Force

If I asked you to define the word force, what would you say? You probably have a feeling for what force means, but you may have trouble putting it into words. It's kind of like asking someone to define the word "and" or "the". Well, this lesson is all about giving you a better feeling for what the word force means. We'll be talking a lot about forces in many lessons to come. So, pay attention! The simplest way to define force is to say that it means a push or a pull like pulling a wagon or pushing a car. That's a correct definition, but there's a lot more to what a force is than just that. Let's take a look.

The Foursome of Forces

There are four types of forces. They are, in order of strength, strong nuclear force, electromagnetism, weak nuclear force, and gravity. That's it. Those are all the forces that do all the pushing and pulling in the entire universe. The strong and weak nuclear forces are responsible for holding atoms together. They are quite important, but unless you're dealing with physics at a quantum (atomic) level they are not something you need to know too much about. So we won't spend any time on them here.

As you look at the list of the fearsome foursome of forces, you may notice a couple of strange things. The first thing you may have asked yourself is, "Gravity is the weakest force!!??" Believe it or not, of all the forces, gravity is the weakling. It is actually much weaker than the other three. In fact, the other three have a tendency to pick on gravity, which isn't very nice.

Some other questions you might be thinking are "Where is friction in the list?" and "What about pulling a wagon, what kind of force is that?" Excellent questions my perceptive pupil! Here comes a bit of a shocker. Friction, which is what allows you to pull a wagon, push a car, and sit in your chair without sliding off, is actually an electromagnetic force. You can sit in your chair because there are electromagnetic interactions between the atoms in your, uh...rear section, and the atoms in the chair. In fact, you aren't touching that chair. Or I should say, your matter is not touching the matter of the chair. The electromagnetic fields around your atoms and the chair's atoms are touching but particles of matter are not. This fact comes in very handy when you're in the back of the car with your brother or sister and they yell, "Will you STOP touching me!" Now you can say with great smugness, "I'm not touching you, only my electromagnetic forces are!" Isn't physics fun?

As for pulling a wagon, you can think of yourself as a living, breathing electromagnetic force maker. When you pull a wagon, you are using electromagnetic force to work your muscles and do what needs to be done to get that wagon going.

Force Fields

You may wonder what force fields have to do with a serious examination of physics like the one in this lesson. You probably consider force fields to be something you might hear about in a science fiction scene such as ...

MEANWHILE, IN SECTION 27B OF THE HORSE CRAB GALAXY, FIRST MATE FRED FRETS, "CAPTAIN CLYDE! THE FORCE FIELD IS TOO STRONG. OUR SHIP WILL NEVER MAKE IT THROUGH." "NEVER WORRY FIRST MATE FRED!" EXCLAIMS CAPTAIN CLYDE CALMLY. "I'VE INCREASED POWER TO THE NEUTRON-FRAPTERS SO WE WILL BE JUST FINE." "CAPTAIN CLYDE, THAT'S GENIUS. YOU'RE MY HERO!" FIRST MATE FRED FAWNS.

Truthfully, however, force fields aren't just something for science fiction writers. They are actually a very real and very mysterious part of the world in which you live. So, what is a force field? Well, I can't tell you. To be honest, nobody can. There's quite a bit that is still unknown about how they work. A force field is a strange area that surrounds an object. That field can push or pull other objects that wander into its area. Force fields can be extremely tiny or larger than our solar system. A way to picture a force field is to imagine an invisible bubble that surrounds a gizmo. If some other object enters that bubble, that object will be pushed or pulled by an invisible force that is caused by the gizmo. That's pretty bizarre to think about isn't it? However, it happens all the time. As you sit there right now, you are engulfed in at least two huge force fields, the Earth's magnetic field and the Earth's gravitational field.

Let's Find Out 1

Get Down and Stay Down

You need:

You

Earth (or any planet that's convenient)

ball

1. **Jump!**
2. **Carefully observe whether or not you come back down.**
3. **Take the ball and throw it up.**
4. **Again, watch carefully. Does it come down?**

Ok, sort of a silly experiment I admit. What I wanted you to see, with maybe a slightly new perspective, is that there is an invisible force acting on you and the ball. As you will see in later lessons, things don't change the way they are moving unless a force acts on them. When you jumped, the force that we call gravity pulled you back to Earth. When you threw the ball, something invisible acted on the ball forcing it to slow down, turn around, and come back down. Without that force field, you and your ball would be heading out to space right now!

