Stop Faking It!

Finally Understanding Science So You Can Teach It

Force and Motion

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Hawker Brownlow EDUCATION

Contents

Preface

When I was in university, 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 primary school teachers, parents who home-school their kids and parents who just want to help their kids with science homework fall into this category. There are lots of "education experts" who 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 university textbook, or subscribing to a science magazine, or reading the incorrect and oversimplified science in an primary 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 non-science geek doesn't mean it's watered-down material. Everything in here is accurate and I'll use maths 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 an-

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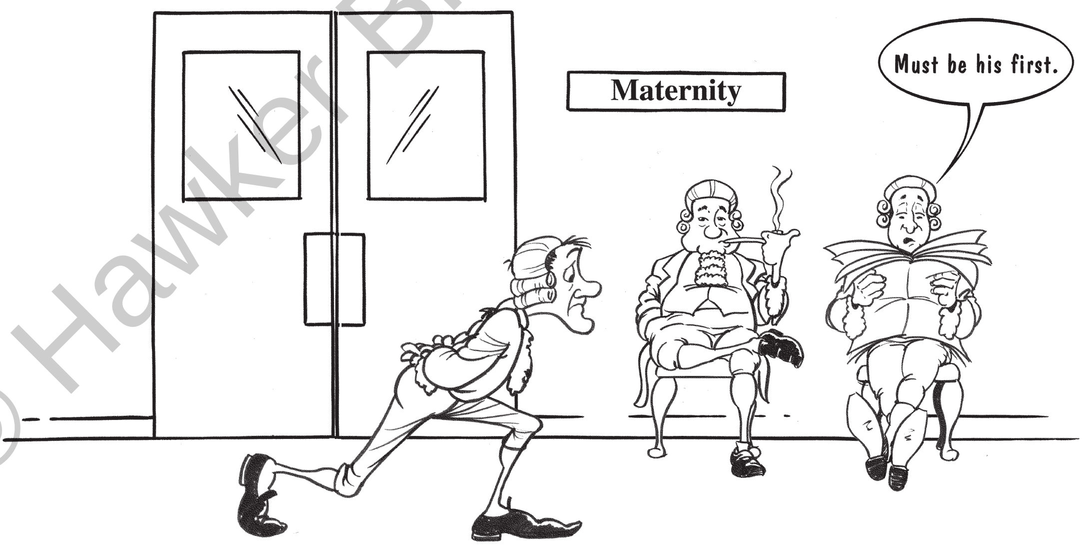
Chapter

Newton's First One

This first chapter deals with one of the most basic principles of motion, which happens to be known as Newton's First Law. Not coincidentally, it has something to do with Isaac Newton. It's a nice law to start out with because it doesn't require any maths and, after all, it is the first law. Just about every textbook I've seen spends very little time on Newton's First Law, presumably because it's so basic and obvious. You'll find out, though, that at least part of the law is far from obvious.

This chapter is also our first step towards understanding what science knowledge you need to plan a trip to the Moon. Not that you necessarily wanted to go to the Moon, but since each chapter builds on previous ones, the Moon-trip chapter (the last one) seemed a fun way to tie everything together. So if you thought you were going to skip around and maybe hit the Moon trip before going through everything else, forget about it!

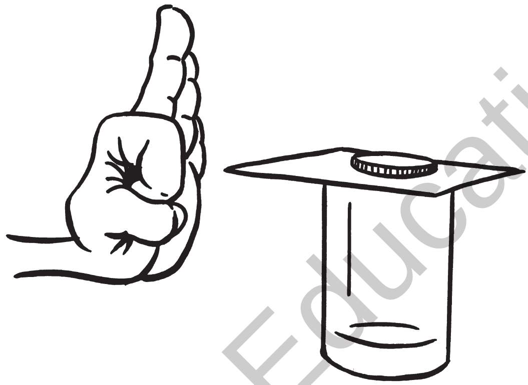


Newton's 1st

Things to do before you read the science stuff

Centre an index card over the top of a glass and place a coin in the middle of the index card (on top might be a good place). Using just one or two fingers, flick the card from the side.

