TAKE-HOME PHYSICS:

65 High-Impact, Low-Cost Labs

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TABLE OF CONTENTS

SECTION 2: Forces and Energy

SECTION 3: Waves, Sound, and Light

Section 4: Electricity and Magnetism

INTRODUCTION

Research has shown that homework can be an effective and meaningful learning tool for high school students if it is relevant, engaging, and hands-on. These take-home physics activities are designed to match those criteria. Educational writer Alfie Kohn said in a 2006 interview that there are only two ways that homework is effective for high school students. One of those is "activities that have to be done at home, such as…a science experiment in the kitchen" (Oleck 2006).

This book is a collection of physics labs that lend themselves to being performed at home with simple materials. It is not intended to be a physics textbook or to cover every topic encountered in high school physics. Most of the labs are written as Structured or Level 2 inquiry (see Inquiry in Physics, page xi), and some include instructions to raise the level of inquiry if the teacher feels comfortable doing so. A few activities just aren't compatible with inquiry at home and are written as verification labs. Most of the activities involve measuring, graphing, calculating, extrapolating graphs, and other science-process skills.

Because this is one piece of a complete physics curriculum, it is assumed that traditional learning and hands-on activities in the classroom will fill in where take-home labs are not practical. Teachers may choose to eliminate some of the labs and substitute others without breaking the flow of the labs.

Used in this way, the hands-on activities can be a powerful tool for learning physics concepts and preparing students for physics assessments that are highly dependent on charts, graphs, and conceptual questions. These activities have been piloted in schools across the United States and used by teachers who received the material during conference presentations. The success that these teachers have had with the labs helps refute the common misconception among teachers and students that lectures are for learning and labs are for fun. Students *can* learn physics from labs.

Although the labs are written as take-home activities for high school students, many of the activities in the book are well suited for home-schooled students as well as those who take online courses. These activities would also be appropriate for family science nights and museum outreach programs. If a teacher does not have sufficient materials to send an activity home with every student, the lab could be performed in class as an alternative. One teacher used the activities in after-school intervention programs for students who were not proficient after being exposed to the concepts in the classroom.

Why Take-Home Labs?

These take-home labs, if implemented effectively, can address most or all of the following problems, which are common with physics labs and homework:

Students won't do homework. This sentiment could be rephrased as *Students won't do busywork at home*. When presented with fun and challenging assignments that open doors to understanding the physical world around them, students will rise to the occasion. Throughout four years of implementing these activities, the homework completion rate improved greatly, and test scores indicate that student achievement increased as well.

Students do poorly on standardized tests. Most standardized science tests are weighted toward science-process skills. These skills include drawing and interpreting charts and graphs, finding patterns, interpreting diagrams, and analyzing experimental data. These take-home labs contribute to the improvement of every one of those skills.

There is not enough class time to cover all the standards. A great deal of class time is used on simple labs that students could do at home. These labs are important, but they consume valuable class time. By having students perform these labs at home, teachers recover days of class time in which new concepts can be taught or reinforced.

Students do not experience enough labs. By assigning take-home lab work, teachers can increase the number of labs students complete over the course of the year to nearly 100 labs in class and at home. This will lead to a more engaging, fulfilling learning experience for students, which will lead to deeper, more lasting learning.

Physics labs are expensive. There are 65 labs in this book, and the collection of materials needed to complete the labs costs around $20, or approximately 31¢ per lab per student the first year. After the first year, only breakages and consumables (mostly batteries) have to be replaced at a cost of less than a couple of dollars per kit.

Physics students lack basic skills when they get to my class. Some of the take-home labs teach about background information and skills that students are supposed to remember from middle school but rarely do. These labs are a good refresher that you can refer back to throughout the year. As mentioned earlier, it can also buy you days of class time to teach the physics curriculum for your grade level.

My school will not let me do take-home labs because of No Child Left Behind. NCLB prohibits some schools from allowing take-home labs because the materials are not provided to every student. That practice, it is argued, puts some students at a disadvantage. However, teachers can easily provide almost every object needed to do *Take-Home Physics* labs, with the exception of a couple of labs that require students to provide water or other common materials. And if students tell the teacher in advance that they do not have certain required items at home, the teacher can provide these materials as well.

