3-1 Making Things Move

Let's say a pen is lying on the desk in front of you, at rest. How could you make the pen move? There are many things you could do, such as:

- Pushing the pen with your hand.
- Picking the pen up and then dropping it.
- Tilting the desk, or the desktop, so the pen slides.

In all these cases, you are either directly applying a force to the pen or you are setting up a situation where something else applies an unbalanced force to the pen. What is a force?

A force is simply a push or a pull. A force is a vector, so it has a direction. The SI unit of force is the newton (N). 1 N = 1 kg m/s^2.

In addition, ***a force represents an interaction between objects***. For instance, the Earth exerts a force on the pen and the pen exerts a force on the Earth. Each object involved in an interaction experiences a force.

Question: Can an inanimate object like a pen or a desk exert a force? If so, describe how it is possible for inanimate objects to exert forces.

Answer: Yes, inanimate objects can exert forces. For instance, if you stand on a trampoline, the trampoline deforms under your weight (see Figure 3.1), and the trampoline exerts an upward force on you to prevent you from falling through it. The forces between atoms and molecules are much like the springs and stretchy material that make up a trampoline, so when a pen is on a desk both the pen and the desk are deformed a little (see Figure 3.2). The deformation is too small for you to observe easily, but the forces associated with it prevent the pen from falling through the desk.

Figure 3.1: Note how the surface of the trampoline deforms when the man exerts a force down on the trampoline, in the top picture, but it is not deformed when the man is in mid-air, in the bottom picture. Photo credit: public-domain image from Wikimedia Commons.

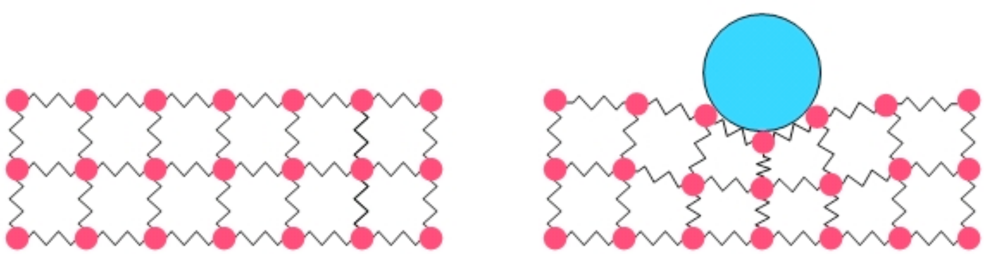

Figure 3.2: A diagram of an array of balls and springs, a model of a solid. A solid deforms when it is supporting an object. In this case, we'll use a model in which the object on top is considerably harder than the solid, so the object on top does not deform. In reality, both the object and the supporting solid would deform.

Some of the forces we'll make use of in the first part of the book include:

The Force of Tension (F_T)

Tension is the force exerted on an object by a string or rope. Remember that you can't push with a string or rope! The force of tension, F_T, on an object always points away from the object along the string or rope.

The Contact Force (F_C)

A contact force, F_C, arises when objects are in contact with one another. We often divide the contact force into its components, which we call the normal force and the force of friction.

The Normal Force (F_N)

The normal force is associated with objects in contact with one another, the normal force being the component of the contact force that is perpendicular to the surface of contact. When a book lies on a horizontal desktop, for instance, the desktop exerts an upward normal force on the book while the book exerts a downward normal force on the desktop. The symbol we will use to represent the normal force is F_N. In physics, "normal" generally means "perpendicular."

The Force of Friction (F_K or F_S)

The force of friction is also associated with objects being in contact with one another, being the component of the contact force that is parallel to the surface of contact. The force of kinetic friction, F_K , applies to situations where one object is sliding over another, while the force of static friction, F_S , applies to situations where the objects do not move relative to one another. We'll get into much more detail about the force of friction in Chapter 5.

The Force of Gravity (F_G)

Unlike the other forces above, which require contact, the force of gravity acts at a distance. The Sun and the Earth, or a book and the Earth, exert a force of gravity on one another without the objects having to be in direct contact. We will explore gravity in more detail later, but let's begin by saying that the force of gravity that one object exerts on another is F_G, and points toward the object exerting the force.

Four Fundamental Forces

As we do above, we often list several forces. When we classify them, it turns out that there are only four fundamental forces (although there is excitement these days about a possible fifth force, associated with an increase in the expansion rate of the universe). The four forces are:

1. The force of gravity – an attractive force between objects that have mass.
2. The electromagnetic force – a force between charged objects, which we'll discuss in the second half of the book). The contact force, and its components the normal force and the force of friction, arise from interactions between tiny objects (e.g., electrons) that have charge – these forces are all manifestations of the electromagnetic force.
3. The nuclear force – the force that holds nuclei together (a nucleus is the collection of protons and neutrons at the center of every atom).
4. The weak nuclear force – associated with radioactive decay (such as when an atom of americium-241 in a smoke detector emits an alpha particle to ionize air molecules, a process that is explained in more detail toward the end of the book).

The electromagnetic force, the nuclear force, and the weak nuclear force, are actually all associated with a single force called the electroweak force. Physicists are currently working on a grand unified theory, attempting to unify gravity and the electroweak force into a single force.

Essential Question 3.1: Jump up into the air. While you are in mid-air, not in contact with the ground, do any of the forces listed above act on you? If so, which?