the string and doing trials until you get at least five trials with five different lengths of string.

12. Now report your results. Take a look at your data and see if you find a trend. Do you get more swings as the string shortens, less swings, or does the length of the string matter? Something interesting to notice is that at a certain length you will get 10 swings in 10 seconds or a swing a second. This is why pendulums are used in grandfather clocks. They keep good time!

## Experiment: A Weighty Problem

*What you need:*

- String
- Several weights of some sort (a bunch of the same kind of washer works very well)
- Tape
- Scale (optional)
- Timer (or a watch with a second hand)
- Use the same pendulum set up you used for "The Size of the Swing" experiment.

1. Make an observation. Play with the pendulum a bit and see how it behaves.

2. Make a hypothesis. How will the weight of the bob (the weight at the end of the pendulum) effect the number of swings in 10 seconds? Will there be more, less, or no change in the number of swings as the bob gets heavier.

3. Set a timer for 10 seconds or get someone who has a watch with a second hand to tell you when 10 seconds are up.

4. Now for the test. Pull the pendulum back as far as you'd like.

5. Start the timer and let go of the weight at the same time.

6. Count the swings the pendulum makes in 10 seconds.

7. Write down what you found (collect the data). This works well if you make a chart with two columns, one for weight of the bob, and one for number of swings.

8. Do two more trials with the same bob.

9. Now change the changing variable. In this case you want to increase the weight of the bob. If you have several washers of the same kind, the easiest way to do this is to just add more washers to the end of the string. You can also add paperclips if you have quite a few of them. If you don't, then change the bob to different objects that get heavier and heavier with each trial. If you change the number of objects, just record how many you have (3 washers, 10 paper clips, etc.). If you change the type of object and have a scale, record the weights of the objects. If you don't have a scale, just put the objects in order of increasing weight. The actual mass of the objects doesn't really matter as you'll see by your conclusions. Remember to change the weight of the bob, but don't change the length of string. The weight of the bob is your changing variable this time. The length of string is… what variable? Constant. Right, you're getting the hang of this!

10. Redo steps 3 through 9.

11. Continue increasing the weight and doing trials until you get at least five trials with five different weights.

12. Now report your results. Take a look at your data and see if you find a trend. Do you get more swings as the weight increases, less swings, or does the weight of the bob matter? Are you surprise by the fact that weight didn't matter? Next lesson we will discuss gravity and then this odd result will make sense.

Feel free to continue playing with the pendulum. You dropped the bob from about the same height each time. Would you get different results if you dropped the bob from different heights? Try it, but remember to keep the string and the weight constant. If you do this experiment, what is your changing variable? The height of the drop, right? See you are paying attention!!

A constant variable is one that does not change from trial to trial. A changing variable is the one variable you are testing for. It does change from trial to trial. One of the most difficult things to do in scientific research is to know what all of your variables are and to keep all but one variable constant. In these pendulum experiments other variables were the temperature of the room, the humidity, the spin of the Earth, the design of the pendulum, etc., etc. We made an assumption that all those variables remained constant and didn't really matter to our experiments. In this case, that's a safe assumption but sometimes you can't be too sure!

Constant and changing variables are around you all the time. What would be some variables in your breakfast? Which ones change from morning to morning? Which ones stay the same? What about some variables in the car? Which are constant and which are changing?

## The Scientific Method: Observation

The first step of the scientific method is observation. In my opinion, this is the most important and enjoyable part of the scientific method. Observation is the skill of "seeing" things that are there, "seeing" things that aren't there and "seeing" things that should be there.

Observation is the skill that separates scientists from super scientists. Einstein, Galileo and Newton, for example, were fantastic observers. They were able to "see" beyond and through what other people were able to "see" before them in order to get to deeper truths inside science.

I'm putting "see" in quotes because there's more to observing then just seeing with your eyes. First, you need to detect something. You can use your eyes, ears and nose to detect things. You can also use instruments like telescopes, microscopes or prisms to detect things. Somehow, something needs to come to your attention.

But that's not all there is to observing something. Next you need to use your knowledge and your intuition, to fully observe what's happening. When you look up into the night sky you might only see bunches of little white dots, but a trained astronomer would see stars of different magnitudes, galaxies and constellations. The astronomer's knowledge allows her to "see" more. This is why I think observation is so much fun.

Observing allows you to know things and knowing things allows you to observe more things! You can't help but get smarter if you spend your time observing! In this lesson, we're going to spend time becoming better observers. Try this activity.

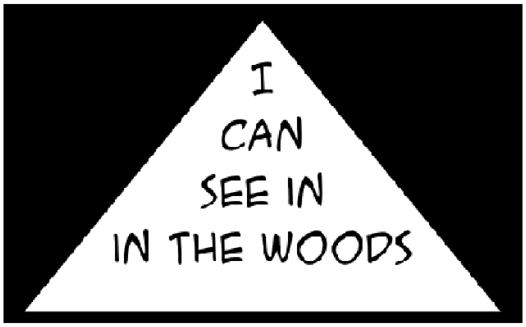
## Experiment: "What Do You Mean, That's Not Right?!"

You need:

- A partner

1. Tell your partner that you are going to give them about 5 seconds to read a sentence.

2. Let your partner take a look at the sentence and count to 5 slowly in your head and then take the sentence away.




3. Ask your partner what the sentence says.

4. If they are wrong, which they almost always are, give the sentence back to your partner and let him or her look at it again.

5. Marvel at how long it takes your partner to find out what the sentence really says!

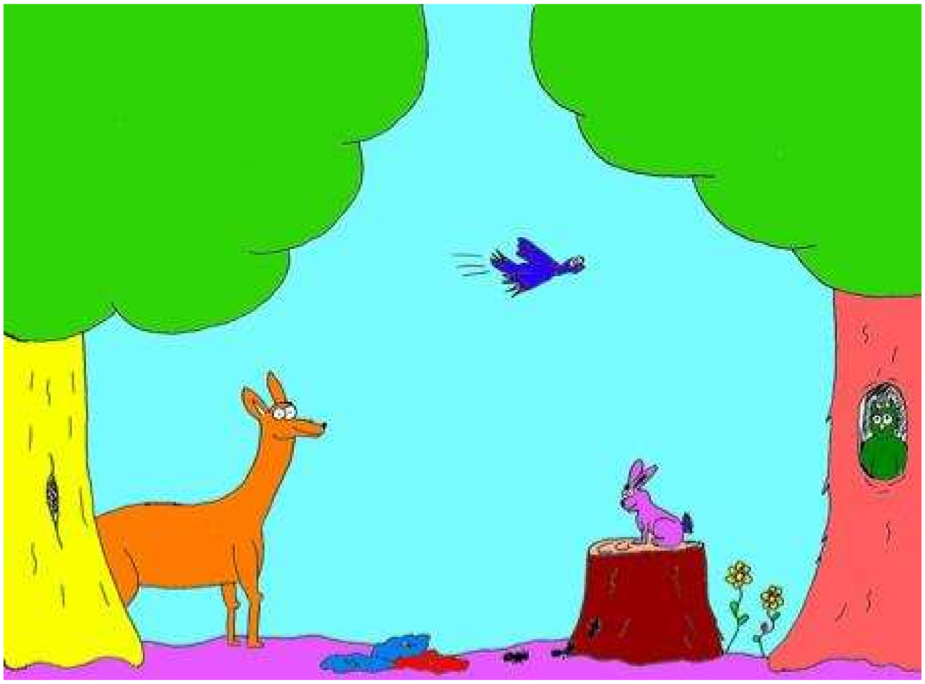
This activity never fails to amaze me. This is a great example of the difference between seeing and perceiving. Your eyes see, your mind perceives and unfortunately, it's not uncommon for something to get messed up along the way! Your eyes saw that second "in" but your mind edited it! In fact, you had to focus quite hard before your mind allowed you to "see" what was really there! Strange, but true.

