Reflect

Gravitational Fields and Forces

Do you see the girl in the picture below sitting in a chair? What keeps her there? Why doesn't she float away into space?

The answer is the force of gravity, which exerts a *gravitational field* and acts at a distance like magnetic or electric fields. Gravity is a force that pulls every object toward every other object. That means we all have our own gravity! However, the force of attraction is very weak unless one of the objects is very large. Because Earth is very large, you can feel it pulling on you. This pull is called your *weight*. You can't feel the pull between yourself and smaller things, such as other people, because the force is too weak. Gravity is always a pull, never a push.

Why don't people float away into space? The force of gravity pulls us all down toward Earth's center. The kids in Australia are standing with their feet toward your feet!

Instead of saying Earth is large, we should say it has a lot of mass. *Mass* is what makes up all things in the universe. The more mass an object has, the harder it is to move. Gravity is the attraction between any two masses. The force of gravity is stronger when the masses are greater or the objects are closer. If you move farther away or decrease the mass, the force gets weaker.

Scientists understand enough about gravity to predict how it will affect different objects. There are even ways to calculate the force of gravity between two objects. Scientists can use these formulas to calculate the mass of newly discovered planets, determine how much fuel a rocket needs to lift off from Earth, or calculate how fast a rover will be going when it lands on Mars. All of these things depend on the force of gravity.

Look Out!

Many people speak of weight and mass as if they are the same thing, but they are not. Mass is the amount of matter something has. Weight measures the gravitational pull on an object's mass.

What if you were standing on a planet that had more mass than Earth? Would you have the same mass? Would you have the same weight? You would have the same mass, because you would be made of the same amount of stuff. You would weigh more, because the larger planet would have a larger gravitational pull. For example, if matter weighs 100 pounds on Earth, the same piece of matter would weigh 236 pounds on Jupiter. When astronauts go to the Moon, their mass doesn't change. However, they weigh much less. Your weight on the Moon is one-sixth of your weight on Earth. Think about when astronauts are on the Moon—they can jump extremely high! On the Moon, you could easily carry a backpack that weighs five times your weight!

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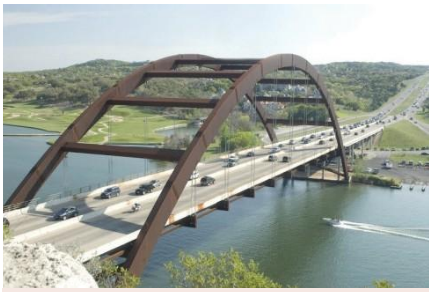
Reflect

Career Corner: Designing Bridges
Picture a long bridge with many cars on it. Imagine how much the cars and the bridge must weigh. We know that weight is the force of gravity pulling on mass. The cars and the bridge have a lot of mass. How do we know the bridge is strong enough to support all that weight?



Gravity pulls down hard on this bridge.

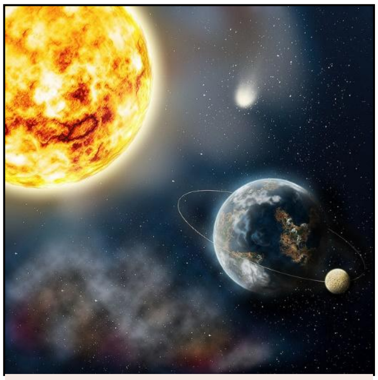
That is the job of an engineer. There are many kinds of engineers. Some design and build bridges. They must identify all the forces acting on a bridge. They need to choose materials strong enough to resist those forces. They must put together the materials in the best way; otherwise, the bridge may collapse.

What Do You Think?

If you live by the ocean, you know its level rises and falls every day. The ocean goes up and down because the ocean waters are always being tugged by the gravity of the Moon and the Sun. The Moon is much closer, so its gravity affects the oceans much more than the Sun's gravity does. There are two high tides at each shoreline on Earth every day, but the Moon only orbits Earth once a month. Why are there high tides every day? Could it have anything to do with the motion of Earth?

Low tide left some boats on land.

Look Out!



The strength of an object's gravitational field is determined by its mass.

Gravitational force is an attractive force; it always pulls and never pushes. Gravitational fields are produced by all objects that have mass. Gravitational force is very hard to measure in objects that are small, but it is still present. Gravitational fields are usually studied on a larger scale, such as with planets and stars. Gravitational field models are used to explain the influence of a massive body on its surrounding objects.

When we study other planets in the solar system, we can see the gravitational field effects of the Sun on each planet. Planets orbit stars because stars are much more massive than planets. However, even though the gravity of the star is much stronger than the gravity of a planet, larger planets can still cause a measurable wobble in the star as a planet's gravity pulls back on the star throughout its orbit. The larger the mass of the planet is, the larger the wobble of the star is.

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Gravitational Forces

Scientists in the Spotlight: Sir Isaac Newton
In the mid-1600s, a young scholar named Isaac Newton developed some fundamental ideas in the history of science. According to legend, Newton had one of his most important ideas after watching an apple fall from a tree to the ground. This experience caused Newton to think about the different forces in the universe. Perhaps a certain force pulls objects toward Earth?

By Newton's time, scientists had begun to accept that the Sun is the center of the solar system. However, they still didn't know what force held the planets in orbit around the Sun. Newton's answer was gravity. Newton's concept of gravity has been crucial to our understanding of the universe.

In 1687, Sir Isaac Newton explained his concept of gravity in an important book, *The Mathematical Principles of Natural Philosophy.*

Try Now

We know that your mass, or the amount of matter in your body, does not change if you travel to other planets. Your weight, however, is affected by the pull of gravity. Calculate the weight of a 35 kg dog traveling the solar system. This is just another way we can use Newton's second law: force = mass x acceleration. The force of gravity (i.e., weight) equals the mass of the object times the acceleration due to gravity on that planet.

Planet	Mass (kg) ×	Gravity (acceleration due to gravity) =	Weight (N)	Weight (lb) 4.45 N = 1 lb
Mercury	35	3.6	126	28
Venus	35	8.9		
Earth	35	9.8		
Mars	35	3.8		
Jupiter	35	26		
Saturn	35	11		
Uranus	35	10.7		
Neptune	35	14.1		

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