Stop Faking It!

Finally Understanding Science So You Can Teach It

Sound

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SCILINKS THE WORLD'S A CLICK AWAY *Featuring sciLINKS®—a new way of connecting text and the Internet. Up-to-the-minute online content, classroom ideas, and other materials are just a click away. Go to page x to learn more about this new educational resource.*

Contents

Preface

When I was back in college, there was a course titled Physics for Poets. At a school where I taught physics, the same kind of course was referred to by the students as Football Physics. The theory behind having courses like these was that poets and/or football players, or basically anyone who wasn't a science geek, needed some kind of watered-down course because most of the people taking the course were—and this was generally true—SCARED TO DEATH OF SCIENCE.

In many years of working in education, I have found that the vast majority of elementary school teachers, parents who homeschool their kids, and parents who just want to help their kids with science homework fall into this category. Lots of "education experts" tell teachers they can solve this problem by just asking the right questions and having the kids investigate science ideas on their own. These experts say you don't need to understand the science concepts. In other words, they're telling you to fake it! Well, faking it doesn't work when it comes to teaching *anything*, so why should it work with science? Like it or not, you have to understand a subject before you can help kids with it. Ever tried teaching someone a foreign language without knowing the language?

The whole point of the *Stop Faking It!* series of books is to help you understand basic science concepts and to put to rest the myth that you can't understand science because it's too hard. If you haven't tried other ways of learning science concepts, such as looking through a college textbook, or subscribing to *Scientific American* or reading the incorrect and oversimplified science in an elementary school text, please feel free to do so and then pick up this book. If you find those other methods more enjoyable, then you really are a science geek and you ought to give this book to one of us normal folks. Just a joke, okay?

Just because this book series is intended for the nonscience geek doesn't mean it's watered-down material. Everything in here is accurate, and I'll use math when it's necessary. I will stick to the basics, though. My intent is to provide a clear picture of underlying concepts, without all the detail on units, calculations, and intimidating formulas. You can find that stuff just about any-where. Also, I'll try to keep it lighthearted. Part of the problem with those textbooks (from elementary school through college) is that most of the authors and the teachers who use them take themselves way too seriously. I can't tell you the number of times I've written a science curriculum only to have colleagues tell me it's "too flip" or "You know, Bill, I just don't think people will get this joke." Actually, I don't really care if you get the jokes either, as long as you manage to learn some science here.

Speaking of learning the science, I have one request as you go through this book. There are two sections titled *Things to do before you read the science stuff* and *The science stuff*. The request is that you actually DO all the "things to do" when I ask you to do them. Trust me, it'll make the science easier to understand, and it's not like I'll be asking you to go out and rent a superconducting particle accelerator. Things around the house should do the trick. By the way, the book isn't organized this way (activities followed by explanations followed by applications) just because it seemed a fun thing to do. This method for presenting science concepts is based on a considerable amount of research on how people learn best and is known as the *Learning Cycle*. There are actually a number of versions of the Learning Cycle but the main idea behind them all is that we understand concepts best when we can anchor them to our previous experiences. One way to accomplish this is to provide the learner with a set of experiences and then explain relevant concepts in a way that ties the concepts to those experiences. Following that explanation with applications of the concepts helps to solidify the learner's understanding. The Learning Cycle is not the only way to teach and learn science, but it is effective in addition to being consistent with recommendations from the *National Science Education Standards* (National Research Council 1996) on how to use inquiry to teach science. (Check out Chapter 3 of the *Standards* for more on this.) In helping your children or students to understand science, or anything else for that matter, you would do well to use this same technique.

The book you have in your hands, *Sound*, starts from the basic of basics and moves to a few more complicated things. I begin with what causes sound, what sound waves are, and how to accurately describe sound waves. Then I move to how sound travels around and how different substances affect the movement of sound. A few specific topics covered are the Doppler effect, harmonics and overtones, resonance, and auditorium acoustics. There's an entire chapter on how musical instruments work, and a final chapter on listening devices, from record players to CD players, to telephones, to the human ear. I spend quite a bit of time explaining how the ear physically functions, and introduce a ton of biological vocabulary words to boot! I do not address a number of sound topics that you might find in a physical science textbook, choosing instead to provide just enough of the basics so you will be able to figure out those other concepts when you encounter them. You might also notice that this book is not laid out the way these topics might be addressed in a traditional high school or college textbook. That's because this isn't a textbook. You can learn a great deal of science from this book, but it's not a traditional approach.

One more thing to keep in mind: You actually CAN understand science. It's not that hard when you take it slowly and don't try to jam too many abstract ideas down your throat. Jamming things down your throat, by the way, seemed to be the philosophy behind just about every science course I ever took. Here's hoping this series doesn't continue that tradition.

