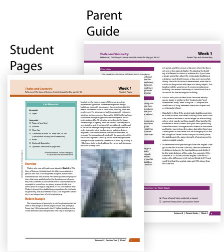
Instructor's Guide Quick Start

The BookShark™ Student Lab Book and Parent Guide is designed to make your educational experience as easy as possible. We have carefully organized the materials to help you and your children get the most out of the subjects covered.

This IG includes a 36 weeks of science lessons and labs that correlate to your History of Science J readings. Here are some helpful features that you can expect from your guide.

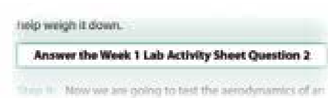


Student Lab Book and **Parent Guide**
Student pages are found in Section Two and contain a weekly science lesson, lab instructions, and Activity Sheets. The corresponding Parent Guide in Section Three contain troubleshooting tips, answer keys, and other notes.


Thales and Geometry
Reference | *The Story of Science: Aristotle Leads the Way* pp. 36–43

One Lab a Week
Complete one lab a week, preferably after the referenced History reading corresponding to the lab has been completed. (Note: some readings will be completed the week before the lab is scheduled.)

Activity Sheet Lab Questions
While completing the lab, watch for indications to complete a question on the Activity Sheet before moving on with the lab.


help weigh it down.
Answer the Week 1 Lab Activity Sheet Question 2
Now we are going to test the aerodynamics of an

How to Assemble Your Guide
The structure of this guide is unique to BookShark. As such, please read the following article on How to Assemble Your BookShark™ Student Lab Book and Parent Guide.

Section Two

Student Lab Lessons and Activity Sheets

Lab Materials

We provide:

- ❑ Masking tape*

You provide:

- ❑ Paper of any kind
- ❑ Scissors
- ❑ Floor fan
- ❑ Cardboard at least 20" wide and 10" tall (can be thick or thin, like a cereal box)
- ❑ Ruler
- ❑ *Optional: Box cutter*
- ❑ *Optional: Thin towel or yoga mat*

**materials will be used again in future labs and should be saved*

Overview

Thales, who you will read more about in **Week 2** of *The Story of Science: Aristotle Leads the Way*, was a Greek genius who worked as a civil engineer, lawgiver, astronomer, mathematician and teacher. He created five propositions that served as a foundation for the development of geometry. He is credited as one of the first to move an axiom (a general rule) to a direct proof with a logical sequence. Thales is known for establishing propositions for the basis of geometry and also referred to as a civil engineer. Geometry is an integral part of civil engineering.

Modern Example

We can see the importance of geometry in civil engineering in the design of the Shanghai Tower. The Shanghai Tower has 128 stories and is the 2nd tallest building in the world behind Dubai's Burj Khalifa. The city of Shanghai is located on the eastern coast of China, an area that experiences typhoons. Whenever engineers design buildings, especially skyscrapers, they must consider the effects of weather such as snow load, flooding, wind and much more. For skyscrapers built in areas with typhoons, wind is a serious concern. During the 2016 Pacific typhoon season the strongest typhoon had wind speeds of 140 mph sustained for 10 minutes, according to the Japan Meteorological Agency. Wind results in a sideways force on a building and, if not carefully considered, could result in structural damage and possibly catastrophic failure. In order to predict wind load on a new building design, engineers use scaled models and wind tunnel tests to measure the interaction of wind with the geometry of the structure. Engineers came up with a novel design for the Shanghai tower to reduce the effects of wind. By putting a 120 degree twist in the building, they were able to reduce the wind load by 24%.

Figure 1: The twisted structure of Shanghai Tower

Deeper into the Scientific Principle

See the generic formula for wind load below:

$$F = A * P * C_d$$

F: Force – the push on an object

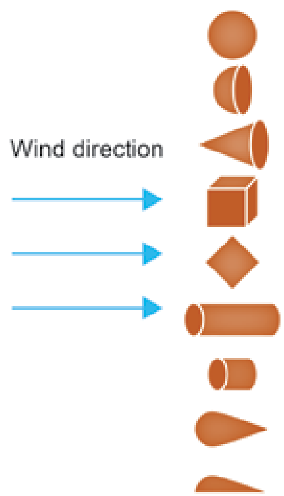
A: Surface area – this is the part of the object that is directly perpendicular to the wind, the surface the wind hits.

P: Pressure – strength of the wind

C_d: The Coefficient of Drag – a measure of how the shape of the object resists wind, how aerodynamic it is. Engineers aim to have the lowest value of drag on their buildings since it reduces how much force the wind can create for it.

While engineers cannot control the wind speed (or pressure) that acts on a building, they can influence the other terms in the equation: area and drag coefficient. The area may be largely constrained by the building owner's square footage requirements (in other words, the building owner requires the engineers to design a building of a certain size), but engineers can influence the shape of the building. Different shapes can have vastly different coefficients of drag, even for the same area. Figure 2 below shows some common shapes and their respective coefficients of drag. Notice how much variance there is in the drag coefficients.The lower the drag coefficient the more arodynamic it is.

Based on the chart, a streamlined body has the lowest drag (think airplane wings). A cube shape has almost the the highest drag.



Shape	C_D
Sphere	0.47
Half sphere	0.42
Cone	0.50
Cube	1.05
Angled cube	0.80
Long cylinder	0.82
Short cylinder	1.15
Streamlined body	0.04
Streamlined half body	0.09

Figure 2: Common shapes and their drag coefficients

In this lab, you will experiment with structures that will withstand wind differently. You will use a floor fan to represent the wind tunnel.

Step 1: Gather the lab materials listed at the beginning of this week's lesson. If your fan is powerful, you'll want to use thick cardboard (like a moving box) for this experiment. If your fan is smaller, you'll want to use thin cardboard (like a cereal box or shirt box).

Step 2: Lay your cardboard out flat on a table. You may want to put a cutting board or protective cover between your cardboard and the table so that you do not cut through and scratch the table.

Step 3: Trim your cardboard so that it is 16 inches long and 10 inches tall. Next, take your ruler and mark every four inches along the long edge of the cardboard. Do the same on the other long edge of your cardboard and draw lines between the top and bottom marks. Do not throw your remaining cardboard away.

Figure 3: Cardboard 16" wide, marked every 4"

Step 4: Bend the cardboard along the lines you drew (at the 4-inch marks). If you're using thick cardboard, you will need to lightly score the cardboard before bending it.

Figure 4: Bend the cardboard along the 4" marks

Step 5: Hold the folded cardboard in a square and tape the two ends together to form a cubed building. Use one long piece of tape to make a seal between the two corners as shown in the first image of **Figure 5** so wind will glide around the corner and not get trapped causing more friction.