## Experiment: "Where Did That Come From?"

You need:

- Paper
- Pencils
- Volunteers

1. Tell your volunteers that you are going to give them 30 seconds to look at a picture and try to remember as many things as they can about the picture.
2. Let them see the picture and count to 30 in your head.
3. Now hand each of them a piece of paper and a pencil or pen.
4. Tell them to draw as much of the picture as they can, in as much detail as possible. Tell them not to worry about being artistic but just try to include as much about the picture as possible in their drawing.
5. Tell them to write the color of the objects on their drawing as well.
6. Let them take about 2-5 minutes to create their drawing.
7. When folks are done, show them the picture again so that they can compare their drawings with the picture.



Did your artist draw everything? Did something get forgotten? Did something get added? Was there something that was the wrong color? Now ask your artist how sure they were that something in their drawing was actually in the picture.

I always enjoy watching the faces of the students when I show them the picture the second time. They always get surprised when something is in the picture that was not in their drawing, or even more fun, when something was in their drawing that was not in the picture!

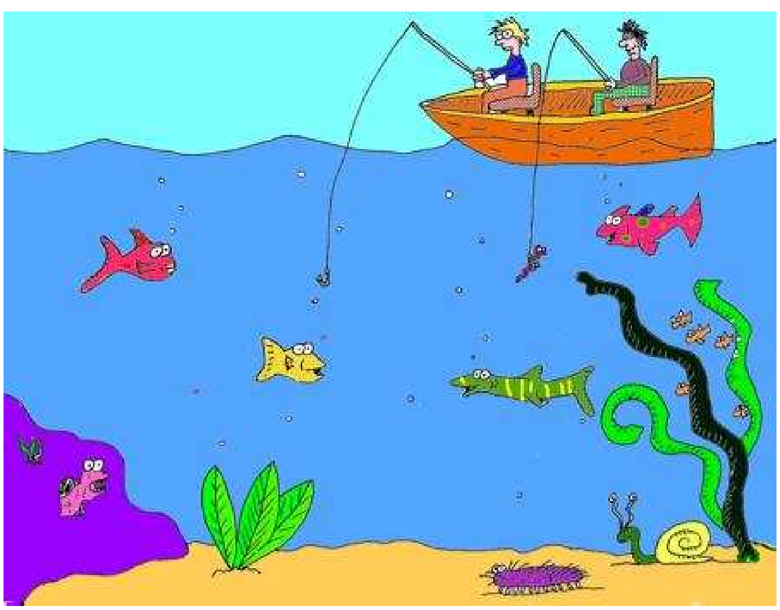
Chances are they were pretty confident that there was a cloud in the picture, or that the dog was yellow or whatever it may have been. Your eyes see what is there, all the colors and shapes. Your mind, however, has to interpret what your eyes see and pretty often it will forget things or completely change them around! Again, your eyes see but your mind perceives!

## Experiment: Picture Detective

You need:

- The question sheet below
- Paper
- Pencils
- Friends

1. Tell your friends you're going to show them a picture for 30 seconds. You want them to try to observe the picture carefully and remember as much about it as possible.
2. Now show them the picture and count to 30 in your head.
3. Take the picture away and hand them a piece of paper.
4. Have them number the paper from 1 to 10.
5. Tell them to try to answer each question as best as they can. Make a guess if necessary. If they can't remember the answer at all, they can leave that question blank.
6. Also, tell them to put a check mark next to any answer they are certain is correct.
7. Read them the questions.
8. When your friends have answered all the questions, let them see the picture and check their answers.
9. Take a look at the answers they were certain they had the right answer. Did they?



*Questions for the Fishy Scene*

1. How many small fish are in the sea weeds?
2. Is the worm on the right or the left hook?
3. How many leaves does the sea weed on the rock have?
4. Is the snail pointing left or right?
5. Is the fellow in the blue shirt smiling or frowning? Can you guess why?
6. What color spots does the spotted fish have?
7. How many fish have stripes?
8. What color hair do the fishermen have?
9. What color is the fish that doesn't have a dorsal fin (the fin on the back)?
10. How many plants are in the picture?

*Answers:*

1. 5 small fish.
2. On the right hook.
3. 3 leaves.
4. The snail is pointing left.
5. He's frowning. Probably because he's not getting any bites since he has no bait.
6. Green spots.
7. One fish has stripes.
8. Blond and Black
9. Yellow
10. 3 plants.

This is an excellent exercise in observation. I highly recommend finding other pictures in books and magazines and doing this several times. It's a great way to get better and better at the skill of observation. It's also a nice way to pass the time in a waiting room!

## Experiment: The Old Switcheroo

You need:

- 5 to 10 small items (pencils, crayons, balls, eraser, toy cars, buttons, whatever is handy)
- A handkerchief or napkin large enough to cover all the items.
- Some friends

1. Lay out all the small items on a table.
2. Cover the items with the napkin.
3. Tell your friends you're going to give them 10 seconds to look at and memorize the items and where they are.
4. Take the napkin off for 10 seconds and let your friends look. Cover it back up when time is up.
5. Now move, take away, or add something to the pile of things without letting your friends see what you're doing.
6. Invite your friends to try to guess what it was you moved, removed, or added.
7. Do it again and take turns being the mover.

This is another great exercise to improve your observation skills. I do this with my family at restaurants. I just grab stuff on the table, lay it out and have my family try to guess what's been changed. (Be careful of grumpy waitresses!)

As you can see, observation is a skill just like any other skill and it can be exercised and improved over time. Being a good observer means always keeping your eyes open and being aware of what's around you. With good observation skills and knowledge the world becomes just that much more wonder-filled!

## The Scientific Method: Communication

Fish in the can saws wild apples dog car sidewalk tree. Shirt the table carpet in the floor roof cloud. What? What do you mean I'm not making sense? I'm using simple English words. Oh, I see. I must not be communicating.

Believe it or not, communication is not as easy as it seems. In this lesson, I'm hoping to show you that hearing what someone is saying, and saying what you want someone to hear is quite a skill. A good skill for life and a vital skill for science.

In science, the ability to tell someone what you did, how you did it, and what happened after you did it, is a key skill in sharing science information. Scientists from around the world share information and their measurements and details of what they did must be very precise. To begin with, let's try this little exercise in giving directions.

## Experiment: A Peanut Butter and Jelly Jam

*You need:*

- Peanut Butter
- Jelly
- Bread
- Butter Knife

(Be prepared to make a mess and have fun.)

