<u>Recognizing Forces Transcript</u>

[MUSIC PLAYING]

Jessie, what are you doing?

I'm Investigating the normal force.

The what?

The force the ground applies to hold you up.

Wait, the ground applies a force.

Absolutely, it does. What would happen if the ground just suddenly disappeared?

I guess I would fall.

Exactly. I was wondering if the normal force is always the same, and is it the same for everybody?

So you jumped on my back to see if the normal force changed?

Exactly, I did. I just realized, we could use a bathroom scale to investigate the normal force more. Before we go too far, let's step back and talk about forces a little bit more.

Oh. Hey, folks. My name is Aaron Osowiecki.

I'm Jesse Southwick.

And we're both teachers in Boston Latin School and authors of Energizing Physics, an introductory physics course for high school students. And we're filming this BLOSSOMS lessons here at MIT. So think for a moment, as you sit in your chair, what forces that are acting on you?

OK, let's talk about those forces. Being near the Earth, there must be a force of gravity pulling you down towards the center of the Earth. To keep you from falling, there must be an upward force from the ground to hold you up.

Now let's quantify those forces. Consider Jack, whose mass is 50 kilograms. At sea level, the strength of Earth's gravitational field is 9.8 newtons per kilogram, which means the Earth pulls down with 9.8 newtons of force on each kilogram of mass.

Take a few minutes and calculate with how many newtons gravity pulls down on Jack.

And then discuss your answer with your teacher and your classmates.

Let's see how you did. You can see that the product of mass times the strength of gravity will give us a force in newton's. Now let's consider the force from the ground, which is often called the normal force, because it's perpendicular to the surface. When standing on the ground, gravity pulls Jack into the ground with a force equal to Jack's weight, i.e. the force of gravity, pressing his feet into the ground with that same force.

Newton's third law of motion states that when two objects interact, they will apply an equal and opposite force to each other. As Jack's feet press into the ground with a force equal to the force of gravity, the ground pushes upward with a force equal to the force of gravity. Hence, when Jack is standing on the ground at rest without any other forces acting on him, the magnitude of the normal force is equal to Jack's weight.

Scientists and engineers often use free body diagrams, sometimes called force diagrams, to model forces. These diagrams do not show the direction of motion, rather they show all the forces acting on an object at a certain instant. Free body diagrams follow these rules.

One, draw a dot to represent the object being investigated. Two, draw an arrow directed away from the center of the dot to represent each of the forces acting on the object. Three, scale the size of the arrows to represent the magnitude of the forces. Four, label the type with the force and the magnitude.

Now take a moment and consider which of these free body diagrams accurately represent the forces acting on Jack as he stands on the ground. Then talk to your teacher in your class.

Hey, welcome back. Let's see how you did. The only diagram that follows all the rules is diagram D. All the arrows come from the center. They are scaled, and they are also labeled with the type of force and the magnitude.

The net force on an object is the sum of all the forces acting on the object. Physicists often handle the vertical y and horizontal x net forces separately by setting up an xy coordinate system as shown in the drawing. In this case, upward forces are positive and downward forces are negative. Let's look at Jack. What is his vertical net force as he stands on the ground, horizontal net force?

With a positive 490 Newton normal force and a negative 490 Newton gravitational force, the vertical net force on Jack is 0. Since there are no horizontal forces, the horizontal net force is also 0. In fact, any time an object remains at rest its net force is 0.

Before moving on, let's try out some of these concepts. Take a few minutes answer the following questions. Then, discuss with your peers. And we'll be back to see how you did.

Welcome back. How did you do? Here are the answers to the questions about Diego. As you can see, at rest, the upward normal force balances with the force of gravity pulling Diego into the ground. To find Diego's mass, you just need to divide the force of gravity by the strength of gravity. If the ground disappeared, the normal force goes away, leaving just the downward force of gravity acting on Diego. Hence, the net force on him will be negative 600 newtons.

Now you're ready to develop your own free body diagrams. Obtain a bathroom scale, and stand on the scale. Next, for each of the three situations shown, develop a free body diagram. Before you go on to part C, make sure you check in about part A and B with your instructor. We'll be back in 10 minutes to see how you did.

Hi, welcome back. Let's see how you did with your own free body diagrams using an online simulation. As you can see, with no other forces, the upward normal force equals the downward force of gravity. If someone pushes down on the box, the normal force increases to balance out gravity in the downward push. If someone pulls up on the box, the normal force decreases, because the upper force and the normal force balance gravity together.

