SUPERCHARGED SCIENCE

Unit 2: Motion

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Appropriate for Grades:
Lesson 1 (K-12), Lesson 2 (K-12)
Duration: 6-12 hours, depending on how many activities you do!

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Key Vocabulary

Acceleration is the rate of change in velocity. In other words, acceleration is a statement of how fast a change in speed and/or a change in direction is happening.

Force is a push or a pull, like pulling a wagon or pushing a car.

Gravity is a force that attracts things to one another. Gravity accelerates all things equally which means that all things speed up the same amount as they fall.

Mass is a measure of how much matter (how many atoms) make up an object.

Terminal velocity means something has speed but no acceleration. This is normally used when something falling cannot gain any more speed because the air resistance pushing against that something is equal to the force of gravity pulling down on that something.

Velocity has both a speed (like 55 mph) and a direction (like northeast).

Weight is a measure of how much gravity is pulling on an object.

Unit Description

We're going to study velocity, acceleration, and Newton's Three Laws of Motion in this unit. You'll get to throw things, build G-force accelerometers, and do much more as you uncover the basis of all physics in our crash course in projectile motion. Here's what you need to know to so we get the most out of this unit together.

Newton has a famous quote that goes, *"If I have seen farther than others, it is because I have stood on the shoulders of giants."* One of the giants he was referring to was Galileo. Thanks to the discoveries of Galileo and others, Newton was able to make many of his own discoveries, the most famous of which are Newton's Laws of Motion.

Objectives

Lesson 1: Velocity

Velocity is how fast and in what direction something is going. **Direction** is what separates the term **velocity** from **speed**. If we were talking about a car, we could say that car is traveling with a velocity of 30 miles per hour due east. We will basically just be using the speed aspect of velocity, since for our purposes, the directional aspect confuses things more than necessary.

There is another term that is useful here—terminal velocity. The term **terminal velocity** is normally used when something falling cannot gain any more speed because the air resistance pushing against that something is equal to the force of gravity pulling down on that something. When those two forces are equal and moving in opposite directions from each other, the falling object stops accelerating and stays at the same velocity.

This is why feathers drop so much more slowly than bowling balls. A feather has a very large amount of air resistance and gravity pulls very lightly on it (the feather is very light). The amount of friction force quickly equals the amount of gravitational force and so the feather accelerates only a small amount, gains little speed, and drops nice and easy.

The bowling ball has very little air resistance and gravity pulls pretty hard on it (the bowling ball is heavy). A bowling ball can accelerate quite a bit and gain a lot of speed before the force of air resistance pushing up equals the force of gravity pulling down.

Quick quiz—how fast does gravity accelerate things? If you said 32 ft/s^2, 9.8 m/s^2 or 22m/h^2, you win!

Highlights for velocity

1. Velocity is the speed and direction of an object.

2. Terminal velocity is when something cannot gain any more speed because the friction pushing against that something is equal to the force of gravity pulling down on that something.

3. You can find how far something falls by using the formula **d=vt** or distance = velocity times time.

Objectives

Lesson 2: Acceleration

Before we get into Newton's Second Law, we need to get up to speed with acceleration. In physics, **acceleration is defined as a change in velocity**. In other words, it is a change in speed or direction. It is how much time it takes something to go from one velocity to another.

Remember that velocity is speed and direction. If you go straight ahead on your bike at a constant speed of 5 mph, you are not accelerating as neither your speed nor direction is changing. Now, if you are stopped at a stop light and it turns green, you are accelerating as your speed increases from 0 to 10 mph. The same thing happens if you are traveling at a nice even 10 mph and slow to a stop.

In physics, we don't use the word deceleration. We use positive and negative acceleration. Now, what happens if you are in a car and it turns a corner at a constant speed of 15 mph? Is it accelerating or not? Well, the speed is not changing but its direction is, so it is indeed accelerating.

Remember back when we talked about gravity? We learned that gravity accelerates things at 32 feet per second squared. Now this may make a little more sense. Gravity makes something continue to increase in speed so that after one second of having the force of gravity pull on something, that something has reached a speed of 32 feet per second. When that thing started falling it was at 0 velocity. After a second it was travelling at 32 feet per second. After 2 seconds it was travelling at 64 feet per second and so on.

It's the old formula **v = gt**, or velocity equals the gravitational constant (32 ft/s^2) times time. If something has an acceleration of 5 ft/s^2, how fast will it be going after 1 second…2 seconds…3 seconds? After one second it will be going 5 ft/s; after two seconds 10 ft/s; and after three seconds 15 ft/s. Again, it's just like **v = gt** (v is velocity, g is the gravitational constant, t is time) but put the rate of acceleration of the object in place of g to get the formula **v = at**, or velocity equals acceleration times time.

Highlights for acceleration

1. Acceleration is the rate of change in velocity. In other words, acceleration is a statement of how fast a change in speed and/or direction is happening.
2. Velocity is speed and direction.
3. A formula for acceleration can be a = (change in velocity)/time

Textbook Reading

Newton has a famous quote that goes, *"If I have seen farther than others, it is because I have stood on the shoulders of giants."* One of the giants he was referring to was Galileo. Thanks to the discoveries of Galileo and others, Newton was able to make many of his own discoveries, the most famous of which are Newton's Laws of Motion.

