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2nd Edition

Physics I For Dummies®

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- Get up to speed on the basic concepts of physics
- Grasp formulas in a clear and concise manner
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Steven Holzner, PhD

Educator and author

Physics I

FOR DUMMIES®

2ND EDITION

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by Steven Holzner, PhD

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Dedication

To Nancy.

Author's Acknowledgments

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Contents at a Glance

Table of Contents

Introduction

Physics is what it's all about. What *what's* all about? Everything. Physics is present in every action around you. And because physics is everywhere, it gets into some tricky places, which means it can be hard to follow. Studying physics can be even worse when you're reading some dense textbook that's hard to follow.

For most people who come into contact with physics, textbooks that land with 1,200-page *whumps* on desks are their only exposure to this amazingly rich and rewarding field. And what follows are weary struggles as the readers try to scale the awesome bulwarks of the massive tomes. Has no brave soul ever wanted to write a book on physics from the *reader's* point of view? One soul is up to the task, and here I come with such a book.

About This Book

Physics I For Dummies, 2nd Edition, is all about physics from your point of view. I've taught physics to many thousands of students at the university level, and from that experience, I know that most students share one common trait: confusion. As in, "I'm confused about what I did to deserve such torture."

This book is different. Instead of writing it from the physicist's or professor's point of view, I wrote it from the reader's point of view. After thousands of one-on-one tutoring sessions, I know where the usual book presentation of this stuff starts to confuse people, and I've taken great care to jettison the top-down kinds of explanations. You don't survive one-on-one tutoring sessions for long unless you get to know what really makes sense to people — what they want to see from *their* points of view. In other words, I designed this book to be crammed full of the good stuff — and *only* the good stuff. You also discover unique ways of looking at problems that professors and teachers use to make figuring out the problems simple.

Conventions Used in This Book

Some books have a dozen conventions that you need to know before you can start. Not this one. All you need to know is that variables and new terms appear in italics, like *this,* and that vectors — items that have both a magnitude and a direction — appear in **bold.** Web addresses appear in `monofont`.

What You're Not to Read

I provide two elements in this book that you don't have to read at all if you're not interested in the inner workings of physics — sidebars and paragraphs marked with a Technical Stuff icon.

Sidebars provide a little more insight into what's going on with a particular topic. They give you a little more of the story, such as how some famous physicist did what he did or an unexpected real-life application of the point under discussion. You can skip these sidebars, if you like, without missing any essential physics.

The Technical Stuff material gives you technical insights into a topic, but you don't miss any information that you need to do a problem. Your guided tour of the world of physics won't suffer at all.

Foolish Assumptions

In writing this book, I made some assumptions about you:

- You have no or very little prior knowledge of physics.
- You have some math prowess. In particular, you know algebra and a little trig. You don't need to be an algebra pro, but you should know how to move items from one side of an equation to another and how to solve for values.
- You want physics concepts explained clearly and concisely, and you want examples that let you see those concepts in action.

How This Book Is Organized

The natural world is, well, *big.* And to handle it, physics breaks the world down into different parts. The following sections present the various parts you see in this book.

Part I: Putting Physics into Motion

You usually start your physics journey with motion, because describing motion — including acceleration, velocity, and displacement — isn't very difficult. You have only a few equations to deal with, and you can get them under your belt in no time at all. Examining motion is a great way to understand how physics works, both in measuring and in predicting what's going on.

Part II: May the Forces of Physics Be with You

"For every action, there is an equal and opposite reaction." Ever heard that one? The law (and its accompanying implications) comes up in this part. Without forces, the motion of objects wouldn't change at all, which would make for a very boring world. Thanks to Sir Isaac Newton, physics is particularly good at explaining what happens when you apply forces. You also take a look at the motion of fluids.

Part III: Manifesting the Energy to Work

If you apply a force to an object, moving it around and making it go faster, what are you really doing? You're doing work, and that work becomes the kinetic energy of that object. Together, work and energy explain a whole lot about the whirling world around you, which is why I dedicate Part III to these topics.

Part IV: Laying Down the Laws of Thermodynamics

What happens when you stick your finger in a candle flame and hold it there? You get a burned finger, that's what. And you complete an experiment in heat transfer, one of the topics you see in Part IV, which is a roundup of thermodynamics — the physics of heat and heat flow. You also see how heat-based engines work, how ice melts, how the ideal gas behaves, and more.