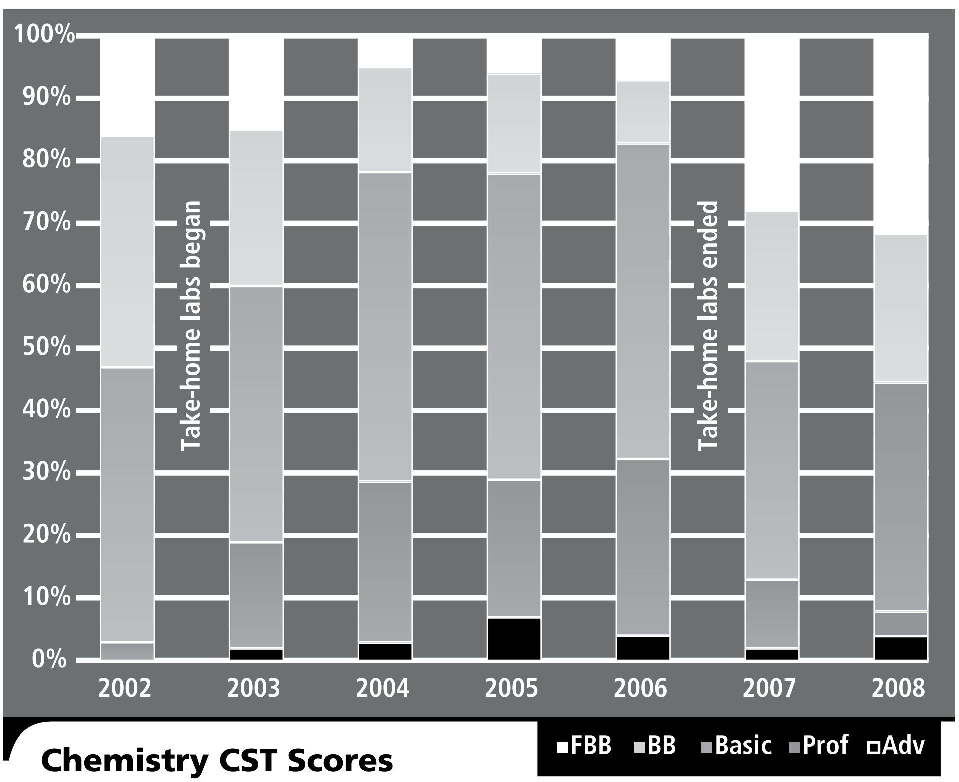
Evidence of Success

A chemistry teaching colleague and I have collected data on the success of these take-home labs. Most of the physics students were 12th graders, but in California 12th graders do not take state tests, and therefore, it was impossible to study the effectiveness of the labs with an independent physics exam. Instead, the effectiveness of the take-home activities was studied among chemistry students. Although the connection to physics may be anecdotal without a state exam, similar results were seen in exams and in student morale for both chemistry and physics classes.

As shown in Figure 1.1, four years of implementing chemistry take-home labs coincided with a nearly tenfold increase (from 3% to 32%) in the proportion of proficient and advanced students in chemistry based on the 2002 baseline. In the same time period, the number of students testing below basic and far below basic decreased

Figure 1.1

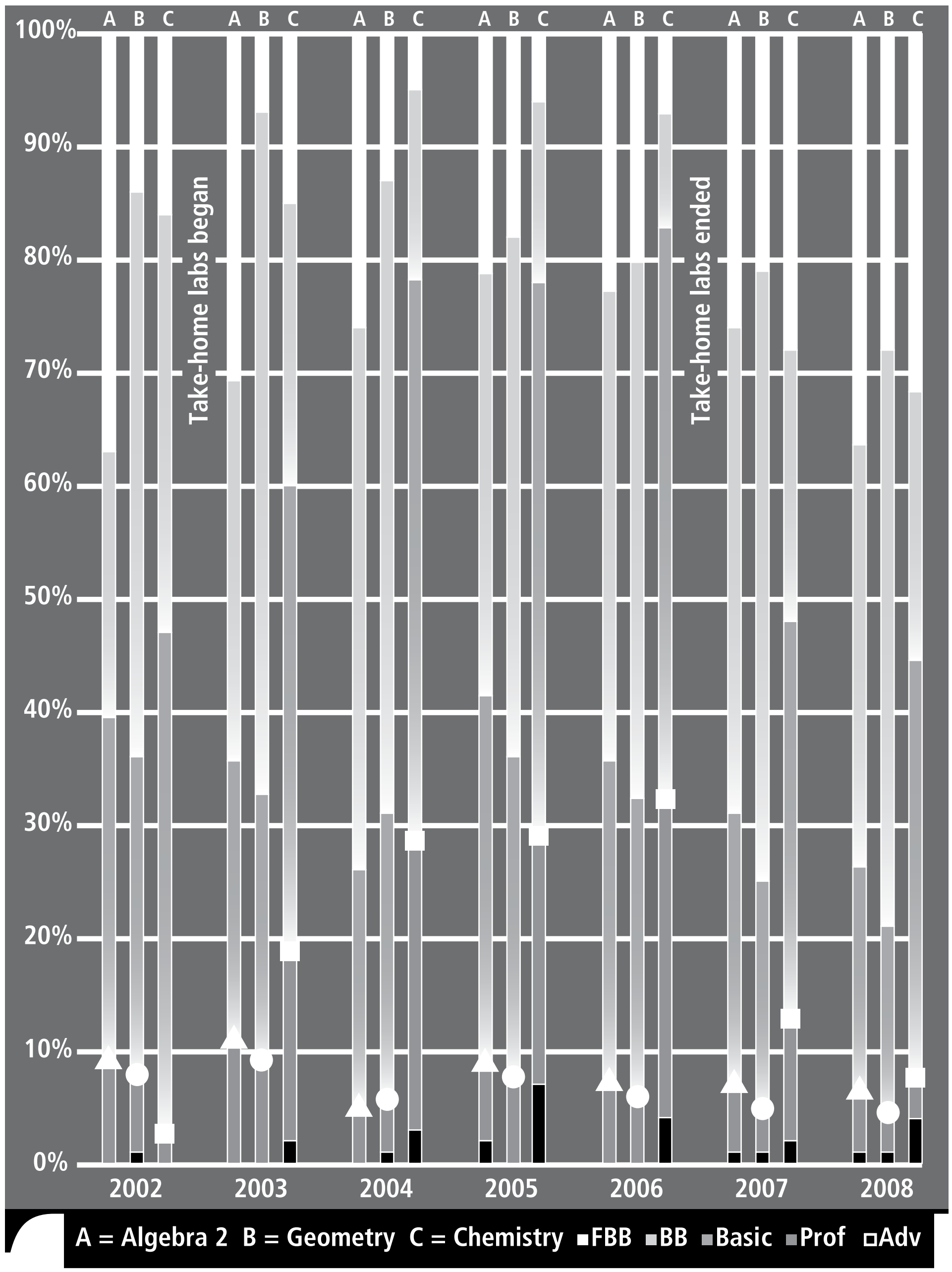
Chemistry Proficiency Before, During, and After Implementation



FBB = Far Below Basic, BB = Below Basic, Prof = Proficient, and Adv = Advanced. California considers FBB, BB, and Basic to be nonproficient.