Let's Find Out 2

Push the Needle

You need:

A compass

Earth

1. Look at the compass
2. Walk anywhere and keep your eye on the compass.
3. Turn around in circles and keep your eye on the compass (don't get too dizzy).

Again a very simple little activity, but I hope you can see the point. No matter where you went or what you did, that needle always pointed the same direction! The Earth's magnetic force field, another strange and mysterious force, always pushes that needle in the same direction. It's invisible and you can't feel it...but the needle can! (Feel free to hum spooky space music here.)

Play the Fields

Remember, there are four different kinds of forces: strong nuclear force, electromagnetism, weak nuclear force, and gravity. There are also four basic force fields that you come into contact with all the time. They are the gravitational field, the electric field, the magnetic field, and the electromagnetic field. Notice that those four force fields really only use two of the four different kinds of force: electromagnetism and gravity. Let's take a quick look at what causes these four fields and what kind of objects they can affect.

Gravitational Field

Gravity is probably the force field you are most familiar with. If you've ever dropped something on your foot you are painfully aware of this field! Even though we have known about this field for a looooong time, it still remains the most mysterious field of the four. What we do know is that all bodies, from small atoms and molecules to gigantic stars, have a gravitational field. The more massive the body, the larger its gravitational field. As we said earlier, gravity is a very weak force, so a body really has to be quite massive (like moon or planet size) before it has much of a gravitational field. We also know that gravity fields are not choosy. They will attract anything to them. All types of bodies, from poodles to Pluto, will will attract and be attracted to any other type of body. One of the strangest things about gravity is that it is only an attractive force. Gravity, as far as we can tell, only pulls things towards it. It does not push things away. All the other forces are both attractive (pull things towards them) and repulsive (push things away). Gravity will be covered more deeply in a later lesson.

Electric Field

You are actually fairly familiar with electric fields too, but you may not know it. Have you ever rubbed your feet against the floor and then shocked your brother or sister? Have you ever zipped down a plastic slide and noticed that your hair is sticking straight up when you get to the bottom? Both phenomena are caused by electric fields and they are everywhere!

An electric field exists when at least one body is electrically charged. Atoms are filled with positively charged protons and negatively charged electrons. If an object has more electrons than protons, it will be negatively charged and if it has fewer electrons than protons, it will be positively charged. Electric fields, like magnetic fields, can attract and repel. If two bodies have the same kind of charge, that is either both are negative or both are positive, they will push themselves away from each other. If one body has a positive charge and the other has a negative charge, they will attract each other. Charged bodies can also attract bodies that are neither positive nor negative but are just neutral.

Electric fields are extremely common. If you comb your hair with a plastic comb, you cause that comb to have a small electric field. When you take off a fleece jacket or a polyester sweat shirt, you create an electric field that may be thousands of volts! Don't worry, you can't get hurt. There may be lots of voltage but there will be very little amperage. It's the amperage that actually hurts you. Electric fields will be coverd in greater detail in later lessons.

Magnetic Field

You're probably also fairly familiar with magnetic fields. If you've ever stuck an "It's Qool to be Quantum" magnet to a refrigerator, you've taken advantage of magnetic fields. (OK, maybe I'm the only person in the world with a "Qool to be Quantum" magnet, but you get the point.) Sticking a magnet to a refrigerator is one of those every day experiences that should just be absolutely flabbergasting. There you are holding an "I'd Rather be Relative" magnet and it sticks to the fridge! But wait a minute, if you put it on the wall… it falls off! How does it "know" what to stick to? Not only does it stick to the fridge, it also pushes some things away, attracts other things and couldn't care less about still other things. What's that all about?! We rarely think about what magnets do but, wow, the things they do are weird!

Magnetic fields come from objects that have a surplus of electrons all moving in the same direction. This can be an electric wire with current running through it or one of several special types of metals. Iron, nickel and cobalt are the most common metals that can be magnetic. Magnetic fields can only affect objects that can be magnetic themselves. That's why a magnet can attract an iron nail, but it can't attract an aluminum can. The iron nail can be magnetic, but the aluminum cannot. Magnets can also be attractive or repulsive. Two magnets with the same kind of poles facing one another will push themselves apart. Two magnets with opposite poles facing one another will pull themselves together. Later lessons will take a closer look at magnets.