Figure 1.1



If you do your flicking just right, the card should fly to the side and the coin should fall into the glass. Ah, yes, science is magic.

Now place the coin on a flat, level surface. Watch it for a while, say about five minutes. Notice whether or not it starts moving all by itself.

The science stuff

You have just demonstrated for yourself the first part of Mr Newton's First Law, which is that **objects tend to remain at rest unless you hit them**. Okay, so Newton didn't say it that way. I'll give you the fancy language later. Hopefully the coin didn't move as you watched it on the flat surface. The index card didn't stay where it was because you hit it, but the coin on top of the card stayed where it was (because you didn't hit it), at least until gravity pulled it into the glass.

Easy stuff, right? Told you science wasn't hard.

More things to do before you read more science stuff

Grab a few things from around the house – some you can roll across the floor (a ball, a toy car, a rolling pin, a glass) and some you can slide across the floor (a book, a block of wood, that fruitcake left over from Christmas – yes, it *is* frightening that Uncle Wally hasn't left yet.) Roll and slide these things across various *level* surfaces, such as tile and carpet. Watch carefully what happens. What do they do? Speed up, slow down, stop, keep going forever? Go outside and try it where you've got lots of room to check out that keep-going-forever thing.

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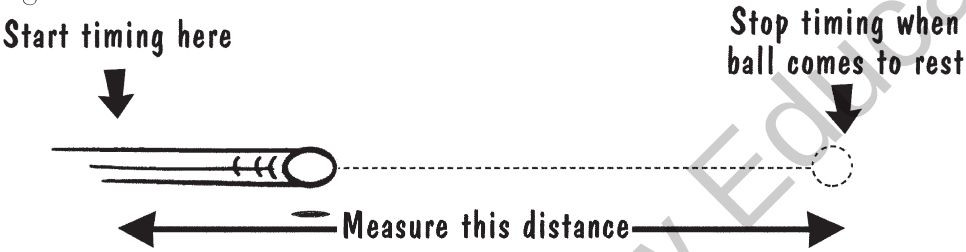
More things to do before you read more science stuff

Grab that ball again and find a surface that will slow the ball gradually to a stop after you've rolled it. Carpet works well. Now you're going to do almost the same thing you did in the previous activity, which is to time how long it takes the ball to travel a certain distance. The catch this time is that you're not going to measure the distance first. Just mark a starting point and time how long it takes the ball to go from there to the point that it stops. Remember that counting is as good as a stopwatch here.

Figure 2.3



Once the ball has stopped, go ahead and measure the distance from the starting point to where the ball stopped. No points for accuracy in measuring the distance, so just go for a quick estimate. Now that you have a distance and a time, figure out the speed using speed = distance/time.

Time to take the show on the road – literally. Hop in your favourite car and find an empty car park or a relatively deserted street. It you can't find a place without lots of cars and people, get someone to drive you because you won't be paying full attention to the road.