Figure 1.2

Comparison of Student Proficiency in Chemistry, Geometry, and Algebra 2



FBB = Far Below Basic, BB = Below Basic, Prof = Proficient, and Adv = Advanced. California considers FBB, BB, and Basic to be nonproficient.

dramatically (53% to 17%). Each year, more activities were added and the procedures were refined.

To strengthen the argument that the score changes were due to the take-home labs and not to other changes in the school or the student body, student performance in Algebra 2 and Geometry over the same period was examined (see Figure 1.2). Those scores stayed nearly the same over this time period. Most chemistry students are in either Algebra 2 or Geometry.

Although I left the classroom at the beginning of the 2005–2006 school year, my chemistry colleague collaborated with the long-term substitute teacher and continued the take-home labs. Figure 1.1 shows that in 2007, when the chemistry colleague became an administrator and the take-home labs ended, the test scores went back almost to where they were before we started. That trend continued in 2008.

My high school was a state-identified underperforming school with more than 70% of the students qualifying for free or reduced-price lunch. More than 40% of parents never graduated from high school and more than 25% of students are English language learners. The state also puts schools into groups of 100 similar schools based on dozens of criteria. My school had far higher chemistry scores than those similar schools, as much as a 156-times-larger ratio of proficient and advanced students to below-basic and far-below-basic students. Overall, the school was ranked in the second decile from the bottom in the state in 2006. In chemistry, the school was above state average, putting it at least five deciles from the bottom. In short, the chemistry scores at this school were above school, district, county, and state averages.

All data in Figures 1.1 and 1.2 were taken from the California Department of Education website (*cde.ca.gov*) for Perris High School in the Perris Union High School District in Riverside County, California.

Inquiry in Physics

The topic of inquiry in science instruction—what it looks like, how best to implement it in the classroom, ways to assess its success—far exceeds the scope of this introduction. The following is a brief explanation of inquiry and how it's defined in this volume. For a full and more detailed discussion of inquiry, please consult the reference list.

When inquiry is discussed in science education, it takes two forms. The first meaning is the creation of an atmosphere of inquiry in the classroom in which students interact with one another and the teacher facilitates open-ended investigation of student-generated questions. The second use of the term *inquiry* refers to inquiry activities. This book alone cannot accomplish the first task, but it is intended to provide the second. The postlab questions take the place of the teacher's guiding questions during an inquiry activity performed in the classroom.

It is a common misconception that inquiry is all or nothing. Most of the research about inquiry activities identifies four levels of inquiry (Banchi and Bell 2008; Colburn 2000; McComas 2005), although the first level is not inquiry at all (see Figure 1.3). What changes at each level is how much information is given to the student (i.e., the question, the procedure, the answer) (Bell, Smetana, and Binns 2005). Herron (1971) first described inquiry by distinguishing among three different levels. Since then, rubrics and matrices have been created with three, four, five, and seven levels (Lee et al. 2001). Because most education researchers refer to four levels, that is the model that will be used here.

Figure 1.3

What Is Provided to Students at the Different Levels of Inquiry

	Question Given	Procedure Given	Answer Known
Level 1	X	X	X
Level 2	X	X	
Level 3	X		
Level 4			

Level 1 inquiry activities are also known as verification, or "cookbook," activities. In a Level 1 activity, students are given the question or problem, they are given the procedure, and they already know the answer to the question. They are simply verifying something that they already learned. This is the least effective form of inquiry.

In a **Level 2,** or "structured inquiry," activity, students are given the question and the procedure, but they do not yet know the answer. Having students do an activity before learning the concept raises the activity to Level 2. In performing this significant step, the teacher is giving all students the same background knowledge, an activity on which to hang the concept in their memory, and a common experience to refer back to in class when covering or practicing the concept. Robert Marzano (2004, p. 3) says, "Students who have a great deal of background knowledge in a given subject area are likely to learn new information readily and quite well. The converse is also true." Dochy, Segers, and Buehl (1999) found through meta-analysis that differences in students' prior knowledge explain 81% of the variance in posttest scores. The research of Langer (1984) and Stevens (1980) shows a well-established correlation between prior knowledge and academic achievement.

Most of the labs in this book are written as Level 2 inquiry, which means the teacher must assign the activities to students before teaching the concept in class. Assigning the activities this way increases the level of inquiry and also allows teachers to afford students prior knowledge when the concept is covered later. Marzano states that "what students *already know* about the content is one of the strongest indicators of how well they will learn new information relative to the content" (2004, p. 1). Douglas Llewellyn, in *Teaching High School Science Through Inquiry: A Case Study Approach* (2005), recommends doing the lab first to raise the inquiry level. Bell (Bell, Smetana, and Binns 2005, p. 33) comments, "The difference between a Level 1 and Level 2 activity can be a matter of timing. A confirmation lab can become a structured inquiry lab by simply presenting the lab before the target concept is taught."