Electromagnetic Field

The electromagnetic field is a bit strange. It is caused by either a magnetic field or an electric field moving. If a magnetic field moves, it creates an electric field. If an electric field moves, it creates a magnetic field. Now check this out. A moving electric field creates a moving magnetic field, which creates a moving electric field, which creates a moving magnetic field and on and on. Pretty strange huh? So an electromagnetic field is both an electric field and a magnetic field all rolled into one.

Light, radio waves, and microwaves are examples of electromagnetic waves created by moving self-creating electronic and magnetic fields. There's a great story here. Until 1820 magnetic fields and electric fields were thought of as two completely separate things. A fellow by the name of Hans Christian Ørsted was preparing for a lecture when he noticed that a compass needle jumped when he flipped a switch that caused electricity to flow through some wires. This chance observation caused him to investigate further and discover that electric fields create magnetic fields and vice-versa. Thus, through a completely random observation, electromagnetism was discovered. Without that discovery we wouldn't have electric engines, radios, cell phones, television or Filbert the Flounder electric toothbrushes! Hooray for Ørsted!

A Summary of Force Fields and Objects

Type of Force Field	Object that Creates Force Field	Objects that are Affected by Force Field	Force Field Can Attract and Repel
Gravitational	Any object	Any object	Only attract
Magnetic	Moving electrons	A metal that can be magnetic	Attract and repel
Electric	An electrically charged body	Any body	Attract and repel
Electromagnetic	A moving magnetic field or a moving electric field	A magnetic or electric field	Attract and repel

The Farther the Weaker, The Closer the Stronger

Have you ever been close to something that smells bad? Have you noticed that the farther you get from that something, the less it smells, and the closer you get, the more it smells? Well forces sort of work in the same way. Forces behave according to a fancy law called the inverse-square law. To be technical, an inverse-square law is any physical law stating that some physical quantity or strength is inversely proportional to the square of the distance from the source of that physical quantity. The inverse-square law applies to quite a few phenomena in physics. When it comes to forces, it basically means that the closer an object comes to the source of a force, the stronger that force will be on that object. The farther that same object gets from the force's source, the weaker the effect of the force. Mathematically we can say that doubling the distance between the object and the source of the force makes the force 1/4th as strong. Tripling the distance makes the force 1/9th as strong. Let's play with this idea a bit.

Let's Find Out #3

Feel the Force Luke

(I had to put at least one reference in here somewhere.)

You need:

A magnet (the stronger the better)

Paper clip

String

Tape

Spring Scale (optional)

Ruler (optional)

1. Tie about 4 inches of string to a paper clip.
2. Tape the magnet to the table.
3. Hold the end of the string that is not tied to the paper clip and let the paper clip dangle.
4. Slowly bring the paper clip closer and closer to the magnet.
5. Notice that the closer you get to the magnet, the stronger the force of the magnetic field is on the paper clip.

If you have a spring scale;

6. Attach the paper clip to the spring scale.
7. Move the paper clip closer to the magnet until the magnetic field affects the paper clip.
8. Measure how far the paper clip is from the magnet with a ruler.

9. Measure how much pull there is on the paper clip. Use newtons if your spring scale shows that measurement, but grams are OK if it doesn't.

10. Bring the paper clip a half inch closer and measure the force of the pull again either in grams or Newtons.

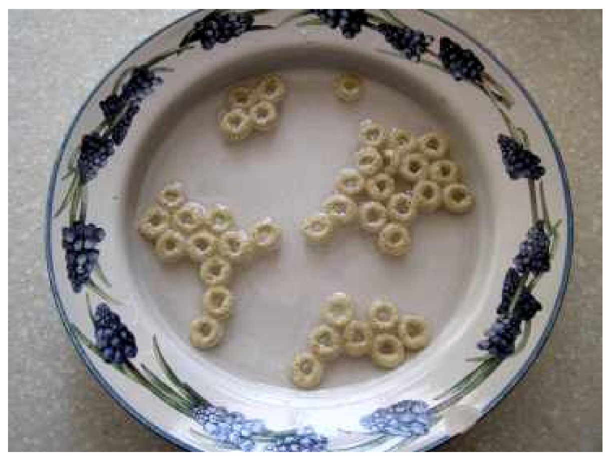
11. Continue to get closer to the magnet half an inch at a time, measuring the force until you can't get any closer.

