Chapter 1

Using Statics to Describe the World around You

In This Chapter

- Defining statics and related studies
- Introducing vectors
- Exploring free-body diagrams
- Looking at specific applications of statics

Statics is a branch of physics that is especially useful in the fields of engineering and science. Although general physics may describe all the actions around you, from the waving of leaves on a tree to the reflection of light on a pond, the field of statics is much more specific.

In fact, statics is actually a part of most physics courses. So if you've ever taken a high school or college physics course, chances are that some of the information in this book may seem vaguely familiar. For example, one of the first areas you study in physics is often Newtonian mechanics, which is basically statics and dynamics.

Physics classes typically cover a wide range of topics, basically because physics has a wide range of applications. Conversely, a statics course is much more focused (which doesn't necessarily mean it's simple). Whoever said that the devil is in the details may well have been talking about statics.

Before you panic, close the book, and begin questioning why you ever thought you could understand statics, let me reassure you that just because statics isn't always simple doesn't mean it's always difficult. If anything, statics does happen to be very methodical. If you follow some basic steps and apply some basic ideas and theory, statics actually can become a very straightforward application process.

Now, about those details . . .

What Mechanics Is All About

The study of the world around you requires knowledge of many areas of physics, often referred to as mechanics. The mathematician Archimedes of Syracuse (287–212 BC) is often credited as being the first person to systematically study the behavior of objects by using mechanics and is attributed with saying "Give me a place to stand and I will move the Earth." This statement, while rather grandiose for his time, proves itself to be at the very heart of the study of mechanics (and, more specifically, statics).

Mechanics refers to one of the core areas of physics, usually concentrated around the principles of Sir Isaac Newton and his basic laws of motion, and is an area of concentration that engineers and scientists often study in addition to basic physics classes. These courses develop the core curriculum for many basic engineering programs and are usually common classes across all disciplines. Specific engineering disciplines may require additional courses in each of these core areas to teach additional (and often more advanced) topics.

One of these core areas is in the area of *statics,* which isn't the study of how you should move across a shag carpet in order to apply a jolt of electricity to your younger siblings or how to implement the latest hygiene techniques to avoid those dreadful bad hair days. In this book, I define *statics* as the mechanical study of the behavior of physical objects that remain stationary under applied *loads* (which I discuss later in this chapter). The behavior of the floor beams in your house as you stand in the middle of your living room is an example of a static application.

The area of *dynamics*, on the other hand, is the study of objects in motion. So as you walk down the hall, your behavior and its effect on your house becomes a dynamic application. The result of a car driving down a bumpy road, the flow of water through a creek, and the motion of those shiny little metallic balls that hang from strings and haunt/hypnotize you with their "clack, clack, clack" as they bounce off each other are all examples of dynamic behavior.

Finally, you come to *mechanics of materials* (sometimes referred to as *strength of materials*), which is yet another branch of mechanics that focuses on the behavior of objects in response to loads. This area of mechanics builds on concepts from both dynamics and statics.

Putting Vectors to Work

One of the most basic tools to include in your basket of statics tricks is the knowledge of vectors, which I discuss in detail in Part II of this book. Think of vectors as being one of the major staples, such as rice or potatoes, of your statics kitchen. Statics forms the foundation for a complete meal of engineering design. Vectors come in all shapes and forms, and you can use them for a wide variety of purposes, which I introduce you to in Chapters 4 and 5.

But the vector discussion doesn't end there. I also show you several different ways to mathematically work with vectors, including building the foundation for a vector's equation (see Chapters 6, 7, and 8).

Peeking at a few vector types

One of the first vectors you need to get familiar with is the *position vector,* which basically tells you how to get from one point to another. These vectors are very handy for giving directions, measuring distances, and creating other vectors; you can read about them in Chapter 5.

The most common type of vector that you deal with has to do with loads, or forces (see the following section). Think of a force as being that number that pops up when you step on your bathroom scale that reminds you that you should have worked out last night instead of eating a second helping of cheesecake. The bigger that number gets, the bigger the force that is being applied to your scale. Forces are one of the major types of actions that can affect a body in statics.

