**Newton’s Laws of Motion**

**Section 1**

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| 00:00:00 | TEACHER: In the warm up, we reviewed force. These ice skaters are using force in order to get moving. And once they're moving, they'll be able to go for a fairly long distance with very little effort. So we have ice skaters that are moving and will stay in motion. The ice skaters that are not moving will stay motionless unless they use force to propel themselves forward. |
| 00:00:26 | This notion, that movement is caused by unbalanced force, is the basis for Newton's first law of motion. In the next segment, you will learn about Newton and his first law of motion. |

**Section 2**

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| 00:00:00 | TEACHER: Here is Sir Isaac Newton himself. Now, though Isaac Newton was known for his laws of motion, he also performed many experiments involving light, gravity, and other mathematical and scientific subjects. He also published works on mathematics, history, and theology. He even created an entire branch of mathematics. |
| 00:00:22 | You've probably heard of it-- calculus. Calculus is the study of how math relates to motion and objects that are in motion. And he also published his most significant book called the Philosophiae Naturalis Principia Mathematica in 1687. Translated, this is "mathematical principles of natural philosophy." And in this, he detailed the work of gravity as a universal force. |
| 00:00:51 | He also featured the three laws of motion that we're going to be looking at today, 300 years after he wrote about it. So let's take a look at that first law of motion. Let's read the slide together. Newton's first law of motion states that "An object at rest stays at rest, and an object in motion stays in motion, |
| 00:01:14 | unless it's acted on by an unbalanced force." Let's look at the bullet points. This is also known as the law of inertia. And inertia is the natural tendency of objects to resist change in motion. If you think about a bowling ball here in the middle of a bowling alley. If it's not moving, it's not going to move unless a force |
| 00:01:38 | acts upon it. In the same way, if the bowling ball is moving, it will continue to move-- disregarding friction anyway. It will continue to move in that direction at that speed unless another force acts upon it. Now, we've brought up friction. And sometimes when we're talking about inertia, we'll need to |
| 00:01:58 | take away some of the outside variables. In this case, we're going to take out the variable of friction. Now, friction is a force that we rely on. It causes our car wheels to grip the road. And it also causes our feet to catch as we walk forward instead of slipping all over the place. But friction also changes our view of motion and inertia. |
| 00:02:19 | So this is why inertia was such a breakthrough with Newton. Because he was able to remove the idea of inertia from friction that affects it. All right, so we know that inertia is why the ball is either in motion or motionless until another force acts on it. And we will ignore friction for the time being. |
| 00:02:44 | So let's look at an example of inertia. |

**Section 3**

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| 00:00:01 | TEACHER: Let's use this nice, neatly set up table in order to demonstrate the concept of inertia. What do you think would happen if I were to take the two ends of this tablecloth and pull really quickly? Maybe you've seen this done before like a magic trick. What do you think will happen to the objects on top of the table? Let's try it and find out. |
| 00:00:21 | So why did the objects stay on the table and not go flying off with the tablecloth? Well, the answer is because the objects have mass. There's substance to them. And the mass of an object is also a measure of its inertia. It keeps it in a constant state. It's also how much force would be required in order for the |
| 00:00:44 | object to be moved. Now, if these objects were polished or smoother, they would move even less. You see them move a little bit, and that's because there's some friction between the surface of the object and the surface of the tablecloth. But, again, the smoother the objects are, the less friction and the more constant they would stay. |
| 00:01:06 | You can even try this experiment on your own. If you take a piece of paper and a coin and put it on a smooth tabletop, if you pull the paper very quickly, the coin should stay on the table. That's because the coin has inertia. |

**Section 5**

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| 00:00:00 | TEACHER: In the last segment, we saw how Newton's first law of motion identifies that an object's motion can be initiated or stopped by an unbalanced force. And we've established that an object will not move or change movement unless a force acts on it. But how can we describe an object's motion or movement once net force has been applied? This description of an object's movement is what |
| 00:00:28 | Newton's second law of motion relates to. Take a look at this picture here. Have you ever tried to help someone whose car's been disabled? This concept is a great illustration of the relationship between the mass of the car, the force needed to push it, and the acceleration. These factors are essential to Newton's second law of motion. |
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**Section 6**