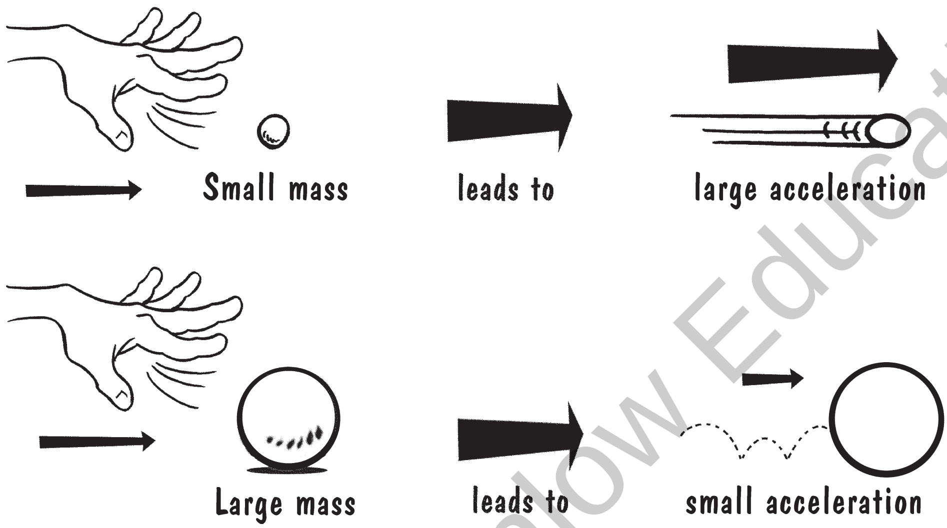
Get in the car and find the odometer, which is the little counter on the dashboard that tells how far you've driven. Just see what this reads and write it down. Now drive the car a small distance, say about 6/10 (0.6) of a kilometre, but don't go a constant speed. Speed up to 50 kilometres per hour (km/h), back to 10 km/h, up to 40 km/h, back to 5 km/h and so on. After you've gone a distance that's measurable on your car's odometer, stop and write down the total distance travelled. Oh yeah, you were supposed to be timing this, too. If you read this entire section before you got in the car, no problem.

Use the distance travelled and the time to calculate your speed for the trip. Something like

$$\text{speed} = 0.6 \text{ kilometres/2 minutes}$$
$$= 0.3 \text{ kilometres/minute}$$

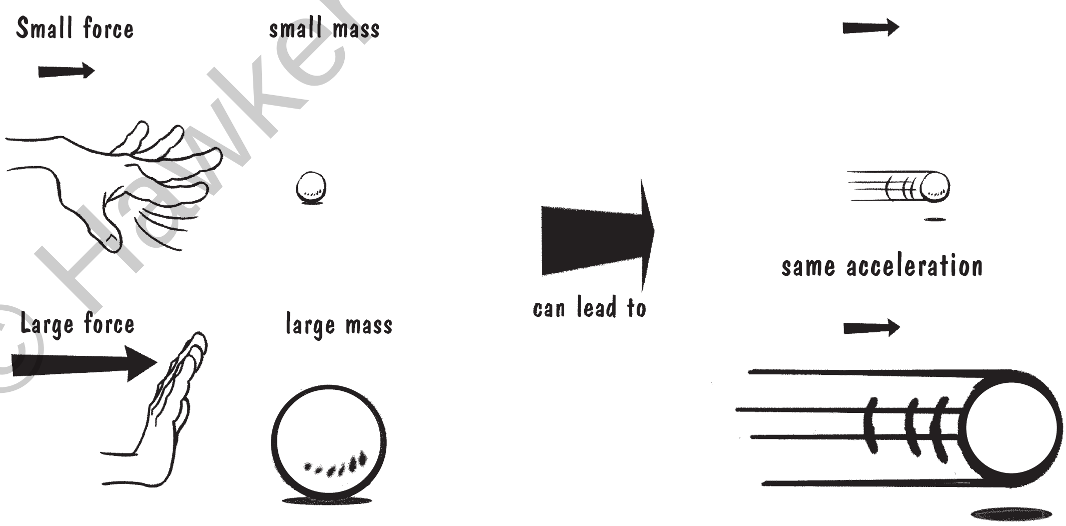
If you apply equal net forces to two objects, the one with the smaller mass will accelerate more (Figure 3.3).

Figure 3.3



If you want to cause two different objects to have the same acceleration, the object with the larger mass will require a larger force (Figure 3.4).

Figure 3.4



Remember that I'm using the term *net* force because if the forces you apply to an object cancel each other out, you're not going to accelerate the object. (Think back to the movers and the couch in the **Applications** section of Chapter 1.) Also, accelerations don't have to involve things speeding up or slowing down. When you hit the ball from the side with different-sized forces, maybe all that happened was the ball made a sharper change in direction each time. Everything else being equal, a large change in direction is a bigger acceleration than a small change in direction (Figure 3.5).

