Forces and Gravity

[MUSIC PLAYING] Our world is full of forces that push and pull on everything in it, including us. They start and stop objects from moving and cause them to change direction. They hold things together and make them break apart. Simply put, if it weren't for forces, nothing on Earth or in the universe would happen.

We're all familiar with gravity, the natural attraction that exists between any two objects. While we take it for granted, on Earth we experience it all the time. Gravity keeps our feet on the ground and causes things to fall by pulling them down. Its pull also gives everything weight.

The story goes that British scientist Sir Isaac Newton watched an apple fall from a tree and came up with the idea of gravity. He wondered why stars didn't come crashing to Earth and concluded that gravity must also exist in space. Eventually, he used his idea to show that it holds the moon and the planets in their orbits. Newton also came up with three laws of motion to explain why things move as they do.

His first law says that an object at rest remains at rest. And an object in motion stays in motion unless acted upon by an outside force. This is called inertia. This hockey puck doesn't move until the stick hits it. And it would slide continuously in a straight line if nothing stopped its progress.

When something affects the motion of an object, that's Newton's second law at work. It says that when a force acts on an object, the object will start to move, slow down, or change direction. This picture provides the force to put the baseball in motion, and the catcher exerts a force to stop it.

A rocket blasting off is a good example of Newton's third law of motion at work. And you don't have to be a rocket scientist to get it. It says that for every action, there is an equal and opposite reaction. In this case, rocket fuel pushes down and propels the rocket skyward.

Sometimes nothing seems to happen when a force acts on an object. This is because one force is balanced by another. Look what happens when you stand still. You're pushing on the ground. But at the same time, the ground is pushing up beneath your feet. These balanced forces are responsible for keeping structures like buildings and bridges from collapsing.

On an arch bridge, for instance, the weight of a car pushing down is transferred to each end. The ends hold the arch together and provide force to support the car. Whether or not the effects are obvious forces are at work on us and on every object everywhere we turn.

Friction is a force to be reckoned with, on the road, in the air, and on water. Vehicles fight friction to get going. They already face an uphill battle. Objects at rest tend to stay that way. That's inertia. Perhaps we can all relate.

Engines give vehicles the jumpstart they need, but friction fights back. Friction is the force that slows down the movement of one surface over another. The road slows the wheel, the water slows the boat, the track slows the train, and air slows them all. Even inside the engine, friction makes it tough.

Forces and Gravity

A car uses about 20% of its engine power just to overcome friction in the moving parts. The hovercraft makes short work of friction on land and water. While a back-engine thrusts this hovercraft forward, a front-engine pushes a cushion of air down into the rubber skirt it rides on, less resistance or friction than from the bottom of a boat. The hovercraft can even conquer snow and ice at speeds up to 70 miles per hour.

Air might offer less friction than land or water, but it can be a real drag if you're a race car driver. Drag happens when air slows the motion of an object. A car with too much drag uses too much fuel and works too hard to accelerate. Drag race cars slice through the air to get going fast.

On the other hand, air's friction is harnessed to keep cars on the ground. Tasmin race car designers use something called downforce to stabilize them. Like airplanes, these Tasmin cars have wings, but they're positioned in front and at the back. This keeps light aerodynamic race cars in contact with the track at high speeds, even upside down.

Air can create disastrous amounts of friction for vehicles at high speeds. When the space shuttle re-enters Earth's atmosphere, friction between air and the hurtling spacecraft would cause it to burn up if it wasn't protected. The space shuttle's specially made aluminum tiles protect it from temperatures as high as 2,500 degrees Fahrenheit.

In the future, new forms of transportation will still have friction to contend with. But as engineers find new ways to define it, it becomes easier for vehicles to slice through the air, walk on water, and defy land, even carry us beyond our atmosphere.

No matter where we go, we can't escape gravity's pull. While it holds us to the ground, it's also one of the most fundamental forces in space. Gravity exists between all particles in the universe. It keeps the planets in motion around the sun and holds every star in its galaxy.

The moon has gravity, for instance, but the results are different than on Earth. These astronauts weigh 1/6 of what they do back home and appear lighter as they move around.

Since the moon has less mass than the Earth, its gravity is not as strong. Even astronauts floating in space are influenced by gravity. They look weightless, but they're still being pulled by the Earth. Along with the spacecraft their free-falling around the planet.

Scientists learn to send things into space and take advantage of the force of gravity. The most obvious examples are satellites. A satellite is any object that orbits around a larger object, thanks to gravity. The Earth is considered a satellite of the sun, and the moon is a satellite of the Earth. Although the gravitational pull of larger objects is stronger, each object has a gravitational effect on the other.

