Light Speed Science Fair Project

Project Guidebook

By Aurora Lipper

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How to Use This Book:

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 fair project! Whether you're looking to blow away the competition or happy just get a decent grade, you've got the keys to a successful science fair project in your hands right now. The tools you'll find in this manual answer the basic question: **"How can I create a science fair project and enjoy the process?"**

We're going to walk step-by-step through every aspect of creating a science fair project 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.

Who am I? My name is Aurora, and I am a mechanical engineer, university instructor, airplane pilot, astronomer, and I worked for NASA during high school and college. I have a BS and MS in mechanical engineering, and for the past decade have toured the country getting kids wildly excited about doing *real* science.

What do the kids I teach learn? After a day or two, my students are building working radios from toilet paper tubes, laser light show from tupperware, and real robots from junk. And they're crazy-wild excited about doing it.

One of the problems kids have, however, is taking their idea and fitting it into something acceptable by science fairs or other technical competitions designed to get kids thinking like a real scientist.

Another problem kids often face is applying the scientific method to their science project. Although the scientific method is not the primary method of investigation by industry, it *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 aren't really ready for. And from my research, there isn't a whole lot of information available on how to do it by the people who really know how.

This report is designed to show you how to do a cool project, 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!

Materials List

Before we start, 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.

- Ruler for measuring
- Large (dark, milk, and white) chocolate bar, two raw eggs, mini and big marshmallows, cheese and crackers, bread and butter, chocolate chips, and anything else that melts easily in the microwave
- Microwave
- Calculator, pencil
- 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

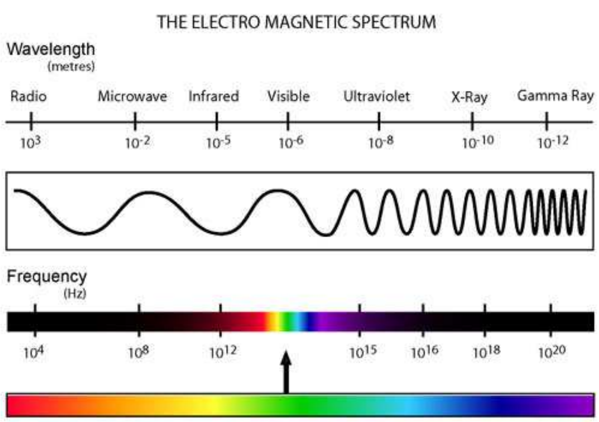
Create a Science Fair Project with Light Waves

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 light, which is really the science of the electromagnetic spectrum.

Imagine tossing a rock into a still pond and watching the circles of ripples form and spread out into rings. Now look at the ripples in the water… notice how they spread out. What makes the ripples move outward is *energy*, and there are different kinds of energy, such as electrical (like the stuff from your wall socket), mechanical (when you shove someone), and others.

The ripples are like light. Notice the waves are not really moving the water from one side of the pond to the other, but rather move energy across the surface of the water. To put it another way, energy travels across the pond in a wave. Light works the same way – light travels as energy waves. Only light doesn't need water to travel through the way the water waves do… it can travel through a vacuum (like outer space).

Light can change speed the same way sound vibrations change speed. (Think of how your voice changes when you inhale helium and then try to talk.) The "speed limit" of light is 186,000 miles per second – that's fast enough to circle the Earth seven times every second, but that's also inside a vacuum. You can get light going slower by aiming it through different gases. In our own atmosphere, light travels slower than it does in space.



Point in the diagram (image left) where the "visible light" section is, indicated by the arrow. This small area shows the light that you can actually see with your eyeballs. Note that the "rainbow of colors" that make up our entire visible world only make up a small part of all the light zooming around the countryside. That means you're constantly being smacking into by waves of all kinds… and you may not even know it. (Sun block, anyone?)

Our eyeballs can see in the 400-700 nm (nanometer) range, which is only a small part of the entire spectrum of light… so we need special detectors to find the rest of the photons zipping around. Radio signals are picked up using an antenna (similar to your satellite dish in the backyard). X-rays are more difficult to detect, because they would rather go *through* the detector than bounce off of it, so we use complicated mathematics and the shadows of the photons to "see" x-rays. Gamma rays are the toughest to detect – they are *very* highly energized packets of light that would rather zoom through mirrors than be detected.