Step 6: Create a top and bottom for your building by tracing the open end of your cube onto your leftover cardboard from Step 3 and cut them out. Next, tape the top and bottom to your cube as shown in the second image of Figure 5.

Figure 5: Tape edges of cardboard

Step 7: Wrap the sides and top of your building in paper to ensure your building is as smooth as possible.

Figure 6: Cubed building wrapped in paper

Step 8: Place the cubed building one to two feet from the fan with the flat surface facing the fan. Turn the fan on low.

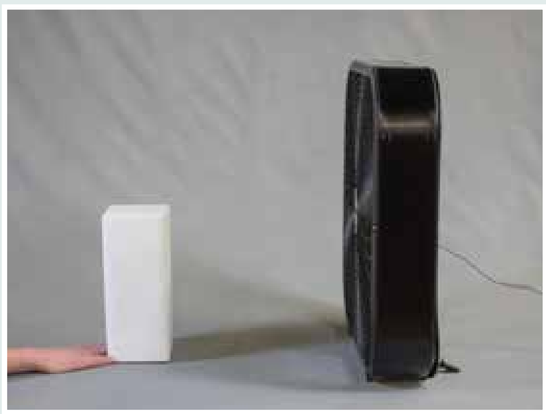


Figure 7: Place building square in front of fan

Answer the Week 1 Lab Activity Sheet Question 1

Step 9: Find and measure the breaking point (the spot where the building is the closest it can be to the fan without blowing over) by moving the building closer or farther from the fan. Measure and record the distance from the fan to the flat surface of the building.

Tip:

If the fan did not cause the cube building to slide or tip over, try setting the fan to a higher speed. Continue turning up the fan until the building begins to move or tip over. If your building slides instead of tipping over, try placing your hand flat on the ground behind the building, or place a very thin towel below the building to increase the friction so it won't slide. If your fan is too powerful for your building at its lowest setting, put something a little heavy like coins on the top of your tower to help weigh it down.

Answer the Week 1 Lab Activity Sheet Question 2

Step 10: Now we are going to test the aerodynamics of an "Angled Cube" building. Take your building and turn it so that one of its corners is facing the fan (as shown in **Figure 8**) instead of the flat surface facing the fan. Start near the spot that the cubed building fell over. Move it closer or further from the fan until it begins to blow over. Measure and record the distance from the fan to the front of the angled building.

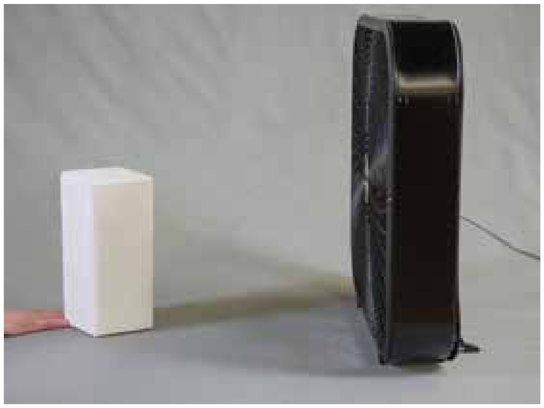


Figure 8: Place building angled in front of fan

Tip:

If your angled cube building keeps blowing over in one direction, it may be that your building isn't perfectly symmetrical or that the front corner is not pointed directly at the fan. Adjust the angle of the building so that the building is just as likely to fall down one direction as the other direction, then continue the experiment. ■

Answer the Week 1 Lab Activity Sheet Questions 3–10

Materials For Next Week

Please save materials with *asterisks* from the Lab Materials List on the Student Lab Book pages for future labs.

For **Week 2**, you will need to provide:

- ❑ Produce bag or plastic grocery bag
- ❑ Scissors
- ❑ Water
- ❑ Piece of wool, paper towel, or carpet
- ❑ *Optional: Disposable cup or plastic bottle*

Week 1 Lab Activity Sheet

1. Was the cube building able to resist the wind load? Or did it slide on the floor, or tip over? Explain what you saw.

Go Back to the Lab Step 9

2. At what distance did the wind load become too much for the cubed building (where the building began to be slide or tip over)?

Go Back to the Lab Step 10

3. At what distance was the wind load too much for the angled cube building?

4. What is the difference in distance between the cubed building's breaking point and the angled cube's breaking point?

5. What percentage closer did the angled cube building get to the fan compared to the cubed building? (Take the difference in distance between the two buildings and divide it by the total distance of the cubes breaking point.)

Math Workspace

6. Does this make sense with what you know about the coefficient of drag for these two shapes? Why or why not? If you got results that were different than what you were expecting, what other factors may influence your building's aerodynamics? ______

7. When doing a science experiment, it is important to make sure the variables of an equation stay the same while you change and test another variable by itself. The variables in our wind force equation were surface area, pressure, and the coefficient of drag. What two variables changed when you turned the cube into an angled cube? Do you think it makes much of a difference?

8. Did you notice any other differences between how each structure handled the wind differently? Try turning the speed up on your fan and doing the experiment again. Are the results different?

9. Engineers utilize this same concept of reducing drag coefficient to design other objects. What other objects benefit from shapes designed to reduce drag coefficients? ______

10. How can reduced drag coefficient affect the environmental impact of vehicles?

Lab Materials

We provide:

- ❑ Balloon
- ❑ PVC pipe*
- ❑ Thumbtack or small copper nail*

You provide:

- ❑ Produce bag or plastic grocery bag
- ❑ Scissors
- ❑ Water
- ❑ Piece of wool, paper towel, or carpet
- ❑ *Optional: Disposable cup or plastic bottle*

**save materials to be used again*

Overview

We've all experienced static electricity: the zap we feel on our fingers when we touch a metal door knob after walking across carpet, or the way our hair stands up after pulling on a sweater. Through experimentation back in the 6th century B.C.E., Thales created static electricity by rubbing amber with a cloth. He didn't know what it was, but he observed that lightweight objects were attracted to the amber. The Greek word for amber, ēlektron, became the root word for electron, the basis of electricity. As we continue to read though the *The Story of Science* books, we will read about William Gilbert who wrote about the phenomenon around the year of 1600, correctly calling it electricity. We'll learn how scientists were able to capture the spark and study it in 1745, after Pieter van Musschenbroek and Ewald Gerog von Kleist simultaneously and independently invented the Leyden jar. The Leyden jar allowed scientists to store electric charges. They used the jar to build up electric potential and then discharge it on command; it functioned as the first battery. This invention opened up the study of electrostatics and electricity.

