Stop Faking It!

Finally Understanding Science So You Can Teach It

AIR, WATER & WEATHER

By William C. Robertson, PhD
Illustrated by Brian Diskin

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Preface

The book you have in your hands is the sixth in the *Stop Faking It!* series. The previous five books have been well received, mainly because they stick to the principles outlined below. All across the country, teachers, parents and home-schoolers are faced with helping other people understand subjects – science and maths – that they don't really understand themselves. When I speak of understanding, I'm not talking about what rules and formulas to apply when, but rather knowing the meaning behind all the rules, formulas and procedures. I *know* that it is possible for science and math to make sense at a *deep level* – deep enough that you can teach it to others with confidence and comfort.

Why do science and maths have such a bad reputation as being so difficult? What makes them so difficult to understand? Well, my contention is that science and maths are *not* difficult to understand. It's just that from preschool to university, we present the material *way* too fast and at too abstract a level. To truly understand science and maths, you need *time* to wrap your mind around the concepts. However, very little science and maths instruction allows that necessary time. Unless you have the knack for understanding abstract ideas in a quick presentation, you can quickly fall behind as the material flies over your head. Unfortunately, the solution many people use to keep from falling behind is to *memorise* the material. Memorising your way through the material is a surefire way to feel uncomfortable when it comes time to teach the material to others. You have a difficult time answering questions that aren't stated explicitly in the textbook, you feel inadequate, and let's face it – it just isn't any fun!

So, how do you go about *understanding* science and maths? You could pick up a school or university science textbook and do your best to plow through the ideas, but that can get discouraging quickly. You could plunk down a few bucks and take an introductory university course, but you might be smack in the middle of a too-much-material-too-fast situation. Primary and middle years textbooks generally include brief explanations of the concepts, but the emphasis is definitely on the word *brief*, and the number of errors in those explanations is higher than it should be. Finally, you can pick up one or fifty "resource" books that contain many cool classroom activities but also include too brief, sometimes incorrect, and vocabulary-laden explanations.

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Given the above situation, I decided to write a series of books that would solve many of these problems. Each book covers a relatively small area of science, and the presentation is unrushed and hopefully funny in at least a few places. Typically, I spend a chapter or two covering material that might take up a paragraph or a page in a standard science book. My hope is that people will take it slow and digest, rather than memorise, the material.

This sixth book in the series is about air, water and weather. It explores the physical science concepts associated with the behavior of air, water, and other fluids (yes, air can be considered a fluid!) and then uses weather as an interesting application of those concepts. As such, you will not find this to be a comprehensive book on weather. Of course, I do hope that the understanding you might gain from this book will help you immensely when you encounter other resources relating to weather concepts. After all, physical science concepts are at the heart of most weather concepts.

There is an established method for helping people learn concepts, and that method is known as the learning cycle. Basically, it consists of having someone do a hands-on activity or two, or even just think about various questions or situations, followed by explanations based on those activities. By connecting new concepts to existing ideas, activities or experiences, people tend to develop understanding rather than rely on memorisation. Each chapter in this book, then, is broken up into two kinds of sections. One section is titled, "Things to do before you read the science stuff", and the other is titled, "The science stuff". If you actually do the things I ask you to do prior to reading the science, I guarantee you'll have a more satisfying experience and a better chance of grasping the material.

It is important that you realize the book you have in your hands is *not* a textbook. It is, however, designed to help you "get" science at a level you never thought possible, and also to bring you to the point where tackling more traditional science resources won't be a terrifying, lump-in-your-throat, I-don't-think-I'll-survive experience.

Dedication

I dedicate this book to my mother, Arletta McIsaac, for her emotional, financial and all other kinds of support that led me to this point. I also dedicate it to Donald McIsaac who, after the death of my father and in his infinite wisdom, became my stepfather and helped make two families even closer than they already were.

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The Scope of This Book

Many people will probably look at the last word in the title and assume that this is primarily a book about weather. They might also assume that my discussion of the properties of air and water will serve only as a prelude to understanding weather. Well, not so. I will deal with a number of concepts related to air and water that have little or nothing to do with weather. The reason for that is that some of these concepts are part of most science curriculums even though they don't relate to weather. If I exclude them, I'm letting you down a bit, I think.