The waves in the electromagnetic spectrum that carry low amounts of energy (radio and microwave) are low frequency and long wavelength. One radio wave can be the size of a football field! The higher amounts of energy (gamma and x-ray) are carried by the short wavelengths and higher frequencies.

So, how does light heat up food? When you warm up leftovers, have you ever wondered why the microwave heats the food and not the plate? (Well, some plates, anyway.) It has to do with the way microwave ovens work.

Microwave ovens use dielectric heating (or high frequency heating) to heat your food. Basically, the microwave oven shoots light beams that are tuned to excite the water molecule. Foods that contain water will step up a notch in energy levels as heat. (The microwave radiation can also excite other polarized molecules in addition to the water molecule, which is why some plates also get hot.)

One of the biggest challenges with measuring the speed of light is that the photons move *fast…* too fast to watch with our eyeballs. So instead, we're going to watch the effects of microwave light and base our measurements on the effects the light has on different kinds of food. Light with a wavelength of 0.01 to 10 cm is in the microwave part of the electromagnetic spectrum. When designing your experiment, you'll need to pay close attention to the finer details such as the frequency of your microwave oven (found inside the door), where you place your food inside the oven, and how long you leave it in for.

Your first step: Doing Research. Why do you want to do this project? What originally got you interested light waves? Is it the idea of high-speed waves? Or does the name of the project just *sound* cool? Do you like the idea of finding the speed of light with a bar of chocolate?

Take a walk to your local library, flip through magazines, and surf online for information you can find about electromagnetic spectrum, frequency, wavelength, and how light travels in outer space. 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 measuring the speed of light right in your own kitchen, using only parts from the grocery store. Go shopping and gather your equipment together now, picking up a few extra chocolate bars so you can run a few trial runs before taking data. (*You'll be able to eat the chocolate after the experiment!)*

Playing with the experiment: First, you'll need to find the 'hot spots' in your microwave. Remove the turntable from your microwave and place a naked bar of chocolate on a plate inside the microwave. Make sure the chocolate bar is the BIG size – you'll need at least 7 inches of chocolate for this to work. Turn the microwave on and wait a few minutes until you see small parts of the chocolate bar start to bubble up, and then quickly open the door (it will start to smoke if you leave it in too long). Look carefully at the chocolate bar without touching the surface… you are looking for TWO hotspots, not just one – they will look like small volcano eruptions on the surface of the bar. If you don't have two, grab a fresh plate and chocolate bar and try again, changing the location of the place inside the microwave. You're looking for the place where the microwave light hits the chocolate bar in two spots so you can measure the distance between the spots. Those places are the peaks of the microwave light wave.

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 food gives the most accurate speed of light measurement?"
- "Does the power setting matter?"
- "Does dish location matter?"
- "Which type of chocolate gives the most accurate results?"
- "Does it matter if the food starts out as hot, warm, cold, or frozen?"

Once you've got your question, you'll need to identify the *variable.* For the question: *"Which food gives the most accurate speed of light measurement?"*, your variable is the type of food you are using, keeping everything else constant (plate location inside the microwave, temperature of food, etc...)

If you wanted to ask the question: "Does it matter how powerful the microwave is?", your hypothesis might be: *"A microwave twice the power will give the same light speed."*

For testing different kinds of microwave ovens, you could visit friends' houses and perform the same experiment over and over (keeping the type of food constant – always using a chocolate bar, for example).

Taking Data: An example of *how* to record your data:
Question *"Which food gives the most accurate speed of light measurement?"*
Hypothesis: "*I think a milk chocolate bar gives the most accurate speed of light measurement."*

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 frequency of microwave, 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.

Open up the door or look on the back of your microwave for the technical specifications. You're looking for a frequency in the 2,000-3,000 MHz range… usually about 2450 MHz. Write this number down at the top of your data sheet – this tells you the microwave radiation frequency that the oven produces, and will be used for calculating the speed of light.

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 #
- Food type – the independent variable
- Hotspot distance (inches or cm) – the dependent variable
- Speed of light (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.

When you're ready, pop in the first food type on a plate (without the turntable!) into the best spot in the microwave, and turn it on. Remove when both hotspots form, and being careful not to touch the surface of the food, measure the center-to-center distance using your ruler. Record the first trial in your data log. Run your experiment again and again, changing the food type each time for at least 8 trials.