1. Pick a person to be the sandwich maker (this works better if it's someone who's kind of in on the game).
2. The sandwich maker tells the group that he or she is a robot who does everything that it is told. However, the robot is very literal, so it does EXACTLY what it is told to do.
3. The rest of the group gives one instruction at a time ("Put the jam on the bread.") until the sandwich is made or until no one can stand laughing anymore.

The key to this activity is the sandwich maker. The robot must do exactly what he or she is told. So when the robot is told to put the jam on the bread, the robot takes the jar of jam and puts it on the bag that the loaf of bread is in! When the robot is told to take the bread out of the bag, the robot can't do it because the bread bag isn't open! Have a lot of fun with this, it's messy and makes a great point.

It's a little harder to tell someone how to make a sandwich than you thought right?! Try telling a robot how to tie its shoes. Or for that matter, walk across the room. It's quite hard. Communication involves a lot of assumptions.

An assumption is when you expect someone to know what you're talking about. You assumed that when you told your "robot" to put the jam on the bread, that the robot would know that it needed to open the jar. Then you might have told the robot to open the jar and it didn't know how to do that either! Again, you assumed something that is obvious to you but not at all obvious, perhaps, to something or somebody else.

My father tells the story of when he learned this lesson the hard way. When he was a kid there was a hole under the porch at his house. His Mom noticed a board sitting on the ground and told my Dad to fill the hole with the wood. Well, my father, being a good little boy, did exactly as he was told and put the wood as far into the hole as he could, leaving a good two feet of board sticking out of the hole. His mother came back from what she was doing, took one look at the wood sticking out of the hole and proceeded to yell at my father for being such a dummy. My father was clueless. As far as he could tell, he did exactly what he was asked to do. However, his mother assumed that when she said fill the hole with the wood, he would use the wood to push dirt into the hole. My father followed the directions correctly but was wrong. His mom gave directions correctly and was also wrong.

As you can see, communication can be very difficult. I'm willing to bet this kind of thing has happened to you. You have told someone to do something and they messed it up or someone told you to do something and you messed it up. Keep this in mind the next time something gets messed up. A little better communication can keep a lot of things from getting messed up (and keep you out of trouble as well).

Communication isn't just giving directions however. It's also hearing what's being said and following directions. How good are you at following directions? Try this.

## Experiment: Get The Picture

*You Need:*

- The instruction sheet, one for each person in the group.
- Pencils for each person in the group

1. Pass the instruction sheet to everyone in your group.
2. Tell everyone to read the instructions carefully and to go ahead and get started.
3. The answers for "Get The Picture" are at the end of the lesson.

## Get The Picture Instruction Sheet

Please follow the following directions exactly.  Do everything that the instructions say. Read all the following directions before beginning.

1. Circle the word circle in this sentence.

2. Write the third word in this sentence here. __________________

3. Draw a large square on the back of this paper.

4. Draw a large triangle on top of the square on the back of this paper.

5. Draw a rectangle inside the square with a short side touching the middle of the bottom of the square on the back of this paper.

6. Draw a small square to the right of the rectangle in the large square on the back of this paper.

7. Draw a circle above the left side of the triangle.

8. Ignore every single instruction on this page but this one. Turn your paper over and draw a big smiley face on the paper. There should be nothing on the back of this page but one big smiley face. After you've drawn your smiley face turn this page back over.

Answer to *Get the* Picture: There should be nothing on the page except for a smiley face on the back! So now you've had a chance to see that giving directions is difficult and following directions is difficult. Let's put it all together with this next activity.

## Experiment: Communication Block

*You need:*

- Identical sets of five different objects for each person in your group. For example, each person in the group has the same set of five different blocks, or everyone in your group has their own fork, apple, napkin, pencil and toy car. It doesn't matter what the items are but for the instructions below I'm going to use blocks as my items.
- Some sort of screen to allow everyone to keep their items hidden from prying eyes. I use file folders. Open them up about 90 degrees, they stand up nice and the kids can keep their stuff hidden behind them.

1. Pick one person to be the "teller". Everybody else will be "listeners".
2. The teller will put his or her blocks together any way he wants. Make sure no one can see how the blocks are laid out. The teller can stack them on top of one another, lay them end to end or do whatever he feels like. I highly recommend only using three blocks the first two or three times.
3. Now, the teller has to carefully tell the listeners what he or she has constructed. The teller's job is to get all the listeners to build exactly what she has built. The teller should only use her voice to explain how the blocks look. She shouldn't hold any blocks up or use her hands to show how the blocks are laid out.
4. As the teller describes what has been built, the listeners should try the best they can to build what's being described.
5. Once the teller feels he or she has explained everything, he should uncover his blocks and let everyone see what he was trying to describe. Take a look at everyone's blocks. How well do they match?
6. Let everyone have a turn being the teller.
7. For the first couple of times don't let anyone ask any questions. It is completely the job of the teller to make sure everyone can make the same block constructions.
8. After a few tries, let the listeners ask the teller questions. Emphasize that now the listeners have a responsibility to make sure they get it right. It's no longer only up to the teller. If they have their blocks set up wrong now, they might not have asked a question when they should have.

This is a great activity and it really shows how hard it is to communicate with someone. It does a great job at pointing out assumptions and showing how careful and detailed you have to be with your instructions. It also shows that the listener has an important role to play. The listener must be very careful not to make assumptions and to be sure to take responsibility for what they are hearing by asking good questions.

One more thing this activity does is show how important definitions are to good communication. When I do this activity with my groups, I do it a few times and then take the time to point out some of the definitions the group has been using. For example, when they call one block the red square everyone knows which block that is. I also point out where a definition can come in handy.

For example "Stand the blue block on its side." Well, which side? Long side, short side, fat side… how do you know? At this point, I take the time with the group to create definitions. "Okay, so when we say long side that always means this side of this block." As you do this activity, you'll see where assumptions are made and definitions can come in handy. In science, good definitions are vital. If somebody says, "I put the apparatus one meter from the ping pong ball." Everyone in the world knows how far a meter is. There is a standard for meters, inches, cups, liters, ohms, joules and all sorts of measurements. Without good definitions no one would know what anyone was talking about!

Well, I hope I was able to communicate how important and how difficult it is to have good communication. Whenever you write something, read something, say something or hear something, be very careful to make sure you're not assuming something. Try to make sure your listener truly hears what you're saying, and vice versa, try to make sure you're hearing what someone's telling you.

We've spend a lot of time exploring all the 'ins' and 'outs' of the scientific method – you should be very comfortable with using it by now. So, let me know you how it's totally possible to do the scientific method on a whiz-bang experiment like the one on the next page. I've included not only the procedures for how to do the experiment, but also a sample written report, exhibit board, oral presentation tips, and everything you need in case you'd want to enter this one in a competition. Enjoy!