Newton's Three Laws of Motion predict the motion of virtually all objects on Earth and in space. You are about to know *all* of them. Newton's Laws are all they have used to launch space craft to the moon and soon you will understand them all. Pretty powerful stuff, eh?

Newton's Three Laws of Motion are…

1. An object at rest tends to stay at rest. An object in motion tends to stay in motion unless a force acts against it.

2. Force is proportional to acceleration.

3. Every action has an equal and opposite reaction.

Newton's First Law

At first glance, Newton's First Law seems rather obvious. Especially the first part, *"An object at rest tends to stay at rest"* Well….of course. When was the last time you saw your table move across the room for no reason? Last time you were eating your potatoes, did they float off your plate and into the lamp? NO! It's really the second part that is an amazing statement, especially if you consider when it was made.

"An object in motion tends to stay in motion." Think about that. When was the last time you saw an object keep moving on its own? If you push a toy car, does it just go and go until it hits the wall? Last time you threw a ball, if your buddy missed it did it just keep sailing down the street? No! Both objects stopped. All objects stop right? Well, yes, but only on a *planet*.

The reason things stop is because of two things we talked about in Unit 1: the forces of gravity and friction. Without them, things would just keep going. This is why planets, comets, space shuttles, meteors and more never stop moving. They have no air resistance (in space there's no air and as such no friction from air) and they may or may not have much gravity pulling on them. Things in orbit (the moon, satellites, etc.) do feel the pull of Earth's gravity but they are moving fast enough to keep falling around the Earth and not into the Earth.

Now imagine Newton sitting there in 1700. He had never seen a frictionless place or a place with no gravity. He had never seen pictures from the space shuttle of things floating around. No one had been to the moon yet. For him to have "seen" the reality that in such places things would never stop moving is pure genius.

Aristotle said the natural state for most objects was to be at rest. Newton, without ever seeing any evidence to the contrary, said the natural state for a moving object was to continue moving. When you can see through what everybody has believed to be true for centuries you are a true genius (or out of your head!).

Why is it hard to move a bowling ball? There is a term in physics that really kind of encompasses Newton's first law, and that is **inertia**. Inertia is a quality of an object that determines how difficult it is to get that object to move, to stop moving, or to change directions. Generally, the heavier an object is the more inertia it has. I like to think of inertia as a mule. It is often very hard to get a mule to move, and once you do get him moving it is very difficult to get him to stop or to change directions!

Quick quiz! Which has more inertia, a ping-pong ball or a train? If you said "train" you're right. It is very easy to get a ping-pong ball to move and it is very easy to get it to stop. A train, on the other hand, is quite difficult to move or stop!

Newton's Second Law

Newton's Second Law is one of the toughest of the laws to understand but it is very powerful. In its mathematical form, it is so simple that is is elegant. Mathematically it is **F=ma** or Force = Mass x Acceleration. An easy way to remember that is to think of your mother trying to get you out of bed in the morning. Force equals MA! (Did I mention physics jokes are usually pretty bad?)

In English, Newton's Second Law can be stated a few different ways: The more mass something has and/or the faster it's accelerating, the more force it will put on whatever it hits. This is stated as F = ma. For example, a car colliding at 30 mph will hit a lot harder than a bumblebee colliding at 30 mph.

The more mass something has, the more force that's needed to get it to accelerate. **a=F/m** This, by the way, is a mathematical definition for acceleration. For example, it is a lot harder to get a train to accelerate than it is to get a ping pong ball to accelerate.

Now here's an interesting definition. The definition of mass can be stated as **m=F/a**. In other words mass is how much force it takes to accelerate something. This is a major difference between mass and weight. Something with great weight on Earth may be weightless in space (since there's no gravity) but it will still be just as difficult to get it to accelerate.

Newton's Third Law

Are you ready for Newton's Third and final law of motion? **Every action has an equal and opposite reaction**. Even though this is the best known of Newton's Three, it seems to me to be the hardest to fully comprehend.

Again, it is a tribute to Newton that he was able to "see" this law. For every action and every force, the same action/force happens in the opposite direction. As you sit on your chair reading this, gravity is pulling down with a certain force (the force of your weight and the weight of the chair). The floor is pushing up with the same force.

Quick quiz! what would happen if the floor pushed up with more force than the force of the chair pushing down? There would be an upward force which would cause an acceleration of the chair, causing your mass to lift upwards! (That's Newton's Second Law, right?) Because the force up and the force down is equal, the net force is zero and there is no motion.

This law helps you walk. As you walk, you push backwards against the ground. The ground gives an equal and opposite push to you so you move forward. Try to imagine someone walking in a canoe. (I don't recommend trying this, unless you know how to swim and are willing to get wet!) As the person steps forward, the canoe moves backward. The equal and opposite force of the walking moves the person forward just as far as it moves the canoe backward.

"But how come as I walk on my floor, my house doesn't move backwards like the canoe?" Ahhh, good, I'm glad you're paying attention. Let's go back to Newton's Second Law again.

Force equals mass times acceleration. What is the mass of you compared to your house? Pretty small right? So the force you create to move your mass forward, is nowhere near the force that is required to move the house backward (especially since your house is anchored to the earth.) You do push backward on your house but due to the immense inertia of the house, it doesn't move.