TIP: If you're using mini-marshmallows or chocolate chips (or other smaller foods), you'll need to spread them out in an even layer on your plate so you don't miss a spot that could be your hotspot!

For older students: Also measure the furthest-edge to furthest-edge distance, which you can transform into your +/- error margins for your measurements.

How to Calculate the Speed of Light from your Data: Note that when you measure the distance between the hotspots, you are only measuring the peak-to-peak distance of the wave… which means you're only measuring *half* of the wave. We'll multiply this number by two to get the actual length of the wave. If you're using cm or inches, you'll also need to convert those to meters or miles.

1 inch = 2.54 cm
1 mile = 5,280 feet = 63,360 inches
1 meter = 100 cm

So, if you measure 2.1 inches between your hotspots, and you want to calculate the speed of light and compare to the published value which is in meters per second, here's what you do:

2,450 MHz is really 2,450,000,000 Hz or 2,450,000,000 cycles per 1 second

Find the length of the wave (in cm): 2 * 2.1 inches = 4.2 inches * 2.54 cm/inch = 10.67 cm

Convert cm to meters: 10.67 cm = 0.1067 m

Multiply the wavelength by the microwave oven frequency:
0.1067 m * 2,450,000,000 Hz = 261,400,000 m/s

Published value for light speed is 299,792,458 m/s = 186,000 miles/second = 671,000,000 mph

Enter in your data in excel and calculate the speed of light for each trial run.

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 *Speed of Light* versus the *Food Type*. In this case, the *Food Type* goes on the horizontal axis (independent variable), and *Speed of Light* (dependent variable) goes on the vertical axis. You can also make another graph showing *Hotspot Location* (vertical) and *Food Type* (horizontal).

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

Conclusion: So - what did you find out? What is the best food to use? Does it matter? Which type of microwaves gave the best results? Does a larger microwave give more hotspots? 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 food thickness
- Change the size of the microwave

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.

Sample Data Sheet

Measuring the Speed of Light

Name | Microwave Frequency

Date

Time

Trial #	Food Type	Hotspot Distance	Calculated Light Speed	% Difference
		(inches)	(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

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
6^{th} grade

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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 type of food most accurately measures the speed of light? After researching the electromagnetic spectrum, microwave ovens, frequency, wavelength, and substances that easily melt, I realized I had all the basics for measuring the speed of light. But which type of food would produce the best measurement results?

I hypothesized that the chocolate bar would have the smallest percent error when compared with the published value for the speed of light. My best guess is that a substance with a melting point near room temperature would be easiest to visualize the results needed for finding the hotspots in a microwave. After raiding the grocery store for chocolate bars, chocolate chips, marshmallows, butter, and cheese, I created a super-simple project for determining the speed of light by melting different substances in the microwave. I ran nine trials varying the type of food melted and measured the distance between the hotspots and calculated the speed of light using frequency information from the microwave oven itself.

I found that my initial hypothesis (chocolate gives the lowest percent error for measuring the speed of light) was supported by the date, but not in the way I expected. **White chocolate have the most accurate measurement (298,704,000 meters/second) with a difference of 0.36% from the published value.**

For further study, I recommend running an experiment to test the various types of microwaves, as well as testing different foods based on water content. This experiment was tasty and a whole 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:

Which type of food most accurately measures the speed of light? After researching the electromagnetic spectrum, microwave ovens, frequency, wavelength, and substances that easily melt, I realized I had all the basics for measuring the speed of light. But which type of food would produce the best measurement results?

Microwave ovens use dielectric heating (or high frequency heating) to heat your food. Basically, the microwave oven shoots light beams that are tuned to excite the water molecule. Foods that contain water will step up a notch in energy levels as heat. (The microwave radiation can also excite other polarized molecules in addition to the water molecule, which is why some plates also get hot.)

One of the biggest challenges with measuring the speed of light is that the photons move *fast…* too fast to watch with our eyeballs. So instead, I planned to watch the effects of microwave light and base the measurements on the effects the light has on different kinds of food. Light with a wavelength of 0.01 to 10 cm is in the microwave part of the electromagnetic spectrum.