Deeper into the Scientific Principle

Every atom contains three main parts: protons, neutrons, and electrons. The protons and neutrons are found in the nucleus (middle) of the atom, and protons are positively charged. The number of neutrons and protons in an atom help identify which element it is. Electrons, orbit around the nucleus and are negatively charged. There are different layers of orbits, and each orbital layer can only hold so many electrons at once. The first orbital holds a maximum of two electrons. The second orbital holds six more electrons for a total of eight. The more orbitals, the more electrons the outer orbital holds. And the inner orbitals must be full before the next layer orbital can begin to accept electrons. Because electrons circle the nucleus, they can move from one atom to another. Usually, an atom has the same number of electrons as protons so that the atom has a zero net charge. However, if an atom loses or gains an electron, the overall charge of the atom either becomes negative (more electrons than protons) or positive (less electrons than protons).

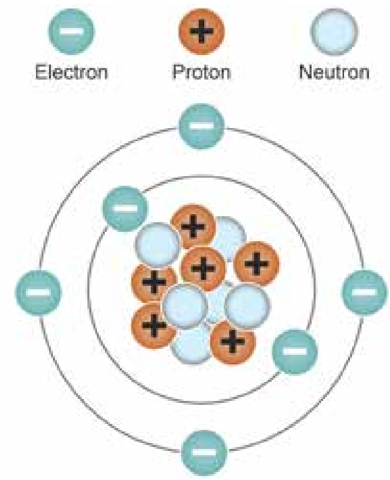


Figure 1: Structure of a neutrally charged atom

Electrostatic shock occurs when two materials have a large difference of positively or negatively charged atoms. The electrons work to achieve a neutral charge again. The measurement of this difference in charge is called **potential difference**.

A potential difference occurs when materials give up or take on electrons. One way this can happen is through friction (see Figure 2). The transfer of electrons through friction is called the **triboelectric effect**. Materials such as dry hands, leather, human hair, and wool want to let go of electrons, while materials such as PVC, Teflon, and silicone rubber tend to gain electrons. The materials that gain electrons have a higher electron affinity. **Electron affinity** is the measure of energy spent to add an electron to an atom or molecule (two or more atoms combined). Some materials are more willing to take on electrons while other materials would rather give them up because of the atomic structure of their atoms or molecules.

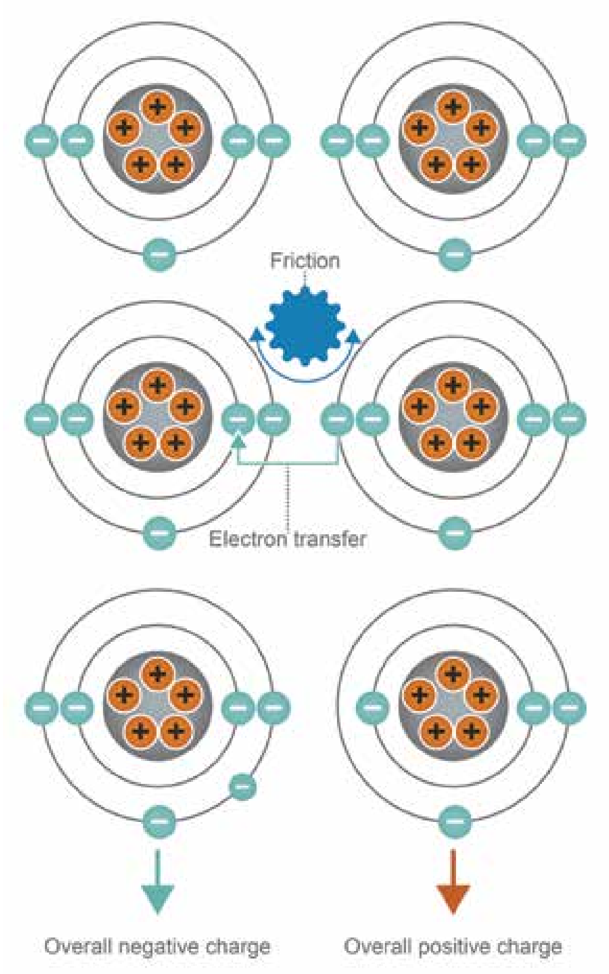


Figure 2: Transfer of electrons via friction

In this lab we will use a balloon, a PVC pipe, a strip of plastic, and a stream of water to demonstrate a static electric phenomenon. Balloons are like PVC in that they want to collect electrons. Notice in Figure 3, before the balloon is rubbed, the atoms are neutrally charged (equal numbers of electrons and protons). After the balloon is rubbed with a material that makes it lose electrons easily, there are more electrons on the balloon's surface and fewer electrons on the other material's surface.

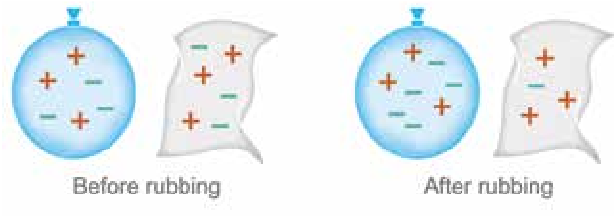


Figure 3: Balloon takes on electrons and cloth gives up electrons

Just like magnets, similar charges repel and opposite charges attract. These charged surfaces do not remain charged forever. After some time has passed, the charged surface will neutralize in the air or when it comes into contact with another surface.

Lab: Experiment with Static

Answer the Week 2 Lab Activity Sheet Question 1

Step 1: Gather the lab materials listed on the previous page.

Step 2: Blow up the balloon fairly large but not so large you risk it popping.

Step 3: Cut a strip of plastic from the produce bag about 1" x 6".

Step 4: Take a piece of wool and rub the top of the balloon for several seconds. If you do not have wool, use a paper towel, a piece of clothing, or rub the balloon on the carpet. Then, set the balloon on the table. Rub the full length of the strip of plastic with the wool vigorously on both sides.

Step 5: Toss the plastic strip up into the air and quickly pull the balloon under the plastic so that the charged side (the side rubbed with the wool) faces the strip of plastic above.

Watch what happens when you keep the balloon under the plastic.

Note: The plastic will be attracted to walls, ceiling fans, and your body so it may take some practice to get the plastic thrown up so that you can pull the balloon under it before it is attracted to something else. Make sure you have plenty of space around you to move the balloon. Have some fun trying to see how long you can keep the plastic up in the air!

Answer the Week 2 Lab Activity Sheet Question 2

Step 6: The balloon is made of rubber and rubber wants to take on electrons from wool through the triboelectric effect. The same thing happens with the strip of plastic. Since both the balloon and the plastic strip have additional electrons, their surfaces repel one another. This force is strong enough to keep the plastic "floating" above the balloon.

Answer the Week 2 Lab Activity Sheet Question 3

Step 7: Turn a faucet on low so it has a small but steady stream. Rub the PVC pipe with a piece of wool until you hear the buildup of static electricity. Bring the PVC pipe toward the stream of water where the stream is narrowest. Don't allow the pipe to get wet. Once it is wet there will no longer be a potential difference on the surface of the pipe and you will need to start over to build up electrons using a piece of wool. Observe what happens to the stream of water as you slowly bring the PVC pipe toward the stream.

