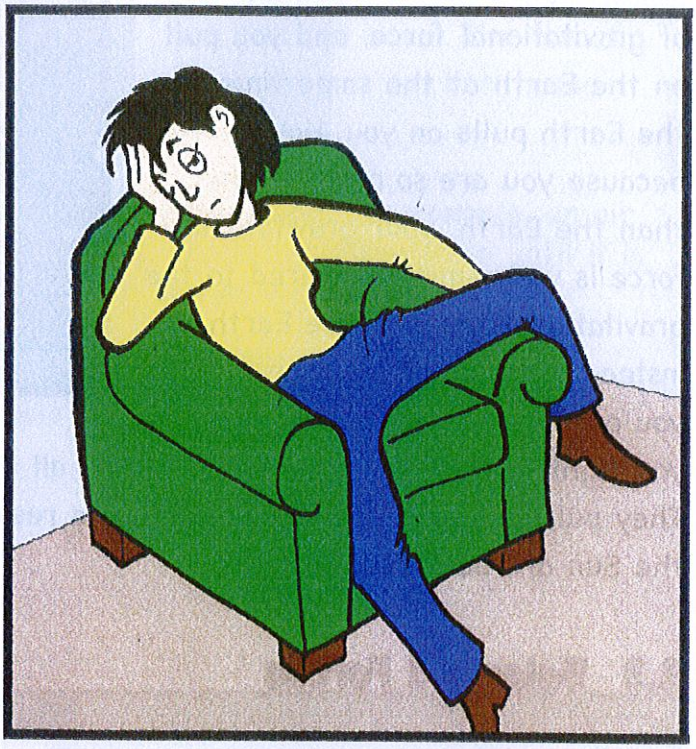
Chapter 2 Force, Energy, and Work

2.1 Introduction

What is energy? When your mom says, "I am out of energy," what does she mean?

Energy is actually defined as "the ability to do work." The term "work," as used in physics, describes what happens when a force moves an object. So your mom may need to rest to get back the energy she needs in order to have the force to move herself and other objects (do work).



This can seem a little confusing, so let's look at force, work, and energy in more detail.

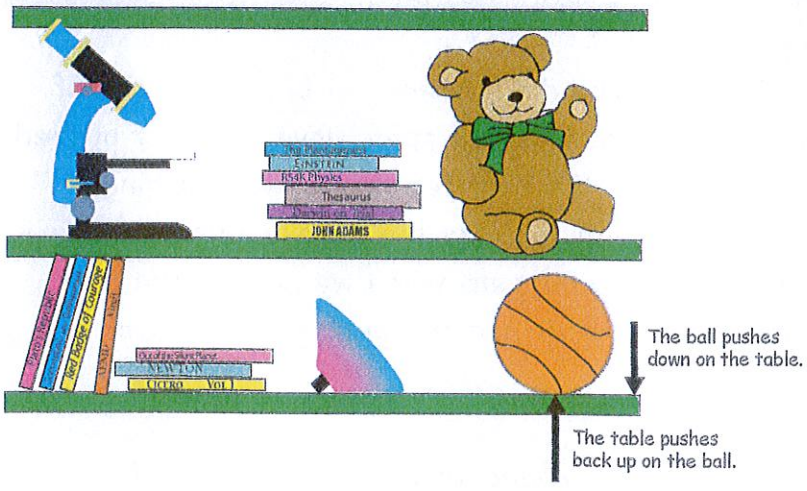
2.2 Force

What is force? Have you ever dropped an egg on the floor? What happened? Probably you heard a noise and noticed that the egg was no longer available for your cake. In fact, you probably had to clean up a sticky mess. What happened to the egg? Why did it break? It broke because of force. The egg hit the floor with enough *force* to break open. Have you ever pushed on a heavy door that just wouldn't open? Did the door feel like it was pushing you back? When we push on a door, we apply a force to the door to open it or to move it. The door pushes back. The same thing happens when we pull on the door; the door pulls back. Both the pushing on the door and the pulling on the door are forces. A force is...

...something that changes the position, shape, or speed of an object.

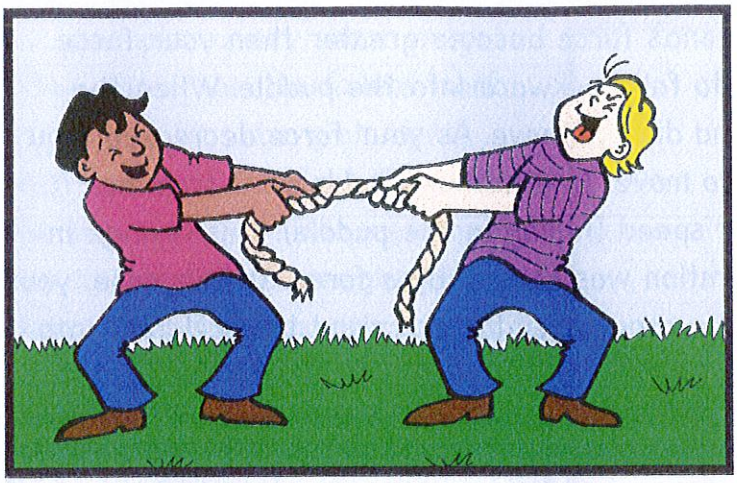
There are many different sources of force. You experience one source of force every day, all day long. That is the force of gravity (gra'-və-tē). The Earth is the source of the gravitational (gra-və-tā'-shə-nəl) force you experience. It pulls on you and makes you, and everything else, stick to the ground. The force of gravity is actually exerted by every object. You also are a source of gravitational force, and you pull on the Earth at the same time the Earth pulls on you. However, because you are so much smaller than the Earth, your gravitational force is very small compared to the gravitational force of the Earth. So, instead of dragging the Earth with you out into space, the Earth keeps you tightly stuck on its surface. In fact, all of the planets exert gravitational force. They pull and push each other and, as a result, their distances and orbits around the Sun are balanced.