When designing the experiment, I had to take into account the finer details, such as the frequency of the microwave oven (found inside the door), where I place your food inside the oven, and how long to leave it in for.

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 chocolate bar would have the smallest percent error when compared with the published value for the speed of light. My best guess is that a substance with a melting point near room temperature would be easiest to visualize the results needed for finding the hotspots in a microwave.

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:

- Ruler for measuring
- Large (dark, milk, and white) chocolate bar, two raw eggs, mini and big marshmallows, cheese and crackers, bread and butter, chocolate chips, and anything else that melts easily in the microwave
- Microwave
- Calculator, pencil
- 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. After raiding the grocery store for chocolate bars, chocolate chips, marshmallows, butter, and cheese, I created a super-simple project for determining the speed of light by melting different substances in the microwave. I ran nine trials varying the type of food melted and measured the distance between the hotspots and calculated the speed of light using frequency information from the microwave oven itself.

I made myself a data logger in my science journal. I placed the food in the perfect spot in the microwave oven such that two hotspots formed when turned on. As soon as the spots bubbled up, I quickly opened the door and measured the center-to-center distance and recorded it in my data sheet. I continued this process, testing different food types for each trial. I later transformed the half-wavelength information (hotspot measurement) into a speed of light calculation using the formula c = l f, where c = speed of light in m/s, l = wavelength in meters, and f = frequency in cycles per second.

Results

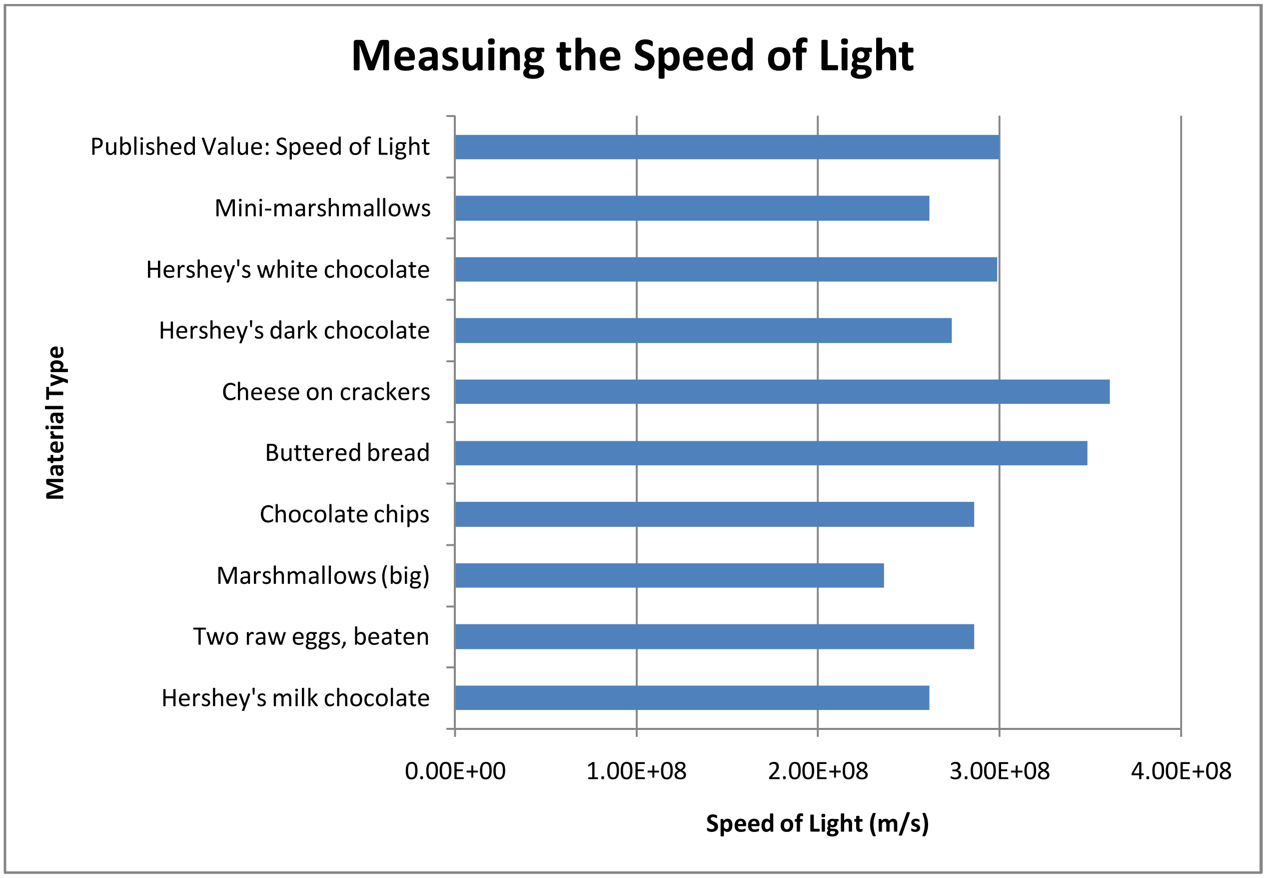
This is the data you logged in your Science Journal. Include a chart or graph – whichever suits your data the best, or both if that works for you. Use a scatter or bar graph, label the axes with units, and title the graph with something more descriptive than "Y vs. X or Y as a function of X". On the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