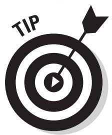
Part V: The Part of Tens

The Parts of Tens is made up of fast-paced lists of ten items each. You discover all kinds of amazing topics here, like some far-out physics — everything from black holes and the Big Bang to wormholes in space and the smallest distance you can divide space into — as well as some famous scientists whose contributions made a big difference in the field.

Icons Used in This Book

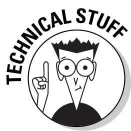
You come across some icons that call attention to certain tidbits of information in this book. Here's what the icons mean:

This icon marks information to remember, such as an application of a law of physics or a particularly juicy equation.



When you run across this icon, be prepared to find a shortcut in the math or info designed to help you understand a topic better.

This icon highlights common mistakes people make when studying physics and solving problems.



This icon means that the info is technical, insider stuff. You don't have to read it if you don't want to, but if you want to become a physics pro (and who doesn't?), take a look.

Where to Go from Here

You can leaf through this book; you don't have to read it from beginning to end. Like other *For Dummies* books, this one was designed to let you skip around as you like. This is your book, and physics is your oyster. You can jump into Chapter 1, which is where all the action starts; you can head to Chapter 2 for a discussion of the necessary algebra and trig you should know; or you can jump in anywhere you like if you know exactly what topic you want to study. And when you're ready for more-advanced topics, from electromagnetism to relativity to nuclear phsics, you can check out *Physics II For Dummies*.

Part I
Putting Physics into Motion

The 5th Wave By Rich Tennant

"Physics explains motion. Like the acceleration of this glass moving backward creating a velocity that results in a displacement. Any weenie knows that.

In this part . . .

Part I is designed to give you an introduction to the ways of physics. Motion is one of the easiest physics topics to work with, and you can become a motion meister with just a few equations. This part also arms you with foundational info on math and measurement to show how physics equations describe the world around you. Just plug in the numbers, and you can make calculations that astound your peers.

Chapter 1

Using Physics to Understand Your World

In This Chapter

- Recognizing the physics in your world
- Understanding motion
- Handling the force and energy around you
- Getting hot under the collar with thermodynamics

Physics is the study of the world and universe around you. Luckily, the behavior of the matter and energy — the stuff of this universe — is not completely unruly. Instead, it strictly obeys laws, which physicists are gradually revealing through the careful application of the *scientific method,* which relies on experimental evidence and sound rigorous reasoning. In this way, physicists have been uncovering more and more of the beauty that lies at the heart of the workings of the universe, from the infinitely small to the mind-bogglingly large.

Physics is an all-encompassing science. You can study various aspects of the natural world (in fact, the word *physics* is derived from the Greek word *physika,* which means "natural things"), and accordingly, you can study different fields in physics: the physics of objects in motion, of energy, of forces, of gases, of heat and temperature, and so on. You enjoy the study of all these topics and many more in this book. In this chapter, I give an overview of physics — what it is, what it deals with, and why mathematical calculations are important to it — to get you started.

What Physics Is All About

Many people are a little on edge when they think about physics. For them, the subject seems like some highbrow topic that pulls numbers and rules out of thin air. But the truth is that physics exists to help you make sense of the world. Physics is a human adventure, undertaken on behalf of everyone, into the way the world works.

REMEMBER

At its root, physics is all about becoming aware of your world and using mental and mathematical models to explain it. The gist of physics is this: You start by making an observation, you create a model to simulate that situation, and then you add some math to fill it out — and voilà! You have the power to predict what will happen in the real world. All this math exists to help you see what happens and why.

In this section, I explain how real-world observations fit in with the math. The later sections take you on a brief tour of the key topics that comprise basic physics.

Observing the world

You can observe plenty going on around you in your complex world. Leaves are waving, the sun is shining, light bulbs are glowing, cars are moving, computer printers are printing, people are walking and riding bikes, streams are flowing, and so on. When you stop to examine these actions, your natural curiosity gives rise to endless questions such as these:

- Why do I slip when I try to climb that snow bank?
- How distant are other stars, and how long would it take to get there?
- How does an airplane wing work?
- How can a thermos flask keep hot things warm *and* keep cold things cool?
- Why does an enormous cruise ship float when a paper clip sinks?
- Why does water roll around when it boils?

