

MENU

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Chapters ⇒ *Chapter 1* ⇒

CHAPTER 1

PHYSICS

Physics is all about predicting and explaining what happens. What are we trying to explain or predict? What's involved? Do those things affect each other? How do they affect each other?

Physics is all about understanding what happens in the physical world, from the extremely small (like atoms or electrons) to the extremely large (like stars and galaxies), and the everyday, human-scale objects in between. In physics, “understanding” is practical: can you predict what will happen next? Can you explain why something happens the way it does?

Like other sciences, physics answers some questions but not others. Because it deals with the physical world, physics is best at answering questions like: If you throw a basketball, will it go through the basket? If you see something unexpected on the road ahead of you, can you stop your car in time? If it's hot outside, how much energy does it take to keep your room cool? How can you connect wires and batteries to make light bulbs shine?

Physics can also tell us why some things happen the way they do. Why does a basketball follow a curved path through the air? Why does the car change its motion and how does it do it? Why does your room get hot if it's hot outside, and how can you cool it? How does electricity work, and why does a battery, hooked up correctly, make a light bulb shine?

Some questions that we can ask about the world make more sense to be answered by sciences other than physics—for example, kinesiology tells us how to throw a basketball most efficiently. Engineering tells us how to build a car so that it can stop quickly or how to build an air conditioner. Chemistry tells us how a battery actually works on the inside.

After all of these questions, there's a very important one we haven't addressed yet: why should you study physics? Although there are as many reasons as there are students, we can identify three common reasons.

1. The universe is an interesting place, full of strange behavior that you want to understand. Physics lets you explain so many interesting phenomena—gravity, rainbows, or atoms. If you're curious about the physical world, physics can help you to understand it.
2. You're a conscientious person, and you want to be an informed citizen. Studying physics helps you read and understand the news on topics like climate change. You can make better decisions for yourself or your

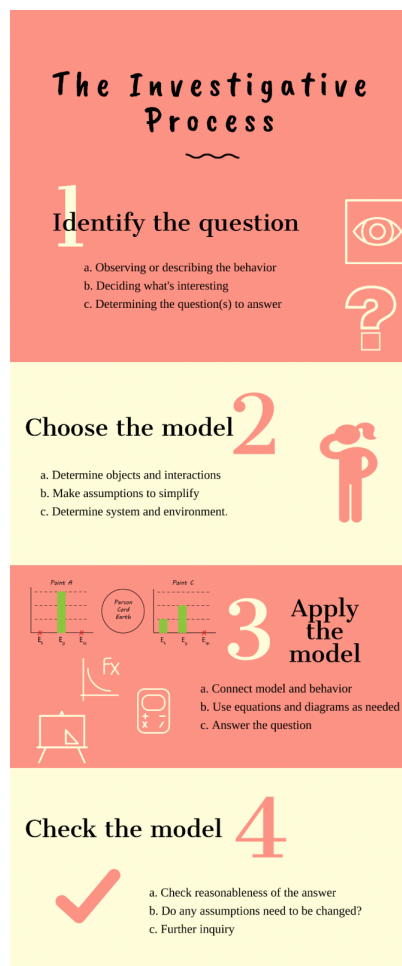


Figure 1 The investigative process that we will follow throughout the book.

community, such as if you should support nuclear power or not. Physics helps you have a better impact on the world.

3. College is a practical avenue for you, a place that helps you reach your professional goals. The actual content of what physics covers isn't as important as the way you learn to think about it. Physics helps build critical thinking skills, training your mind to address complex problems in your profession.

No matter which reason resonates most with you, you'll get that from this course.

We'll want to answer a wide range of questions and look a huge variety of messy, real life situations. We need a useful, consistent approach to finding these answers. The approach we'll use is outlined in Figure 1 : The Investigative Process. We'll start using that process in the next Chapter 1, when we apply it to a bungee jumper falling from a bridge. Before we can get there, however, we need to explore some of the basics of describing behavior—describing motion, identifying interactions, and understanding energy.

DESCRIBING MOTION

Say a baseball player hits the ball and it flies through the air. What happens after that depends on the observations the other players are making about its *motion*—is it a pop fly, easy for someone to catch? Is it low to the ground and bouncing? Is it a lofty home run, or will it drop down just inside the back fence, into the outfielder's glove?

In general, the kinds of questions we ask about motion are the following:

- Where is the object?
- Is it moving?

- If it's moving, how fast is it going?
- What direction is it moving in?
- Are any of these things changing?

When we say where an object is, we're naming its *position*. The ball is in the pitcher's hand before the throw, or after the hit it might be at a point in the air above the pitcher's head. Positions are just locations. We'll use meters as our default units for measuring position; 1 m is about 3 feet long.

Often, we measure the value of the position relative to some point, called the *origin*. If we chose the home plate as our origin, then before the throw, the ball is 18 m away from the origin in the positive x direction (" x " is our generic label for horizontal directions. The x -axis is essentially a number line). Figure 2 shows the baseball diamond with both the origin and the direction of the positive x -axis marked.



Figure 2 A baseball diamond with origin at the home plate and positive x -axis pointed at the pitcher's mound.

When we measure how far the position of the ball is compared to our origin, we're measuring the ball's *displacement*. Displacement is a similar idea to distance, but displacement is always just a comparison of positions. When you travel from one position to another, you have to follow some kind of path, and distance tracks the length of that path. Figure 3 shows two possible

paths that a ball could take going from the home plate to the pitcher's mound. The blue, low path has a shorter distance than the tall orange one. Both of the paths, however, have the same displacement, since they both start and stop at the same places. Almost always, we care more about displacement than we do distance, because we're usually just comparing two points to each other.

