Name _____

Newton's Second Law of Motion

Newton's 2ⁿᵈ Law states: "Acceleration and force are proportional, and there is an opposite proportional relationship between acceleration and mass (simplified)."

What is mass? _____

What is acceleration? _____

Experiment 1: Balls – Force and Acceleration

Hypothesis: What will happen to the ball's acceleration when a greater force is applied?

IF… a greater force is applied to the ball

THEN…_____

BECAUSE…_____

_____

Experiment 2: Balls – Acceleration and Mass

Based on the second part of Newton's second law, discuss the following:

Which ball will move away faster? _____

Why? _____

Experiment 3: Nerf Gun – Acceleration and Mass

Based on the second part of Newton's law, and after seeing what happened to the larger ball in our last experiment, write out a hypothesis on what you think will happen to the nerf bullet that has more mass (the *large* screw).

Hypothesis:

IF… a large screw is placed in a nerf bullet

THEN*…_____*

BECAUSE*…_____*

_____

Review:

- ✓ What is acceleration?
- ✓ What happens to the acceleration when we increase the mass?
- ✓ What happens to the acceleration when we decrease the mass?
- ✓ What happens to the force when we increase the acceleration?
- ✓ What happens to the force when we decrease the acceleration

Newton's First Law of Motion

Teacher Notes

Newton's 2nd Law states: "Acceleration and force are proportional, and there is an opposite proportional relationship between acceleration and mass (simplified)."

What is mass? How much matter an object possesses (simplified).

What is acceleration? A change in speed that occurs during a period of time.

Teach

Lots of people get confused with Newton's second law, but it is simply a formula! The most common expression of this formula is F = ma, where Force = Mass x Acceleration. That's it! Essentially, in Newton's first law, he was telling us that objects remain in the state they are unless a force acts on them, and remember, this is because of the object's inertia (mass). In the second law, Newton is telling us what forces are composed of and how these different variables, like mass and acceleration relate to one another. In other words, he *quantified* his description of a force and put it into a formula.

Write the three variables for force on the board. Don't put them into an equation, just keep it simple. So, F = force, m = mass, and a = acceleration. Ask them to define a force. From the last two labs, they should be able to tell you that a force is a "pull" or a "push." Next, ask them to define mass. Again, from the last two labs, they should be able to tell you that mass is the amount of matter in an object. You must now define acceleration for them. Acceleration is just a change in speed divided by time. They should know what speed is; like 60 mph, or 20 m/s. The way to "show" them acceleration is to have a ball roll down a ramp, and then let it roll across the floor until it stops. Show them that as the ball goes down the ramp, its speed increases (it gets faster). This means its speed is changing, and this is occurring in an interval of time, therefore this is acceleration. You can extend the explanation by asking them if the ball is accelerating when it gets to the flat ground. It is not. As soon as it leaves the ramp it stops accelerating. The ball will actually have a constant speed for a little while when it is on the flat ground, then friction will really kick into gear and slow the ball down till it stops. This means the ball is slowing down (deceleration). If it is slowing down over a period of time, this is also called acceleration! It's just that it is "negative" acceleration and we call it "deceleration."

Experiment 1: Balls – Force and Acceleration

Use a ping pong ball and an elastic band. Set the ball on the ground where it can roll easily. Stretch the rubber band back about three inches and let it hit the ball which will accelerate away (as in video). Do this again, but next time, stretch the rubber band back twice as much. The ball will accelerate away much faster than the first time.

Teach

Before you perform the experiment, go back to Newton's second law and explain to the students the first part, "that the acceleration and force are proportional." Explain to them that "proportional" just means that acceleration and force will do the exact same thing. If one goes up, the other will go up by the same amount. If one goes down, the other will go down

by the same amount. Now explain to them what you are going to do. Then perform part 1 of the experiment, and as you go, explain that the "push" the rubber band provides is the *force*, that the ball provides the *mass*, and that when the ball moves away, this is *acceleration*.