Faucet difficulties? Locate a disposable cup or plastic bottle and, using a thumbtack or nail, puncture a small hole in the bottom of the cup. Cover the hole on the bottom of the cup with your finger and fill it with water. Then hold the cup in the air and allow the water to stream out of the hole.

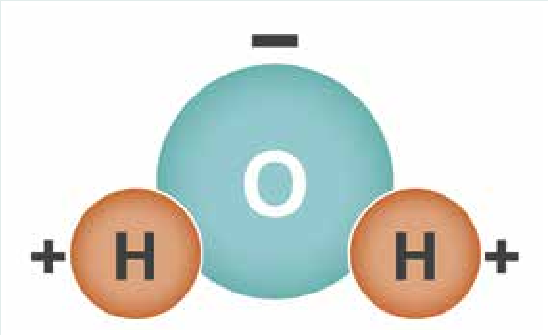


Figure 4: Water molecule 1 negative oxygen atom and 2 positive hydrogen atoms

Step 8: Take a look at the water molecule in Figure 4 and notice it has a negatively charged oxygen atom and two positively charged hydrogen atoms. The PVC pipe has a negatively charged surface. As it is brought toward the stream of water the negative surface repels the oxygen atom and attracts the hydrogen atoms. Water bends due to the attraction between the positive hydrogen atoms and the negatively charged surface of the pipe.

Answer the Week 2 Lab Activity Sheet Question 4

Figure 5: Bending stream of water

If you think static electricity is just a nuisance in the winter time when you go to open a door, think again. An entire industry is devoted to the control of static discharge. In the manufacturing and repairing of sensitive electronic parts, static electricity can zap components resulting in a total loss, so assemblers and technicians wear special wrist bands which ground them and prevent electrostatic discharge (ESD). Electrostatic discharge can impact the safety of people. Static electricity can cause fires and explosions at gas pumps which is why it is always important to discharge any static electricity by touching something metal before picking up the pump handle. Grain elevators are particularly susceptible to static discharge and explosions happen every year. Understanding static electricity is important and controlling it is vital to the safety of products and human lives. ■

Materials For Next Week

For **Week 3**, you will need to provide:

- ❑ Corrugated cardboard strip 1.5″ x 6″
- ❑ Various household objects to drop
- ❑ Ruler
- ❑ Hammer

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Week 2 Lab Activity Sheet

1. Hypothesize what you think will happen when a negatively charged strip of plastic is tossed above a negatively charged balloon. When you have written down your prediction and reasoning, perform the steps to see if you are correct. (A hypothesis is a statement that predicts what will happen and is testable. It often includes a reason why you believe the results will be as you predict. For example, instead of just guessing "The cubed building will fall over first," guess "The cubed building will fall over first because its shape gives more air resistance than the second building's.")

Go Back to the Lab Step 1

2. Look back at the hypothesis you wrote in Question 1. Did you predict correctly? Rewrite your hypothesis here to match what you saw in your test, and in your hypothesis include the reason you believe you found these results.

Go Back to the Lab Step 6

3. Read Step 7 and hypothesize what you think will happen. Include why you made this prediction.

   Hint: Will the water be attracted or repelled when you hold the pvc pipe next to the stream? Why?

Go Back to the Lab Step 7

4. If necessary, rewrite your second hypothesis according to the results that you found. In the world of science, rewriting and re-testing hypotheses is important to discover the true reasons behind scientific events.

Go Back to the Lab Final Paragraph

Lab Materials

We provide:

- ❑ 1 Wood Block*
- ❑ 2 Popsicle sticks
- ❑ 1 Jumbo craft stick
- ❑ 1 Small copper nail*
- ❑ 1 Long rubber band
- ❑ 2 Ping-pong balls*
- ❑ Hot glue gun* and glue stick
- ❑ *Optional: Masking tape**

You provide:

- ❑ Corrugated cardboard strip 1.5" x 6"
- ❑ Various household objects to drop
- ❑ Ruler
- ❑ Hammer

**save materials to be used again*

Note: Hot glue gun needs to heat up for several minutes to work most efficiently.

Overview

Next week you will learn an idea that Aristotle got wrong. As you have already learned, there are many times when scientists make a wrong hypothesis, and that's okay. Good scientific processes help us to eventually come to the right answers. You will have a chance in this lab to make some of your own hypotheses and then test to see if your guess is correct.

Deeper into the Scientific Principle

Mass versus weight, what's the difference? When you step on a scale you are finding your weight. Weight is a function of (depends on) gravity. Weight and gravity function proportionally, which means if gravity increases so does weight and if gravity decreases weight does too. For example if you could weigh yourself on Mars, you would weigh only about 40% of what you weigh on Earth. A person's weight is the *force* that they are exerting (applying) to the Earth.

Mass is the amount of matter in an object and is always the same regardless of weight. The mass of a person standing on Earth does not change if the person travels to Mars. Mass and Weight are related to gravity by the following equation

$$F = m * a$$

where F is the force or weight of the person, m is the mass of the person, and a is the acceleration or gravity the person is experiencing. Gravity on Earth is $9.8\ \frac{m}{s^2}$ and it is a constant.

Lab: Build a Launcher

In this lab you will learn a little more about gravity. What is gravity and how does it act on objects of different masses? What occurs when an object is thrown horizontally versus dropped, which one will hit the ground first?

Part 1

Step 1: Gather the lab materials.

For the various household objects, find a few different objects around your house of different masses. Make sure to choose objects that are safe to drop such as: shoe, pencil, tennis ball, soccer ball, golf ball, screw, etc. Try to not choose objects that are light and/or catch a lot of air resistance as they fall, like paper, a feather, or a piece of clothing.

Think about what you learned about aerodynamics in **Week 1** and choose a couple of objects that have similar air resistance but different masses.

Answer the Week 3 Lab Activity Sheet Questions 1–5

Part 2

What happens if you take 2 identical objects and drop one straight down while at the same time you launch the other horizontally from the same height at the same time? To perform this experiment you will need to build a launcher so that one object will drop while the other is propelled through the air at the same height and at the same time.

Step 1: Gather the lab materials listed on the previous page.

Step 2: Cut a strip of cardboard that is 1.5" wide by 6" long if you haven't already. On one end of the cardboard strip, cut out a 1.5" long slit $\frac{3}{16}$" wide, as seen in Figure 1. Be careful to not bend the cardboard strip in any way, it needs to be completely flat for the experiment to work.