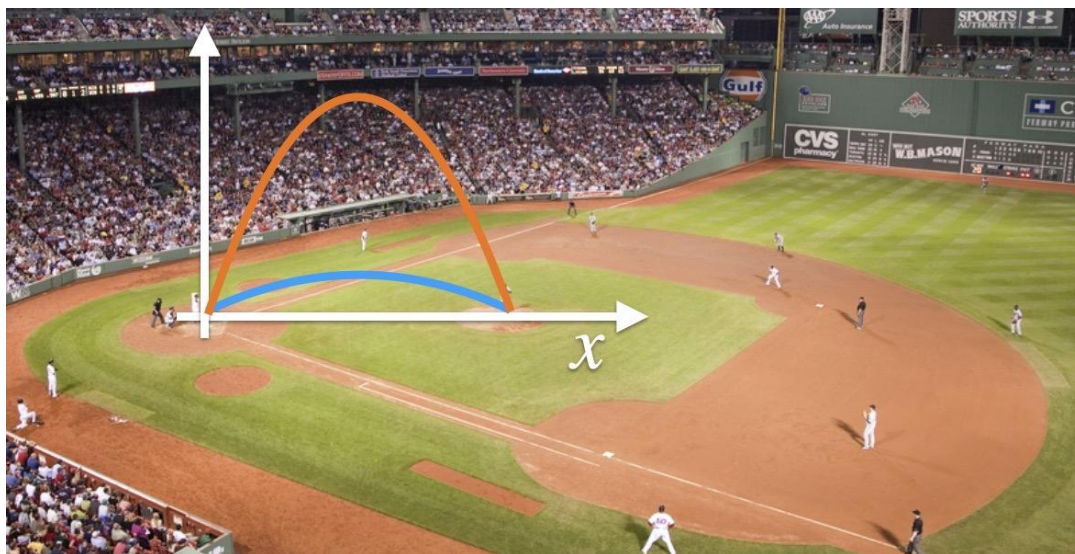


Figure 3 A blue path and an orange path go from the home plate to the pitcher's mound, both starting and stopping at the same places.

It takes time to change the position of an object. A nonplayer might throw the ceremonial first pitch in a slow lob and it takes about 1 s to reach the plate; the professional pitcher throws a fastball and it takes only four-tenths of a second. Both pitches have the same displacement, but the fastball gets there in a shorter time because it is, as the name implies, faster.

Velocity is the way we measure how fast an object travels. Velocity is determined by how far an object moves in a given amount of time. Going a long way in a short time means the object is very fast; going a short way in a long time means the object is very slow. If the two pieces of information that determine velocity are displacement and time, what can we do with that information to get the velocity? What makes the most sense—the combination that gives us a large number when moving fast and small number when moving slow—is to define velocity as the displacement divided by the time.

For both displacement and velocity, we care about the direction of travel. A pitcher throwing the ball toward the batter and the ball leaving the bat toward the outfield is traveling in opposite directions. One is forward and the other is backward. We consider any forward motion, in the direction of the $+x$ -axis, to be positive. Any backward motion, toward the direction of the $-x$ -axis, is negative. Figure 4 shows these directions on the baseball diamond.

Velocity can be represented by an arrow, as in Figures 4 and 5, because the arrow gives us both important pieces of information: the length of the arrow represents how fast the object is traveling, and the direction of the arrow tells us what direction the object is traveling in. A longer arrow means the ball is faster, and a shorter arrow means the ball is slower. Figure 5 shows the two velocities that would represent the ceremonial first pitch and the fastball.

Two different batters take their turns. Both hit balls that move almost straight toward different areas of the baseball field. The first (Ball A) is slower and gets caught by the shortstop but the other ball (Ball B) is a line drive that makes it to the outfield. What if we want to compare these two motions? Instead of just describing them in words, we could also represent their motions using a *motion diagram*.

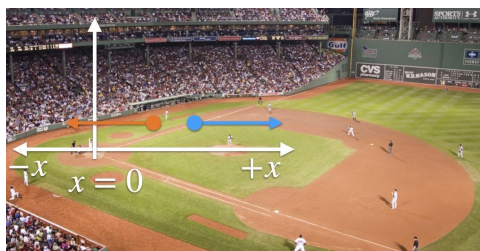


Figure 4 A ball traveling in the blue direction has positive velocity, and a ball traveling in the orange direction has negative velocity.

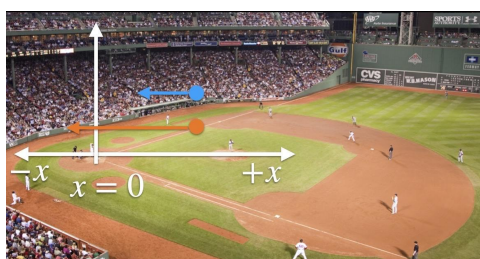


Figure 5 The blue arrow is shorter and represents the ceremonial first pitch by the nonplayer. The orange arrow is longer and represents the fastball of the professional player. Both are negative velocities.

A motion diagram is a series of dots that track the position of the object at several moments in time. The time in between each dot is the same (it could be 1 s, or 0.1 s, or any other time that makes sense for the motion. This amount of time is called the *time step*). Figure 6 shows the motion diagram for Ball A as an animation.