Now, before you conduct the second part, have them write out their thoughts in terms of a hypothesis.

***Hypothesis*: What will happen to the acceleration when a greater force is applied?**

- ➢ **IF… a greater force is applied to the ball**
- ➢ **THEN…**the ball will quickly move away
- ➢ **BECAUSE…**force is proportional to acceleration. As force goes up, so does acceleration.

Experiment 2: Balls – Acceleration and Mass

Now put the ping pong ball and a ball with more mass down on the floor as before. This time, you will want to stretch the rubber band back and hit both balls with the *same* amount of force (so, the rubber band is stretched back by the same length both times). The ball with greater mass will not move away as fast and will not move as far as the ping pong ball.

Teach

Explain to the students that the force will be the same on both balls. But ask them to discuss amongst themselves the result, based on the second part of Newton's law: "there is an opposite proportional relationship between acceleration and mass." Have the students weigh and feel both balls.

Which ball will move away faster and move the farthest? The ball with the most mass

Why? Because Newton's law says, that there is an opposite proportional relationship between mass and acceleration. According to this, the ball with more mass will move away at a slower acceleration and will not move as far.

As review for *Newton's first law*, ask the students *why* the ball with the greater mass did not accelerate as much as the ball with less mass? It's because the ball with more mass has more inertia and so resists a change in its speed (in other words, it resists being accelerated). Remind the students that this is why all objects require a force to act upon them to change their state of motion or speed (this is Newton's first law).

Experiment 3: Nerf Gun – Acceleration and Mass

This experiment is designed for FUN! Use a cheap nerf gun that has at least three nerf bullets. Pull the plastic top off of two of them. Now find a screw or some object that you can push into the hole in place of the plastic top. Make sure it is heavier than the plastic cap. Now find a third object that is heavier than the screw. So now you have three nerf bullets that increase in their mass. Make sure the screws or objects you use completely block the hole because nerf guns work by pushing air into the bullet, and you don't want air leaking through the top. You can have the students perform this experiment, just make sure they wear safety glasses! Have a student shoot the "lightest" bullet. Then have another shoot the second and another shoot the third. Each bullet should progressively fall at a shorter and shorter distance.

Teach

After the first student has fired the first bullet, have them discuss what they think will happen when the other two bullets are fired. Then have them fill out the hypothesis based on the second part of Newton's law. Remind them that the force is the same (the "air pushing), and that there is no way to change the amount of force.

Hypothesis 2: **What will happen to the other two bullets in comparison to the first?**

- ➢ **IF... a large screw is placed in a nerf bullet**
- ➢ **THEN...**it will not travel far
- ➢ **BECAUSE...**according to Newton's second law, mass and acceleration have an opposite proportional relationship. If mass goes up, then acceleration must go down

Teach

Lastly, and this is only for those that may understand, you can explain all of this using the equation: $a = \frac{F}{m}$. Using the white board, fill it in like this: $1 m/s2 = \frac{1\,N}{1\,kg}$. Acceleration has units of meters per second squared, force has units of newtons, and mass has units of kilograms. Show them that the math works. Now increase either the acceleration or the force by doubling it. Show them, that in order for the math to work, the force must also increase by the same amount as the acceleration (confirming the first part of Newton's second law). Now leave acceleration blank, and ask students to do the math based on the $\frac{1\,N}{1\,kg}$. The answer is 1 m/s². Then increase the mass in the denominator to 2 kg. Have the students do the math again. The answer this time is 0.5 m/s². This confirms the second part of Newton's second law. Notice that the acceleration went down when the mass went up.

Review:

- ➢ What is acceleration?
- ➢ What happens to the acceleration when we increase the mass?
- ➢ What happens to the acceleration when we decrease the mass?
- ➢ What happens to the force when we increase the acceleration?
- ➢ What happens to the force when we decrease the acceleration?