In a **Level 3** activity, referred to as "guided inquiry," students are given an appropriate question and are asked to determine the procedure and develop the answer on their own. Many activities can be converted to Level 3, simply by removing the procedure and having students determine how to accomplish the task. For example, a lab inviting students to follow a procedure to determine what affects the period of a pendulum could be increased to Level 3 by changing the activity to "Which affect(s) the period of a pendulum—length, angle of release, and/or mass of the pendulum bob?" Some of these take-home labs are already Level 3 and teachers are free to modify others to meet the Level 3 criteria. Most of the extension activities, which are often provided at the end of the activities, are opportunities for Level 3 inquiry, and several of the post-lab questions encourage students to test ideas on their own. Teachers can remove some steps in the procedure, add unnecessary steps and have students identify them, remove data tables and have students create their own, add extensions, or rearrange the steps in order to transition to Level 3 gradually (Llewellyn 2005). Some of the labs in this book already expect students to create the data charts.

In a **Level 4** activity, referred to as "open inquiry," students pose their own question and are given the resources to answer that question. This type of inquiry is most easily demonstrated with science fair projects. Students investigate their own questions following their own procedures and draw their own conclusions. Many teachers also use this type of inquiry as differentiation activities. If a student clearly understands a concept while doing an inquiry lab, he or she may be invited to come up with additional questions to answer independently. It is not the intent of this book to provide Level 4 inquiry activities, but teachers are encouraged to motivate students to perform deeper follow-up activities to answer questions that they may have after an activity. Students can certainly extend experiments to answer their own questions, hence independently creating their own Level 4 inquiry activities. Some of the extension activities could be replaced with a more general Level 4 question, such as "What other questions do you have about this topic? Create an activity that will lead you to the answer."

Many teachers are discouraged when they begin using inquiry activities and do not immediately see the achievement gains they expected. Students need experience using inquiry activities to learn. They do not relate classroom lab activities with learning because they have always done verification labs. I have seen low performance the first few times questions were given on a test about a subject learned via inquiry. However, when students were reminded of the activity, they immediately began writing again and performance increased greatly. After a little experience, students no longer need to be reminded and make the connection automatically. Please be warned that providing question stems such as "Remembering the string and protractor lab…" is never a good idea because high-stakes tests will not do so.

Some of the labs in this book are not inquiry-based. They are included to overcome student misconceptions, provide experiences that allow students to see physics phenomena, or enable students to collect and analyze data that will assist them in understanding a concept more thoroughly. Some topics just do not lend themselves well to inquiry at home, but they are far fewer than those topics that do.

Teacher Feedback

Keep in mind that feedback of some type should be given on each lab that students do. This can be time consuming but very valuable.

The purpose of these labs is not to add more items to the teacher's grade book. Homework should be used as formative assessment. Often, formative assessments are not even graded. The teacher uses them to judge where the students are in relation to proficiency on the relevant standard. If the purpose of the lab is to give common background information to the students, then the teacher may also consider this a situation that need not be graded formally. But keep in mind that whether the teacher grades the labs or not, there must be feedback in the classroom. Some teachers may choose to give the labs credit/no credit or credit/redo marks.

Marzano (2006) reports that students who do not receive feedback after a formative assessment do no better on the summative assessment than if they had not been given the formative assessment at all. He lists several different ways of offering that feedback and gives the pre- and posttest gains that can be expected. Just putting a grade at the top of the paper has a negative effect. If the teacher decides to grade the labs, then the feedback should be deeper than a simple overall grade. Having students prepare short written summaries, explain their logic aloud to the class, or discuss the activities while the teacher rotates around to deal with misconceptions are examples of ways teachers can check for understanding without formal grading. It is also helpful for the teacher to identify the criteria used to deem a conclusion satisfactory and allow students to redo the activity until it is satisfactory.

Many schools have not gotten to the point where formative assessments are used this way, however. Teachers may want to give credit for these labs simply to encourage students to perform the labs. Although it is worth repeating that these activities do not have to be graded, following are some tips for easing that burden if the teacher chooses to do so. A compromise could be that the teacher only grades some of the labs but the students do not know in advance which labs will be graded.

Teachers should create a grading guide that identifies which parts of each lab are the most important and assesses only those parts. For those labs that are graded, not every section has to be graded. And for every section that is graded, not every question or detail has to be analyzed.

A grading guide could look something like this:

Name__________________________ Period____________________

Dist/Time Graphs 1
Graphs _____/ 10 Total ____/10

Dist/Time Graphs 2
Data ____ /5 Graphs ____/5 Total ____/10

Average Speed
not graded

Acceleration of G 1
Post-lab Questions ___/10 Total ____/10

Acceleration of G 2
Data ____/5 Conclusion ____/2 Total ____/7

Final Velocity
Data ____/2 Graph ____/5 Total ____/7

Reaction Time not graded

Completeness and Setup of Lab Notebook Total ____/15

Grand Total ____/59

Lab Notebooks

Because students may perform as many as 65 activities, a lab notebook is a useful tool for students to keep track of their lab write-ups; plus, teachers may choose to collect the notebooks after, say, five or ten activities have been completed as a means of assessment. The teacher should determine in advance the format for the notebooks (e.g., Purpose, Procedure, Data, Calculations), and establish a set of rules for using the notebooks. These rules help students stay organized and save teachers time when reviewing the notebooks. The students' write-ups should include data charts, graphs, and post-lab questions, as called for in a given activity's directions. Composition-style notebooks, spiral notebooks, or three-ring binders are all acceptable "notebooks." Teachers may consult a local university instructor to find out how freshmen are required to organize their notebooks, and then ask their own students to set up their notebooks in a similar fashion.