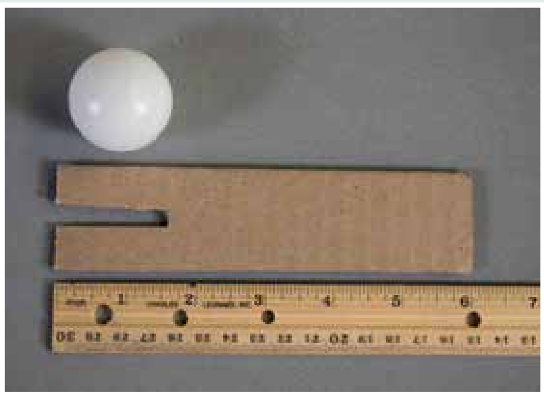

Figure 1: Slit in cardboard should be same length as ball

Step 3: Hammer the small copper nail part-way into the wood block. It should be as close to the short edge of the block as possible, at the halfway mark between the two long sides. Do not nail the copper nail all the way in, leave over half an inch of the nail sticking out of the wood, as seen in Figure 2.

Step 4: Lay the cardboard on the wood block with the slit aimed towards the nail. Move the cardboard back and forth to make sure that the slit is able to slide without being obstructed by the nail. If the slit catches anywhere on the nail, widen the slit a little. Push the cardboard as far as possible so that the nail is as far into the slit as possible. The area of the cardboard sticking past the nail should be large enough for a ping-pong ball to sit on, and the area between non-slit edge of the cardboard and the edge of the wood should also be just large enough to hold a ping-pong ball. Hot glue two popsicle sticks to the wood block alongside the cardboard strip, being careful to not get any glue on the cardboard or in the area where the cardboard will be sliding. The ends of the popsicle sticks should line up with the end of the slit cardboard. See Figure 2 for clarity. The purpose of the popsicle sticks is simply to help keep the cardboard straight when it slides back and forth.

Figure 2: Popsicle sticks guide the cardboard, do not glue cardboard

Step 5: Remove the cardboard from the wood block and glue the jumbo craft stick perpendicularly across the edge of the non-slit edge of cardboard. The craft stick needs to stand straight up and down, not leaning forwards or backwards.

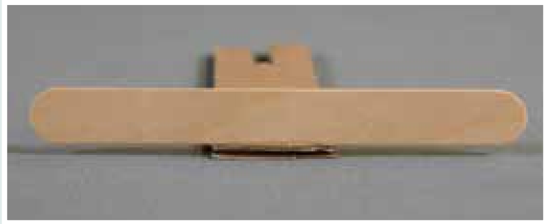

Figure 3: Glued craft stick on top of cardboard edge

Step 6: Place the cardboard on the wood block with the slit towards the nail. Line up the craft stick end of the cardboard with the short edge of the wood block opposite the nail. See Figure 4 for clarification.

Step 7: Make a single cut in the long rubber band.

Glue the two ends of the rubber band to the corner edges of the wood block as shown in Figure 4 and 5. Then lay and glue the middle of the rubber band halfway back on the cardboard strip. The rubber band shouldn't stretch out yet, but should be close to stretching if the cardboard moves backwards. Use plenty of glue on the rubber band so it does not break off. Allow the glue to completely cool.

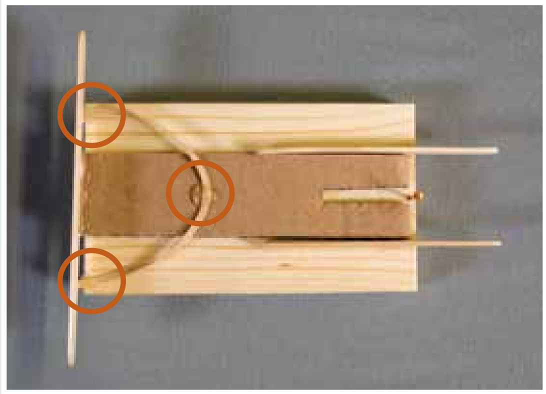

Figure 4: Unstretched rubber band is glued to edge of wood block and cardboard

Step 8: Once the glue is set, pull the cardboard strip backwards (towards the nail) and hold it with your thumb. Place one ping-pong ball over the cardboard slit and another on the edge of the wood against the craft stick. Slide the cardboard forward slightly. The craft stick should push off its ball at the same time that the slitted cardboard allows its ball to drop. Make adjustments to the cardboard, craft stick, or nail as necessary to ensure the balls begin to fall at the same time. If the balls keep rolling off by themselves, roll up tiny pieces of tape so they remain steady until the launcher pushes them off.

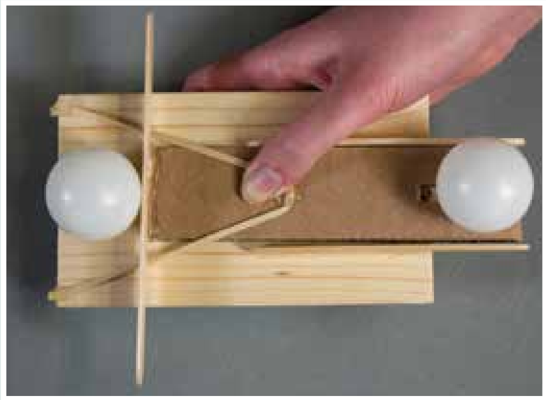

Figure 5: Pull back and hold with thumb while placing ping-pong balls

Step 9: Once adjustments are finalized, you should be able to pull back and release with your thumb so that one ball drops while the other ball flies forward. You will need to either hold the contraption completely level, or place it on a railing or the corner of a table to allow both balls to fall to the ground without hitting anything else.

Figure 6: Place launcher on solid surface where ping-pong balls won't hit anything when falling

Answer the Week 3 Lab Activity Sheet Questions 6–8

The ball that travels in a projectile motion is traveling in both x (horizontal) and y (vertical) directions. These directions are perpendicular to each other and that makes them independent of each other. The ball dropped only in a vertical direction will fall just as fast as the one that is launched in a horizontal direction. This is because the horizontal direction has no effect on the vertical force of gravity. No matter if an object is traveling horizontally or just dropping straight down, gravity has the same effect on either object. ■

Materials For Next Week

For **Week 4**, you will need to provide:

- ❑ Scissors
- ❑ Large tub or bowl full of water
- ❑ Ruler

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Week 3 Lab Activity Sheet

1. Make a hypothesis: which object will hit the ground first, the heavier more massive object, or the lighter weight object? Why? Include in your answer which two objects you plan to drop.

2. Place both objects on a high, flat surface like a table or countertop and push them off at the same time to see which one hits the ground first. Repeat 3 more times and write down what you saw.

3. Is this different than what you predicted? How so?

4. Choose 2 more objects of different masses and repeat the experiment. What is your conclusion?

5. What happens if you drop a flat piece of paper and a shoe at the same time? Which one hit the ground first? Explain what you think happened.