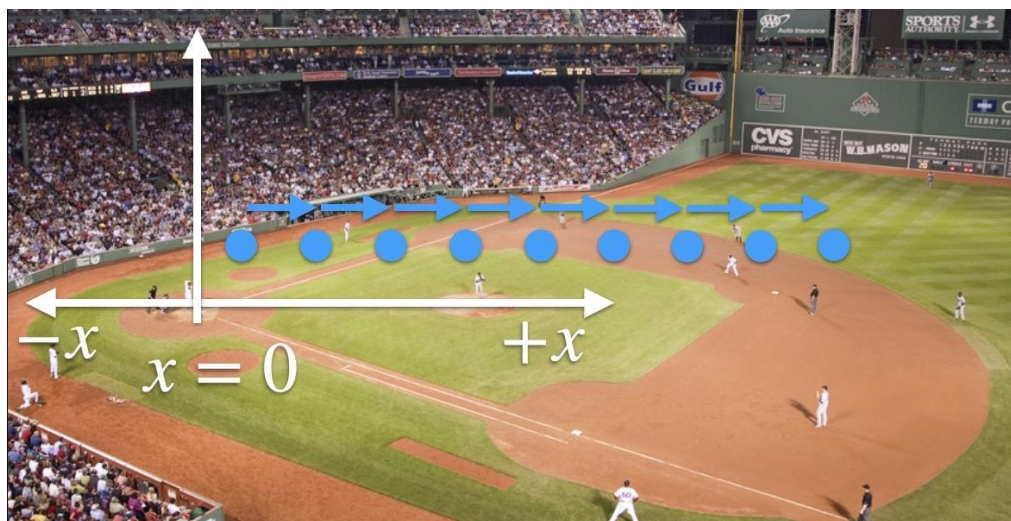
Figure 6 As the ball moves, its motion is tracked with dots after each time step.

Let's compare that motion now to Ball B, which was faster and went farther. Figure 7 shows Ball B's motion diagram.

Figure 7 As the ball moves, its motion is tracked with dots after each time step.

The faster ball moves farther in each time step, which shows up in the motion diagram as larger spacing between dots.

We can also add velocity arrows between each dot, to help clarify the direction of movement. That's especially helpful if we're drawing a motion diagram on paper rather than creating a video. Figure 8 shows both motion diagrams, including the arrows. The faster ball has longer velocity arrows.



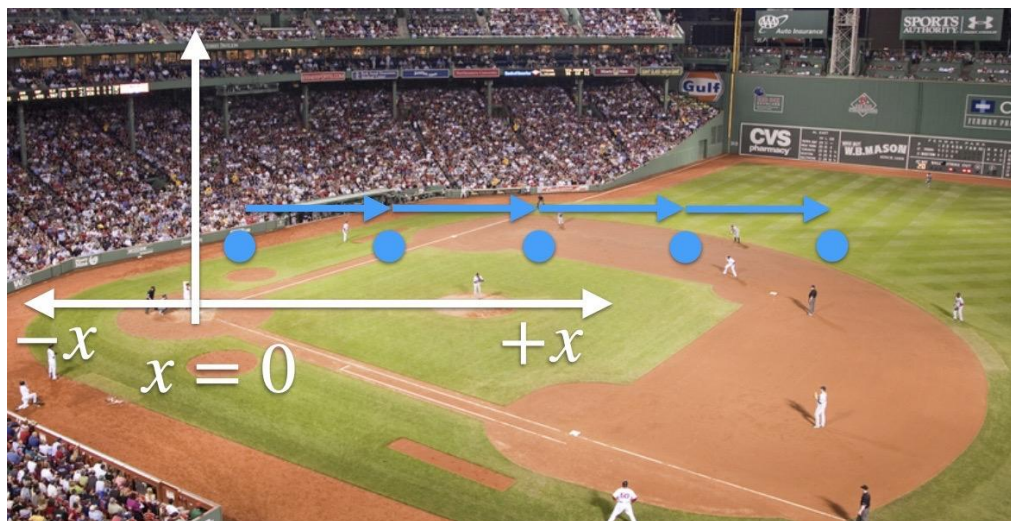
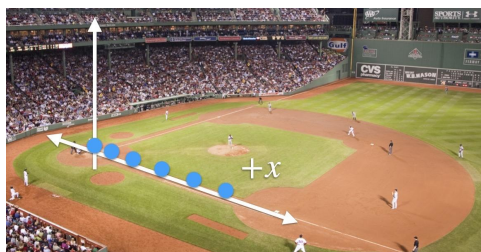


Figure 8 Left—Ball A has slower, positive motion. Right—Ball B has faster, positive motion.

We can also use motion diagrams to explore how motion can change—after all, motion that stays consistent from one moment to the next does happen, but it's always interesting when instead something happens to make it change. Maybe the object speeds up, or slows down, or even switches direction.

The player at bat hits the ball, then starts running toward first base. At the beginning of their motion, they're standing at the home plate, since they just swung their bat. Then, they have to speed up as they run toward the base. In the motion diagram in Figure 9, we see that when they start, the distance between dots is small—the batter is covering less distance in each time step. Later, the distance between dots is large—the batter is now covering more distance between each time step, because they're going faster.

What would it look like if the base runner were slowing down to stop on the base? Instead of increasing distance between dots, the distance in between would decrease, as shown in Figure 10.



The third way the motion of an object can change is by changing direction. That could be by veering off to the side, by turning around, or by going in circles.

After a ball is hit into the air, what kind of motion does it have? Right after being hit, it has a huge velocity, launched by the bat. A ball in the air will go upward for a while, slowing down, but at some point, it comes back down, speeding back up. Figure 11 shows the motion diagram for a ball that's been launched up at an angle into the air.

IDENTIFYING INTERACTIONS

When a baseball player hits the ball, the bat and the ball interact during the moment of impact. Then, the ball flies through the air, interacting with the air molecules and with the planet Earth (thanks to gravity). Finally, the ball interacts with the outfielder's glove when it lands. Each of these interactions has a different effect on the motion of the ball—the bat launches it up, the air slows it down, the Earth pulls it back down, and the glove brings it to a stop. That's why, in order to understand, analyze, and predict motion, we need to be able to identify the interactions an object has with the other objects around it.

Figure 9 Blue dots track the motion of the batter leaving the home plate and running toward first base, speeding up. The x-axis has been shifted to match the direction of the runner.