# Use the Scientific Method with Magnets

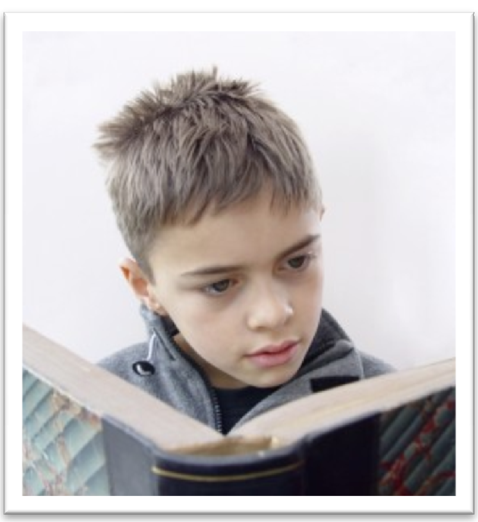
**Before we start diving into experimenting, researching, or even writing about the project, we first need to get a general overview of what the topic is all about. Here's a quick snippet about the science of magnetism.**

There are two ways to create a magnetic field. First, you can wrap wire around a nail and attach the ends of the wire to a battery to make an electromagnet. When you connect the battery to the wires, current begins to flow, creating a magnetic field. However, the magnets that stick to your fridge are neither moving nor plugged into the electrical outlet… which leads to the second way to make a magnetic field: by rubbing a nail with a magnet to line up the electron spin. You can essential "choreograph" the way an electron spins around the atom to increase the magnetic field of the material.

There are several different types of magnets. Permanent magnets are materials that stay magnetized, no matter what you do to it… even if you whack it on the floor (which you can do with a magnetized nail to demagnetize it). You can temporarily magnetize certain materials, such as iron, nickel, and cobalt. And an electromagnet is basically a magnet that you can switch on and off and reverse the north and south poles.

The strength of a magnetic field is measured in "Gauss". The Earth's magnetic field measures 0.5 Gauss. Typical refrigerator magnets are 50 Gauss. Neodymium magnets (like the ones we're going to use in this project) measure at 2,000 Gauss. The largest magnetic fields have been found around distant magnetars (neutron stars with extremely powerful magnetic fields), measuring at 10,000,000,000,000,000 Gauss. (A neutron star is what's left over from certain types of supernovae, and typically the size of Manhattan.)

Linear accelerators (also known as *linacs*) use different methods to move particles to very high speeds. One way is through *induction*, which is basically a pulsed electromagnet. We're going to use a slow input speed and strong magnets and multiply the magnetic and momentum effect to generate a high output speed.



One of the biggest challenges with super-strong magnets (like neodymium) is keeping them from smacking into each other and shattering. Although these rare-earth magnets are super-strong, they are also super-brittle. You'll need to become familiar with how to place your magnets on the table so you don't accidentally knock one into the other.

When designing your experiment, you'll need to pay close attention to the finer details such as the spacing between the magnets, size and shape of the magnets, and the size of the ball bearings.
**Your first step:** Doing Research. *Why* do you want to do this project? What originally got you interested a gauss rifle or linear accelerator? Is it the idea of smacking together high-speed objects? Or does the name of the project just *sound* cool? Do you like the idea of putting a small amount of energy into a system and getting *big* results?

Take a walk to your local library, flip through magazines, and surf online for information you can find about magnetism, including information about the element *neodymium*, James Maxwell, electromagnetism, and where magnetism comes from. Learn what other people have already figured out before you start re-inventing the wheel!

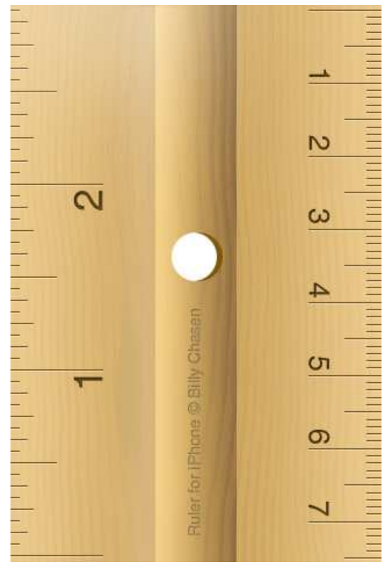
Flip open your science journal and write down things you've find out. Your journal is just for you, so don't be shy about jotting ideas or interesting tidbits down. Also keep track of which books you found interesting. You'll need these titles later in case you need to refer back for something, and also for your bibliography, which needs to have at least three sources that are not from the internet.

**Your next step:** Define what it is that you really want to do. In this project, we're going to walk you step by step through creating a hand held linear accelerator (or gauss rifle) made entirely out of easy-to-find parts. Go shopping and get all your equipment together now. Be VERY careful with the magnets – don't let them snap together or *they will break*! ***These magnets are super-strong, but also super-brittle!***

## Linear Accelerator (Gauss Rifle) Experiment: Materials List

Before we start experimenting, you'll need to gather items that may not be around your house right now. Take a minute to take inventory of what you already have and what you'll need.

- Wood or plastic ruler with a groove down the center
- Thick rubber bands or strong, super-sticky tape
- Four super-strong magnets (try 12mm or ½" neodymium magnets) – order online from our website for $10 – we'll show you where to order.
- Nine steel ball bearings (1/2", 5/8", or other sizes) – You can order these online for $4 – we'll show you how.
- Camera to document project
- Composition or spiral-bound notebook to take notes
- Display board (the three-panel kind with wings), about 48" wide by 36" tall
- Paper for the printer (and photo paper for printing out your photos from the camera)
- Computer and printer




## Linear Accelerator Experiment: How to Do the Scientific Method

**Playing with the experiment:** It's time to build your gauss rifle. This should take you anywhere between 10-15 minutes. Go watch the video and learn how to build a gauss rifle, and play with it a bit to get the feel for how it works. Here's a direct link to the video: http://www.superchargedscience.com/media/gauss-rifle.wmv

**Formulate your Question or Hypothesis:** You'll need to nail down ONE question or statement you want to test. Be careful with this experiment - you can easily have several variables running around and messing up your data if you're not careful. Here are a few possible questions:

- "Which size ball bearing gives the fastest output speed?"
- "Do rare earth magnets work better than iron, nickel, or cobalt magnets?"
- "Does magnet position matter?"
- "Which sizes of magnets work best?"
- "Does it matter if the magnets are hot, warm, cold, or frozen?"
- "How many magnets does it take for the final ball to reach 10 feet per second (7 mph)?"
- "What is the optimum distance for the first ball for maximum speed on the last ball?"
- "How does the angle of the rifle affect the output speed?"

Once you've got your question, you'll need to identify the *variable.* For the question: *"Which input distance gives the highest output speed?"*, your variable is the amount of distance from the first ball to the first magnet, keeping everything else constant (spacing between magnets, types of balls, size of balls and magnets, angle of the rifle, temperature of magnets, etc...)

If you wanted to ask the question: "Does it matter how powerful the magnet is?", your hypothesis might be: *"A magnet twice the size (or magnetic strength) will generate twice the output speed."*

You could also change the distance between the magnets. Your hypothesis might be: "Increasing the spacing between the magnets increases the output speed (of the last ball)."

For testing the angle of the rifle, you could try several different angles (using a protractor to measure accurately). You can also double the length of the linac by increasing the number of magnets to eight instead of the original four.