Now if you were writing a book about forces and accelerations, you might want a shorthand way to state everything that I just stated above. First, I'll write it in words:

Net force acting on an object = (mass of the object)(acceleration of the object)

In symbols, it looks like this:

$$F = ma$$

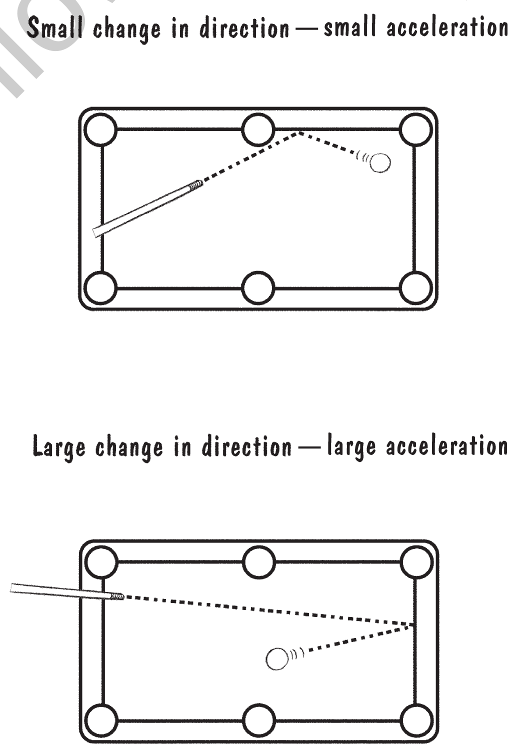
Those three little letters, plus the equals sign, are a statement of **Newton's Second Law**. What I'm going to do is put some numbers in for *F*, *m* and *a* in order to show how this relationship describes the results you got with rolling balls and such. What I don't want you to do is worry about how one decides that a force has a value of 10 or a mass has a value of 2 and so on. Just concentrate on the overall relationship. Any physicist who's reading this right now is cringing because the numbers should also have *units* attached to them – things like kilograms. But that would get in the way of your understanding, so go ahead and let them cringe.

Anyway, suppose you're pushing on a ball that has a mass whose value is 5. The first time you push, you push with a force of 10 and the second time you push, you push with a force of 20 (twice as big a push). If you put a force of 10 and a mass of 5 into Newton's Second Law, you get

$$F = ma$$

$$10 = (5)(?)$$

Figure 3.5



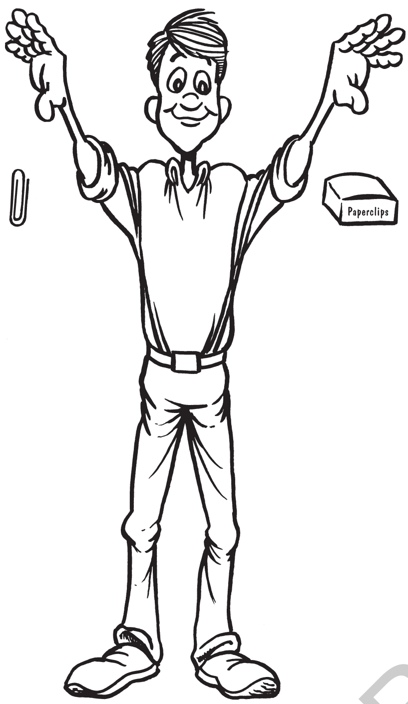
4 Chapter

There's No Such Thing as Gravity - The Earth Sucks

The title of this chapter is a stupid joke you learn early on if you ever take a physics course, and it's best appreciated in adolescence, arrested or otherwise. Before starting, let me use gravity to illustrate a point about science. In doing workshops for teachers, I often drop something and then ask the teachers to tell me why the object fell. The answer is "gravity". I then ask what gravity is. After some hemming and hawing, we all arrive at an answer something like "Gravity is the thing that makes objects fall to the Earth". So, objects fall to Earth because of gravity and gravity is the thing that makes objects fall to Earth. See any circular reasoning there? The point is that you haven't explained *why* objects fall; you've just given it a name. After reading through this chapter, you should know more about gravity than you did before but you still won't know *why* objects fall to Earth. They do it because that's the way things are. If you want to know why things happen, consult your favourite religion, because science never does answer the "why" question. This doesn't account for people whose religion *is* science, but I'll save that for another book.