Understanding some purposes of vectors

One purpose of vectors is to help define direction. Many forces act along straight lines but aren't necessarily acting at a distinct point. By creating a *unit vector* (a special type of vector with a specific length), you can define the direction of these lines without actually knowing the specific coordinates or location data; unit vectors also prove to be very useful for creating forces (another type of vector). Check out Chapter 5 for more on these vectors as well.

REMEMBER

You can also use vectors to define the *rotational behaviors* (or spinning effects) of an object, which I explain in Chapter 12.

You can also combine multiple vectors to create a single combined vector, which can be useful for dealing with multiple forces. In addition, knowing how you can break down vectors into smaller vectors and calculate their size allows you to determine, say, how big a chair needs to be to support a given weight, including figuring out the size of its legs and even the number of legs necessary. In fact, for three-dimensional statics problems, vectors are practically mandatory. Chapters 7 and 8 deal with combining and breaking down vectors, respectively.

Defining Actions in Statics

In mechanics, you must become familiar with a large number of actions to be able to study how an object behaves, ranging from velocity and momentum in dynamics, to thermal effects, stress, and strain in mechanics. Fortunately, the types of effects in statics are contained in a fairly brief list:

- **Forces:** *Forces* are a type of load that causes an object to *translate* (move linearly) in the direction of the applied force. Forces can be spread out or acting at a single location, but they always cause an object to want to translate. You can use forces to measure the intensity of one object striking another, the weight of a car as it drives across a bridge deck, or the effect of water pressure on the side of a submarine. Flip to Chapters 9 and 10 for more on forces.
- **Moments:** *Moments* are a type of load that causes an object to rotate in space without translation. Moments are usually the result of some sort of twisting or spinning effect, such as a shaft attached to a motor, or a reaction from a second object that is acting on the other. For example, turning the handle of a wrench applies a moment to a bolt, which then causes it to rotate. Chapter 12 gives you the lowdown on moments.

One of your biggest challenges in statics is how to accurately depict and determine the type of action or behavior being applied to a system. If an elephant sits on your favorite living room recliner, you can easily tell what the final outcome of that action will probably be: You now have a broken chair, and a trip to the furniture store is in your future. Although most people will wonder how you got an elephant in your living room in the first place, as a statics enthusiast you're more interested in exploring the behavior of the elephant's weight and determining how much force is transmitted through the seat, into the legs, and ultimately into the ground. This field is where your study of statics begins (don't worry, no zoology or elephant anatomy knowledge is required).

Because forces and moments are such an important part of statics, you need to be able to calculate them for different kinds of problems. In Part III, I show you how to calculate forces and moments in both two- and three-dimensional situations. Load effects in statics are typically classified into three basic categories:

- **Concentrated forces:** *Concentrated forces* (or forces that act at a single point) include the force from a ball as it's thrown toward a wall, or even the force that your shoes exert on the floor from your self weight. I cover these forces more in Chapter 9.
- **Distributed forces:** *Distributed forces* are forces that are spread over an area and are used to represent a wide variety of forces on objects. The

weight of snow on the roof of your house or of soil pressure on your basement wall is a distributed load. Chapter 10 shows you how to determine their net effect (or the *resultant*), and Chapter 11 illustrates how to determine the location where this resultant is acting.

- **Concentrated moments:** *Concentrated moments* are a type of load that causes a rotation effect on an object. The behavior of your hand on a door knob or a wrench on a nut is an example of rotational behaviors that are caused by moments. I describe the types of moments and how they are created in more detail in Chapter 12.

Sketching the World around You: Free-Body Diagrams

The ability to draw a *free-body diagram* (or F.B.D., the picture representations of the problem you want to investigate) is vital when you start a static analysis because F.B.D.s depict the problem you're trying to solve, and they help you write the equations you need for performing a static analysis. In fact, if you don't get the F.B.D. completely correct, you may end up solving for a completely different problem altogether.

