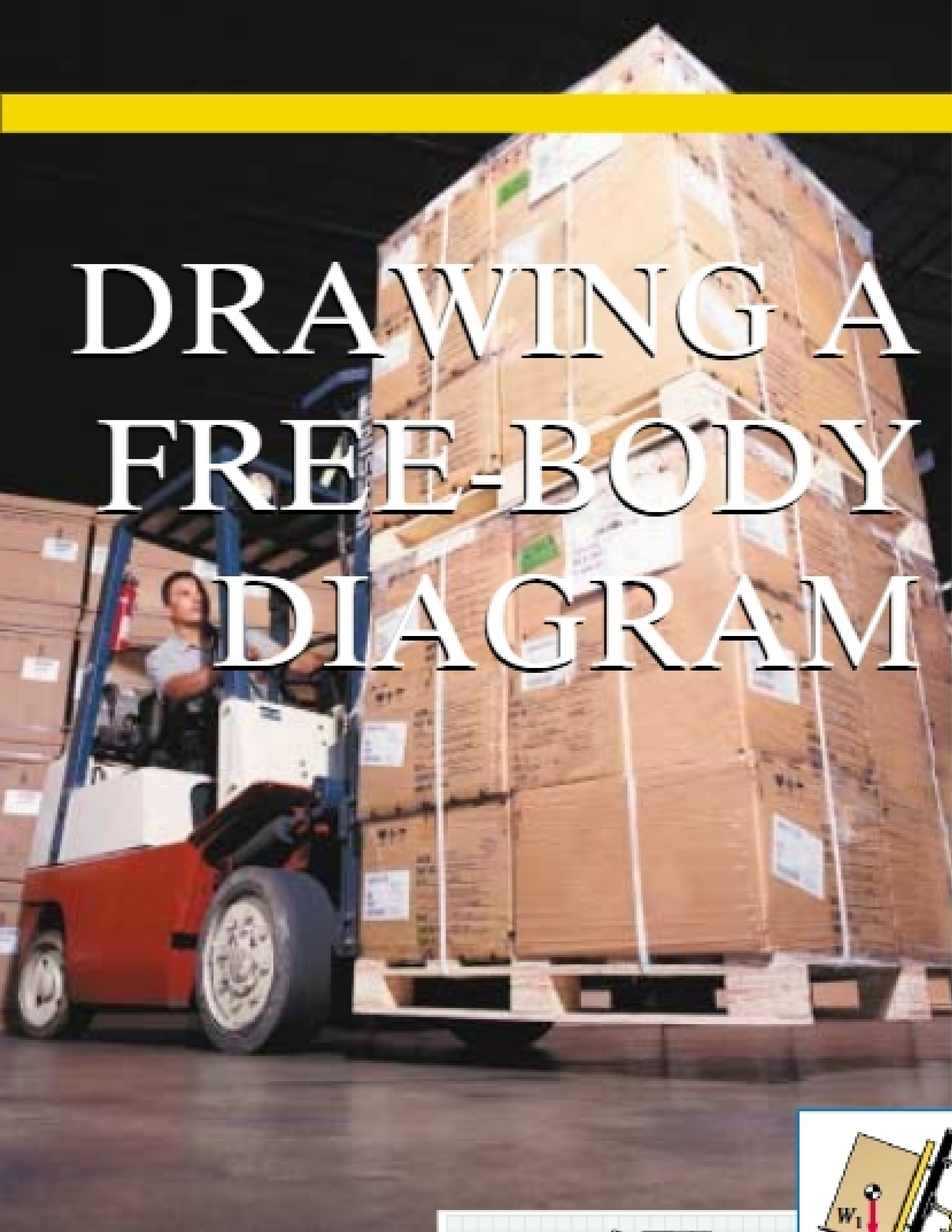
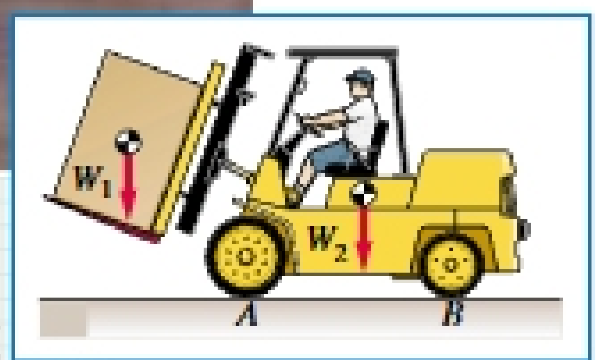
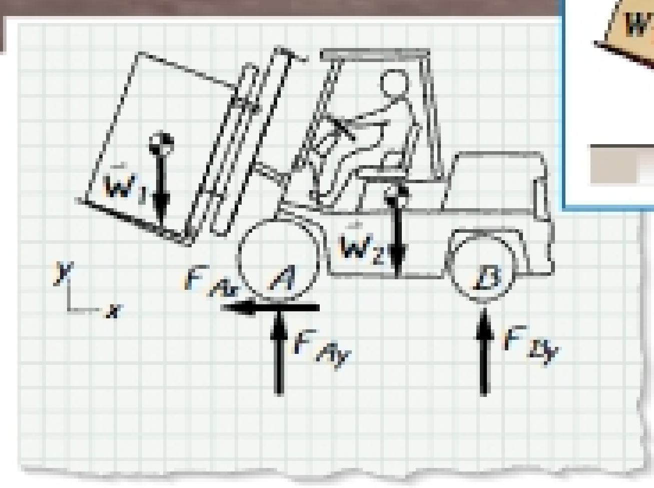