Go Back to the Lab Part 2

6. If you have a smart phone, start recording video in slow motion and capture what happens when both balls are launched from the pad. If you do not have a smart phone, perform the experiment over a hard floor and listen to when exactly the balls hit the ground. What happened to the balls?

7. Repeat the experiment 3 more times while recording or listening, and write down what happened.

8. This test set-up has limitations since you are not using a precise piece of scientific equipment. The results will not always be perfect. However, there is much that can be gained from looking at these results. For small variations in results, what are some of the factors that could have caused these variations? Think about the test set-up. How do you think the test could be improved to reduce some of the variables that cause the results to vary?

Go Back to the Lab Final Paragraph

Section Three

Parent Guide
Lab Tips & Answer Key

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Overview

This week your students will learn about some basic engineering concepts: aerodynamics and the coefficient of drag. The coefficient of drag is a measure of how the shape of the object resists wind. The lower the coefficient, the more aerodynamic it is. Your student will build a rectangular building and test its aerodynamics, then will turn the building to see how the aerodynamics change when the wind hits an angled edge as opposed to a flat edge.

Note for Parents

Some cardboard may be able to be cut easily using scissors. However, if your students are having trouble you may wish to use a box cutter. Please discuss safety procedures when using a box cutter, such as cutting away from your body and placing your free hand to the side of or behind the blade.

There is a good chance there will be some discrepancies in the results you and your students get from those stated in the lab. Below are some tips on how to modify the activity based on equipment that you have that might be different than what was used to develop this lab. Please tweak the procedures as required to accomplish the overall goals which are most important.

Experiment Tips

- When the students are asked to place the rectangular building in front of the fan one to two feet away, keep in mind this is just a guideline. Given enough wind power any design will fail so finding the best distance for the building is critical. Hopefully your fan has varying speeds. Ideally the rectangular building would remain stationary when the fan is on the lowest speed, and then move or tip over when the fan is set one or two speeds higher. Try placing the building at different locations to achieve this. If you have a single speed fan, place the rectangular building at a distance such that it moves or tips over somewhat slowly. Once this location is determined, mark the location on the ground with tape or a heavy object. This location will be used to see if a more aerodynamic building can remain stationary at a wind load that is too much for the rectangular building.
- Discuss with your students how the more aerodynamic shape is similar to the "angled cube" and "streamlined body" seen in Figure 2 of the Student Lab Book. Compare the coefficients of drag between these two shapes and a rectangular shape.
- Hopefully in Step 9 the angled cube building got closer to the fan than the cubed building. If this wasn't the case, make sure there is are no edges on the building where wind may be getting caught. Also, look for the variances in wind currents that your fan is producing. Some fans have a stronger wind currents in the center and lighter currents on the edges, but other fans have a weak point in the center but are stronger just to the left or right of center. Make sure your student places the buildings in the same strength of wind current to reduce variable results.
- To determine what percentage closer the angled cube got to the fan than the cube did, take the difference in distance between the two buildings and divide it by the total distance of the cube. For example, if the cube fell at 11.5 inches and the angled cube fell at 5 inches, the difference is 6.5 inches. Divide 6.5/11 and you'll find that the angled cube got 56.5% closer than the cube did.

Materials For Next Week

Please save materials with *asterisks* from the Lab Materials List on the Student Lab Book pages for future labs.

For **Week 2**, you will need to provide:

- ❑ Produce bag or plastic grocery bag
- ❑ Scissors
- ❑ Water
- ❑ Piece of wool, paper towel, or carpet
- ❑ *Optional: Disposable cup or plastic bottle*

Week 1 Lab Activity Sheet

1. Was the cube building able to resist the wind load? Or did it slide on the floor, or tip over? Explain what you saw.

   (Answers may widely vary depending on the fan you use. Possible: The building did slide a little bit until it was placed on a yoga mat. Sometimes it began to tilt backwards but then came back to a resting position. It did not fall over.)

Go Back to the Lab Step 9

2. At what distance did the wind load become too much for the cubed building (where the building began to be slide or tip over)?

   (Answers may widely vary depending on the fan you use. Possible: 11.5 inches)

Go Back to the Lab Step 10

3. At what distance was the wind load too much for the angled cube building?

   (Possible: 5 inches)

4. What is the difference in distance between the cubed building's breaking point and the angled cube's breaking point?

   (Possible: 6.5 inches)

5. What percentage closer did the angled cube building get to the fan compared to the cubed building? (Take the difference in distance between the two buildings and divide it by the total distance of the cubes breaking point.)

   (Example: 6.5in/11.5in=56.5%... the angled cube got 56.5% closer to the fan than the cube did.)

Math Workspace

Difference in Distance/Total Distance

Example: 6.5in/11.5in=0.565
0.565 = 56.5%... the angled cube got 56.5% closer to the fan than the cube did.)

Week 1 Lab Activity Sheet

6. Does this make sense with what you know about the coefficient of drag for these two shapes? Why or why not? If you got results that were different than what you were expecting, what other factors may influence your building's aerodynamics? *(Answers will vary; other factors affecting the aerodynamics may include the size of the fan, drafts in the room, how symmetrical and smooth the building was built, the length of the base and perpendicular surface area [an angled cube has a slightly longer base and more surface area than its cubed counterpart], weight of the building, etc.)*

7. When doing a science experiment, it is important to make sure the variables of an equation stay the same while you change and test another variable by itself. The variables in our wind force equation were surface area, pressure, and the coefficient of drag. What two variables changed when you turned the cube into an angled cube? Do you think it makes much of a difference?
(the coefficient of drag and the surface area changed when rotating the building. The surface area of the cubed building was 4 inches wide, while the angled cubes suface area is 5.66 inches wide ($a^2+b^2=c^2$). Although the surface area of the angled cube is larger it was able to get much closer to the fan)

8. Did you notice any other differences between how each structure handled the wind differently?
Try turning the speed up on your fan and doing the experiment again. Are the results different?
(Answers may vary. Possible: The angled cube often tried to turn to the side before blowing over. The cube almost tipped over backwards without completely falling over more often, probably because its base was more stable. Etc. Results should be similar, except that the distances are further from the fan.)

9. Engineers utilize this same concept of reducing drag coefficient to design other objects. What other objects benefit from shapes designed to reduce drag coefficients? *(Some examples are cars, trains, planes, boats, and bicycles)*

10. How can reduced drag coefficient affect the environmental impact of vehicles?
(reduced drag improves fuel efficiency)

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Overview

Static electricity occurs due to the structure of atoms. An atom has protons and neutrons in its nucleus, with electrons orbiting in electron shells. Electrons can transfer between atoms. Materials can give up or take on electrons according to their electron affinity (how easy or hard electrons transfer according to the strength of the bonds within the atom). When two objects are rubbed together, electrons transfer from one material to another, creating a buildup of negative charge. This is called static. Your students will experiment with multiple materials to see how static charges interact, including how water can become polarized because its two hydrogen atoms hold a positive charge while the oxygen holds a negative charge. Students will also create hypotheses, which are testable predictions.