2.3 Balanced Forces



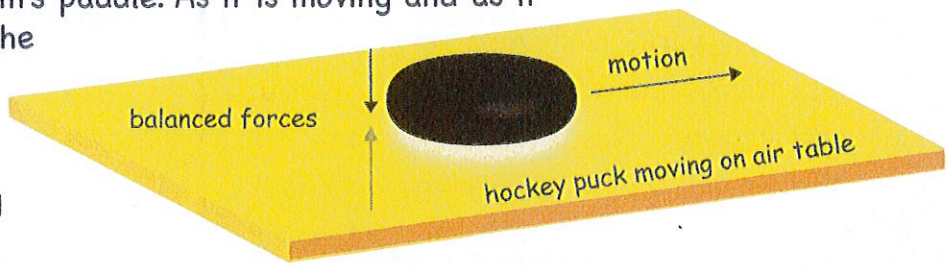
Balanced forces
Equal in size -- opposite in direction

An object that is not moving has balanced forces. For example, a toy sitting motionless on your bookshelf is actually applying a force downward toward the shelf, and the shelf is applying a force upward toward the toy. The forces are balanced; they cancel each other out, so the toy does not move.



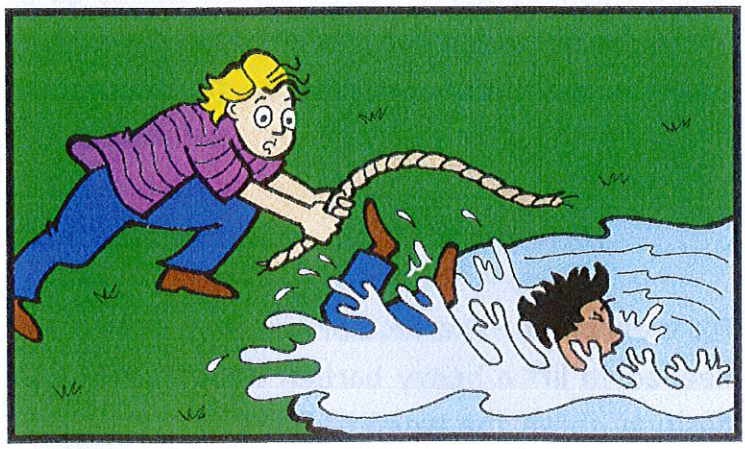
Another way to look at this is to consider what happens if you and your friend are pulling a rope in opposite directions. If you both pull with equal strength and neither of you can move the other, then the forces with which you pull are equal. The forces are balanced. You both remain motionless.

Balanced forces can also occur with objects that are moving. For example, an air hockey puck slides gracefully, at the same speed, across a hockey table until it is struck with an opponent's paddle. As it is moving and as it is at constant speed, the forces between the puck and the table are balanced. This happens with anything that slides, like snow skis, ice skates, or even magnetic trains!



2.4 Unbalanced Forces

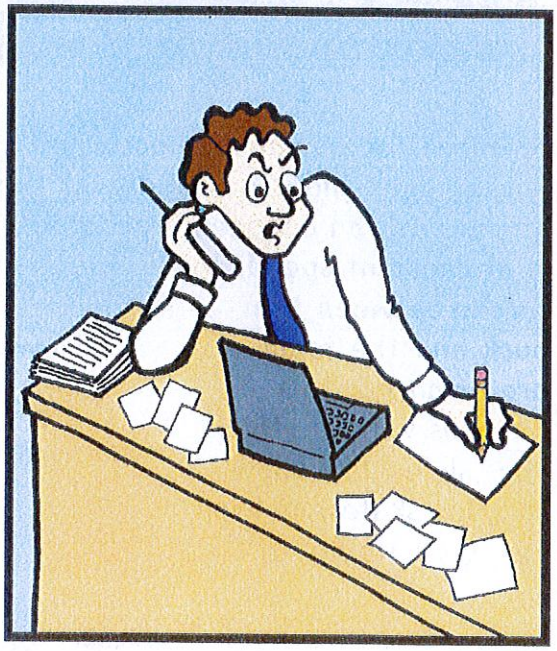
If the forces are unbalanced, that is, one force is greater than the other, the object will move. As long as the force keeps acting on the object, the object keeps moving faster. If the object keeps going faster and faster, it is said to accelerate (ik-se'-lə-rāt). Unbalanced forces always cause acceleration.