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| 00:00:00 | TEACHER: Let's take a look at this together. Newton's second law of motion states that the total net force acting on an object is equal to mass times acceleration. And you can see it written here in an equation-- F equals m times a. In this equation, F represents force which is also called newtons which is kilograms times |
| 00:00:30 | meters per seconds squared. The m in the equation represents mass written in kilograms. And the a represents acceleration, which is written in meters per seconds squared. Now, this equation can be manipulated to solve for any one of the variables. So if we wanted to find mass, we can simply divide force by |
| 00:01:06 | acceleration. Or if we wanted to find acceleration, we could divide force by the mass. Now, let's remember that mass and weight are not the same thing. Mass is the substance of an object whereas weight includes the forces that are acting on that object. Now, let's look at some examples using this formula. |
| 00:01:30 | Imagine someone asks you to calculate the force needed to accelerate an object to 4.3 meters per second squared. The object has a mass of 2.2 kilograms. And then, round the answer to the nearest 10th. How would you go about solving this problem? Let's start with our known variables. We know that it has an acceleration of 4.3 meters per second squared. |
| 00:02:01 | We also know that it has a mass of 2.2 kilograms. What we don't know is the force. So that's what we'll be solving for. Now, we can apply the formula. Remember force equals mass times acceleration? So we're going to multiply. Let's fill that in here. The mass is 2.2 kilograms times 4.3 meters per second |
| 00:02:33 | squared equals-- have you figured this out yet? 9.46-- but remember it said to round to the nearest 10th. So this rounds to 9.5. And our units of measure for this will be newtons. That's sort of a nice privilege of a scientist who pioneers a new concept or theory. |
| 00:02:56 | They get measurements named after them. So our force will always be measured in newtons. Next, you're going to apply this second law of motion by solving a problem on your own. |

**Section 8**

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| 00:00:01 | TEACHER: Let's say that you had to calculate the acceleration of a moving object, given that the object is 500 grams and has a force of 6.5 newtons. How would you go about solving this problem? Let's start with the variables that we do know. We know that the mass is 500 grams. We also know that the force is 6.5 newtons. The unknown is what we're looking for-- the |
| 00:00:32 | acceleration. So acceleration is unknown. Now we can rearrange the formula and plug in the numbers. So if we're looking for acceleration, we'll be dividing force by mass. Let's go ahead and substitute the values now. We have a force of 6.5 newtons divided by 500 grams. |
| 00:00:57 | But we need to convert that to kilograms. So 500 grams equals 0.5 kilograms. So now we can divide by 0.5 kilograms, which equals-- have you solved it-- 13 meters per second squared. Next, you'll have an opportunity to use Newton's second law in order to solve for acceleration, given the variables mass and force. |
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**Section 10**

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| 00:00:00 | TEACHER: Let's take a look at a career that uses Newton's laws of motion. Scientists at NASA study forces involved with mass and acceleration when they'd study and plan for a mission called Deep Impact. This mission was to study the ejected material by sending an unmanned spacecraft on a collision course with a comet, Temple 1. |
| 00:00:22 | Here, you can see the two-part unmanned spacecraft. This is the impact portion, and this is the support craft, or fly by, which orbits and collects data. And it took a series of images that you will get to see next. |

**Section 13**

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| 00:00:00 | TEACHER: So far, we have identified that motion is initiated by force, and force is based on mass and acceleration. This picture here is a picture of Apollo 16 launching into space. This is a rocket with engines that create 7 million pounds of thrust. This is an enormous force that's needed in order to |
| 00:00:22 | accelerate the rocket payload up into orbit. Now, how does this huge thrust back out of the engines propel the rocket up into space? Newton's third law of motion will help explain why and how rockets work. |

**Section 14**

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| 00:00:01 | TEACHER: Let's take a look at this together. Newton's third law of motion states: that for every action, there is an equal and opposite reaction. Considered action and reaction forces. So if you take a look at this picture of the ice skater, and you look at her ice skate pushing down, the ice skate blade is an active force pushing down on the ice. The ice is the reactive force pushing back up. |
| 00:00:28 | This may seem a little difficult to understand-- ice pushing back up on the skater-- but if you think about it, if there were no force back, then she would fall right through the ice. In the same way, she's pushing up against the wall. This is the active force. The reactive force, or resistance, is the wall pushing back. |
| 00:00:47 | And again, if that force wasn't there she would fall right through. Now if you think about that Apollo 16 rocket-- I'll try my best to draw a little picture of it here-- here's the rocket. And remember, the jet gases were pushing out of the engine, down towards the ground. This means there will be an opposite and equal reaction, |
| 00:01:09 | and the rocket will be thrust up into space. More examples will likely help your understanding of this, so let's take a look at a few. Here in the first picture, we have a picture of holding hands, a father and a baby. Now, there's an action and reaction force going on here. It's felt independently, based on the point of view of the observer. |
| 00:01:32 | The baby does not really feel its own hand, but feels the pressure of the dad's hand pushing down on its hand. There's your active force. Now the dad can feel the baby's hand resist, and that would be the resistance, or reaction force. If we were to add numeric values to this, you might say that this is a 0.1 newton force against a 0.1 newton force. |
| 00:01:59 | It's a gentle touch. If you look at the next picture-- helium balloons-- the gases inside of the helium balloon are pushing outward. This is an active force, an action force. The gases are pushing up against the elastic of the balloon. The balloon elastic is pushing back on those gases in a |
| 00:02:23 | reactive force. Now, in addition, there's also atmospheric gases that are pushing on the balloon. So there is actually a lot of reaction force up against all of this |