Acknowledgments

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About the Author

Bill Robertson is a science education writer, teaches online math and physics for the University of Phoenix, and reviews and edits science materials. His numerous publications cover issues ranging from conceptual understanding in physics to how to bring constructivism into the classroom. Bill has developed K–12 science curricula, teacher materials, and award-winning science kits for Biological Sciences Curriculum Study, The Wild Goose Company, and River Deep. Bill has a master's degree in physics and a Ph.D. in science education.

About the Illustrator

The soon to be out-of-debt humorous illustrator Brian Diskin grew up outside of Chicago. He graduated from Northern Illinois University with a degree in commercial illustration, after which he taught himself cartooning. His art has appeared in many books, including *The Golfer's Personal Trainer* and *5 Lines: Limericks on Ice*. You can also find his art in newspapers, on greeting cards, on T-shirts, and on refrigerators. At any given time he can be found teaching watercolors and cartooning, and hopefully working on his ever-expanding series of *Stop Faking It!* books. You can view his work at *www.briandiskin.com.*

How can you avoid searching hundreds of science web sites to locate the best sources of information on a given topic? SciLinks, created and maintained by the National Science Teachers Association (NSTA), has the answer.

In a SciLinked text, such as this one, you'll find a logo and keyword near a concept, a URL (*www.scilinks.org*), and a keyword code. Simply go to the SciLinks web site, type in the code, and receive an annotated listing of as many as 15 web pages—all of which have gone through an extensive review process conducted by a team of science educators. SciLinks is your best source of pertinent, trustworthy Internet links on subjects from astronomy to zoology.

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1 Chapter

Stop Children, What's That Sound?

Aging hippies might recognize the title of this chapter from an old Buffalo Springfield song. Others will just have to ignore it, and realize that this is the first chapter in a book on sound. As you go through this book, you'll be exposed to scientific models of what sound is and how it behaves. To get us started, though, we're just going to focus on what produces sound and what causes different kinds and qualities of sound—in other words, we're starting with the basics.

Topic: What is sound?
Go to: *www.scilinks.org*
Code: SFS01

Things to do before you read the science stuff

Just so you get the idea that doing science is fun, we're going to start with a scavenger hunt. Woo hoo. Well, not a regular scavenger hunt, but a "sound" scavenger hunt. Find a bunch of things that produce sounds. Pretty easy task, because there are lots of things that produce sounds—radios, televisions, musical instruments, wind blowing through the trees, kids banging on objects, adults banging on objects, adults yelling at kids for banging on objects, and pages of this book turning.

Now follow that easy scavenger hunt with an answer to the following question. What do all of these sound-producing things have in common? In other words, is there one thing these sound producers are doing that results in sound? That's not such an easy question, so I'll help you figure it out.

Find a guitar, a violin, a piano, or some other stringed instrument. If you don't have anything like that, use a stretched rubber band. Pluck one of the strings and describe the motion of the string. Yes, it is moving pretty fast, but do your best.

Now take the cover off a stereo speaker and watch what the various little speakers inside do as music plays. See any similarity between this motion and the motion of the instrument strings that were producing sound?[1] That's about the easiest question you'll be asked in this book!

Talk while placing your fingers on the front of your neck. Does your neck feel any different when you're talking and when you're silent?

One more easy thing to do. Tap your finger lightly on a table. Produces a sound, yes? Now tap lightly on a pillow. No sound. Why the difference?

The science stuff

Vibrations produce sound. Oh my gosh, stop the presses! Yes, you probably already knew that. The vibrations that produce sound are fairly obvious when watching a plucked string or watching stereo speakers move in and out. The vibrations might not be so obvious in the case of, say, rustling leaves, but if you

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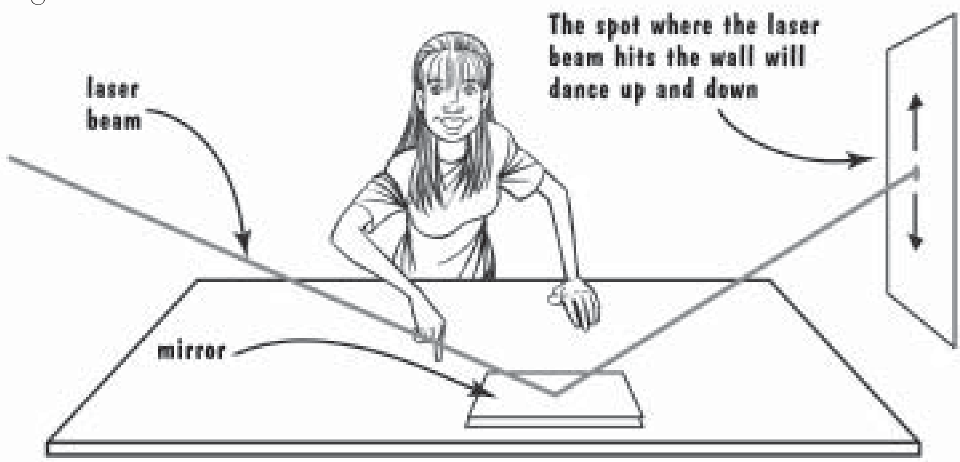
[1] By the way, the motion of these speakers is caused by the interaction of magnets in the speakers with electrical current that comes from the amplifier. I'll discuss that a bit more in Chapter 7, but for a detailed discussion of electromagnetic interactions, look for the *Stop Faking It!* book on Electricity and Magnetism (in press).