We put a bunch of our own satellites up there-- 100's in fact. And they dramatically changed the way we live. Today we use them for banking, and weather reports, television programs, and phone messages. They also give us valuable information about the universe and our own planet that we couldn't get from the ground.

The key to all of this is getting a satellite up there and keeping it in orbit. This is where speed and gravity work together. It's a delicate balance. To accomplish this, satellites are launched by powerful rocket boosters at speeds of at least 17,000 miles per hour. If it doesn't travel fast enough, it will fall back to Earth. But if it travels too fast, it will leave the Earth's gravitational pull and wind up elsewhere in space.

Satellites are put into different orbits at different speeds depending on the job they need to do. Some are placed closer to us at only 200 to 300 miles away. These can orbit the entire Earth in just 90 minutes. Others are more than 20,000 miles above us and move at the same speed as the Earth. This keeps them in the same spot over the Earth, which is useful for transmitting communication and weather data.

Once in orbit, satellites keep going until something stops them. Over time they usually lose speed and gradually come in contact with too much of the Earth's atmosphere. When this happens, the force of friction increases, generating heat that eventually causes them to break apart. Sometimes they disintegrate in dramatic style.

We can now send satellites to other planets by launching them beyond the pull of Earth's gravity and positioning them to intercept the pull of another planet. Spacecraft have successfully reached almost every planet that revolves around the sun. As we find new ways to use gravity in space, we're able to learn more about our universe.

For centuries people dreamed of being more like the birds. While we can't sprout wings, our desire to overcome gravity has carried us to new heights, literally. Today it's tough to imagine our world without the ability to fly. When we fly within our atmosphere, we're flying through a fluid, air.

Gravity holds air to the Earth the same way it holds us to the ground. Since we rarely notice it, it's easy to forget that air has weight and substance. It exerts pressure on everything in it. Somehow we've got to get through it.

One way that happens is with engines. Piston and jet engines provide the power to overcome inertia. They thrust planes forward and into the sky, carrying us higher and faster all the time.

Airplane designers also took a cue from the birds. They built airplane wings like bird's wings, curved on the top and flat underneath. This shape is called streamlined, meaning air can move smoothly over it. So how does a wing manage to lift us? From his car, airplane designer Burt Rutan shapes his hand like a wing to help explain.

This is something that every child has done who has at least thought about lift. When I thrust my hand out the window and turn my hand down like this and deflected some air, it forced my hand up.

Forces and Gravity

Here's how it works. Like a wing, air flows faster over the top of your hand than it does under the bottom. And where the air flows faster, you find less pressure. On a wing, the faster moving air exerts less pressure on top of it.

That means there's slower air and more pressure underneath. That extra pressure pushes the wing up and gives us lift. The faster the air moves around it, the greater the lift. That's why planes travel so fast during takeoff.

Airplane designers are always looking for new ways and new materials to make planes lighter. Less mass means less lift is needed to get the plane off the ground. As planes become more efficient and more powerful, it becomes easier to forget about gravity, but it's still there. We're just finding better ways to work with it.

Hop on a roller coaster, and forces are with you. Thank goodness for seat belts that keep you in the car. Because of inertia, your body tries to keep you moving in a straight line as you travel through loops and corkscrews at high speeds.

As these kids move through a loop their food and drinks continue to head straight up, but the car and the curved track force their bodies in another direction. Forces go to work on other rides too. Like a ball whirled around on a string, your body whirling in a circle seems to push outward. This is centripetal force, and it's easy to see in this old rotor rider.

When you move in a circle or through a curve, centripetal force is also at work. It pushes you inward and helps you continually change direction as you turn. Then there's always gravity to contend with, known as, g-forces, increasing and decreasing them provides the real thrill of rides. Just ask coaster designer John Roberts.

The g-forces you suffer on a ride like this go up to about 4g positive.

[YELLING]

And about 1/2 a g negative.

[YELLING]

That's the equivalent of four times your body weight, added on the way up, or half of it subtracted on your wild ride down.

So at about 6g, then most people's noses will begin to bleed.

[SCREAMING]

Which is why you experience only 3.5g positive when you're flying around at 85 miles per hour on The Big One, a terrifying roller coaster in Blackpool England.

Forces and Gravity

[SCREAMING]

As you spin and move your way through an amusement park, you're probably not thinking about physics, but these thrilling rides provide great examples of forces at work.

[MUSIC PLAYING]