The more you practice creating free-body diagrams, the more proficient you become. Free-body diagrams must feature various items, including dimensions, self weight, support reactions, and the various forces I discuss in Part III. (Head to Chapter 13 for a full checklist of required items.) You can also break a larger F.B.D. into additional diagrams; this tactic is useful because you can use these smaller diagrams to find information that helps you solve for a wide variety of effects, such as *support reactions* (physical restraints) and internal forces, that you may not notice on the larger drawing. You can find information on these topics in Chapter 14.

When you're working with F.B.D.s with multiple applied loads and supports, simplifying those diagrams can make your work a lot, well, simpler. Chapter 15 gives you several tricks for simplifying F.B.D.s; one of the most useful techniques is the *principle of superposition,* which allows you to quickly compute behaviors by simply adding the responses of the individual cases. You can also simplify your diagram by moving a force from one location on an object to another while preserving the original behavior; you can read more about this in Chapter 15 as well.

Unveiling the Concept of Equilibrium

Isaac Newton (1642–1727) helped establish the laws of motion and gravity (covered in Chapter 16) that are still used today. *Equilibrium* is a special case of Newton's laws where acceleration of an object is equal to zero (that is, it isn't experiencing an acceleration), which results in an object being in a stable or balanced condition. If you lean back in your chair such that it's supported by two legs, you notice that you reach a special point where you remain somewhat balanced. (But don't try this at home.) However, if you lean a little bit forward, the chair starts to rock forward and usually winds up safely back on the front two legs. This simple motion means that equilibrium hasn't been maintained. If you lean too far back, the chair starts to lean backward and unless you catch yourself, you soon find yourself lying on the ground. But good news: While you're lying on your back counting the little birds circling your head, you've actually arrived at a new equilibrium state.

Although you can simplify statics down to three basic equilibrium relationships for two-dimensional problems (and six equations for three-dimensional problems, though they're similar in concept), you can investigate a wide variety of problems with these relationships. Flip to Chapters 17 and 18 for more on equilibrium in two and three dimensions, respectively.

Applying Statics to the Real World

So what's an engineer to do after getting a handle on F.B.D.s, loads, equilibrium, and other statics trappings? Why, put them to use in actual applications, of course!

Real-world statics is where all the conceptual info you read about becomes much more interesting and much more practical. You can employ statics concepts to a wide variety of applications; some of the most common ones include the following:

- **Trusses:** *Trusses* are systems of simple objects interconnected to create a single combined system. They're commonly used in roof systems and as bridges that span large distances. In Chapter 19, I explain the basic assumptions of trusses and then illustrate the *method of joints* and the *method of sections* for analyzing forces within the truss.
- **Beams and bending members:** The majority of objects you work with in statics have up to three different types of internal forces (axial, shear, and moment, which I cover in Chapter 20). These internal forces are what engineers use to design structural members within a building. The

forces sometimes cause a member to *deflect* (move away from being parallel), creating a *bending member*. You analyze these bending members by using shear and moment diagrams, which you can also read about in Chapter 20.

- **Frames and machines:** Frames and machines, though similar to trusses, can experience similar behaviors to beams and bending members. In fact, a large number of structural objects and tools that you use on a daily basis are actually either a frame or a machine. For example, simple hand tools such as clamps, pliers, and pulleys are examples of simple machines. *Frames* are more general systems of members that you can use in framing for structures. Chapter 21 gives you the lowdown on working with frames and machines.
- **Cable systems:** *Cable systems* are a unique type of structure and can produce some amazing architectural bridges known as *suspension bridges*. In Chapter 22, I describe the assumptions behind cable systems and present the techniques you need to solve cable problems.
- **Submerged surfaces:** *Submerged surfaces* are objects that are subjected to fluid pressure, such as dams. Fluids can apply hydrostatic pressure and pressure from self weight to submerged surfaces, and I describe both of those in Chapter 23.

A discussion of statics applications wouldn't be complete without talking about *friction,* the resistance an object feels along a contact surface as it moves in a particular direction. The two main types of frictional behavior are *sliding* (where the object moves across the surface in response to a force) and *tipping* (where the object responds to a force by toppling over rather than moving across a surface). These friction forces are the source of a large number of strange behaviors and require you to make assumptions about a behavior and then use free-body diagrams and the equations of equilibrium to verify them. Chapter 24 is your headquarters for all things friction.