

# What keeps us stuck to the Earth?

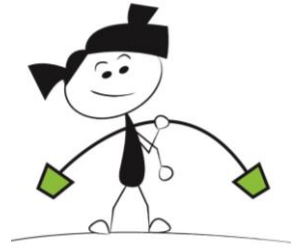
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Scientific models explain our observations.

What makes a rod bend?

Why does an apple fall?

Why do objects have weight?



The common answer to these questions is **GRAVITY**—a mysterious force that pulls things towards the ground. In this **force model** objects fall because there is one force acting on them (gravity) and objects have weight because there are two forces acting on them (gravity and normal).

How confident are you with this explanation? Do you question any part of your model?

*“That one body may act upon another, at a distance through vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man who has in philosophical matters a competent faculty of thinking, can ever fall into it.”*  
- Isaac Newton

Newton revolutionized the world when he showed that the laws of motion that worked here on the Earth described the motion of the Moon and planets correctly. He could not explain how gravity actually worked but he could predict the orbits of the planets and that was a tremendous feat. However, it was a temporary success because as observations improved it became clear that his law did not correctly predict the orbits... something was **WRONG!!**

Let's go back to the original questions. Is there another way that we can explain 'weight', 'bending' and 'freefall'?

The alternative answer to these questions is **ACCELERATION**—easy if we imagine being in a rocket ship deep in space, not so easy for behaviour on Earth. In this **acceleration model**, there is **NO** force of gravity acting on them. Objects fall because the ground rushes up and hits them. Objects have weight because the ground is pushing up as it accelerates—there is **NO FORCE** of gravity!!

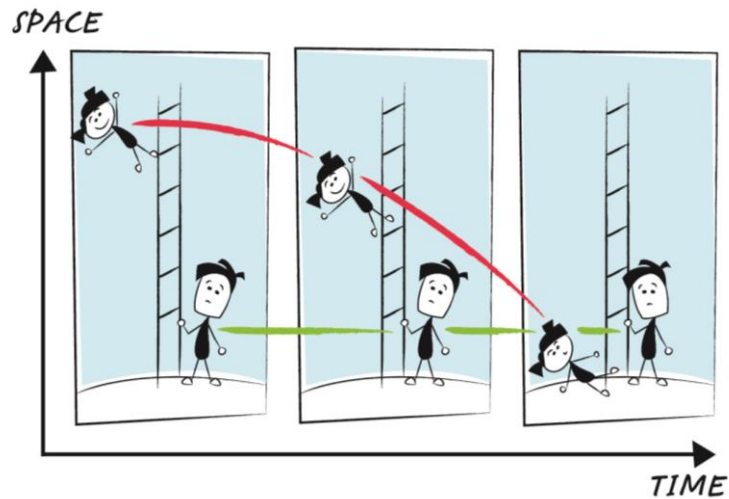
How does this model sit with you? What problem do you have with it?

*“I was sitting in a chair at the patent office in Bern, when all of a sudden a thought occurred to me: If a person falls freely, he will not feel his own weight. I was startled. This simple thought made a deep impression on me. It impelled me toward a theory of gravitation”.*

- Albert Einstein (happiest thought)

How can the surface of the Earth be accelerating up without moving up?

Let's look at a simple scenario: Alice falling off a ladder while Bob stands at the bottom.



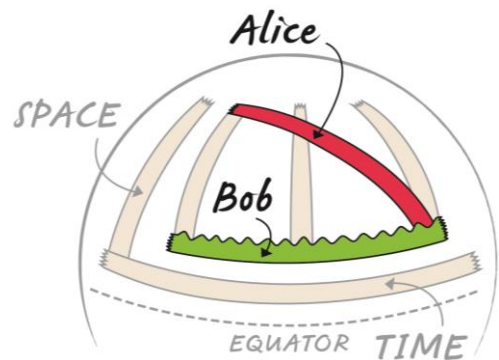
If we sketch the path of Alice as she falls we see that she traces out a **CURVED** line and Bob traces out a **STRAIGHT** line. This makes sense to us because we believe in the force of gravity so Alice should be accelerating and Bob should be not moving.

Using masking tape on a flat surface we see that a curved line is crinkled and a straight line lies flat so we will use that as our definition for accelerating and not accelerating.

According to Einstein, there is **NO FORCE** of gravity! Alice should trace out a straight line while Bob should trace out a curved line because *he* is the one who is accelerating. We need a way for Alice to trace out a **STRAIGHT** line as she falls from the top of the ladder to the bottom and for Bob to trace out a **CURVED** line as he stands at the bottom of the ladder.

The solution: Draw the picture on a curved surface!

The tape that represents Alice will now lie flat (ie. it is **STRAIGHT**) and the tape that represents Bob will be crinkled (ie. it is **CURVED**). We have succeeded in showing how Alice can fall without accelerating and Bob can accelerate without moving! All we need to do is change the **GEOMETRY** of spacetime—gravity is not a force it is the warping of spacetime!



Look at the top of the ladders on your beachball. What happens if Alice stays on the ladder?

She will trace out a shorter path through time than Bob—relativity predicts that gravity will distort time!! This prediction is worked out every day in the GPS system.

The atomic clocks on GPS satellites run 45 microseconds fast every day because spacetime is curved differently at an altitude of 20 000 km.