Any law of physics comes from very close observation of the world, and any theory that a physicist comes up with has to stand up to experimental measurements. Physics goes beyond qualitative statements about physical things — "If I push the child on the swing harder, then she swings higher," for example. With the laws of physics, you can predict precisely how high the child will swing.

Making predictions

Physics is simply about modeling the world (although an alternative viewpoint claims that physics actually uncovers the truth about the workings of the world; it doesn't just model it). You can use these mental models to describe how the world works: how blocks slide down ramps, how stars form and shine, how black holes trap light so it can't escape, what happens when cars collide, and so on.

When these models are first created, they sometimes have little to do with numbers; they just cover the gist of the situation. For example, a star is made up of this layer and then that layer, and as a result, this reaction takes place, followed by that one. And pow! — you have a star. As time goes on, those models become more numeric, which is where physics students sometimes start having problems. Physics class would be a cinch if you could simply say, "That cart is going to roll down that hill, and as it gets toward the bottom, it's going to roll faster and faster." But the story is more involved than that — not only can you say that the cart is going to go faster, but in exerting your mastery over the physical world, you can also say how much faster it'll go.

There's a delicate interplay between theory, formulated with math, and experimental measurements. Often experimental measurements not only verify theories but also suggest ideas for new theories, which in turn suggest new experiments. Both feed off each other and lead to further discovery.

Many people approaching this subject may think of math as something tedious and overly abstract. However, in the context of physics, math comes to life. A quadratic equation may seem a little dry, but when you're using it to work out the correct angle to fire a rocket at for the perfect trajectory, you may find it more palatable! Chapter 2 explains all the math you need to know to perform basic physics calculations.

Reaping the rewards

So what are you going to get out of physics? If you want to pursue a career in physics or in an allied field such as engineering, the answer is clear: You'll need this knowledge on an everyday basis. But even if you're not planning to embark on a physics-related career, you can get a lot out of studying the subject. You can apply much of what you discover in an introductory physics course to real life:

- In a sense, all other sciences are based upon physics. For example, the structure and electrical properties of atoms determine chemical reactions; therefore, all of chemistry is governed by the laws of physics. In fact, you could argue that everything ultimately boils down to the laws of physics!
- Physics does deal with some pretty cool phenomena. Many videos of physical phenomena have gone viral on YouTube; take a look for yourself. Do a search for "non-Newtonian fluid," and you can watch the creeping, oozing dance of a cornstarch/water mixture on a speaker cone.

- More important than the applications of physics are the problem-solving skills it arms you with for approaching any kind of problem. Physics problems train you to stand back, consider your options for attacking the issue, select your method, and then solve the problem in the easiest way possible.

Observing Objects in Motion

Some of the most fundamental questions you may have about the world deal with objects in motion. Will that boulder rolling toward you slow down? How fast do you have to move to get out of its way? (Hang on just a moment while I get out my calculator. . . .) Motion was one of the earliest explorations of physics.

When you take a look around, you see that the motion of objects changes all the time. You see a motorcycle coming to a halt at a stop sign. You see a leaf falling and then stopping when it hits the ground, only to be picked up again by the wind. You see a pool ball hitting other balls in just the wrong way so that they all move without going where they should. Part I of this book handles objects in motion — from balls to railroad cars and most objects in between. In this section, I introduce motion in a straight line, rotational motion, and the cyclical motion of springs and pendulums.

Measuring speed, direction, velocity, and acceleration

Speeds are big with physicists — how fast is an object going? Thirty-five miles per hour not enough? How about 3,500? No problem when you're dealing with physics. Besides speed, the direction an object is going is important if you want to describe its motion. If the home team is carrying a football down the field, you want to make sure they're going in the right direction.

When you put speed and direction together, you get a vector — the velocity vector. Vectors are a very useful kind of quantity. Anything that has both size and direction is best described with a *vector.* Vectors are often represented as arrows, where the length of the arrow tells you the magnitude (size), and the direction of the arrow tells you the direction. For a velocity vector, the length corresponds to the speed of the object, and the arrow points in the direction the object is moving. (To find out how to use vectors, head to Chapter 4.)

