

## **2362 Blossoms - Hanging By A Thread v3 1**

[MUSIC PLAYING]

Hello. My name is Frank Lenox. I teach physics at East Greenwich High School here in Rhode Island. Newton's laws of motion are an important part of our physics curriculum. And I'm here today to talk to you about Newton's three laws of motion. Newton is often associated with the apple. This is probably because he grew up on an orchard and spent a lot of time sitting beneath apple trees, contemplating the forces of the universe.

Most of you can probably recite Newton's three laws of motion. His first law, the law of inertia, states, an object in motion remains in motion. Likewise, an object at rest remains at rest, unless acted upon by an unbalanced force. His second law is best summed up as  $F$  equals  $ma$ , force equals mass times acceleration. His third law states, for every action, there is an equal and opposite reaction. Reciting Newton's laws can be fun, but they are difficult to understand. We use these laws to help us construct force diagrams, and demonstrations can be useful in helping us develop this understanding.

In this BLOSSOMS lesson, we will use Newton's laws to explain the motion that results from various forces acting on a mass. Much like an apple suspended from a tree, I will have a mass that has a thread tied to the top and to the bottom. If I pull quickly on the bottom thread, with the top thread or the bottom thread break? Likewise, if I pull slowly on the bottom thread, will the top thread or the bottom thread break? Make a prediction, and consider making a diagram to explain your prediction. And we'll meet back in that classroom to continue our lesson.

Welcome back. I hope you were able to discuss some possible outcomes of our mass thread system. I have here a setup of our demonstration. And obviously, your choices are limited to the top thread or the bottom thread. Let's see if we can identify the forces that are present in our system so that we can create a force diagram, what physicists call a free-body diagram. A free-body diagram is a type of model that describes the interacting forces on an object or objects.

So focusing on the mass, the force of gravity of the earth acts downward, while tension force in the top thread acts upward. Since the mass and the thread are at rest, we know they are in equilibrium. If we shift our focus to the bottom thread, as I begin to pull, the tension force increases in the bottom thread. The harder I pull, the greater the tension. As a result, the mass will begin to react to the force, creating a reaction, transferring some of that tension to the top thread. What you need to consider is, will the tension be greater in the top thread or the bottom thread?

I'm going to perform the demonstration now. Let's see how your predictions hold up. With the first mass, I'm going to pull the bottom thread very quickly. Let's observe what happens. With the second mass, I will pull the bottom thread slowly, until one of the threads breaks. Let's observe what happens.

[CLACK]

Were you surprised? Record your observations and see if you can explain what is happening through your force diagram. On a large white sheet of paper or on a whiteboard, see if you can explain your diagram to your classmates. While you're doing this, I want you to consider which of Newton's laws was best demonstrated. I'll see you in a few minutes.

Welcome back. How did you do with your explanations? Don't be discouraged if your prediction was incorrect. Scientists learn most by trying to explain their misunderstandings. Regarding the first scenario, your explanation should indicate that the tension force was greater in the bottom thread compared to the top thread. Conversely, in the second situation, the tension force was greater in the top thread.

So does your force diagram make this evident? How would a classmate know this by looking at your diagram? A force diagram allows us to see the forces at work. It's a model that represents the forces. It makes the invisible visible. They allow us to see the forces. And in doing so, they serve as a model.

A model is a representation of a system that explains just one part of that system. For example, a globe is a model of the surface of Earth, but it tells us nothing about the interior of the planet. Our force diagrams serve as models for the magnitude of the forces and the direction of the forces in each scenario. See if you can form a hypothesis that will explain what caused the threads to break.

Remember, a hypothesis is a statement that you wish to prove true or false. For example, you might say that the cause of the top thread breaking is because there was more tension in the top thread compared to the bottom thread. Most importantly, your hypothesis should be testable, indicating whether or not your statement is true or false.

As you begin to prepare procedures for your experiment, think about these questions and how you might answer them. Your teacher will supply you with a similar mass, thread, a ruler, and spring scales to assist you in your investigation. From the measurements you perform and the data you collect, you should be able to support or reject your hypothesis. Your force diagram should serve as a model for what measurements you want to perform and what data you need to collect. Let's meet back here after your investigation when you've had an opportunity to collect some data.