What you may have noticed here was that the closer you got the paper clip to the magnet (the object causing the force field) the stronger the force was on the paper clip. You have just seen the inverse-square law in action!

Here's another rather wacky way to play with the idea of the inverse square law.

Let's Find Out #4

The Cereal Galaxy



You need:

Some sort of "O" shaped cereal

Water or milk

Bowl

Spoon

1. Fill the bowl with water or milk

2. Put about 20 pieces of cereal into the bowl.

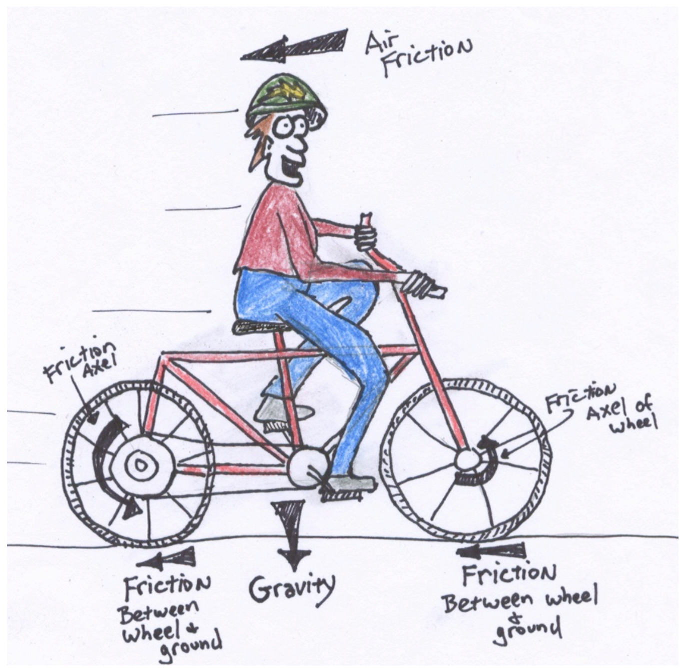
3. Stir up the bowl a little and watch what happens.

4. Feel free to eat the cereal. (This is especially fun if you imagine that you're Gorgonaticula the Planet Consuming Energy Being from the 23rd Dimension!)

If you watched carefully, you saw that as the cereal "O's" got close to one another, they attracted each other. The closer they got, the stronger was their attraction to each other and the faster they moved towards each other. If you wait and watch long enough, you get a nice tight batch of cereal all clustered together in one or two big blobs. This activity is a great illustration of what is meant by the inverse square law because the attraction between "O's" was stronger the closer they got to each other. I discovered this activity one morning as I was eating cereal. The same thing happens with bubbles when you're doing the dishes. Science is everywhere! (Yes, I do spend a lot of time staring into bowls.)

Net Force

It is very rare, especially on Earth, to have an object that is experiencing force from only one direction. A bicycle rider has the force of air friction pushing against him. He has to fight against the friction between the gears and the wheels. He has gravity pulling down on him. His muscles are pushing and pulling inside him and so on and so on. Even as you sit there, you have at least two forces pushing and pulling on you. The force of gravity is pulling you to the center of the Earth. The chair is pushing up on you so you don't go to the center of the Earth. So with all these forces pushing and pulling, how do you keep track of them all? That's where net force comes in. The net force is when you add up all of the forces on something and see what direction the overall force pushes in. The word "net", in this case, is like net worth or net income. It's a mathematical concept of what is left after everything that applies is added and subtracted. The next activity will make this clearer.