watch leaves carefully as wind blows through a tree, you'll see the tiny vibrations. The vibrations also are not so obvious when someone speaks, but you can certainly feel the vibrations (of your vocal chords) when you place your fingers against your neck.

What about tapping your finger on a hard surface? It makes a sound, but where are the vibrations? Actually, the surface itself is vibrating. It's just that the vibrations are so small that you can't see them. You can, however, feel them. Have someone tap a table while you place your fingers lightly on the surface. You should be able to feel the vibrations. If you have a laser around, you actually *can* see the vibrations of the surface. If you were to shine a laser beam on a mirror that's on the surface, as in Figure 1.1, the reflection of the beam would dance up and down when you tapped the surface, indicating that the surface itself was vibrating.

Figure 1.1

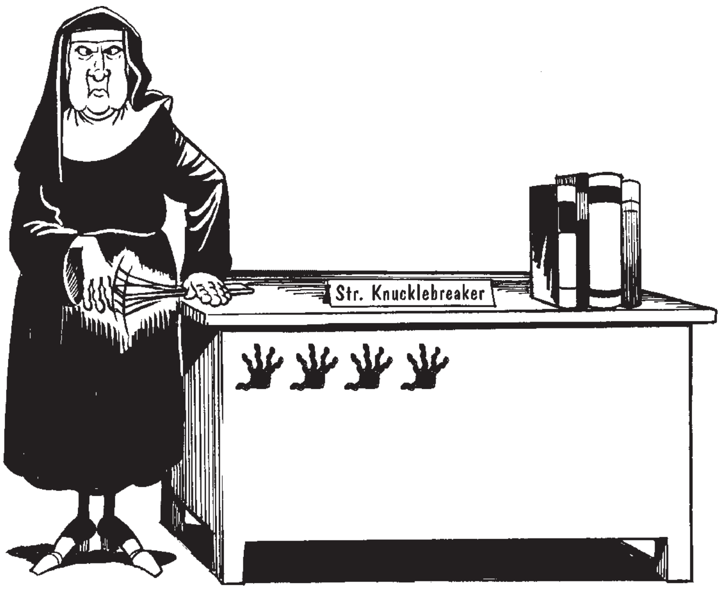


Because a pillow is soft and simply yields to your finger when you tap it, there are no vibrations and hence, little or no sound.

More things to do before you read more science stuff

Go back to that stereo speaker with the cover off. Gradually change the volume of the music you might be playing, and notice any difference in the motion of the speakers. At low volumes you might not even notice any motion, but you should definitely notice the motion at high volumes.

Figure 1.2



Grab a plastic ruler and hold it on a table so that half the ruler hangs out over the edge of the table (Figure 1.2). Pluck the free end of the ruler lightly and then with a big whack. The ruler vibrates in each case, producing a sound. Notice any difference in the sound produced when you pluck it lightly and when you really hit it hard?

If you have a guitar or other stringed instrument around, pluck one of the strings lightly and then hard. You should get the same kind of difference in sound as with the ruler. And in case you haven't noticed, we're easing into the concepts slowly!

More science stuff

When you pluck a ruler softly and then hard, you are changing the size of the vibration produced in the ruler. The difference in the size of vibration is pretty obvious with the ruler and with the speakers, and maybe not so obvious with the stringed instrument. In scientific terms, we say you are changing the **amplitude** of the vibration. Larger amplitudes produce louder sounds. Notice also that changing the amplitude of vibration changes *only* the loudness, and not any other property of the sound such as pitch or quality. I'll define these terms later in the chapter.