Everything has a velocity, so velocity is great for describing the world around you. Even if an object is at rest with respect to the ground, it's still on the Earth, which itself has a velocity. (And if everything has a velocity, it's no wonder physicists keep getting grant money — somebody has to measure all that motion.)

If you've ever ridden in a car, you know that velocity isn't the end of the story. Cars don't start off at 60 miles per hour; they have to accelerate until they get to that speed. Like velocity, acceleration has not only a magnitude but also a direction, so acceleration is a vector in physics as well. I cover speed, velocity, and acceleration in Chapter 3.

Round and round: Rotational motion

Plenty of things go round and round in the everyday world — CDs, DVDs, tires, pitchers' arms, clothes in a dryer, roller coasters doing the loop, or just little kids spinning from joy in their first snowstorm. That being the case, physicists want to get in on the action with measurements. Just as you can have a car moving and accelerating in a straight line, its tires can rotate and accelerate in a circle.

Going from the linear world to the rotational world turns out to be easy, because there's a handy physics *analog* (which is a fancy word for "equivalent") for everything linear in the rotational world. For example, distance traveled becomes angle turned. Speed in meters per second becomes angular speed in angle turned per second. Even linear acceleration becomes rotational acceleration.

So when you know linear motion, rotational motion just falls in your lap. You use the same equations for both linear and angular motion — just different symbols with slightly different meanings (angle replaces distance, for example). You'll be looping the loop in no time. Chapter 7 has the details.

Springs and pendulums: Simple harmonic motion

Have you ever watched something bouncing up and down on a spring? That kind of motion puzzled physicists for a long time, but then they got down to work. They discovered that when you stretch a spring, the force isn't constant. The spring pulls back, and the more you pull the spring, the stronger it pulls back.

So how does the force compare to the distance you pull a spring? The force is directly proportional to the amount you stretch the spring: Double the amount you stretch the spring, and you double the amount of force with which the spring pulls back.

Physicists were overjoyed — this was the kind of math they understood. Force proportional to distance? Great — you can put that relationship into an equation, and you can use that equation to describe the motion of the object tied to the spring. Physicists got results telling them just how objects tied to springs would move — another triumph of physics.

This particular triumph is called *simple harmonic motion*. It's *simple* because force is directly proportional to distance, and so the result is simple. It's *harmonic* because it repeats over and over again as the object on the spring bounces up and down. Physicists were able to derive simple equations that could tell you exactly where the object would be at any given time.

But that's not all. Simple harmonic motion applies to many objects in the real world, not just things on springs. For example, pendulums also move in simple harmonic motion. Say you have a stone that's swinging back and forth on a string. As long as the arc it swings through isn't too high, the stone on a string is a pendulum; therefore, it follows simple harmonic motion. If you know how long the string is and how big of an angle the swing covers, you can predict where the stone will be at any time. I discuss simple harmonic motion in Chapter 13.

When Push Comes to Shove: Forces

Forces are a particular favorite in physics. You need forces to get motionless things moving — literally. Consider a stone on the ground. Many physicists (except, perhaps, geophysicists) would regard it suspiciously. It's just sitting there. What fun is that? What can you measure about that? After physicists had measured its size and mass, they'd lose interest.

But kick the stone — that is, apply a force — and watch the physicists come running over. Now something is happening — the stone started at rest, but now it's moving. You can find all kinds of numbers associated with this motion. For instance, you can connect the force you apply to something to its mass and get its acceleration. And physicists love numbers, because numbers help describe what's happening in the physical world.

Physicists are experts in applying forces to objects and predicting the results. Got a refrigerator to push up a ramp and want to know if it'll go? Ask a physicist. Have a rocket to launch? Same thing.

Absorbing the energy around you

You don't have to look far to find your next piece of physics. (You never do.) As you exit your house in the morning, for example, you may hear a crash up the street. Two cars have collided at a high speed, and locked together, they're sliding your way. Thanks to physics (and more specifically, Part III of this book), you can make the necessary measurements and predictions to know exactly how far you have to move to get out of the way.