DRAWING A FREE-BODY DIAGRAM

The **free-body diagram** is the most important tool in this book. It is a drawing of a system and the loads acting on it. Creating a free-body diagram involves mentally separating the system (the portion of the world you're interested in) from its surroundings (the rest of the world), and then drawing a simplified representation of the system. Next you identify all the loads (forces and moments) acting on the system and add them to the drawing.





OBJECTIVES

On completion of this chapter, you will be able to:

- **Isolate a system from its surroundings and identify the supports**
- **Define the loads associated with supports and represent these loads in terms of vectors**
- **Inspect a system and determine whether it can be modeled as a planar system**
- **Represent the system and the external loads acting on it in a diagram called a free-body diagram**

As an example of creating a free-body diagram, consider the two friends leaning against each other in **Figure 6.1*a***. The free-body diagram of Friend 1 is shown in **Figure 6.1*c***. In going from **Figure 6.1*a*** to **6.1*c***, we zoomed in on and drew a boundary around the system (Friend 1) to isolate him from his surroundings, as shown in **Figure 6.1*b***. This boundary is an imaginary surface and the system is (by definition) the "stuff" inside this imaginary surface. The system's surroundings are everything else. You can think of the boundary as a shrink wrap around the system.

After drawing the boundary, we identified the external loads acting on the system either at or across this boundary and drew them at their points of application. These loads represent how the surroundings push, pull, and twist the system. In a free-body diagram we draw the system somewhat realistically and replace the surroundings with the loads they apply to the system. It is important to recognize that we are not ignoring the surroundings—we simply replace them with the loads the system experiences because of them. For example, in **Figure 6.1*c*** we replace the back of Friend 2 with the normal force he applies to the back of Friend 1 ($\boldsymbol{F}_{\text{normal, back 2 on back 1}}$).

This chapter is devoted exclusively to creating free-body diagrams. We build on the work in prior chapters on forces and moments and on the engineering analysis procedure presented in Chapter 1. Creating a free-body diagram is part of the DRAW step in the analysis procedure.

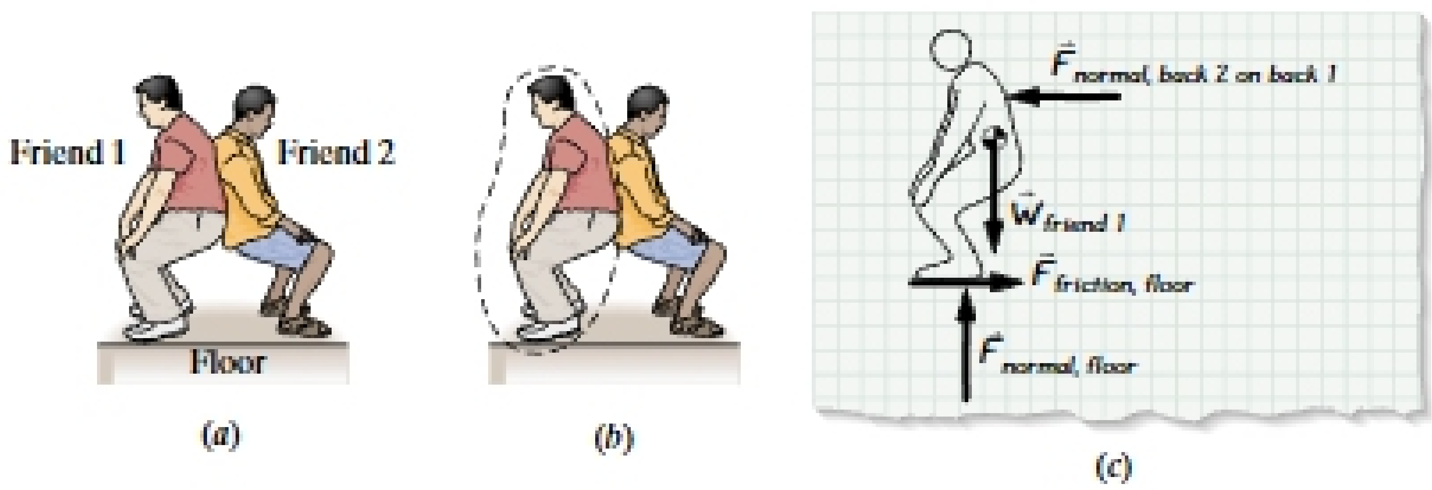


Figure 6.1 (*a*) Two friends leaning against one another; (*b*) isolate Friend 1 by drawing a boundary. Friend 1 is the system; (*c*) a free-body diagram of Friend 1

6.1 TYPES OF EXTERNAL LOADS ACTING ON SYSTEMS

Some of the external loads acting on a system act *across* the system boundary; the principal example of this type of load is **gravity** (which manifests itself as weight). Another example is the magnetic force, which results from electromagnetic field interaction. The magnetic force is what turns a motor.