On the other hand, my treatment of weather in this book is not comprehensive. I pretty much limit myself to weather concepts that are good applications of the physics of air and water, and ignore those that aren't. For example, I don't discuss lightning, damage due to cyclones, the scale used for measuring winds, or cloud types. Fortunately for you, there are lots of books in existence that cover these topics adequately. No sense in me redoing what's done well elsewhere.

So, this is not a book that covers every single property of air and water, nor is it a comprehensive book on weather. It's a book that combines portions of each of those topics, and, hopefully, helps you gain a basic understanding of enough concepts that you can do a better job teaching in all three areas.

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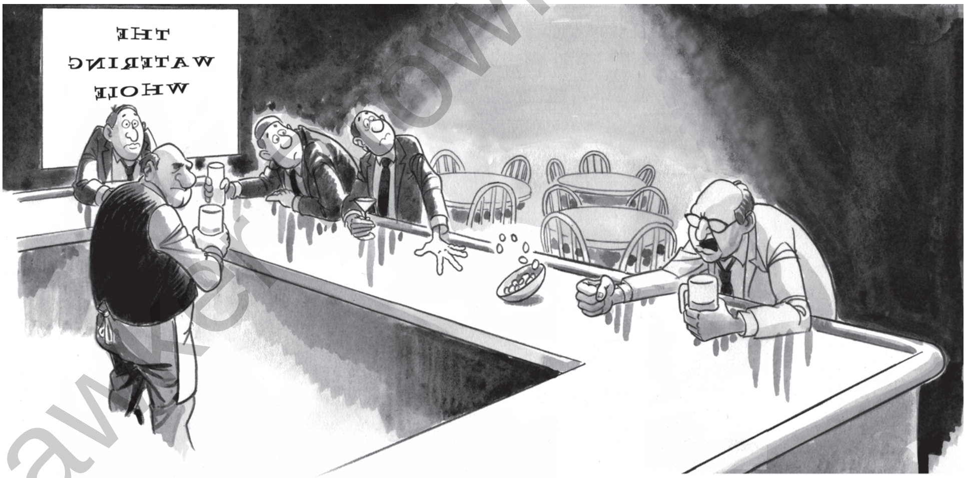
1 Chapter

Under Pressure[1]

The first thing I ought to address is why this book combines air, water and weather. I addressed that in a preceding page, but it's worth another comment. In a regular physics textbook you'll find chapters on air and water and how they behave, and you can certainly find lots of books about weather. The reason I combine them here is that once you know a lot about air and other **gases** – and water and other **liquids** – you have many of the basics from which to understand weather patterns, what causes them, and how you can predict the weather. Of course, the air and water stuff is pretty interesting all by itself. If I didn't think that, I wouldn't waste your time and I'd spend my time on more profitable things, like delivering pizzas.



"Pressure!! You want of know what pressure is?!! Air molecules trapped in a rigid container heated up to 100 degrees Celsius. Unable to escape and moving faster than you can blink. That's pressure!!"

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[1] I have no idea what your tastes in music might be, but if a David Bowie song comes to mind as you read this chapter heading, we're on the same wavelength.

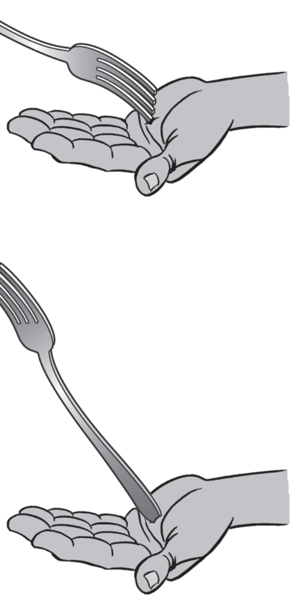
I'm sure you are well aware of the distinction between solids, liquids and gases, which might make you think that I'd treat air and water as very different things. But it turns out that as far as scientists are concerned, liquids and gases behave in ways that are so much alike that we treat them as just about the same kind of thing – **fluids**. So, much of what we cover here will apply to both air and water. Those two things aren't exactly alike though, so we'll take different approaches from time to time. Do expect, however, that I'll be jumping around between the behavior of air and other gases, and water and other liquids – all the while pointing out where the two are similar and where they're different.