Before going on, I'll expand just a bit on the "why" issue. When I say that science doesn't answer the "why" question, I mean in an ultimate, grand-scheme-of-things sense. In a *practical* sense, of course science explains things. When you ask "Why is the sky blue?" there's a scientific answer (see the *Stop Faking It!* book on Light). To go back to the gravity example, you could ask why things have a gravitational attraction for one another. There are scientific answers for that. A learned person, in answer to your question, might launch into an explanation involving "gravitons" or the "curvature of space-time". But then you could ask why gravitons exist or why space-time is curved. Depending on the person's knowledge of physics, they could possibly take you to another level of explanation, but at some point, when you ask why the latest explanation is the correct one, your inquisitee will have to resort to something such as "Because that's just the way things seem to be." Either that, or the person will give you an answer that is religious in origin. Scientific explanations are powerful, but they have their limits.

Figure 4.1



Things to do before you read the science stuff

Get the light and heavy balls you used in the previous chapter. Also see if you can find a box of paperclips or drawing-pins. Go outside (or stay indoors if you have carpeting) and drop the heavy and light balls side by side, from the same height, at the same time. Which one hits the ground first? Now take one paperclip out of the box and answer the following question: which has more mass, a single paperclip or a box of paperclips? If you answered "the single paperclip", go get a cup of coffee and try again. Drop the single paperclip and the box of paperclips (might be a good idea to close the box) side by side, from the same height, at the same time. Which hits the ground first? You might have to repeat this little experiment a few times before you decide.

Throw a ball straight up into the air and watch what it does. Describe its motion. You know, where does it slow down, speed up, stop and all that? Is the ball accelerating? If you think the ball is accelerating, decide what force or forces are acting on the ball in order to accelerate it. (Quick review: an acceleration is any change in speed and/or direction and accelerations are caused by forces.)

The science stuff

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Just in case you haven't gotten that coffee yet, I'll remind you that when you drop something it falls to the ground. Though it might not be obvious, the object speeds up as it falls. That means it's accelerating (change in speed) and there must be a force acting on it. The force that's acting on it is – all together now – **gravity**. I'll discuss gravity that has nothing to do with the Earth later, but for now let's just say that gravity is the Earth's pull on things.

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7
Chapter

To the Moon, Alice!

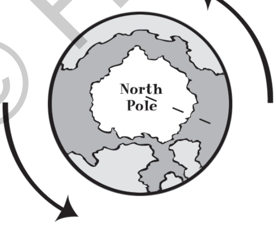
You now know enough about force and motion to design a trip to the Moon. Yesireee, break out the champagne! Okay, so maybe you're not jumping up and down, but at least this chapter will give you an idea of how much you've learned. After all, if they can get a man on the Moon, you can understand science. We're not going to go into any detailed calculations, because that's not the purpose of this book. I just want you to be able to follow the general concepts.

This chapter doesn't have the same format as the others because there's only one activity for you to do. There are two sections. The second one is about getting to the Moon once you're in orbit. Before you do that, though, you have to think about –

Getting into orbit

First let's choose a spot from which to launch the rocket that's getting us to the Moon. Cape Canaveral, Florida, in the United States of America is a handy place because they already have all the necessary equipment, museums, guided tours and such. But suppose you wanted to build your own launch pad. Should you put yours in America, too? Keep in mind they have cockroaches the size of panda bears there. Why not choose Sydney, Australia, so you can get watch the beautiful beaches as you launch? Here's why you want to choose Florida. Take a look at a globe. The Earth spins on its axis. Which part of the Earth spins faster, the North Pole or the equator? Looking down from above the North Pole, the Earth is just a 3-D version of a turntable. The further out you are from the centre, the further you have to go in one revolution.

Figure 7.1



The closer you are to the equator, the further you are from the centre of rotation