Having mastered the ideas of energy and momentum helps at such a time. You use these ideas to describe the motion of objects with mass. The energy of motion is called *kinetic energy,* and when you accelerate a car from 0 to 60 miles per hour in 10 seconds, the car ends up with plenty of kinetic energy.

Where does the kinetic energy come from? It comes from *work,* which is what happens when a force moves an object through a distance. The energy can also come from *potential energy,* the energy stored in the object, which comes from the work done by a particular kind of force, such as gravity or electrical forces. Using gasoline, for example, an engine does work on the car to get it up to speed. But you need a force to accelerate something, and the way the engine does work on the car, surprisingly, is to use the force of friction with the road. Without friction, the wheels would simply spin, but because of a frictional force, the tires impart a force on the road. For every force between two objects, there is a reactive force of equal size but in the opposite direction. So the road also exerts a force on the car, which causes it to accelerate.

Or say that you're moving a piano up the stairs of your new place. After you move up the stairs, your piano has potential energy, simply because you put in a lot of work against gravity to get the piano up those six floors. Unfortunately, your roommate hates pianos and drops yours out the window. What happens next? The potential energy of the piano due to its height in a gravitational field is converted into kinetic energy, the energy of motion. You decide to calculate the final speed of the piano as it hits the street. (Next, you calculate the bill for the piano, hand it to your roommate, and go back downstairs to get your drum set.)

That's heavy: Pressures in fluids

Ever notice that when you're 5,000 feet down in the ocean, the pressure is different from at the surface? Never been 5,000 feet beneath the ocean waves? Then you may have noticed the difference in pressure when you dive into a swimming pool. The deeper you go, the higher the pressure is because of the weight of the water above you exerting a force downward. *Pressure* is just force per area.

Got a swimming pool? Any physicists worth their salt can tell you the approximate pressure at the bottom if you tell them how deep the pool is. When working with fluids, you have all kinds of other quantities to measure, such as the velocity of fluids through small holes, a fluid's density, and so on. Once again, physics responds with grace under pressure. You can read about forces in fluids in Chapter 8.

Feeling Hot but Not Bothered: Thermodynamics

Heat and cold are parts of your everyday life. Ever take a look at the beads of condensation on a cold glass of water in a warm room? Water vapor in the air is being cooled when it touches the glass, and it condenses into liquid water. The condensing water vapor passes thermal energy to the glass, which passes thermal energy to the cold drink, which ends up getting warmer as a result.

Thermodynamics can tell you how much heat you're radiating away on a cold day, how many bags of ice you need to cool a lava pit, and anything else that deals with heat energy. You can also take the study of thermodynamics beyond planet Earth. Why is space cold? In a normal environment, you radiate heat to everything around you, and everything around you radiates heat back to you. But in space, your heat just radiates away, so you can freeze.

Radiating heat is just one of the three ways heat can be transferred. You can discover plenty more about heat, whether created by a heat source like the sun or by friction, through the topics in Part IV.

Chapter 2

Reviewing Physics Measurement and Math Fundamentals

In This Chapter

- Mastering measurements (and keeping them straight as you solve equations)
- Accounting for significant digits and possible error
- Brushing up on basic algebra and trig concepts

Physics uses observations and measurements to make mental and mathematical models that explain how the world (and everything in it) works. This process is unfamiliar to most people, which is where this chapter comes in.

This chapter covers some basic skills you need for the coming chapters. I cover measurements and scientific notation, give you a refresher on basic algebra and trigonometry, and show you which digits in a number to pay attention to — and which ones to ignore. Continue on to build a physics foundation, solid and unshakable, that you can rely on throughout this book.

Measuring the World around You and Making Predictions

Physics excels at measuring and predicting the physical world — after all, that's why physics exists. Measuring is the starting point — part of observing the world so you can then model and predict it. You have several different measuring sticks at your disposal: some for length, some for mass or weight, some for time, and so on. Mastering those measurements is part of mastering physics.

Using systems of measurement

To keep like measurements together, physicists and mathematicians have grouped them into *measurement systems.* The most common measurement system you see in introductory physics is the meter-kilogram-second (MKS) system, referred to as SI (short for *Système International d'Unités,* the International System of Units), but you may also come across the foot-pound-second (FPS) system. Table 2-1 lists the primary units of measurement in the MKS system, along with their abbreviations.