SCILINKS
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Topic: properties of sound

Go to: *www.scilinks.org*

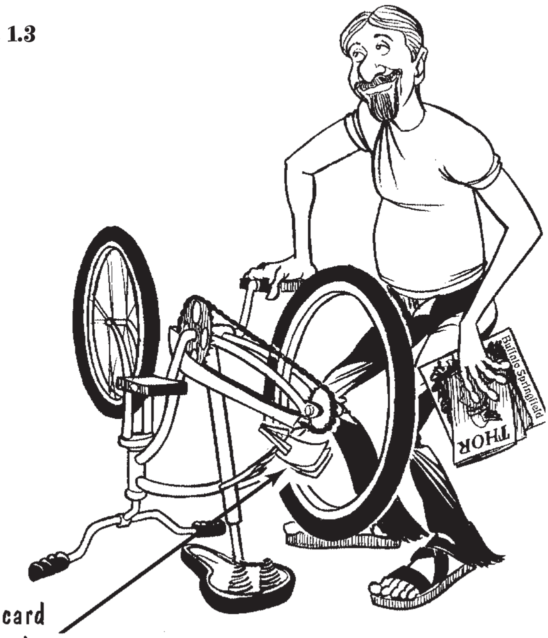
Code: SFS02

Even more things to do before you read even more science stuff

Back when I was a kid, one way to be really cool was to tape a playing card to your bike so the spokes on the wheel hit the card as you rode along. Being cool was easier in those days! To re-create the magic of youth, get a bike and turn it upside down so the wheels turn freely when you crank the pedals. Tape or clothespin a playing card or index card to the frame so the wheel spokes hit the card as the wheel spins.

Crank the pedals by hand and the vibrating card should make some noise. Crank the pedals at different speeds and notice what happens to the sound produced by the card. As you change the pedal speed, what do you think is happening to the speed at which the card vibrates?

Figure 1.3



Ruler-plucking time again. Place the ruler as before, so it hangs over the edge of a table. Pluck the ruler and notice the sound. Now reposition the ruler so either more or less of the ruler hangs over the edge. Pluck it again and notice any change in the sound. Practice a bit and you can play *Mary Had a Little Lamb* or *In-A-Gadda-Da-Vida* just by changing the position of the ruler as you pluck it.

Even more science stuff

With the card and the ruler, you produced different sounds by changing the speed at which the object vibrated. That difference in speed of vibration should have been easy to see with the ruler. A more precise way of describing the speed of vibration is to refer to the **frequency** of vibration. Frequency is defined as the number of vibrations per second. The more vibrations per second, the higher the frequency. Low-frequency vibrations produce low notes, and high-frequency vibrations produce high notes.

The perceived "lowness" or "highness" of a note is called the **pitch** of the note, so we can just state that changing the frequency of vibration changes the pitch of the sound produced.

And that's about it for the first chapter—short and sweet. It's always good to start with a confidence builder!

SCILINKS
THE WORLD'S A CLICK AWAY

Topic: sound quality

Go to: *www.scilinks.org*

Code: SFS03

Chapter Summary

- Vibrating objects produce sound.
- The distance through which a vibrating object moves is known as the *amplitude* of vibration.[2] The larger the amplitude of vibration, the louder the sound produced.
- The number of vibrations per second is known as the *frequency* of vibration of an object. Increasing the frequency of vibration of an object increases the perceived pitch of the sound produced. Decreasing the frequency of vibration of an object decreases the perceived pitch of the sound produced.

Applications

1. One of the more annoying sounds in the world is when chalk squeaks as you write with it on a chalkboard. That sound alone is enough to make you appreciate the invention of dry-erase boards. What causes that sound? In other words, what's vibrating? Chalk squeaks when you don't slant it enough as you write, keeping it in a position that's almost straight out from the board. When you do this, the end of the chalk "catches" on the chalkboard and then slips. This causes the chalk to vibrate, giving you that high-pitched squeak. In other words, it's all in your technique!
2. While we're on annoying sounds, what about that high-pitched squeal that a mosquito makes as it does a fly-by on your ear as you're trying to get to sleep? Is that a mosquito scream or what? Nah, it's just the vibration of the mosquito's wings. Because a mosquito is tiny, with tiny wings, those wings vibrate really fast (a high frequency), producing a high-pitched sound. Contrast that sound with the sounds produced by larger insects, such as flies and bees. The larger wings on these beasts are harder to move (at least for the insects), so the vibration is slower, leading to a lower frequency and lower pitch. A discerning ear can detect the difference between large flies and small flies, and between bumblebees and honeybees.
3. If you live where it snows, you might have noticed that sometimes snow squeaks when you walk on it, and sometimes not. You might also have noticed that whether or not the snow squeaks depends on the temperature. Cold snow (around 10 degrees Fahrenheit or colder) squeaks, while warmer

[2] The proper definition of amplitude is actually *half* the total distance the object moves, but we can safely ignore that for the scope of what we're covering in this book.

snow doesn't. The reason is that cold snow is a bit more rigid than warm snow. When you walk on cold snow, the snow under your foot rubs against the snow around it (much like two rocks rubbing against each other). This produces vibrations, which are the squeaks. Warmer snow, being less rigid, "gives" more easily, and no vibrations are produced.