It is clear when students cheat on a take-home lab. For most of the labs, there is a very small chance that any two people would get the exact same answer. If two students do get the exact same answers, it is clear that they copied. They cannot say that they were partners like with an in-class lab as long as the teacher makes it clear that each student is expected to collect his or her own data.

Again, it is not imperative to grade every lab or every part of those that are graded. Formal summative assessments will determine which students did the work and which students did not. These labs are not about assigning grades. They are about learning physics. Each lab should be reviewed by the teacher to check for understanding, and feedback should be given in one form or another.

Tips for Using This Book

Teachers may opt to use *Take-Home Physics* labs exactly as they are presented or adapt them to better suit the needs of a particular class. Labs may be written on the board or posted via overhead projector for students to copy into their lab notebooks, or teachers may choose to pass out copies to each student. Copies, of course, can be stored in materials boxes and reused from year to year.

Figure 1.4

Small Sample of Materials for Lab Boxes

Figure 1.5

Some Items Ready to Distribute

Assembling the Materials

Once you decide to assign the labs in this book, you will need to start planning. A list of materials is included in each lab to assist teachers in determining what materials will be needed. A master materials list is included at the end of this section.

The basic idea is that you will send a (plastic shoe-box size) box of materials home with the students with which they can complete all of the activities in this book. The box is pictured in Figures 1.4 and 1.5 (p. xvi). Sending all of the materials home in one box is preferable to sending individual activities home in plastic sandwich bags because of the time that it will take to check in and out each of the bags. All of the materials can fit into one box, which may be purchased for around a dollar, or alternatively a 1-gallon plastic freezer bag.

After determining which labs you will assign and how much of each item is necessary, it's time to go shopping. Most of the items can be found at discount stores—from the boxes themselves to the cups, batteries, and magnets. A few items such as nails, sandpaper, and washers can be purchased at a home improvement store. Many items can be purchased at a much lower cost online than in stores or catalogs. For example, 12 resistors at a local electronics store go for about $2.50, but on sites like eBay, you may find a roll of 1,500 resistors for $10. The two most expensive materials are the multimeters and the stopwatches. Multimeters can be purchased for around $5 from many electronics distributors online or from hardware stores such as Harbor Freight Tools (*http://harborfreight.com*). Stopwatches can be purchased in larger quantities for about $6 each from education supply companies. Rubber balls can be purchased online very inexpensively, but beware of high shipping costs. The website *www.rebeccas.com* sells 250 bouncy balls for less than $22, including shipping. At an electronics store, two stopwatch batteries can cost $3.75, but *www.cheapbatteries.com* sells 100 for 10¢ each.

Be sure to buy a few extra of each item in case of loss and breakage. Once purchased, the items will take up quite a bit of space. (Figure 1.4 shows a small sample of the materials used to make lab boxes.) Don't plan on storing them in the back of your classroom. (Tip: Purchase a few extra boxes to store items in while you dispense them.)

When all materials have been purchased, put each item in its own box for easier distribution (see Figure 1.5). Find a large space to spread out the boxes in an assembly line so students can walk by, pick up the boxes, and fill them with the materials. Attach a 3 × 5 in. index card with the quantity that students need to take written on it to each box and instruct students to follow the cards in order (for example, pick up six marbles, four paper clips, one rubber ball, etc.).

Remind students that they are to return all nonconsumable items with the boxes at the end of the year or upon transferring to another class or school.

Master Materials List

* Students will be expected to have these items at home. If they do not, the teacher should have some extras to loan out.

- Aluminum foil (20 x 20 cm)
- Batteries, 9 V (2)
- Batteries, D-cell (2)

- Baking soda (50 ml)
- Balloon, helium (optional)
- Balloons, standard (2)
- *Bathroom scale
- Bead, wooden or plastic with a hole through the center, size of a standard marble (can be taken off a beaded necklace from a discount store)
- Bell wire, enameled (~1 m)
- Boat drawings on transparency (see p. 94)
- Bouncy ball, any size
- *Calculator
- *Cans of soup (1 clear, e.g., chicken broth; 1 creamy, e.g., cream of mushroom)
- Card (3 x 5 in.) with hole punched (anywhere on card)
- Cardboard, corrugated (8 ½ x 11 in.)
- Cardboard or thick paper (8 ½ x 11 in.)
- CD case or other piece of hard plastic
- Chalk
- Coffee filters, any size (3)
- Compass or circular objects of different sizes
- *Computer monitor
- Concentric circles printed on transparency material (see pp. 213–214)
- Cups, small plastic salsa (2)
- Dominoes, coins, or small blocks of wood (similar to Jenga pieces) (8–10)
- Flashlight
- Flashlight bulb, 1.5–3 V
- Food coloring (optional)
- *Glass, drinking, transparent
- Graph paper (2 sheets)
- Graphite artist's pencil, with solid graphite core (may be cut into 4 pieces and sharpened) (Mechanical pencils may be used but do not work as well.)
- *Hole punch
- *Insulators (a variety of materials that the students think up themselves)
- *Lamp
- LED, with current-limiting resistor
- Lightbulb
- *Liquid soap or detergent (a few drops)
- Magnets, small (2) (can be removed from magnetic toys such as magnetic alphabet)
- Magnifying glass
- Marble, large, glass
- Marble, small, glass (5)
- Marble, small, metal
- Marking pen (nonpermanent)
- Mechanical pencil lead refills (0.5 mm and 0.7 mm)
- Multimeter
- Nail, iron
- Oil, cooking