So I hope you found your investigation helpful in understanding the forces at work in our demonstration. I also hope that you found your force diagram helpful in identifying the forces and their magnitudes so that you could identify which thread would break. As you move forward, you will discover that force diagrams are very important to us in being able to predict motions.

Previously, I had asked you to consider which of Newton's laws is best demonstrated in our demonstration. Let's revisit this question. So which of Newton's laws was best demonstrated in your investigation? It's important to recognize that all three of Newton's laws apply to every motion. However, in some situations, one law is more apparent than the others.

When we ask which of Newton's laws was most apparent in our demonstration, we could argue that the first law, the law of inertia, applies. In reference to the first mass, an object at rest wants to remain at rest. The mass resisted when I pulled quickly. And as a result, all the tension remained in the bottom thread. In reference to the second mass, when I pulled slowly, the tension had time to transfer to the top thread where the additional gravitational force of the mass made the tension greater.

Use your force diagrams to walk yourself through the process, and you will find that each of Newton's laws are connected to each other. I hope you found this BLOSSOMS lesson valuable in understanding Newton's laws. On the surface, they are simple statements. But as we apply them to various situations, you will find that they reveal a great deal of information about forces and motion. Continue to practice with your force diagram models, and you will find them useful in solving most physics problems. Good luck.

Thank you for choosing to use this BLOSSOMS lesson. This lesson serves two purposes. The first is to guide students through the practice of creating models using force diagrams, what we refer to as free body diagrams. Free body diagrams are diagrams that are used to show the relative magnitude and direction of forces acting on an object in a defined system. This can be a challenge for students who are just beginning to learn about forces, and it's complicated by the fact that forces are invisible.

Being able to account for all the forces acting within a system and determining the magnitude and direction is important in solving most physics problems. The use of models provides you, the teacher, with the ability to formatively assess students, and help shape their thinking, and address any misconceptions that they may have. This demonstration, however, would not be good for introducing force diagrams, simply because there are multiple forces at work.

The second purpose of this lesson is to convey to students that while Newton's laws are easy to recite, they are difficult to comprehend. Students may have difficulty simply identifying the forces that are present. In particular, action/reaction forces.

If I use the example of kicking a soccer ball, many students will describe the reaction as the ball flying off. This misconception can be corrected by simply pointing out that the reaction should be opposite the motion of the action, the student kicking the ball.

Make a point to reiterate Newton's laws later in concepts of momentum, centripetal force, gravitation, so that students will begin to appreciate the insightfulness of Newton and build upon their understanding. Referring to segment one of the video, encourage students to create a force diagram before making their prediction. You can encourage this by drawing a model of the cylinders on the board and encouraging them to draw arrows of specific links indicating the forces up and down. Ask students to think about the forces in each thread and draw them as arrows representing the forces.

In segment two of the video, the demonstration, rest assured, this demonstration is very reliable. With a quick pull, the bottom string will always break. And with a slow pull, the top string will always break. Just make certain you are using fresh thread each time.

Regarding segment three of the video, students plan and conduct an investigation. Students may take different approaches to their investigation, and this should be encouraged. They could perform the demonstration with spring scales attached to the thread at the top and the bottom, and compare the tension values. For the quick pull, recording the scales with a camera will actually assist them in being able to record the tension. Or once they determine the breaking tension of the thread, they could determine which thread will reach that tension first, without actually breaking the threads.

Prompting students with structured questions is an important tool for this activity. I found that redirecting students back to Newton's laws through questioning using crosscutting concepts is very valuable. For example, "Which of Newton's laws do you think applies within this system?" is a great question to ask students. Or "How would Newton's laws explain the different pull effects on the outcome?"

Students tend to focus on the pulling force. However, Newton's laws focus on the motion of the object. Ask students what they think is happening to the mass in each situation. From a student's perspective, the mass responds the same in both scenarios by not moving. But, in fact, it doesn't.

Some possible assessments for this lesson could be one of the following. One, you could create a force diagram with a double mass system, a second mass hanging from the first mass. Have the students create a force diagram for a gradual force being applied to the bottom thread, and rank the tension in each thread from the strongest to the weakest, or from smallest to largest.

A second possible assessment would be the classic horse cart dilemma. Introduce students to the classic horse cart dilemma, and ask them to create a force diagram explaining how the horse is able to pull the cart, despite the fact that for every action, there is an equal and opposite reaction. Paul Hewitt provides a cartoon of this situation that is ideally suited for secondary physics students.

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