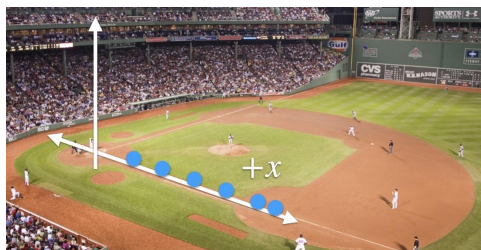


Figure 10 Blue dots track the motion of the batter running toward first base, slowing down to stop on the base.

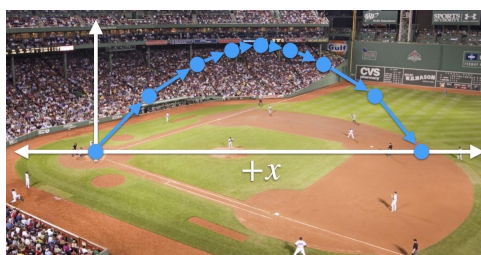


Figure 11 Blue dots track the motion of the ball flying through the air. Arrows indicate the velocity at each time step.

Two objects are involved in each interaction, the exact nature of which depends on which objects they are. Generally, interactions are pushes and pulls, but it's important to note that both objects will always be pushing or pulling on the other during an interaction. If the two objects are named A and B, then in general we'll call it an "A and B interaction". Figure 12 shows the bat and ball interaction, which only occurs when the bat and ball are in contact.

Many interactions are **contact** interactions, where they only occur when the two objects are actually touching each other. The ball and the bat interact when they are touching, but not when the ball is still approaching the bat. On the other hand, some interactions are **noncontact** interactions. After all, when the ball flies through the air, the Earth is pulling down on it (if it weren't, the ball would keep going up and up). But the ball isn't directly touching the Earth while they interact—it would have to be rolling along the ground for that. Figure 13 shows the ball and Earth interaction, which occurs during the entire motion of the ball.

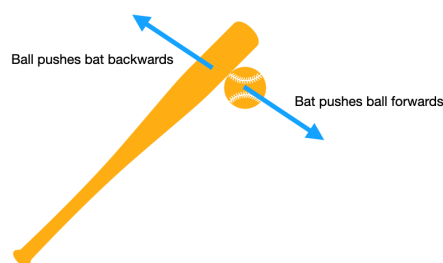


Figure 12 The bat and ball interaction that is made of the bat pushing on the ball and the ball pushing on the bat.

In Figure 12, it may have made some sense that the ball pushes on the bat just as the bat pushes on the ball—if you've ever hit a ball with a bat, you might have noticed that the bat bounces a bit backward. However, Figure 13 might seem more suspicious. The Earth pulls the ball down, of course, we see the ball come back down. But the ball pulls up on

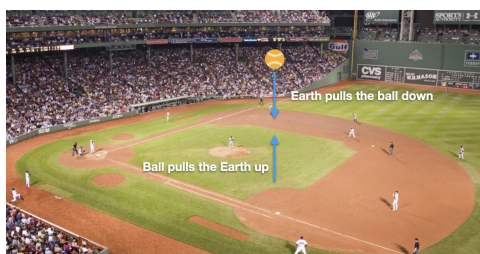


Figure 13 The ball and Earth interaction that is made of the Earth pulling down on the ball and the ball pulling up on the Earth

the Earth? That seems strange, but the way to resolve this is to recognize that the *effect* of the same interaction might be very different for the two different objects involved. The ball's effect on the Earth will be so small that it's practically unmeasurable. We'll explore the effects of interactions more at a later point.

We're starting to see that not all interactions are the same kind. In fact, we can identify several different interaction types that we typically encounter.

NORMAL INTERACTION

Whenever the surfaces of two objects are pressing against each other, the interaction is called **normal**. Here, the word doesn't mean "usual"; instead, it's an older meaning, which is "perpendicular." That's important because it's telling us the direction of the pushes: always perpendicular to the surface. Figure 14 shows a close up of the baseball in the bat and ball interaction. Because the surfaces of the two objects push on each other, this is a normal interaction, which means that the push from the bat on the ball is perpendicular to the surface of the bat at the point where the bat and ball touch.

Other examples of normal interactions include the interaction of feet and the ground, or books and a desk, or someone's arm if they lean against a wall, as shown in Figure 15.

How strong the normal interaction is, depends on how hard the two objects push against each other. If you barely touch the wall, the interaction is small.

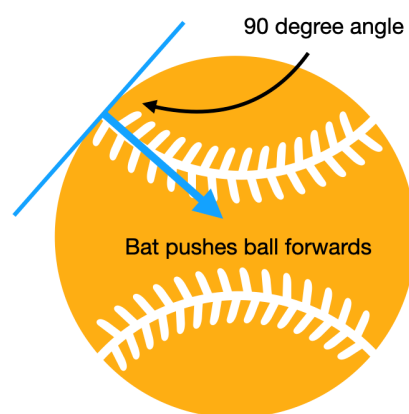


Figure 14 The push of the bat on the ball is perpendicular, or 90 degrees, from the line showing the surface of the bat.

But, if you push really hard, then the wall will also push really hard back against you.

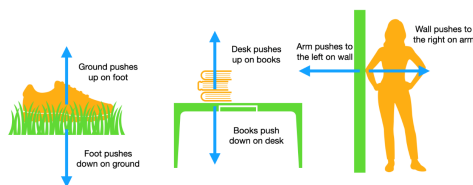


Figure 15 Several examples of normal interactions. In each case, the push is perpendicular to the surfaces that are interacting.