Suppose that when you and your friend are both pulling on the rope, you suddenly pull less hard on your end. What happens? Your friend keeps his force the same, but because you are pulling less hard, BAM! He's in the puddle! Why?

Your force decreased, and so your friend's force became greater than your force. These unbalanced forces caused him to fall backward into the puddle. When the forces were equal, you and your friend did not move. As your force decreased (you pulled less hard), your friend began to move. In other words, he went from no speed (standing still), to some greater speed (falling in the puddle). This change in speed is acceleration, and this acceleration was caused by a force. In this case, your pulling less strongly on your end of the rope caused your friend to accelerate into the puddle.

2.5 Work



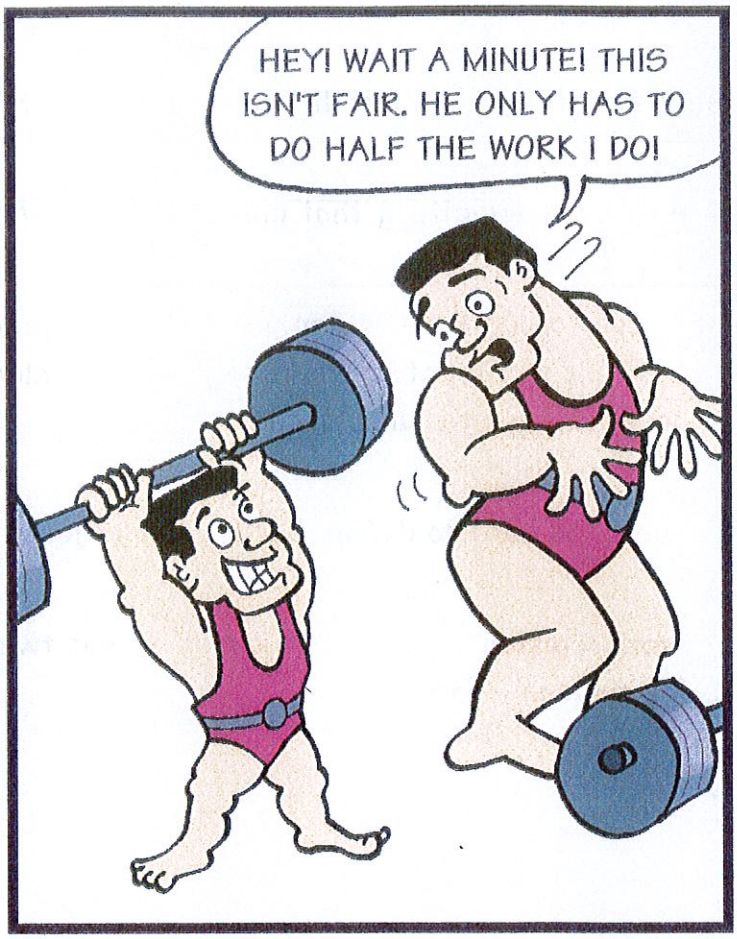
What is work? You probably hear comments like, "I am late for work," by your dad, or "I have too much work," exclaimed by your mom. You might think that work is a very grown-up thing that causes lots of stress, and your parents might agree. But in physics, work is something very simple. Work is simply the result of a force moving an object a certain distance.

When force is used to move an object a given distance, work has been done on that object. The amount of work done is calculated by multiplying the force times the distance the object has traveled.

$$\text{work} = \text{distance} \times \text{force}$$

For example, as the face of a weight lifter shows, a tremendous amount of work is needed to lift a heavy barbell from its resting position on the ground to its final position above the weight lifter's head. The amount of work the weight lifter does is proportional to the distance he has to lift the barbell. Proportional means that work and distance are related; if there is twice as much distance, the weight lifter does twice as much work.

For example, a very short weight lifter would have to do less work to get the bar above his head than a very tall weight lifter. If the short weight lifter were half the size of the tall weight lifter, then he would do exactly half the amount of work.



2.6 Energy

When work has been done, and forces have been used to do that work, energy has been used. It's hard to define energy exactly, but one thing energy *does* is to give objects the ability to do work. Take a look at the weight lifter we studied in the last section. When the barbell is on the ground, it requires the force of pulling up on the barbell to lift it above the weight lifter's head. When this happens, work has been done. But where did the weight lifter get what he needs to lift the barbell? Wheaties! Yes! The weight lifter had to have energy in his body to be able to use his muscles to do the work of lifting the barbell above his head! Living things get one type of energy from food.

There are actually different kinds of energy because there are different ways to do work. The different types of energy are given different names. Some of these different types of energy are potential energy, kinetic energy, and heat energy, to name a few. We will look at these in more detail in later chapters.

2.7 Summary

Here are the main points to remember from this chapter:

- A force is something that changes the *position, shape, or speed* of an object.
- Forces can be balanced or unbalanced. Objects that are not moving, or objects that are moving at constant speed, have balanced forces. Objects that are accelerating have unbalanced forces.
- Energy is hard to define, but it gives objects the ability to do work.
- Work = distance x force. This means that twice the distance gives twice the wo for the same force.