On to the contents of this chapter: We're going to deal with **air pressure** and water pressure and what causes those things to increase and decrease. We'll also deal with the real-world results of those increases and decreases in air and water pressure.

Things to do before you read the science stuff

Get a metal fork. Push on the palm of one of your hands with one prong of the fork (Figure 1.1). Don't do this so hard that you draw blood, but it should hurt just a bit. Now turn the fork around and push on the palm of your hand with the non-business end of the fork. Try to push just as hard as you did with the single prong, and compare the level of pain you get with the single tine and the non-stabbing end of the fork.

Figure 1.1



Here's something potentially more painful but maybe easier to get the point across. Get a flat-head nail, one of those that's pointed on one end (wouldn't be much of a nail if one end weren't pointed) and a completely flat surface on the other end. Push on the palm of your hand first with the pointed end and then with the flat end. Try to use an equal push each time and please, please don't draw blood with the pointed end. Best to avoid poking yourself with nails unless you enjoy getting tetanus boosters.[2] Compare the level of pain with the pointed end and with the flat end.

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[2] This is probably a good time to emphasize that this is a book for adults, and not a collection of activities for use in the classroom. Yes, you can adapt most of these activities for classroom use, but take care when doing so. For example, you probably don't want to turn a bunch of kids loose after telling them to poke themselves with forks.

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The science stuff

Assuming you did as I told you and didn't end up in the ER, you should have noticed something. Even though you pushed *equally hard* with flat ends and sharp ends of things, the sharp ends hurt more. If you pushed equally hard, then that meant you pushed with the same **force** each time.[3]

Okay, if you pushed with the same force each time, why didn't it hurt the same amount each time? The answer has to do with how widely distributed that force was each time. When you pushed with the pointed end of the nail, the force was distributed over a very tiny area, and when you pushed with the flat end of the nail, the force was distributed over a much larger area. To take this to the extreme, suppose someone smashed his or her elbow into you with a force of about 50 kilograms.[4] That would definitely hurt and leave a mighty bruise, and to be clear, I'm not recommending you have it done. Now suppose someone smashes a steel spike into you with a force of 50 kilograms (apologies for the violence in this chapter so far!). That wouldn't just hurt, but would rather do serious damage or even kill you.

Now that I've made my point, here's a concept that helps you take into consideration not just how big a force one might exert, but the amount of area over which that force is spread. That concept is called **pressure**, and pressure is defined by

$$pressure = \frac{force}{area}$$

In case your maths is a wee bit rusty, that line on the right means "divided by". Because force is in the numerator of that fraction on the right, a larger force means a larger pressure, and a smaller force means a smaller pressure. The area, however, is in the denominator. So, a larger area means a smaller pressure (the force is more spread out so the pressure is smaller) and a smaller area means a larger pressure (the force is more localised, so the pressure is larger).

SCILINKS
THE WORLD'S A CLICK AWAY

Topic: pressure
Go to: *www.scilinks.org*
Code: SFAWW01

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[3] First shameless promotion for one of the other books in this series, *Force and Motion: Stop Faking It! Finally Understanding Science So You Can Teach It*. I'm not going to pretend that you can't find out what the term *force* means by looking somewhere else than the dictionary, but if you want the thorough treatment, well …

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[4] Since this is a science book, we really should be using the correct *Système International* units (which would be newtons for force), but I figure it's okay just this once given that most people have a good idea of how big a force 50 kilograms is and very little idea how big a force 50 newtons is. For the record, a force of 50 kilograms is equal to a force of around 490 newtons.

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Before moving on, I should tell you why pressure is such an important concept in dealing with air and water. The reason is that we're dealing with large numbers of atoms or molecules, and we tend to be concerned about the collective effect of all those atoms or molecules pushing on something. Having to worry about the individual forces exerted by millions upon millions of tiny particles is a royal pain, so we use the concept of pressure that describes their cumulative effect without dealing with individual forces.

More things to do before you read more science stuff

What I want you to do in this section are things you've probably already done, so maybe all you need is a good memory. If you haven't done these things, you'll get to go on an excursion, so be sure to have your parents sign that permission slip.