Experiment Tips

- We recommend using a produce bag from the grocery store, as its plastic is extremely light and holds a charge very well. However, you can use a simple plastic shopping bag as well.
- If you do not have a piece of wool to use when rubbing the balloon, plastic, PVC, etc., find another fuzzy cloth material or silk, nylon, fur, human hair, upholstery, paper towel, or carpet.
- Make sure your students do the first part of this experiment in a large open space away from walls that can affect the static buildup.

Activity Sheets

Question 3:

Hint: Static electricity is like a magnet and positive and negative ions attract. What is the overall charge of the water and the overall charge of the PVC pipe?

Further explanation: The negative polarity of the PVC pipe causes the water molecules to orient with the negative oxygen atom being repelled facing away from the PVC pipe and the positive hydrogen atoms are attracted to the PVC pipe. This causes the water to bend toward the pipe. You might be tempted to ask why the water bends toward the pipe when the oxygen atom is negative. Wouldn't they cancel each other out? Think about a magnet. There is a positive and negative side to a magnet. Imagine two magnets. If you bring the negative side of magnet A toward the negative side of magnet B, magnet A will flip around and the positive side will be attracted to the negative side of magnet B. That is what the water molecules do, which allows the stronger positive side of water to flip and pull itself towards the PVC pipe.

Materials For Next Week

For **Week 3**, you will need to provide:

- ❑ Corrugated cardboard strip 1.5″ x 6″
- ❑ Various household objects to drop
- ❑ Ruler
- ❑ Hammer

Week 2 Lab Activity Sheet

1. Hypothesize what you think will happen when a negatively charged strip of plastic is tossed above a negatively charged balloon. When you have written down your prediction and reasoning, perform the steps to see if you are correct. (A hypothesis is a statement that predicts what will happen and is testable. It often includes a reason why you believe the results will be as you predict. For example, instead of just guessing "The cubed building will fall over first," guess "The cubed building will fall over first because its shape gives more air resistance than the second building's.")

   (Answers will vary. Encourage your student to include a testable prediction and a reason for their prediction in the hypothesis. Example: The plastic strip will float above the balloon because they are both negatively charged and therefore repel each other)

Go Back to the Lab Step 1

2. Look back at the hypothesis you wrote in Question 1. Did you predict correctly? Rewrite your hypothesis here to match what you saw in your test, and in your hypothesis include the reason you believe you found these results.

   (Answers will vary. If your student's hypothesis in Question 1 was not similar to ours or did not match the results they found; encourage them to reread the lesson and determine where the positive and negative charges lie and how they will affect each other)

Go Back to the Lab Step 6

3. Read Step 7 and hypothesize what you think will happen. Include why you made this prediction.

   Hint: Will the water be attracted or repelled when you hold the pvc pipe next to the stream? Why?

   (Possible: The water will be attracted to the PVC pipe because the water is positive and the PVC is negative. Although the water molecule has positive and negative atoms, it is overall a positive molecule. The PVC pipe, however, has collected a lot of electrons so it is negative)

Go Back to the Lab Step 7

Week 2 Lab Activity Sheet

4. If necessary, rewrite your second hypothesis according to the results that you found. In the world of science, rewriting and re-testing hypotheses is important to discover the true reasons behind scientific events.

(Answers will vary. See our further explanation in the Parent Guide for Question #3 if your student needs help understanding why the water bends towards the PVC pipe.)

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Overview

Mass is the amount of matter in an object. Weight is the effect of the force of gravity on the mass of the object. Gravity on Earth makes all objects fall at 9.8m/s², regardless of the object's mass. However, air resistance can also have an effect on falling objects. If one object is dropped downward at the same time that a similar object is launched horizontally, gravity has the same effect on both of them and both objects will hit the ground at the same time. Your students will drop various objects to see the effects of gravity, as well as build a launcher to test the effect of horizontal motion on an object's gravitational pull.

Note for Parents:

Your student will be using a hammer and nail today. The nail will need to be very close to the edge of the wood block provided in your science kit. If your students are inexperienced using hammers, you may wish to review safety procedures or help them complete this step.

There is a good chance there will be some discrepancies in the results your students get from those stated in the lab. Keep in mind as with any home built experiment, there are limitations since you are not using precise scientific equipment. The results will not always be perfect. However, there is much that can be gained from looking at these results.

Experiment Tips:

Below are some tips you may want to talk through with your students to explain what is happening. Please tweak the procedures as required to accomplish the overall goals which are most important.

- Make sure you don't choose objects to drop that are heavily affected by air resistance. Solid, compact objects work best.
- Have a second student or parent capture the falling subjects using the slow motion setting on a smart phone camera to see the exact results of dropping objects.

Find some great videos of Neil Armstrong dropping a feather and a hammer on the moon and you can see them hit the ground at the same time. You and your students may want to watch one of these videos you can easily find on the internet.

If your students find the information about horizontal movement not affecting vertical movement interesting, they can learn more about this by reading about orthogonality (lines at right angles.)

Materials For Next Week

For **Week 4**, you will need to provide:

- ❑ Scissors
- ❑ Large tub or bowl full of water
- ❑ Ruler

Week 3 Lab Activity Sheet

1. Make a hypothesis: which object will hit the ground first, the heavier more massive object, or the lighter weight object? Why? Include in your answer which two objects you plan to drop.

   (Answers will vary, and at the hypothesis stage it is ok if they make an incorrect assumption about gravity. Example: The heavier object (a shoe) will hit the ground at the same time as the lighter object (a golf ball) because gravity makes all objects fall at the same rate.)

2. Place both objects on a high, flat surface like a table or countertop and push them off at the same time to see which one hits the ground first. Repeat 3 more times and write down what you saw.

   (Your student should observe that the objects hit the ground at about the same time unless they chose objects that have high air resistance.)

3. Is this different than what you predicted? How so?

   (Answers will vary.)

4. Choose 2 more objects of different masses and repeat the experiment. What is your conclusion?

   (Guide the student to choose objects not affected by air resistance since this will be discussed in the next question. Objects, unless very affected by air resistance, should hit the ground around the same time.)

Week 3 Lab Activity Sheet

5. What happens if you drop a flat piece of paper and a shoe at the same time? Which one hit the ground first? Explain what you think happened.

   (Since we are on planet Earth, not all objects will hit the ground at the same time because of air resistance.)

Go Back to the Lab Part 2

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6. If you have a smart phone, start recording video in slow motion and capture what happens when both balls are launched from the pad. If you do not have a smart phone, perform the experiment over a hard floor and listen to when exactly the balls hit the ground. What happened to the balls?

   (Possible: The two balls hit at exactly the same time.)