So, Aaron, pushing down on you doesn't change the force of gravity acting on?

No, Jesse. That's just annoying. My mass and strength of gravity are the same. So that means the force of gravity has to stay the same. The only thing that changes is that the normal force increases to keep me at rest.

I wonder how Newton's third law applies here.

Well, Jesse, you can recall that Newton's third law says that every force comes with an equal and opposite pair. There are three rules to these pairs. First, they always have to be equal and opposite. Second, they always coexist together. And thirdly, they always must act on separate objects.

So what do you guys think? The force of gravity and the normal force are two forces. According to these rules, do you think these two forces are a third law pair? Discuss it, and we'll be back in a minute.

Hey, welcome back. So, Jesse, are the normal force and the force of gravity acting on you right now third law pairs?

No. Actually, they fail all three tests. First, as you guys found, the normal force and gravity are not always equal.

Secondly, they don't always co-exist. If the ground disappears, you still have gravity, but there is no more normal force. Third, these forces both act on me. Third law pairs must act on two different objects and represent interaction between those two objects.

So, Jesse, what would be gravity's third law pair?

Well, since the earth pulls you down with the force of gravity, the third law pair is you pull up on the earth. So you fall down towards the Earth, and the earth falls up towards you. However, because the Earth is so big, it moves very, very slowly, in fact, so slowly you can't observe it.

Well, we would help you feel more comfortable identifying forces and drawing force diagrams.

Aaron, when I jumped on your back, I increased your normal force.

Well, in this lesson, we looked at the at-rest situation, but normal forces can get much more complicated. Here are some questions you can think about to explore the normal force more.

How does an normal force behave while jumping? What about in an elevator? Can a wall apply a normal force? How about the normal force on a hill?

So we hope we have just wetted your appetite to learn even more about forces. Understanding forces can be a foundation for your lifelong learning of physics.

Hello, teacher, glad you're here. I'm Aaron Osowiecki.

I'm Jesse Southwick.

All right, while forces cause all the motion that we observe in our environment, force concepts challenge our students. Unable to see forces, students have difficult to identifying what forces that are acting on objects.

Oftentimes, students are asked to consider forces in an abstract situation having little to do with anything or little to do with what they're doing. This lesson introduces students to forces by having them collect data on the actual forces and build their own free body diagram. Building their own free body diagrams really help students connect the arrows to the actual situations something real.

So this 45 minute lesson will help students meet the following objectives. First, they're going to learn how to identify forces acting on the object and then quantify the force using gravity, using mass times the gravitational field strength, and then use Newton's laws of motion to quantify other forces, and then graphically represent these forces on an object with a free body diagram, and lastly determine the net force acting on an object using a free body diagram.

As an introductory force lesson, there are no hard prerequisites. However, students will do better if they know a little bit about mass and also are familiar with using units.

The first part of the lesson introduces students to the force of gravity, normal force, and force diagrams. Have students go through the questions on their own and then share their response with each other. Often, this process will alleviate issues that the students have. After you allow them to discuss, review the answers as a class to ensure everyone is ready for the hands-on part of the lesson.

And for the second part of the lesson, students will collect their own data while standing on a bathroom scale. Often some students refuse to stand a scale due to concerns about their weight. Hopefully, you can get at least one person in the group to stand on the scale, but if not you can volunteer to stand on the scale yourself or have another classmate volunteer to be a stand-in for that group.

When drawing the force diagrams, they usually get the first one correct. However, often they will think that-- when someone pushes down on them, it affects the force of gravity and not the normal force. As you encounter this issue, ask students did the person on the scale lose any mass? Did the strength of gravity change? No, than the force of gravity must remain the same.

As you go around the room, ensure that everyone gets force diagram and A and B correct. Use the diagram C as a formative assessment to see if they really understand.

Lastly, the ending question is related to Newton's third law of motion. The ending question always challenges students. After going through the experiment and measuring situations when the normal force does not equal to the force of gravity, they still say, yes, they are a third world pair. You may need to help them see how it fails all three checks.

Is it always equal? Does the normal force always exist with gravity? Are they acting on different objects?

As always, allow for a little chaos in your classroom, and let the students do most of the talking and exploring. Let them make mistakes and challenge them to figure out those mistakes as they share and discuss with each other.

If you liked this lesson, we've written entire introductory physics curriculum called Energizing Physics. It's a student-centered, project-focused yearlong curriculum centered around energy. It's available at energizingphysics.com. And we'd be happy to help. Just send us an email with questions.

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