Your first task is to undergo a reasonably large change in altitude. You can do this by taking a ride in your car in the mountains so you change altitude by at least 150 metres (easy if you live in a mountainous region like I do, but a difficult task in other areas), taking off and landing in a plane (expensive excursion!) or finding a tall building and riding the elevator up and down at least 20 floors. If you choose the last option, try to find an express elevator that isn't likely to stop every few floors. You'll get the effect better if you travel all the floors without stopping. Skyscrapers that offer observation decks for tourists tend to have elevators like this.

As you do any one of those tasks, or remember what it was like the last time you did, focus on the effect on your ears. Depending on whether you go up or down in altitude, and how far you have gone up or down, your ears will feel stopped up or they'll "pop" at some point. Some people can actually tell the difference in the feeling in their ears depending on whether they're going up or down in altitude, but to me it feels pretty much the same.

Okay, your next excursion is to a bathtub or a swimming pool. The swimming pool is a better option, but the bathtub (filled with water) will do. Basically, repeat your "change in altitude" procedure on a small scale. Move your submerged ears from one depth to another and notice changes in feeling in your ear. One caution, though. While there's no danger to your ears when you do this in a bathtub, it *is* possible to damage your eardrum doing this in a quick depth change in a pool (or a really large bathtub) of as little as a metre. So, just go for depth changes that are enough for you to feel a change in your ears. There's a safe way to change depths in water quickly. You plug your nose, close your mouth, and blow out gently as you submerge. This

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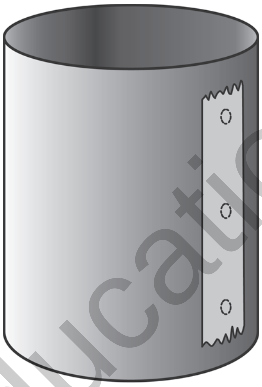
is called "clearing your ears", and it also works as you go *down* in altitude while you are in the air.[5]

Figure 1.2

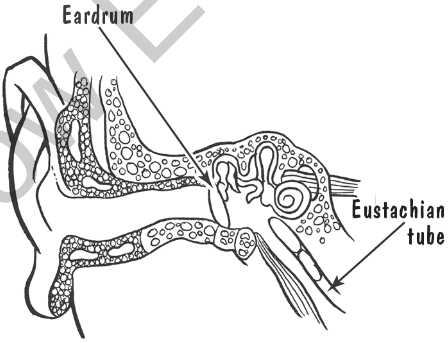


One more fun thing to do: Take a large coffee can or something similar. Use a hammer and nail to poke three holes in the side of the can, one near the top, one at the middle and one at the bottom (see Figure 1.2).

Use a strip of duct tape to cover all the holes, and then fill the can with water. Hold the can over a sink or outside, and quickly remove the tape. Notice how strong the water stream is that comes from each of the three holes in the can. There should be a difference between the results at each hole.

More science stuff

Figure 1.3



I'm guessing that it's no surprise to you that the reason you felt changes in your ears was due to changes in air pressure and water pressure. To really understand what's going on, it helps to have a basic idea of what the inside of your ear looks like, so take a look at Figure 1.3.

Notice that your **eardrum** separates your inner ear from your outer ear. One side of the eardrum is exposed to the outside of your ear and the outside air. On the other side of the eardrum is something called the **Eustachian tube**, which leads to your sinus cavities, your nose and your mouth. In other words, this tube connects to the outside air through a different path that goes through your nose and mouth.

Your eardrum is sensitive to differences in pressure on either side of it. When the pressure on the inside of the eardrum is equal to the pressure on the outside of the eardrum, everything feels just fine. If the pressure on one side is greater than the pressure on the other side, the eardrum gets pushed out of its normal position and you get that "stopped up" feeling that can even get a little painful. If the difference in pressure gets too large, your eardrum can rupture, which can't be a good thing.

Before moving on, let's state something that might be relatively obvious:

Areas of high pressure tend to push things
toward areas of low pressure.

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[5] If this method doesn't work easily for you, don't push it. I'd really hate to get sued because someone broke an eardrum after reading this book!

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