- *Paper (1 sheet)
- Paper clips
- Paper cutout from thick paper (3 cm square)
- Pencil
- Pennies (4)
- Pepper
- Pie pan
- Piezo sparker from inexpensive barbecue lighter
- Ping-Pong ball
- Plastic bag, resealable snack- or sandwich-size
- Plastic box, shoe-box size (the box that holds the materials)
- Plate, paper or Styrofoam, small with rim around the edge
- Protractor
- Push pins
- Quarters (2) (optional)
- Rock
- Rubber band, thick
- Rubber band, thin (2)
- Ruler, plastic with groove down the middle, metric
- *Salt (a pinch)
- Sand, pennies, or other weights
- Sandpaper square
- *Scissors
- Soda bottle, glass or plastic (any size)
- *Soda cans, empty (2)
- Soda can, unopened
- Spoon, large, shiny
- Static electricity materials: PVC pipe (~15 cm long, ½ or ¼ in. diameter), glass (test tube, microscope slide, etc.), balloon, aluminum can, wood, plastic ruler, turkey roasting bag (cut into 15 x 15 cm squares), paper, wool, fur, aluminum foil, silk, salt, pepper, dirt, crisped rice cereal, thread, Christmas tree icicle
- Stopwatch
- Straws, bendable (2)
- String, kite (~30 cm)
- Tape, Scotch or other clear variety
- Thread, small spool
- Thumbtacks (2)
- Tone generator program (free trial download)
- T-pin
- Triple-throw switch (left, middle off, right)
- *Tube television (not a flat screen)
- Vinegar (~125 ml)
- Washers, large (6)
- Water
- Wires (4 pieces, 6 in., stripped both ends; 2 pieces, 12 in., stripped both ends)
- *Wooden plank to use as a ramp

Managing the Boxes

Before assigning take-home labs, consider how you will manage the materials boxes—especially how they will be collected at the end of the school year. Incomplete or lost boxes are a waste of time and money.

Make the distribution of box lids a routine part of the new school year. For example, if the school librarian manages textbook distribution and collection at your school, have that person also assist with the check-in and check-out process for your materials boxes. In my school, when students enrolled in physics and picked up their textbooks from the library, they also signed out the physics lab materials in the form of a box lid. That is, the lids were labeled with bar codes and checked out to students, and the boxes (in my classroom) were labeled with a matching bar code. When a student brought a lid to class, I gave him or her the matching box to be filled with materials. (Tip: Don't put the materials away yet as you will certainly have students checking into your class late. Just put the lids on the boxes of extra materials and store them somewhere convenient.)

Even with such a system in place, you will need to keep careful watch over the boxes. Students may transfer out of the class or the school and take the box with them. If so, send a letter to their new classes (if they are still enrolled in the school), home, or new school asking for the boxes to be returned. If the boxes are still not returned, treat them just like a textbook and charge a fee to cover the loss. Students should not receive transfer grades until all debts are cleared, including the boxes. It is always preferable—and less costly—to get the box back than to receive money for a new box.

Tell students at the beginning of the year that the boxes must be returned at the end of the year and that some items will be used up while others will still remain. Also tell them approximately how much each item is worth in case they are lost or broken. The librarian, or whoever collects textbooks at the end of the year, can charge these partial damages just like damage to a book. After students return the boxes, the teacher determines if all the materials are there and takes the lids and a list of missing items back to the library.

Do not wait until the last day of the school year to collect the boxes, as students inevitably will be absent or forget to bring their boxes. Rather, start collecting the boxes as soon as the last lab is finished. This will give you several weeks to collect them.

Safety

Every lab in this book is safe when the directions are followed properly. No dangerous chemicals, flammables, fire, or explosives are used. But there is always a chance of accidental injury. Teachers should always remind students to perform activities safely. If your policy is to require goggles with every lab, a pair of goggles can be provided for a small additional cost. Suitable impact-resistant goggles may be purchased at hardware stores.

There are possible choking hazards for very small children. Emphasize to your students that the boxes of lab materials *must* be kept out of the reach of small children. On the next page is a label that should be on the top of all boxes before they are distributed. Just print the page onto peel-and-stick paper, cut out the stickers, and place a sticker on each box or lid. If the peel-and-stick paper is made for the computer printer, you may need to scan the page first.

See page xxii for a letter to parents that explains the possible dangers of the box of lab materials. This letter should be sent home, signed, and returned.

WARNING!

KEEP OUT OF REACH OF SMALL CHILDREN. KEEP THE LID ATTACHED FIRMLY AT ALL TIMES AND THE BOX ON A HIGH SHELF. CHOKING AND SWALLOWING HAZARDS FOR SMALL CHILDREN CONTAINED INSIDE.

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WARNING!

KEEP OUT OF REACH OF SMALL CHILDREN. KEEP THE LID ATTACHED FIRMLY AT ALL TIMES AND THE BOX ON A HIGH SHELF. CHOKING AND SWALLOWING HAZARDS FOR SMALL CHILDREN CONTAINED INSIDE.

Dear Parent or Guardian:

Soon your child will be bringing home a box of materials to perform physics labs at home. These activities will give your child more skill in performing labs, analyzing data, and creating charts and graphs, and they will free up more time in class to cover other important topics.