**Taking Data:** An example of *how* to record your data:
Question *"Which input distance gives the highest output speed?"*
Hypothesis: *"I think 24 mm away will give the fastest output speed."*

Here's how to record data. Grab a sheet of paper, and across the top, write down your background information, such as your name, date, time of day, type and size of magnets (including magnetic field strength information, if you have it), ball bearing type and diameter, ruler size, and anything else you'd need to know if you wanted to repeat this experiment *exactly* the same way on a different day. Include a photograph of your invention also, so you'll see exactly what your project looks like.

Get your paper ready to take data… and write across your paper these column headers, including the things in ( ): (Note – there's a sample data sheet following this section).

- Trial #
- Input distance (distance between first ball and first magnet) – the independent variable
- Output distance (meters or feet) – the dependent variable
- Time to travel 2m or 6 feet (seconds) – dependent variable
- Output speed (meter/second or feet/second) – a calculated dependent variable

Be sure to run your experiment a few times before taking actual data, to be sure you've got everything running smoothly. Have someone snap a photo of you getting ready to test, to enter later onto your display board. Place two parallel lines of tape on the ground 6' or 2m apart, so you can clock the time it takes the ball to travel a set distance. You will use this later to calculate your average output speed.

Record the first trial – say, at 3mm (or 1"). Place your ball 3mm from the first magnet, line up the end of the ruler with the taped 'start line'. Get your stopwatch ready and when you're set, fire away! Clock the time it takes for the ball to travel 6' (or 2m), and measure the total distance the ball traveled. Record both in your data log. Run your experiment again and again, increasing the spacing by 3mm (or 1") each time for at least 8 trials.

**Analyze your data.** Time to take a hard look at your numbers! What did you find? Does your data support your original hypothesis, or not?

Make yourself a grid (or use graph paper), and plot the *Distance Traveled* versus the *Input Distance*. In this case, the *Input Distance* goes on the horizontal axis (independent variable), and *Distance Traveled* (dependent variable) goes on the vertical axis. You can also make another graph showing *Output Speed* (vertical) and *Input Distance* (horizontal).

Using a computer, enter in your data into an Excel spreadsheet and plot a scatter graph. Label your axes and add a title.

**Conclusion:** So - what did you find out? What is the best input distance to use? Which type of magnets gave the furthest distance? Does a larger magnet give higher speeds? Is it what you originally guessed? Science is one of the only fields where people actually *throw a party* when stuff works out differently than they expected! Scientists are investigators, and they get *really* excited when they get to scratch their heads and learn something new.

*Hot Tip on Being a Cool Scientist* One of the biggest mistakes you can ever make is to fudge your data so it matches what you wanted to have happen. Don't *ever* be tempted to do this… science is based on observational fact. Think of it this way: the laws of the universe are still working, and it's your chance to learn something new!

**Recommendations:** This is where you need to come up with a few ideas for further experimentation. If someone else was to take your results and data, and wanted to do more with it, what would they do? Here are a few spins on the original experiment:

- Vary the length of the linac
- Change the size of the magnets
- Change the size of the ball bearings
- Try electromagnets instead of neodymium (NIB) magnets

**Make the display board.** Fire up the computer, stick paper in the printer, and print out the stuff you need for your science board. Here are the highlights:

- Catchy Title: This should encompass your basic question (or hypothesis).
- Purpose and Introduction: Why study this topic?
- Results and Analysis (You can use your actual data sheet if it's neat enough, otherwise print one out.)
- Methods & Materials: What did you use and how did you do it? (Print out photos of you and your experiment.)
- Conclusion: One sentence tells all. What did you find out?
- Recommendations: For further study.
- References: Who else has done work like this?

**Outline your presentation.** People are going to want to see you demonstrate your project, and you'll need to be prepared to answer any questions they have. We'll detail more of this in the later section of this guidebook, but the main idea is to talk about the different sections of your display board in a friendly, knowledgeable way that gets your point across quickly and easily. Test drive your presentation on friends and relatives beforehand and you'll be smoothly polished for the big day.

# Gauss Rifle/Linear Accelerator

Name Size/Type of Magnet
Date Size/Type of Ball Bearing
Time Number of Magnets

| Trial # | Input Distance | Time to Travel 2m | Output Distance Traveled | Calculated Average Speed |
|---|---|---|---|---|
| | (mm) | (seconds) | (meters) | (meters / second) |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |

Create this table yourself using Microsoft Excel. You can download your free copy at this link:
*http://www.ability-usa.com/download.php*

OR...download your free 60-day trail copy from Microsoft at this link:
*http://office.microsoft.com/en-us/excel/default.aspx*

# Linear Accelerator Experiment: Sample Report

In this next section, we've written a sample report for you to look over and use as a guide. Be sure to insert your own words, data, and ideas in addition to charts, photos, and models!

# Title of Project

(Your title can be catchy and clever, but make sure it is as descriptively accurate as possible. Center and make your title the LARGEST font on the page.)

by Aurora Lipper

123 Main Street,
Sacramento, CA 10101

Carmel Valley Grade School
6th grade

# Table of Contents

# Abstract

**This is a *summary* of your entire project. Always write this section LAST, as you need to include a brief description of your background research, hypothesis, materials, experiment setup and procedure, results, and conclusions. Keep it short, concise, and less than 250 words.**

***Here's a sample from Aurora's report:***

**Which drop height generates the fastest bullet speed?** After researching electromagnetism, rare earth elements, magnetic fields, electron spin, induction, and ferromagnetic materials, I realized I had all the basics for making a hand-held linear accelerator (linac). But which initial ball distance gives the fastest output speed?

I hypothesized that the further distances give the fastest speeds. My best guess is that the 24mm drop distance will generate the fastest output ball bearing speed. After finding inexpensive neodymium-iron-boron (NIB) magnets and steel ball bearings from the hardware store, I created a hand-held linac that could fire ball bearings across the room. I ran ten trials varying the initial drop distance and measured both the output distance traveled and time to travel a set distance (for calculating average velocity).

I found that my initial hypothesis of the greatest drop distance generating the fastest output speeds was in fact supported by the data. **The gauss rifle had the highest speed (0.87 meters/second) with a drop distance of 24 mm.**

For further study, I recommend running an experiment to test the various sizes of magnets and also another test for optimum ball bearing sizes. This experiment was a lot of fun!

# Introduction/Research

**This is where all your background research goes. When you initially wrote in your science journal, what did you find out? Write down a few paragraphs about interesting things you learned that eventually led up to your main hypothesis (or question).**

*Here is a sample from Aurora's report:*

There are two ways to create a magnetic field. First, you can wrap wire around a nail and attach the ends of the wire to a battery to make an electromagnet. When you connect the battery to the wires, current begins to flow, creating a magnetic field. However, the magnets that stick to your fridge are neither moving nor plugged into the electrical outlet… which leads to the second way to make a magnetic field: by rubbing a nail with a magnet to line up the electron spin. You can essential "choreograph" the way an electron spins around the atom to increase the magnetic field of the material.

There are several different types of magnets. Permanent magnets are materials that stay magnetized, no matter what you do to it… even if you whack it on the floor (which you can do with a magnetized nail to demagnetize it). You can temporarily magnetize certain materials, such as iron, nickel, and cobalt. And an electromagnet is basically a magnet that you can switch on and off and reverse the north and south poles.