Unless we're astronauts traveling to the Moon or a rocket halfway to Mars, gravity is an interaction that we experience every day. The gravitational interaction happens whenever two objects have mass. Mass is a measurement of how much stuff is in an object; a feather might have small mass (perhaps a few grams) while a person has more mass (tens of kilograms). Because they both have mass, a feather and a person will actually have a gravitational interaction. However, the interaction is incredibly weak, so neither would feel any real push from the other.

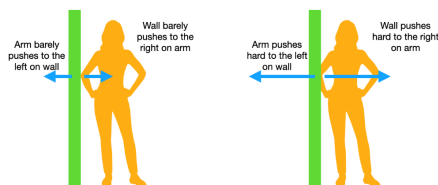


Figure 16 When the objects barely connect, the normal interaction is small. When they push into each other more forcefully, the interaction is larger.

To actually feel the effect of gravity, we need an enormous amount of mass. We need a *planet-sized* amount of mass! The Earth has about 10^{24} kg of mass—that's about 10 thousand billion billions times the mass of a human adult! That's enough mass that when we stand near the planet, we can measure the interaction between ourselves and the planet. The effect of this interaction is also called **weight**. Figure 17 compares the interactions between the Earth and a baseball, and the Earth and a bowling ball. Because the bowling ball has more mass, the interaction is stronger. The baseball and the bowling ball would also attract each other with a gravitational interaction, but it'd be so small that we'll only ever see the effect of the Earth's interaction with each ball.

Gravity is different from the other interactions we've seen in another way as well: it always pulls. The Earth will always pull us toward itself, and we will always pull it toward us. This is called an attractive interaction, because the two objects are attracted to each other.

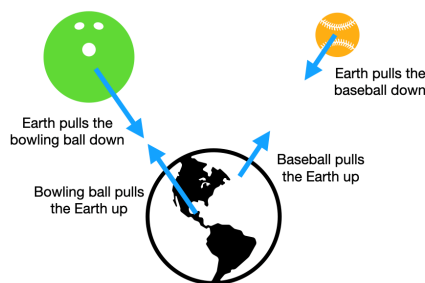


Figure 17 The interaction between the ball and the Earth is stronger when the mass of the ball is bigger.

FRICION INTERACTION

Friction is a common interaction that we usually don't notice until it's not there. If you've ever had a car tire spin out on sand or snow, or your foot slip on ice or water, then you've experienced the lack of friction. Like the normal interaction, friction is an interaction between surfaces. But where normal interactions are perpendicular to the surfaces, friction is parallel to the surface. Figure 18 shows the friction interaction of a stack of books sliding to the right across a desk.

Friction is easiest to spot when the two surfaces are moving against each other. The interaction is actually happening as a result of the roughness of the surfaces as they attempt to slide past each other. Figure 19 shows a zoomed in view of two rough surfaces; the parts that stick out will bump into each other, providing a contact interaction with each bump.

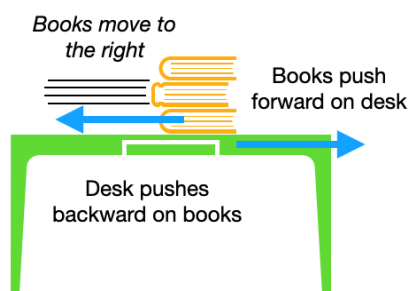


Figure 18 The desk pushes the books backward and the books push the desk forward.

Because friction is a result of roughness, we expect that smoother surfaces will have a weaker interaction, which is in fact the case. A hockey puck slides faster and easier across ice than it would across concrete. However, another factor that influences the friction interaction is actually the normal interaction. The normal is also a surface interaction, and it's determined by how hard the two surfaces push together. As Figure 20 shows, when two surfaces push together harder, more of the jagged pieces will bump into each other, as they're all closer together. That increases the amount of friction experienced by the surfaces.

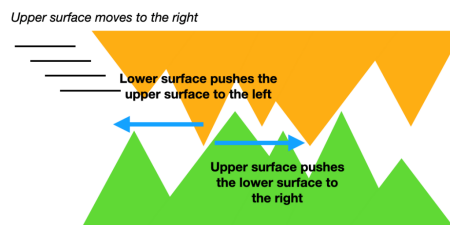


Figure 19 The upper, green surface moves to the right. The upper and lower surface interact each time a jagged piece bumps into another.

The friction interaction can also occur when one object is just about to move. If a pile of books is sitting on a desk and you push them with your hand, there is a moment where you push but they don't slide. That's because the surfaces are locked together by their jagged pieces, and you have to push harder to overcome that static friction interaction. Figure 21 shows the interaction of the surfaces as the hand pushes, but before the surfaces move.

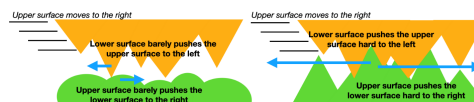


Figure 20 In both figures, the upper green surface moves to the right. On the left, a smooth surface has fewer bumps, so the friction interaction is smaller. On the right, two surfaces that have been pushed together by a large normal interaction will bump more, so the friction interaction is also large.

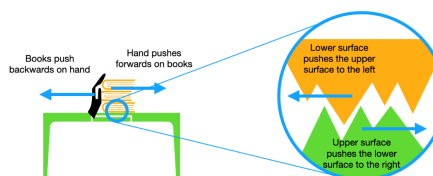


Figure 21 The rough surfaces of the book and desk create a friction

TENSION INTERACTION

Walking a dog on a leash, catching a fish on a line, or a punching bag hanging from a ceiling are all examples of the tension interaction.

Whenever an object interacts with a rope or string, we call that **tension**. Having a large tension interaction makes the rope taut; a loose rope has no tension. Ropes are interesting because you can pull on a rope to create tension, but you can't push on a rope—the rope just collapses and folds up on itself.

interaction even before the books move, as long as the hand is pushing on the books.