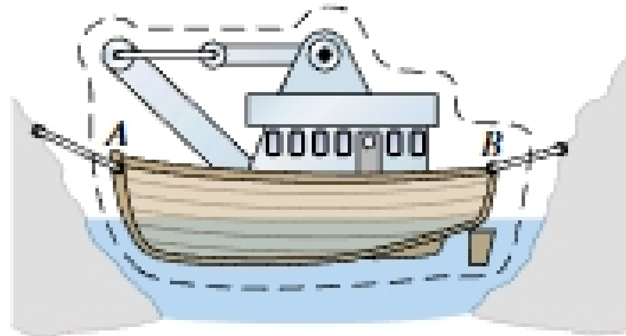
Other external loads act *directly on* the boundary. Consider where:

- The boundary passes through a connection between the system and its surroundings, commonly referred to as a **boundary support** (or **support** for short). A support may be, for example, a bolt, cable or a weld, or simply where the system rests against its surroundings. We replace each support with the loads it applies to the system. These loads consist of the contact forces discussed in Chapter 4 (normal contact, friction, tension, compression, and shear). Synonyms for the term *supports* are *reactions* and *boundary connections*.
- The boundary separates the system from fluid surroundings. We refer to this as a **fluid boundary**. We replace the fluid with the loads the fluid applies to the system. This load consists of the pressure (force per unit area) of the fluid pressing on and/or moving along the boundary.

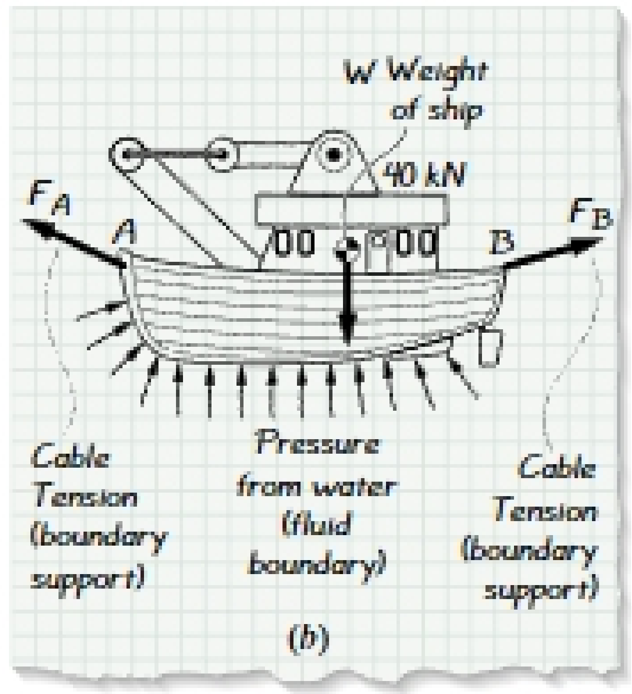
In practice, a system may be acted on by a combination of cross-boundary loads (usually gravity), loads at supports, and loads at fluid boundaries, as illustrated in **Figure 6.2**.

Notice that at some boundary locations no loads act. At other locations there are what are called **known loads**—for example, in **Figure 6.2**, the 40-kN gravity force is a known load.

Depending on the nature of an external load acting on a system, when that load is drawn on a free-body diagram it is represented either by a vector acting at a point of application or as a distributed load acting on an area. The load is given a unique variable label, and its magnitude (if it is a known load) is written next to the vector.



(*a*)



(*b*)

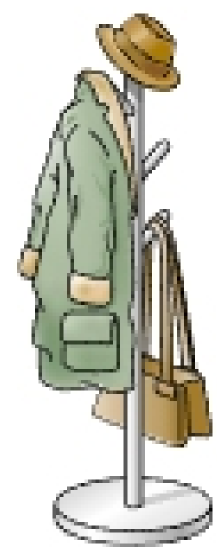
Figure 6.2 (*a*) Isolate the ship by drawing a boundary. The ship is the system; (*b*) a free-body diagram of the ship

EXERCISES 6.1

6.1.1. The system to be considered is a coat rack with some items hanging off of it as shown in **E6.1.1**. In your mind draw a boundary around the system to isolate it from its surroundings.

a. Make a sketch of the coat rack and the external loads acting on it. Show the loads as vectors and label them with variables, and where possible give word descriptions of the loads.

b. List any uncertainties you have about the free-body diagram you have created.



E6.1.1