The strength of a magnetic field is measured in "Gauss". The Earth's magnetic field measures 0.5 Gauss. Typical refrigerator magnets are 50 Gauss. Neodymium magnets (like the ones we're going to use in this project) measure at 2,000 Gauss. The largest magnetic fields have been found around distant magnetars (neutron stars with extremely powerful magnetic fields), measuring at 10,000,000,000,000,000 Gauss. (A neutron star is what's left over from certain types of supernovae, and typically the size of Manhattan.)

Linear accelerators (also known as a *linac*) use different methods to move particles to very high speeds. One way is through *induction*, which is basically a pulsed electromagnet. I'm going to use a slow input speed and strong magnets and multiply the effect to generate a high output speed. Does it really matter *where* I start the input ball bearing on the gauss rifle? If so, does it matter *much*?

# Purpose

**Why are you doing this science fair project at all? What got you interested in this topic? How can you use what you learn here in the future? Why is this important to you?**

Come up with your own story and ideas about why you're interested in this topic. Write a few sentences to a few paragraphs in this section.

# Hypothesis

**This is where you write down your speculation about the project – what you think will happen when you run your experiment. Be sure to include *why* you came up with this educated guess. Be sure to write at least two full sentences.**

*Here's a sample from Aurora's report:*
I hypothesized that the further drop distances give the fastest speeds. My best guess is that the 24mm distance between the first ball bearing and the first magnet will generate the fastest output ball bearing speed.

# Materials

**What did you use to do your project? Make sure you list *everything* you used, even equipment you measured with (rulers, stopwatch, etc.) If you need specific amounts of materials, make sure you list those, too! Check with your school to see which unit system you should use. (Metric or SI = millimeters, meters, kilograms. English or US = inches, feet, pounds.)**

*Here's a sample from Aurora's report:*

- Wood or plastic ruler with a groove down the center
- Thick rubber bands or strong, super-sticky tape
- Four super-strong magnets (try 12mm or ½" neodymium magnets)
- Nine steel ball bearings (1/2", 5/8", or other sizes)
- Camera to document project
- Composition or spiral-bound notebook to take notes
- Display board (the three-panel kind with wings), about 48" wide by 36" tall
- Paper for the printer (and photo paper for printing out your photos from the camera)
- Computer and printer

# Procedures

**This is the place to write a highly detailed description of what you did to perform your experiment. Write this as if you were telling someone else how to do your exact experiment and reproduce the same results you achieved. If you think you're overdoing the detail, you're probably just at the right level. Diagrams, photos, etc. are a great addition (NOT a substitution) to writing your description.**

*Here's a sample from Aurora's report:*
First, I became familiar with the experiment and setup. I build the gauss rifle and tested out different spacing distances between the magnets, getting a better idea of what I could expect from this experiment. Once I was comfortable with the setup, I could now focus on my variable (drop distance) and how to measure my results (speed and time). I found it difficult to measure the time it took the last ball to travel any distance shorter than 2 meters, so I set the start and finish lines to this minimum 2 meter distance.

I made myself a data logger in my science journal. I placed the ball bearings between the magnets and found a friend to clock the time for me. I dropped the first ball a distance of 3mm from the first magnet, clocked the distance to travel 2 meters, and waited for the ball to reach a stop across a smooth tile floor. I measured the distance and read off the time, recording both in my data sheet. I continued this process, increasing the drop distance by 3mm for each trial.

# Results

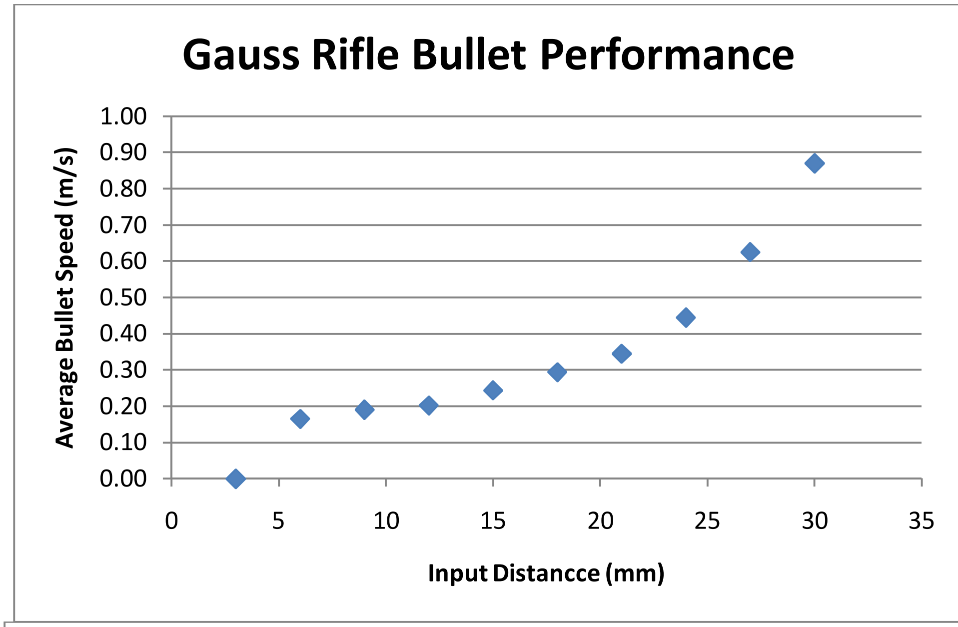
**This is the data you logged in your Science Journal. Include a chart or graph – whichever suits your data the best, or both if that works for you. Use a scatter or bar graph, label the axes with units, and title the graph with something more descriptive than "Y vs. X or Y as a function of X". On the vertical (y-axis) goes your dependent variable (the one you recorded), and the horizontal (x-axis) holds the independent variable (the one you changed).**