Figure 22 shows the tension interaction for a woman walking a dog on a leash. The direction for the interaction is always along the rope. Similar to the normal interaction, in order to create a bigger tension interaction, the object pulls harder on the rope.

SPRING INTERACTION

A spring is made of a coil of metal, and it can be compressed or stretched. Importantly, it doesn't stay that way, but will stretch back out or compress again back to its original position.

Some springs we interact with are fairly obvious—the suspension coil in a car, the spring of a child's pogo stick, or the spring on a door that prevents it from slamming shut. Other objects can still have a spring interaction, as long as they're **elastic**: they bounce back after they've been compressed or stretched. The rope used for a bungee jump, a rubber band, or a foam mattress are all elastic materials that interact with objects with a spring interaction.



Figure 22 The dog pulls the rope forward, and the rope pulls the dog backward.

Whenever an object pushes against a spring, the spring will push back against it; whenever an object pulls against a spring, the spring will pull back on it. Figure 23 shows this interaction, comparing what happens when an object stretches a spring and when it compresses it. The fundamental interaction is the same whether the spring is stretched or compressed.

Two factors influence the strength of the spring interaction: how far the spring is stretched or compressed and how stiff the spring is. The farther the spring is stretched (or compressed), the larger the interaction, as shown in Figure 24.

The other factor is the stiffness of the spring. Some coils, like the suspension in a car, are incredibly stiff and difficult to compress or stretch. Others, like a Slinky, are loose and easy to stretch and compress. The easier it is to stretch or compress the spring, the smaller the interaction.

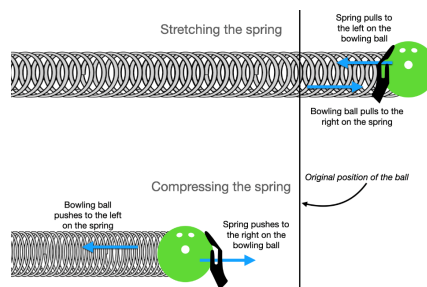


Figure 23 On the top, a spring is stretched by an attached bowling ball, and pulls back on it. On the bottom, the bowling ball compresses the spring, which pushes back up on the ball.

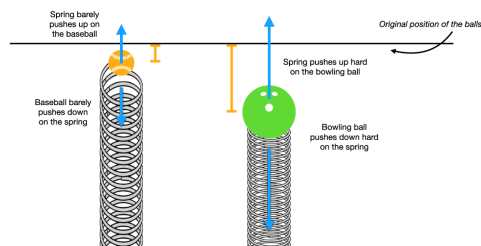


Figure 24 On the left, a baseball does not compress the spring very far, and the interaction is small. On the right, the bowling ball compresses the spring farther, and the interaction is larger.

MAGNETIC INTERACTION

Magnets are both delightful and useful. We can stick them to our fridges to hold papers or just look fun. But how do they work? Well, the magnet and the metal in the fridge door have a **magnetic** interaction. In this case, just like with gravity, the interaction is an attractive one, and the magnet and the fridge door are pulled toward each other. However, magnets can also produce a **repulsive** interaction, where they would push each other apart.

Every magnet has two poles: north (N) and south (S). “Unlike” poles (i.e., N and S) will attract each other, while “like” poles (S and S, or N and N), will repel each other. Figure 25 shows this interaction, using a traditional horseshoe magnet.

The magnetic interaction depends on the material of the objects involved; some materials are naturally magnetic, while others (like iron) can be “magnetized” either permanently or temporarily. The fridge door itself is not a magnet, but it can still have a magnetic interaction with the magnet stuck to it. A fridge magnet would not, however, stick to a wall made of drywall.

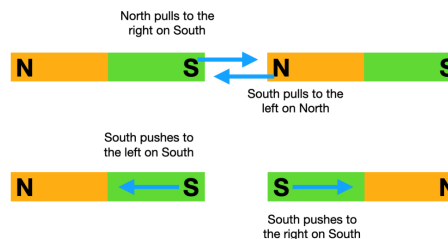


Figure 25 The North and South poles have an attractive interaction, while the South and South poles have a repulsive interaction.

ELECTRIC INTERACTION

The electrical interaction most often shows up for every small object—on the scale of atoms and molecules. Those small particles come in two flavors, called “positive” (+) and “negative” (–) charges. Similar to the magnetic interaction, unlike charges (+ and –) will attract, while like charges (+ and + or – and –) will repel. Figure 26 shows an example of the electrical interaction between charges.