7. Repeat the experiment 3 more times while recording or listening, and write down what happened.

   (One ball should launch out horizontally while one ball drops, but they should both land at the same time.)

8. This test set-up has limitations since you are not using a precise piece of scientific equipment. The results will not always be perfect. However, there is much that can be gained from looking at these results. For small variations in results, what are some of the factors that could have caused these variations? Think about the test set-up. How do you think the test could be improved to reduce some of the variables that cause the results to vary?

   (Answers will vary. Possible equipment issues could include; the rubberband wasn't evenly distributing the pressure; the ball that was launched horizontally started on a flat surface whereas the ball that dropped vertically already had air underneath it.)

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Science J—Weekly Subject List

Week	Subject	History Reference
1	Aerodynamic shapes; engineering; Force = surface area * pressure * coefficient of drag; Newtons	Thales / *Aristotle Leads the Way*, pp. 36-43
2	Atomic structure; electron shells; static electricity; electron affinity; friction; electron transfer; hypotheses	Thales / *Aristotle*, p. 38
3	Mass; weight; F=m*a; gravity; $g=9.8m/s^2$; the effect of horizontal motion on a freefalling object	Aristotle, Newton / *Aristotle*, pp. 94-105
4	Hydraulics; mechanical advantage; Pressure = Force / Area	Hero of Alexandria / *Aristotle*, pp. 130-135
5	Basic machines; lever, pulley, wedge, wheel and axle, screw, inclined plane; Mechanical Advantage of Wheel and Axle = Radius of Wheel/Radius of Axle	Hero of Alexandria / *Aristotle*, pp. 130-135
6	Basic machines; First-class levers; mechanical advantage; Mass 1 * Distance 1 = Mass 2 * Distance 2	Archimedes / *Aristotle*, pp. 146-159
7	Compound Machines; inclined plan and screw; Archimedes' Screw;	Archimedes / *Aristotle*, pp. 146-159
8	Density = Mass / Volume; intrinsic value of coins; finding volume using water displacement; reading a meniscus	Archimedes / *Aristotle*, pp. 150-153
9	Compound Machines; wheel and axle; inclined plane; Work = Force * Distance	Filippo Brunelleschi / *Newton at the Center*, p. 7
10	Bridge efficiency; Da Vinci self-supporting bridge	Leonardo Da Vinci / *Newton* p. 33
11	Pendulums; periods and cycles; effect of weight and length of pendulum on the period; Period = $2 * \pi \sqrt{l/g}$	Galileo Galilei / *Newton* pp. 65-66
12	Telescopes; concave and convex lenses; radius of a lens; focus of a lens; angles of incidence and refraction	Galileo, Newton, Digges / *Newton* p. 108
13	Newton's Law of Universal Gravitation; $F = G * (m_1*m_2/r_2)$; F=m*a; g = 9.8 m/s^2; although objects drop at the same rate, objects with more mass can hit with more force	Isaac Newton / *Newton* pp. 144-153
14	Newton's Third Law: For every action there is an equal and opposite reaction;	Isaac Newton / *Newton*, pp. 172-177
15	Newton's Second Law: F = m*a; acceleration = $\Delta V/\Delta t$; momentum = mass * ΔV; interaction between Newton's Second and Third Laws	Isaac Newton / *Newton*, p. 174
16	Newton's First Law, Law of Inertia; inertia vs. momentum	Isaac Newton / *Newton*, p. 173
17	Bernoulli's Principle; fluid dynamics; drag, lift, and gravity;	Daniel Bernoulli / *Newton*, pp. 220-229
18	Bernoulli's Law; the height of a column of fluid affects the pressure and therefore velocity of an escaping stream of fluid; conservation of energy; velocity = $\sqrt{(2*g*height)}$	Daniel Bernoulli / *Newton*, pp. 220-229
19	Electrolysis; electroplating; anodes; cathodes; ions; anions; cations; electric current	Humphry Davy / *Newton*, p. 331
20	Electromagnetism; electric and magnetic fields flow at 90º to each other; Lenz Effect; conductive materials	James Clerk Maxwell / *Newton*, p. 361
21	Sounds waves; wavelength and frequency; compressing air molecules; frequency; harmonics; $v=f*\lambda$; out-of-family results in a lab test	Pythagoras, Hertz / *Newton* pp. 366-368
22	Waves; $v=f*\lambda$; Hertz; speed of electromagnetic waves and light; electromagnetic spectrum	Albert Michelson / *Newton* p. 424
23	Magnets; poles; magnetic fields; free-body diagrams; vectors	William Gilbert / *Einstein Adds a New Dimension*, pp. 10-12
24	Light duality; light acts as a particle; photoelectric effect; photons; UV light; electromagnetic spectrum; electroscopes	Christiaan Huygens, Albert Einstein, Robert Millikan / *Einstein*, pp. 82-94

Science J—Weekly Subject List

Week	Subject	History Reference
25	Light duality; light acts as a wave; double-slit experiment; wave interference patterns; parallel and concentric light waves	Thomas Young, Louis de Broglie / *Einstein*, p. 88
26	Bohr's atom; electron shells; photons; elemental absorption and emission spectrums; wavelengths of visible light	Niels Bohr / *Einstein* pp. 114-127
27	Thermodynamics; entropy; probability; statistics in quantum physics; Gaussian curves	Werner Heisenberg / *Einstein* pp. 150-157
28	1st Law of Thermodynamics: energy can be transformed but not destroyed; types of energy: chemical, gravitational, mechanical, nuclear, potential, kinetic, heat;	Julius Robert von Mayer / *Newton* pp. 394-399
29	2nd Law of Thermodynamics: entropy is always increasing, work must be added to return to a state of lower entropy; entropy; effects of temperature on particles	William Thomson, Ludwig Boltzmann / *Newton* pp. 400-411
30	Quantum electrodynamics; magnetism; creating magnets; electron spin; atomic energy levels	Robert Oppenheimer / *Einstein*, pp. 254-259
31	Speed of sound; $v=f*\lambda$; resonation of sound	Various / *Einstein* p. 273
32	Electric motors; homopolar motors; Lorentz Force; electric fields; magnetic fields; current; right-hand-rule	Hendrik Lorentz / *Einstein*, pp. 61, 160, 271, 283, 289
33	Doppler Effect; relative frequency; sound and light waves	Christian Doppler / *Einstein*, p. 331
34	Archimedean spiral; cartesian graphs; polar graphs; rotation angle (θ); the scientific method; $f_{observer} = f_{source}/(1 \pm (v/c))$	Archimedes / *Archimedes and the Door of Science*, Appendix
35	Angular momentum; right-hand-rule; vectors along x, y, and z axis; torque; $\tau=F*r$; gyroscopic precession in relation to gravity;	N/A
36	Review	N/A