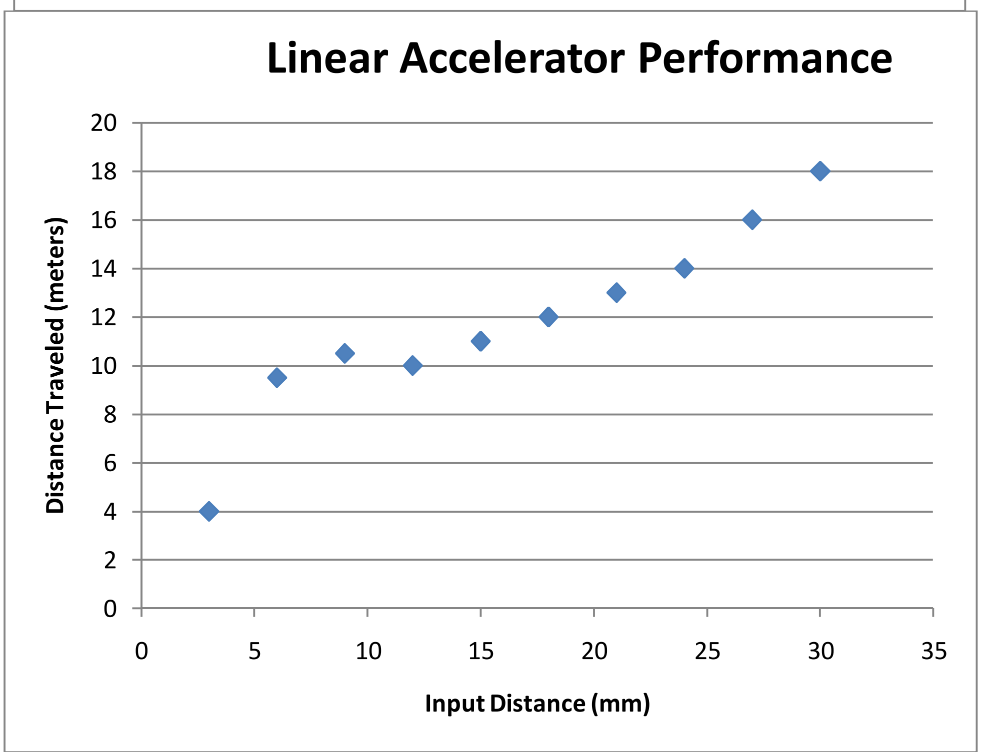
## Gauss Rifle/Linear Accelerator

| | | | |
|---|---|---|---|
| Name | *Aurora Lipper* | Magnet: | *Four 1/2" NIB magnets* |
| Date | *Nov. 12, 2009* | Ball Bearing: | *Nine 5/8" steel ball bearings* |
| Time | *12:09 PM* | | |

| Trial # | Input Distance | Time to Travel 2m | Output Distance Traveled | Calculated Average Speed |
|---|---|---|---|---|
| | (mm) | (seconds) | (meters) | (m/s) |
| 1 | 3 | stopped at 4m | 4 | 0.00 |
| 2 | 6 | 12.1 | 9.5 | 0.17 |
| 3 | 9 | 10.5 | 10.5 | 0.19 |
| 4 | 12 | 9.9 | 10 | 0.20 |
| 5 | 15 | 8.2 | 11 | 0.24 |
| 6 | 18 | 6.8 | 12 | 0.29 |
| 7 | 21 | 5.8 | 13 | 0.34 |
| 8 | 24 | 4.5 | 14 | 0.44 |
| 9 | 27 | 3.2 | 16 | 0.63 |
| 10 | 30 | 2.3 | 18 | 0.87 |

***NOTE: The numbers above are NOT real! Be sure to input your own.***




***NOTE: The numbers above are NOT real! Be sure to input your own.***

# Conclusion

**Conclusions are the place to state what you found.  Compare your results with your initial hypothesis or question – do your results support or not support your hypothesis?  Avoid using the words "right", "wrong", and "prove" here.   Instead, focus on what problems you ran into as well as why (or why not) your data supported (not supported) your initial hypothesis.  Are there any places you may have made mistakes or not done a careful job?  How could you improve this for next time?  Don't be shy – let everyone know what you learned!**

***Here's a sample from Aurora's report:***
I found that my initial hypothesis of the greatest drop distance generating the fastest output speeds was in fact supported by the data. **The gauss rifle had the highest speed (0.87 meters/second) with a drop distance of 24 mm.**

For further study, I recommend running an experiment to test the various sizes of magnets and also another test for optimum ball bearing sizes.  It was difficult to measure the time distance because the rifle engaged so quickly.  I did not have absolute control over the floor conditions, and sometimes the ball bearings would hit a piece of dirt and change course.  Next time, I'd recommend bringing a broom.

# Bibliography

**Every source of information you collected and used for your project gets listed here. Most of the time, people like to see at least five sources of information listed, with a maximum of two being from the internet. If you're short on sources, don't forget to look through magazines, books, encyclopedias, journals, newsletters… and you can also list personal interviews.**

***Here's an example from Aurora's report on Rocketry:***
*(The first four are book references, and the last one is a journal reference.)*


Fox, McDonald, Pritchard. Introduction to Fluid Mechanics, Wiley, 2005.

Hickam, Homer. Rocket Boys, Dell Publishing, 1998.

Gurstelle, William. Backyard Ballistics, Chicago Review Press, 2001.

Turner, Martin. Rocket and Spacecraft Propulsion. Springer Praxis Books, 2001.

Eisfeld, Rainer. "The Life of Wernher von Braun." Journal of Military History Vol 70 No. 4. October 2006: 1177-1178.

# Acknowledgements

**This is your big change to thank anyone and everyone who have helped you with your science fair project. Don't forget about parents, siblings, teachers, helpers, assistants, friends…**

**Formatting notes for your report:** Keep it straight and simple: 12 point font in Times new Roman, margins set at 1" on each side, single or 1.5 spaced, label all pages with a number and total number of pages (see bottom of page for sample), and put standard information in the header or footer on every page in case the report gets mixed up in the shuffle (but if you bind your report, you won't need to worry about this). Create the table of contents at the end of the report, so you can insert the correct page numbers when you're finished.
Add a photo of your experiment in action to the title page for a dynamic front page!

## Linear Accelerator Experiment: Exhibit Display Board

Your display board holds the key to communicating your science project quickly and efficiently with others.  You'll need to find a tri-fold cardboard or foam-core board with three panels or "wings" on both sides.  The board, when outstretched, measures three feet high and four feet long.

Your display board contains *all* the different parts of your report (research, abstract, hypothesis, experiment, results, conclusion, etc.), so it's important to write the report *first*. Once you've completed your report, you'll take the best parts of each section and print it out in a format that's easy to read and understand.  You'll need to present your information in a way that people can stroll by and not only get hooked into learning more, but can easily figure out what you're trying to explain. Organize the information the way museums do, or even magazines or newspapers.

**How to Write for your Display Board** Clarity and neatness are your top tips to keep in mind. The only reason for having a board is to communicate your work with the rest of the world. Here are the simple steps you need to know:

Using your computer, create text for your board from your different report sections.  You'll need to write text for the title, a purpose statement, an abstract, your hypothesis, the procedure, data and results with charts, graphs, analysis, and your conclusions.  And the best part is - it's all in your report!  All you need to do is copy the words and paste into a fresh document so you can play with the formatting.

The title of your project stands out at the very top, and can even have its own 'shingle' propped up above the display board.  The title should be in Times New Roman or Arial, at least 60 pt font...  something strong, bold, and easy to read from across the room.  The title has to accurately describe your experiment *and* grab people's attention.  Here are some ideas to get you started:

- Gauss Rifle: Small Input Speed Yields BIG Output Speeds
- Handheld Linear Accelerators: Studying the Effect of Temperature on Induction
- Linacs: Just Where Should You Place the Magnets without Losing Power?
- How to Turn Magnets into Power: Investigating the Effects of Magnet Spacing

On the left panel at the top, place your abstract in 16-18 pt font.  Underneath, post your purpose, followed by your hypothesis in 24 point font.  Your list of materials or background research can go at the bottom section of the left panel. If you're cramped for space, put the purpose in the center of the board under the title.

In the central portion of the board, post your title in large lettering (24-60 pt. font).  (You can alternatively make the title on a separate board and attach to the top of the display board… which is *great* if you really want to stand out!)  Under the title, write a one-sentence description of what your project is really about in smaller font size (24-48 pt. font) Under the title, you'll need to include highlights from your background research (if you haven't put it on the left panel already) as well as your experimental setup and procedures. Use photos to help describe your process.