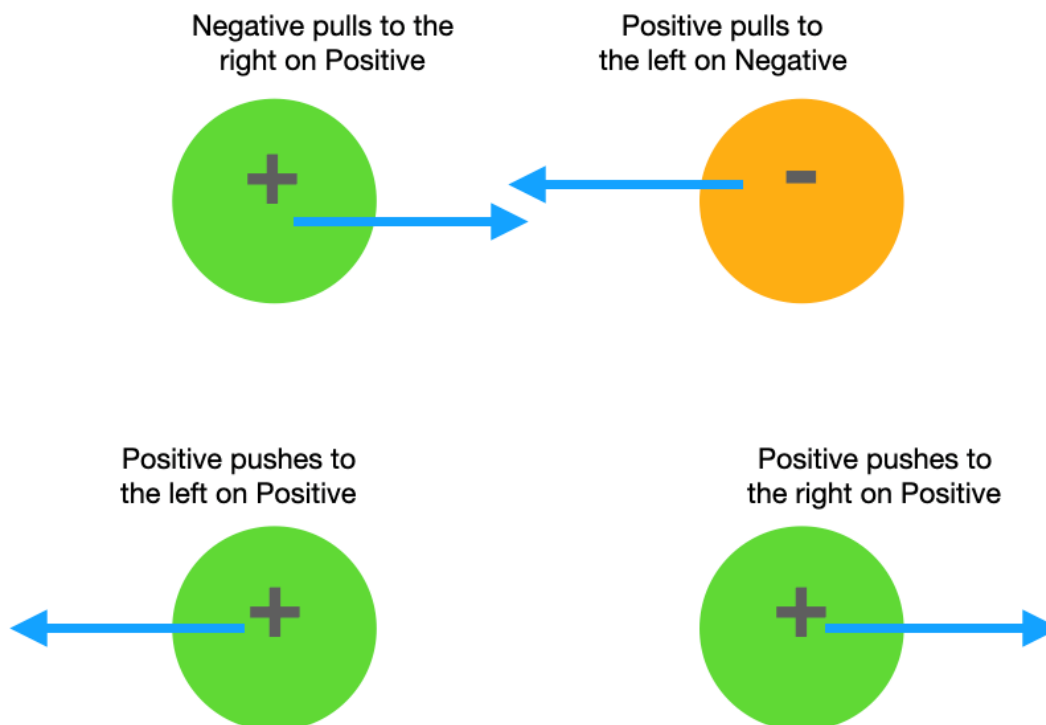


Figure 26 On top, the opposite charges have an attractive interaction. On bottom, the similar charges have a repulsive interaction.

Most objects are neutral; they're neither positive or negative. In that case, they won't have an electrical interaction. But, it's possible to charge them by dropping excess + or - onto them, and then they will have an electrical interaction. An example of this is rubbing a balloon onto your hair—they don't originally have an electrical interaction, but the process of rubbing gives them unlike charge, so they'll attract, as shown in Figure 27.



Figure 27 A person's hair is attracted to a balloon, after they've been rubbed together.

The strength of the electrical interaction depends on two factors: how much charge there is and how far away the charges are. Since having no excess charge means there's no interaction, we can guess that having more charge will create a bigger interaction, which is the case. Distance between charges also matters, and the closer the charges are to each other, the larger the interaction will be. Figure 28 compares the interactions for different amounts of charge and different distances.

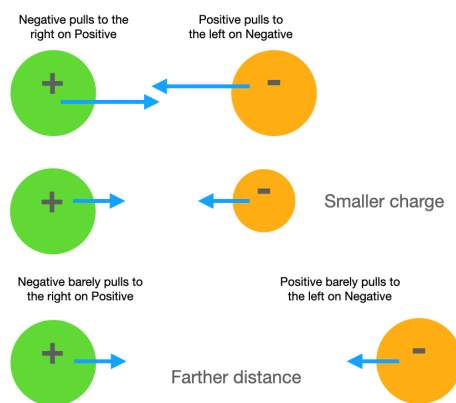
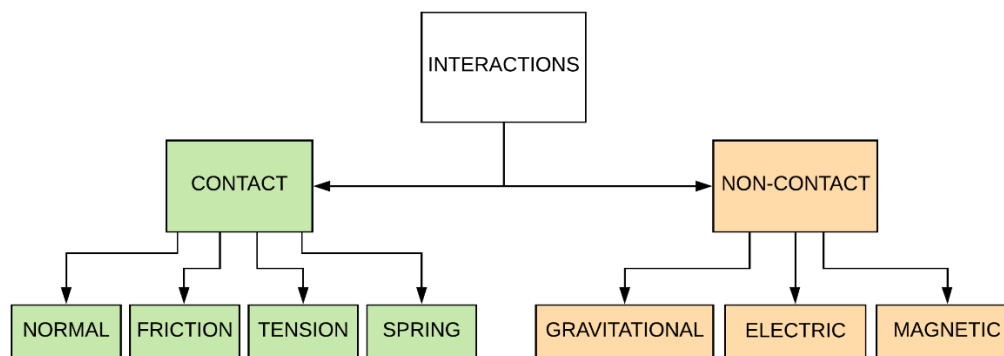


Figure 28 At the top, regular amount of charge and distance creates an electrical interaction. In the middle, a smaller charge at the same distance creates a smaller interaction. On the bottom, the regular charges at a larger

distance creates a smaller interaction.



UNDERSTANDING ENERGY

Now that you’ve seen how to describe motion and how to identify interactions, we need to start connecting these in a way that will help us eventually predict and analyze the motion. **Energy** is the connection we need. Interactions are always between two objects, and those interactions can affect their motion and positions. Different types of energy are associated with certain interactions and changes in energy describe the result of those interactions. However, there is only type of energy associated with motion. Let’s see what energies are associated with motion and with interactions.

THE ENERGY OF MOVEMENT

A car traveling at 60 mph has more energy of movement than a car sitting on a street. The faster any object is, the more **kinetic energy** it has. “Kinetic” means motion (both it and “cinema”—the movies—come from the same Greek word for motion). Kinetic energy also depends on how much mass the object has. More massive objects at the same velocity as lighter objects will have more kinetic energy, as you can see in Figure 29.

Although kinetic energy depends on the motion of an object, it does not depend on the direction of motion. That's why the amount of energy is represented as a bar, rather than an arrow.

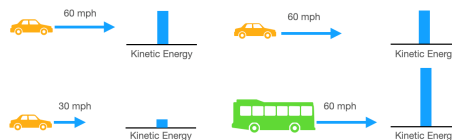


Figure 29 The amount of kinetic energy is represented by a blue bar. On the left, a car that's moving at 60 mph has more kinetic energy than the same car at 30 mph. On the right, a bus and a car that are both moving at 60 mph also have different kinetic energies; the heavier bus has more.