Although all of the labs are safe, there is always a chance of an accident. Please encourage your child to always perform these activities safely and to follow all directions. I assure you that there are no dangerous chemicals, explosives, flammables, sharp objects, or poisons contained in the materials, but there are small objects that could present a choking hazard for small children (such as marbles and a rubber ball).

The box will have a warning sticker on top to discourage young children from opening it. Students should keep the lid on the box at all times and keep the box out of reach of children.

Sincerely,

I have read and understand that if performed properly, these labs are safe. Abuse of these labs could possibly lead to harm. I do not hold the teacher, school, author, or publisher responsible for injuries sustained while performing these labs.

____

Printed Name

____

Signature Date

Acknowledgments

Most of the ideas in this book have some basis in my experience as a teacher and teacher educator. Although ideas cannot be copyrighted, it is my intent to try to provide credit where credit is due for the ideas. The books and websites that are listed below are valuable resources, and the ideas for many of the labs may have originated in them.

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LAB 32: BERNOULLI'S PRINCIPLE

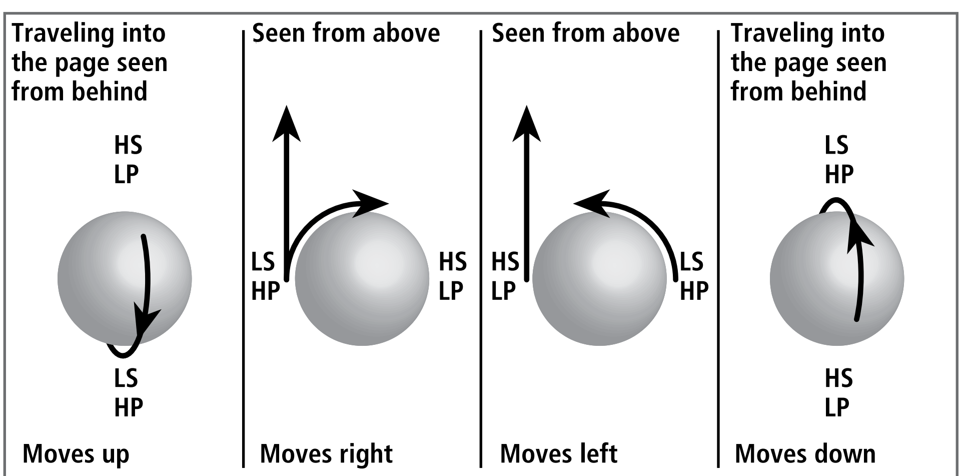
In this lab, students will use a little background information about Bernoulli's principle to figure out how the spinning of a moving ball affects its trajectory. The activity is inquiry in that students will be discovering this relationship on their own. Those with baseball, tennis, or soccer experience may already have some intuition as to how this works.

It takes some coordination to get the ball to roll down the ruler and then throw it with a whipping motion. Practice will help. If a student cannot get this to work, he or she can use the cardboard tube at the center of a roll of paper towels to make it easier.

SCILINKS THE WORLD'S A CLICK AWAY
Topic: Bernoulli's Principle
Go to: *www.sciLINKS.org*
Code: THP20

Post-Lab Answers

1. Step 2: up; Step 3: right (left for lefties); Step 4: left (right for lefties); Step 5 (very difficult to accomplish): down
2. The ball will deflect left if spinning counter-clockwise (from above) and right if clockwise. It will curve up with backspin and down with topspin. General rule: The ball will curve toward the side of the ball that is spinning back toward the person throwing the ball.
3. Diagrams should show the side spinning into the "wind" having a higher relative speed and lower pressure than the side spinning away from the "wind."



HS=High Speed LS=Low Speed HP=High Pressure LP=Low Pressure

LAB 32: BERNOULLI'S PRINCIPLE

QUESTION

How does spin affect the motion of a projectile?

SAFETY

It is best to do this activity outside on a day with no wind to avoid hitting someone or breaking something.

MATERIALS

Plastic ruler with groove down the middle or a cardboard paper-towel tube, Ping-Pong ball

PROCEDURE

Air exerts pressure on surfaces. Bernoulli's principle says that when air is moving parallel to a surface, it does not impart much force to that surface. The faster the air is moving, the less force it imparts. This is part of the explanation for how an airplane wing works (it also has to do with "angle of attack"). It's also why a "ragtop" convertible top on a car bulges upward on the freeway. When the car is at rest, air pressure inside and outside are equal, and the top stays flat. As the car speeds up, the fast flowing air along the top of the car exerts less pressure than when at rest, while the air pressure inside the car remains constant. There is more pressure upward than downward, so the soft top bulges upward.