Measuring the Speed of Light

		Microwave	
Name	*Aurora Lipper*	Frequency	*2450 MHz*
Date	*Nov. 12, 2009*		
Time	*12:36pm*		

Trial #	Food Type	Hotspot Distance	Calculated Light Speed	% Difference
		(inches)	(meters / second)	
1	Hershey's milk chocolate	2.1	261,366,000	12.82
2	Two raw eggs, beaten	2.3	286,258,000	4.51
3	Marshmallows (big)	1.9	236,474,000	21.12
4	Chocolate chips	2.3	286,258,000	4.51
5	Buttered bread	2.8	348,488,000	16.24
6	Cheese on crackers	2.9	360,934,000	20.39
7	Hershey's dark chocolate	2.2	273,812,000	8.67
8	Hershey's white chocolate	2.4	298,704,000	0.36
9	Mini-marshmallows	2.1	261,366,000	12.82
10	White chocolate chips	2.3	286,258,000	4.51

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 (chocolate gives the lowest percent error for measuring the speed of light) was supported by the data, but not in the way I expected. **White chocolate has the most accurate measurement (298,704,000 meters/second) with a difference of 0.36% from the published value.**

For further study, I recommend running an experiment to test the various types of microwaves, as well as testing different foods based on water content. This experiment was tasty and a whole lot of fun!

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!

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:

- Light Speed: Measuring the speed of light using a chocolate bar.
- Microwave Radiation: Studying the Effect of Focused Power
- How to Turn Food into Scientific Instruments: Capturing Light Waves Using Microwave Radiation Hotspots

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 speed of light exhibit, you can add zooming photons or lightning up the edges of your display board and around the top of your board in gold or blue. Add a test specimen (something with hardened hopspots) at the top of your board as an attention-getter. Have a tiny microwave on display (if you're allowed to bring one in and plug it in) with a stack of chocolate bars… 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)

Oral Presentation

You're now the expert of the Light Speed 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 type of food most accurately measures the speed of light? After researching the electromagnetic spectrum, microwave ovens, frequency, wavelength, and substances that easily melt, I realized I had all the basics for measuring the speed of light. But which type of food would produce the best measurement results?

Question/Hypothesis Card: I hypothesized that the chocolate bar would have the smallest percent error when compared with the published value for the speed of light. My best guess is that a substance with a melting point near room temperature would be easiest to visualize the results needed for finding the hotspots in a microwave.

Procedure/Experiment Card: After raiding the grocery store for chocolate bars, chocolate chips, marshmallows, butter, and cheese, I created a super-simple project for determining the speed of light by melting different substances in the microwave. I ran nine trials varying the type of food melted and measured the distance between the hotspots and calculated the speed of light using frequency information from the microwave oven itself.

Results/Conclusion Card: I found that my initial hypothesis (chocolate gives the lowest percent error for measuring the speed of light) was supported by the data, but not in the way I expected. **White chocolate has the most accurate measurement (298,704,000 meters/second) with a difference of 0.36% from the published value.**

Recommendations Card: For further study, I recommend running an experiment to test the various types of microwaves, as well as testing different foods based on water content. This experiment was tasty and a whole 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!