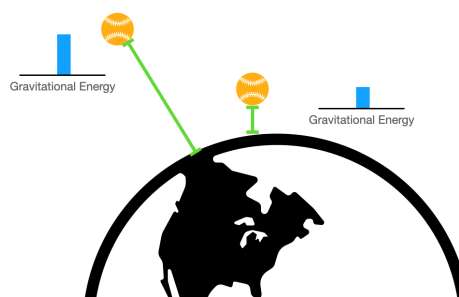
THE ENERGY OF INTERACTIONS

While all interactions are associated with a type of energy, some of those interactions will allow us to change the form of that energy to another type, and then, importantly, get that energy back in the original form. For other interactions, once that energy has changed form, it can't be recovered. We'll look here at two examples of the first kind: gravitational energy and spring interaction energy.

GRAVITATIONAL ENERGY

When we're close to the surface of the planet Earth, the gravitational energy depends on three factors: the mass of the planet (indirectly), the mass of the object, and distance between the two. A baseball and the Earth will have smaller energy due to their interaction if the ball is farther from the Earth, as shown in Figure 30.

The gravitational interaction also depended on the mass of the object, and that's true also for the gravitational energy. More mass (for either object in the interaction) results



in more gravitational energy. Figure 31 compares the gravitational energy of the bowling ball and the baseball.

SPRING INTERACTION ENERGY

The spring interaction depends on both the stiffness of the spring and the distance the spring is stretched or compressed by the attached object, and the spring interaction energy will depend on these same two factors. It does not matter which way the spring is moved—if it's stretched or compressed by the same distance, the spring and object will have the same amount of energy. Figure 32 demonstrates this with the bowling ball attached to the spring.

But, stretching or compressing by a farther amount will increase the amount of spring interaction energy, as shown in Figure 33.

Stretching or compressing a stiffer spring will also create a larger spring interaction energy, while stretching or compressing a loose spring will create a smaller spring interaction energy. Compressing a car's suspension coil

Figure 30 The gravitational energy is represented by a blue bar. On the left, the ball that's farther away has larger gravitational energy with the Earth. On the right, the ball that's closer has smaller gravitational energy with the Earth.

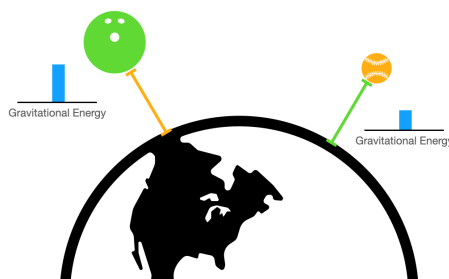


Figure 31 The bowling ball and baseball are the same distance from the planet, but the bowling ball has more mass, so it has more gravitational energy with the planet.

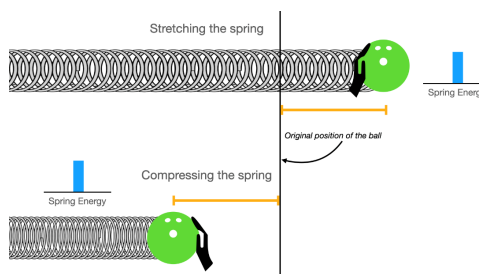


Figure 32 The spring interaction energy is represented by a blue bar. The stretched spring and compressed spring are the same distance from their original position, so they have the same spring interaction energy.

by a centimeter will produce a much larger energy than stretching a slinky by the same centimeter.

Interestingly, however, something that *doesn't* matter is the mass of the object attached to the spring. A baseball and a bowling ball, attached to the same spring, stretching it by the same amount, will produce the same spring interaction energy!

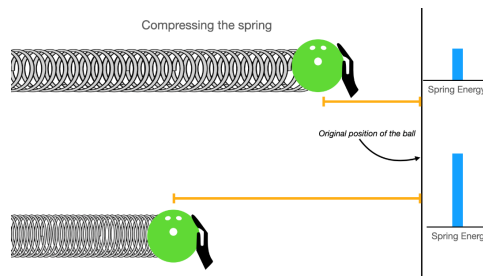


Figure 33 The bowling ball on the top compresses the spring a smaller distance, so it has a smaller spring energy. The bowling ball on the bottom compresses the spring a larger distance, so it has a larger spring energy.

USING ENERGY

Energy can transform from one type to another, resulting in changes to the objects' motion and/or positions. Imagine you're holding a ball up above the ground. It has mass and is near the planet Earth, so it has a gravitational interaction with the Earth and gravitational energy with the planet. If you let go, the ball falls toward the ground. It loses height, and hence its gravitational energy is getting smaller. It's also picking up speed, so its kinetic energy is getting larger. The gravitational energy is being converted into kinetic energy as the motion of the ball changes. When the ball hits the ground, it has a normal interaction with the surface of the ground that changes its direction so it then bounces back up into the air. After the bounce, the ball is moving fast and has a large kinetic energy. As it travels back upward, it's gaining gravitational energy, but losing kinetic energy as the energy changes form again. If it had a very elastic bounce off of the ground, all of the energy that was converted into kinetic during the fall and rise of the ball is converted back into gravitational energy, and the ball can reach the same height that it was dropped from.

Now, the normal interaction is *not* one that has recoverable energy, so some of the energy is usually transferred to the ground during the impact with the ground. If you drop a ball, it usually bounces back up to a lower height than it started from. We'll discuss these kinds of energy transfers later in the book.

How will we use energy to help us predict and analyze motion? Consider the ball that has bounced up from the ground—if we know how much gravitational energy it started with due to its original height above the ground, and we know how much energy it loses during its impact with the ground, we could determine how much gravitational energy it will have at the top of the bounce, and therefore, how high it ends up. We could also determine how much kinetic energy it has as it bounces off the ground, and so we could determine how fast it's moving at that moment. Energy is a quantity that we can track for the interacting objects, and accounting for how much is what type of energy let us analyze and predict the objects' motions and positions.

And that means we're now ready to use our investigative process to analyze real world, complicated situations!

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