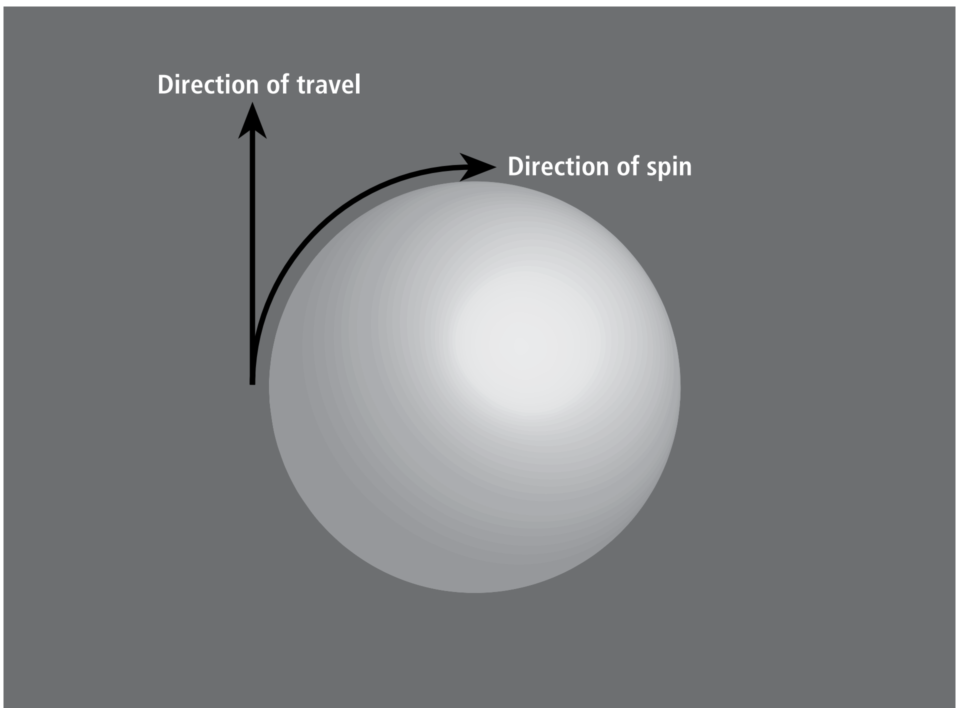
When an object is spinning and moving (see Figure 32.1), the air moves across one side faster than on the other side of the spinning object, so a similar force is created. In this activity, you will determine how the direction of spin is related to the direction that the ball curves. Keep in mind that when a ball moves through the air, there is "wind" flowing past it. If the ball is spinning into that "wind," it slows it down. If it is spinning away from that "wind," it speeds it up.

Note that there is another explanation of how a ball curves that relies on the Magnus effect. It says that the spinning ball throws air in one direction and action/reaction moves the ball in the opposite direction. It is likely that both effects contribute to the motion.

Remember that Bernoulli's principle only applies when the air is flowing along a surface, not when it collides directly with it. The front grill on a car does not experience Bernoulli's forces because the air collides with it directly.

Figure 32.1

Diagram of a Spinning Ball



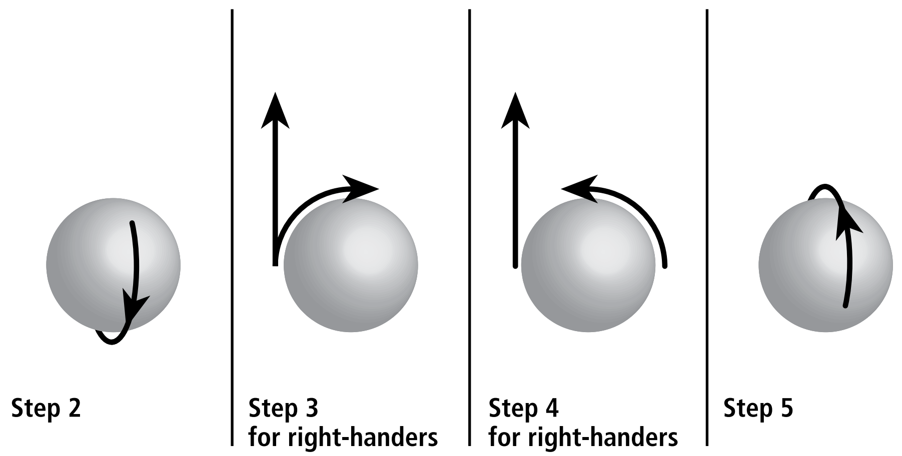
1. You will be using a ruler with a groove in it to throw a Ping-Pong ball. Allow the ball to roll quickly along the ruler and launch it with a "whipping" motion to create a high spin.
2. Throw the ball overhand so that the bottom is spinning in the direction of motion (backspin). Record whether the ball moves up, down, left, or right compared to a spinless throw.
3. Throw the ball sidearm so that the side closest to you is spinning in the direction of motion. Record whether the ball moves up, down, left, or right compared to a spinless throw.
4. Try to throw the ball with the opposite spin from Step 3. Either use the same hand but with a backhand motion (your throwing arm starts across

your body) or use the other hand. Record whether the ball moves up, down, left, or right compared to a spinless throw.

5. Now attempt to throw the ball underhand so that the top of the ball is spinning in the direction of motion. Record whether the ball moves up, down, left, or right compared to a spinless throw.
6. If you have difficulty doing this with a ruler, use a cardboard paper towel tube.

Post-Lab Questions

1. Looking at the ball from above, draw an arrow on each one of the diagrams below to show which way the ball was diverted from its normal path.



2. Write a general rule for which direction the ball will move compared to its spin.
3. Draw a diagram for Steps 2, 3, 4, and 5 similar to those in question 1 and include:
   a. direction of spin
   b. observed direction of motion
   c. side of the ball where the air is moving faster relative to the spinning ball (top or bottom for Steps 2 and 5 and left or right for Steps 3 and 4)
   d. side of the ball where the air is moving slower relative to the spinning ball
   e. direction that Bernoulli's principle predicts the ball will move based on the difference in pressure

   Did the direction that Bernoulli's principle predicts match your observations in question 1?

INDEX