Let's Find Out #5

Take It To The Net Force

You need:

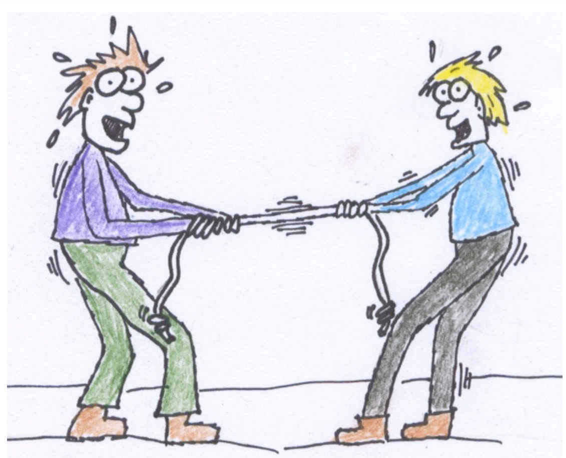
A rope (at least 3 feet long is good)

A friend

A sense of caution

Be careful with this. Don't pull too hard and please don't let go of the rope. This is fun but you can get hurt if you get silly.

1. You and your friend each grab an opposite end of the rope.
2. Both of you pull just a bit on the rope.
3. Have your friend pull a bit harder than you. Notice the direction that you both move.
4. Now you pull harder than your friend. Now which way do you go?
5. Lastly, both of you pull with the same strength on the rope. Even though you are both pulling, neither one of you should move.



In this experiment, there were always at least three forces pulling on the rope. Can you think of the three? They are you, your friend and gravity. You were pulling in one direction. Your friend was pulling in another direction and gravity was pulling down. When one of you pulled harder (put more force on the rope) than the other person, there was a net force in the direction of the stronger pull. The rope and you guys went in that direction. When both of you were pulling the same amount, there was an equal force pulling the rope one way and another equal force pulling the rope the other way. Since there were two equal forces acting in two opposite directions, the net force equaled zero, so there was no movement in either direction. No net force in this case means no movement. As you'll see when you learn about Newton's second law, no net force means no acceleration.

Let's take another look at the bicycle rider we talked about earlier. To make things easier, we'll call him Billy. For Billy to speed up, he needs to win the tug of war between all of the forces involved in riding a bicycle. In other words, his muscles need to put more force on the forward motion of the bike than all of the forces of friction that are pushing against him. If he wants to slow down, he needs to allow the forces of friction to win the tug of war so that they will cancel out his forward motion and slow down the bike. If he wants to ride at a steady speed, he wants the tug of war to be tied. His muscles need to exert the same amount of force pushing forward as the friction forces pulling in other directions.

Forcing the Issue

Hopefully this lesson forced you to have a good feeling for the different forces and force fields. You did a lot of work here. Take a little break, go outside and force a ball around the yard or force a bicycle around the block. I'm going to go force a hamburger into my mouth!

In a Nutshell

-A force is a push or a pull.

-There are four fundamental forces. In order of strength they are strong nuclear force, weak nuclear force, electromagnetism and gravity.

-A force field is an invisible area around an object within which that object can cause other objects to move.

-A force field can be attractive (pull an object towards it) or repulsive (push an object away).

- The closer something gets to the object causing the force, the stronger the force gets on that object. This is the inverse-square law.

- The four basic force fields are gravity, magnetic, electric, and electromagnetic.

- An object will be pushed or pulled in the direction in which the overall net force is acting on it.

-The net force is the sum of all the forces on an object.

Did You Get It

1. Name at least one force that is acting on you right now.

2. Name at least two invisible force fields that are surrounding you right now.

3. What kind of an object can be affected by a gravitational force field?

4. What kind of an object can be affected by an electrical force field?

5. What kind of an object can be affected by a magnetic force field?

6. What happens to the force on an object as it gets closer and closer to a magnet?

7. How does the force of the Sun's gravitational pull on Neptune (the farthest planet from the Sun if you don't count Pluto) compare to the force of the Sun's gravitational pull on Mercury (the closest planet to the Sun).

Answers

1. Gravity is pulling on you. If you're sitting your chair is pushing up on you as well.

2. Gravity and magnetic fields. To be honest, you are probably also sitting in an electromagnetic field as well. Can you get a radio or a cell phone to work where you are? If so, you're in an electromagnetic field.

3. Any object can be pulled by a gravitational force field.

4. Any object. An electrically charged object or a neutral object can be pushed or pulled by an electric field.

5. Another magnet or something with a metal in it that can be magnetic.

6. The force the magnet exerts on the object becomes greater and greater as the object gets closer. The inverse-square rule is a way of describing how force increases as objects get closer together.

7. Since Neptune is farther away, the inverse-square rule says that the Sun's gravitation pull on it is much less than the Sun's pull on Mercury.