The right panel holds your results with prominent graphs and/or charts, and clear and concise conclusions. You can add tips for further study (recommendations) and acknowledgements beneath the conclusions in addition to your name, school, and even a photo of yourself doing your project.

Use white copy paper (*not* glossy, or you'll have a glare problem) and 18 point Times New Roman, Arial, or Verdana font. Although this seems obvious, spell-check and grammar-check each sentence, as sometimes the computer does make mistakes! Cardstock (instead of white copy paper) won't wrinkle in areas of high humidity.

Cut out each description neatly and frame with different colored paper (place a slightly larger piece of paper behind the white paper and glue in place. Trim border after the glue has dried. Use small amounts of white glue or hot glue in the corners of each sheet, or tape together with double-sided sticky tape. Before you glue the framed text descriptions to your board, arrange them in different patterns to find the best one that works for your work. Make sure to test out the position of the titles, photos, and text together before gluing into place!

In addition to words, be sure to post as many photos as is pleasing to the eye and also helps get your point across to an audience. The best photos are of *you* taking real data, doing real science. Keep the pictures clean, neat, and with a matte finish. Photos look great when bordered with different colored paper (stick a slightly larger piece of paper behind the photo for a framing effect). If you want to add a caption, print the caption on a sheet of white paper, cut it out, and place it near the top or bottom edge of the photo, so your audience clearly can tell which photo the caption belongs to. Don't add text directly to your photo (like in Photoshop), as photos are rich in color, and text requires a solid color background for proper reading.

Check over your board as you work and see if your display makes a clear statement of your hypothesis or question, the background (research) behind your experiment, the experimental method itself, and a clear and compelling statement of your results (conclusion). Select the text you write with care, making sure to add in charts, graphics, and photos where you need to in order to get your point across as efficiently as possible. Test drive your board on unsuspecting friends and relatives to see if they can tell you what your project is about by just reading over your display board.

**How to Stand Out in a Crowd** Ever try to decide on a new brand of cereal? Which box do you choose? All the boxes are competing for your attention… and out of about a hundred, you pick *one*. This is how your board is going to look to the rest of the audience – as just one of the crowd. So, how do you stand out and get noticed?

First, make sure you have a BIG title – something that can be clearly seen from across the room. Use color to add flair without being too gaudy. Pick two colors to be your "color scheme", adding a third for highlights. For example, a black/red/gold theme would look like: a black cardboard display board with text boxes framed with red, and a title bar with a black background with red lettering highlighted with gold (using two sets of "sticky" letters offset from each other). Or a blue/yellow scheme might look like: royal blue foam core display board with textboxes framed with strong yellow. Add color photographs and color charts for depth. Don't forget that the white in your textboxes is going to add to your color scheme, too, so you'll need to balance the color out with a few darker shades as you go along.

It's important to note that while stars, glitter, and sparkles may attract the eye, they may also detract from displaying that you are about 'real science'. Keep a professional look to your display as you play with colors and shades. If you add something to your board, make sure it's there to help the viewer get a better feel for your work.

For a gauss rifle exhibit, you can add sparks of electricity and magnets up the edges of your display board and around the top of your board in gold or blue. Add a spare rifle at the top of your board as an attention-getter. Have the rifle working on display so people can see your experiment in action.

If you're stuck for ideas, here are a few that you might be able to use for your display board. Be sure to check with your local science fair regulations, to be sure these ideas are allowed on your board:

- Your name and photo of yourself taking data on the display board
- Captions that include the source for every picture or image
- Acknowledgements of people who helped you in the lower right panel
- Your scientific journal or engineer's notebook
- The experimental equipment used to take data and do real science
- Photo album of your progress (captions with each photo)

## Linear Accelerator Experiment: Oral Presentation

You're now the expert of the Gauss Rifle Science Experiment… you've researched the topic, thought up a question, formulated a hypothesis, done the experiment, worked through challenges, taken data, finalized your results into conclusions, written the report, and build a display board worthy of a museum exhibit. Now all you need is to prep for the questions people are going to ask. There are two main types of presentations: one for the casual observer, and one for the judges.

**The Informal Talk** In the first case, you'll need quick and easy answers for the people who stroll by and ask, "What's this about?" The answers to these questions are short and straight-forward – they don't want a highly detailed explanation, just something to appease their curiosity. Remember that people learn new ideas quickly when you can relate it to something they already know or have experience with. And if you can do it elegantly through a story, it will come off as polished and professional.

**The Formal Presentation** The second talk is the one you'll need to spend time on. This is the place where you need to talk about everything in your report without putting the judges to sleep. Remember, they're hearing from tons of kids all day long. The more interesting you are, the more memorable you'll be.

*Tips & Tricks for Presentations:* Be sure to include professionalism, clarity, neatness, and 'real-ness' in your presentation of the project. You want to show the judges how you did 'real' science – you had a question you wanted answered, you found out all you could about the topic, you planned a project around a basic question, you observed what happened and figured out a conclusion.

Referring back to your written report, write down the highlights from each section onto an index card. (You should have one card for each section.) What's the most important idea you want the judges to realize in each section? Here's an example:

**Research Card: Which drop height generates the fastest bullet speed?** After researching electromagnetism, rare earth elements, magnetic fields, electron spin, induction, and ferromagnetic materials, I realized I had all the basics for making a hand-held linear accelerator (linac). But which initial ball distance gives the fastest output speed?

**Question/Hypothesis Card:** I hypothesized that the further distances give the fastest speeds. My best guess is that the 24mm drop distance will generate the fastest output ball bearing speed.

**Procedure/Experiment Card:** After finding inexpensive neodymium-iron-boron (NIB) magnets and steel ball bearings from the hardware store, I created a hand-held linac that could fire ball bearings across the room. I ran ten trials varying the initial drop distance and measured both the output distance traveled and time to travel a set distance (for calculating average velocity).

**Results/Conclusion Card:** I found that my initial hypothesis of the greatest drop distance generating the fastest output speeds was in fact supported by the data. **The gauss rifle had the highest speed (0.87 meters/second) with a drop distance of 24 mm.**

**Recommendations Card:** For further study, I recommend running an experiment to test the various sizes of magnets and also another test for optimum ball bearing sizes. This experiment was a lot of fun!

**Acknowledgements Card:** I want to express my thanks to mom for clearing out the kitchen so I could have enough floor space for testing, for my teacher who encourages me to go further than I really think I can go, for my friends for helping chase the balls down, and for dad for helping me unstuck the magnets when I knocked them together accidentally.

---

**Putting it all together…** Did you notice how the content of the cards were already in your report, in the abstract section? The written report is such a vital piece to your science fair project, and by writing it first, it makes the rest of the work a lot easier. You can do the tougher pieces (like the oral presentation) later because you took care of the report upstream.

As you practice your oral presentation, try to get your notes down to only one index card. Shuffling through papers onstage detracts from your clean, professional look. While you don't need to memorize exactly what you're going to say, you certainly can speak with confidence because you've done every step of this project yourself.

**You're done! Congratulations!!** Be sure to take lots of photos, and send us one! We'd love to see what you've done and how you've done it. If you have any suggestions, comments, or feedback, let us know! We're a small company staffed entirely human beings, and we're happy to help you strive higher!