Table 2-1 Units of Measurement in the MKS System

Measurement	***Unit***	***Abbreviation***
Length	meter	m
Mass	kilogram	kg
Time	second	s
Force	newton	N
Energy	joule	J
Pressure	pascal	Pa
Electric current	ampere	A
Magnetic flux density	tesla	T
Electric charge	coulomb	C

WARNING!

Because different measurement systems use different standard lengths, you can get several different numbers for one part of a problem, depending on the measurement you use. For example, if you're measuring the depth of the water in a swimming pool, you can use the MKS measurement system, which gives you an answer in meters, or the less common FPS system, in which case you determine the depth of the water in feet. The point? When working with equations, stick with the same measurement system all the way through the problem. If you don't, your answer will be a meaningless hodgepodge, because you're switching measuring sticks for multiple items as you try to arrive at a single answer. Mixing up the measurements causes problems — imagine baking a cake where the recipe calls for 2 cups of flour, but you use 2 liters instead.

From meters to inches and back again: Converting between units

Physicists use various measurement systems to record numbers from their observations. But what happens when you have to convert between those systems? Physics problems sometimes try to trip you up here, giving you the data you need in mixed units: centimeters for this measurement but meters for that measurement — and maybe even mixing in inches as well. Don't be fooled. You have to convert *everything* to the same measurement system before you can proceed. How do you convert in the easiest possible way? You use conversion factors, which I explain in this section.

Using conversion factors

TIP

To convert between measurements in different measuring systems, you can multiply by a conversion factor. A *conversion factor* is a ratio that, when you multiply it by the item you're converting, cancels out the units you don't want and leaves those that you do. The conversion factor must equal 1.

Here's how it works: For every relation between units — for example, 24 hours = 1 day — you can make a fraction that has the value of 1. If, for example, you divide both sides of the equation 24 hours = 1 day by 1 day, you get

$$\frac{24\text{ hours}}{1\text{ day}} = 1$$

Suppose you want to convert 3 days to hours. You can just multiply your time by the preceding fraction. Doing so doesn't change the value of the time because you're multiplying by 1. You can see that the unit of *days* cancels out, leaving you with a number of hours:

$$\frac{3\text{ days}}{1} \times \frac{24\text{ hours}}{1\text{ day}} = \frac{3\ \cancel{\text{days}}}{1} \times \frac{24\text{ hours}}{1\ \cancel{\text{day}}} = 72\text{ hours}$$

REMEMBER

Words such as *days, seconds,* and *meters* act like the variables x and y in that if they're present in both the numerator and the denominator, they cancel each other out.

To convert the other way — hours into days, in this example — you simply use the same original relation, 24 hours = 1 day, but this time divide both sides by 24 hours to get

$$1 = \frac{1\text{ day}}{24\text{ hours}}$$

Then multiply by this fraction to cancel the units from the bottom, which leaves you with the units on the top.

Consider the following problem. Passing the state line, you note that you've gone 4,680 miles in exactly three days. Very impressive. If you went at a constant speed, how fast were you going? Speed is just as you may expect — distance divided by time. So you calculate your speed as follows:

$$\frac{4{,}680\text{ miles}}{3\text{ days}} = 1{,}560\text{ miles/day}$$

Your answer, however, isn't exactly in a standard unit of measure. You have a result in miles per day, which you write as miles/day. To calculate miles per hour, you need a conversion factor that knocks *days* out of the denominator and leaves *hours* in its place, so you multiply by *days/hour* and cancel out *days:*

$$\frac{\text{miles}}{\cancel{\text{day}}} \times \frac{\cancel{\text{days}}}{\text{hour}} = \frac{\text{miles}}{\text{hour}}$$

Your conversion factor is *days/hour*. When you multiply by the conversion factor, your work looks like this:

$$\frac{1{,}560\text{ miles}}{1\text{ day}} \times \frac{1\text{ day}}{24\text{ hours}}$$

Note that because there are 24 hours in a day, the conversion factor equals exactly 1, as all conversion factors must. So when you multiply 1,560 miles/day by this conversion factor, you're not changing anything — all you're doing is multiplying by 1.

When you cancel out *days* and multiply across the fractions, you get the answer you've been searching for:

$$\frac{1{,}560\text{ miles}}{1\ \cancel{\text{day}}} \times \frac{1\ \cancel{\text{day}}}{24\text{ hours}} = 65\text{ miles/hour}$$

So your average speed is 65 miles per hour, which is pretty fast considering that this problem assumes you've been driving continuously for three days.

TIP

Looking at the units when numbers make your head spin

Want an inside trick that teachers and instructors often use to solve physics problems? Pay attention to the units you're working with. I've had thousands of one-on-one problem-solving sessions with students in which we worked on homework problems, and I can tell you that this is a trick that instructors use all the time.

As a simple example, say you're given a distance and a time, and you have to find a speed. You can cut through the wording of the problem immediately because you know that distance (for example, meters) divided by time (for example, seconds) gives you speed (meters/second). Multiplication and division are reflected in the units. So, for example, because a rate like speed is given as a distance divided by a time, the units (in MKS) are meters/second. As another example, a quantity called *momentum* is given by velocity (meters/second) multiplied by mass (kilograms); it has units of kg·m/s.

As the problems get more complex, however, more items are involved — say, for example, a mass, a distance, a time, and so on. You find yourself glancing over the words of a problem to pick out the numeric values and their units. Have to find an amount of energy? Energy is mass times distance squared over time squared, so if you can identify these items in the question, you know how they're going to fit into the solution and you won't get lost in the numbers.

The upshot is that units are your friends. They give you an easy way to make sure you're headed toward the answer you want. So when you feel too wrapped up in the numbers, check the units to make sure you're on the right path. But remember: You still need to make sure you're using the right equations!

You don't *have* to use a conversion factor; if you instinctively know that you need to divide by 24 to convert from miles per day to miles per hour, so much the better. But if you're ever in doubt, use a conversion factor and write out the calculations, because taking the long road is far better than making a mistake. I've seen far too many people get everything in a problem right except for this kind of simple conversion.

Eliminating Some Zeros: Using Scientific Notation

Physicists have a way of getting their minds into the darndest places, and those places often involve really big or really small numbers. Physics has a way of dealing with very large and very small numbers; to help reduce clutter and make them easier to digest, it uses *scientific notation.*

In scientific notation, you write a number as a decimal (with only one digit before the decimal point) multiplied by a power of ten. The power of ten (10 with an exponent) expresses the number of zeroes. To get the right power of ten for a vary large number, count all the places in front of the decimal point, from right to left, up to the place just to the right of the first digit (you don't include the first digit because you leave it in front of the decimal point in the result).

For example, say you're dealing with the average distance between the sun and Pluto, which is about 5,890,000,000,000 meters. You have a lot of meters on your hands, accompanied by a lot of zeroes. You can write the distance between the sun and Pluto as follows:

$$5{,}890{,}000{,}000{,}000 \text{ meters} = 5.89 \times 10^{12} \text{ meters}$$

The exponent is 12 because you count 12 places between the end of 5,890,000,000,000 (where a decimal would appear in the whole number) and the decimal's new place after the 5.

Scientific notation also works for very small numbers, such as the one that follows, where the power of ten is negative. You count the number of places, moving left to right, from the decimal point to just after the first nonzero digit (again leaving the result with just one digit in front of the decimal):

$$0.0000000000000000005339 \text{ meters} = 5.339 \times 10^{-19} \text{ meters}$$

Using unit prefixes

Scientists have come up with a handy notation that helps take care of variables that have very large or very small values in their standard units. Say you're measuring the thickness of a human hair and find it to be 0.00002 meters thick. You could use scientific notation to write this as 2×10^{-5} meters (20×10^{-6} meters), or you could use the unit prefix μ, which stands for *micro:* 20 μm. When you put μ in front of any unit, it represents 10^{-6} times that unit.

A more familiar unit prefix is *k*, as in *kilo,* which represents 10^3 times the unit. For example the kilometer, km, is 10^3 meters, which equals 1,000 meters. The following table shows other common unit prefixes that you may see.

Unit Prefix	***Exponent***
mega (M)	10^6
kilo (k)	10^3
centi (c)	10^{-2}
milli (m)	10^{-3}
micro (μ)	10^{-6}
nano (n)	10^{-9}
pico (p)	10^{-12}