Marshmallow Mayhem

Overview

Students will explore and understand the concept of air pressure and its relationship to Newton's Second Law of Motion by conducting hands-on experiments with a marshmallow launcher. Using an air compressor and PVC pipe, students will investigate how air pressure generates force to accelerate a marshmallow and how force, mass, and acceleration interact. They will also examine how varying the length of the PVC pipe (short, medium, and long) affects the distance, speed, and acceleration of the marshmallow. Through this activity, students will apply Newton's Second Law, F = ma, to understand how changes in force (air pressure) and distance traveled influence the marshmallow's motion.

Background

Air pressure is the force exerted by the weight of the air molecules in the atmosphere. In our activity, we use an air compressor to artificially compress air, increasing the pressure inside a PVC pipe. When the air pressure inside the pipe is greater than the air pressure outside, the air seeks to escape and equalize the pressure. By releasing the valve of the air compressor, the compressed air rapidly exits the pipe, creating a force that pushes the marshmallow out of the launcher.

The force exerted by the compressed air is responsible for the motion of the marshmallow. This force causes the marshmallow to accelerate as it moves through the pipe and out into the air. The greater the difference in air pressure (the higher the pressure inside the pipe), the greater the force applied to the marshmallow, and the farther and faster it will travel.

Newton’s Second Law of Motion is a fundamental principle of physics that describes the relationship between force, mass, and acceleration. It states:

$$F=ma$$

Where:

- F is the force applied to an object (in our case, the force generated by the compressed air).
- m is the mass of the object (the marshmallow).
- a is the acceleration of the object (how quickly the marshmallow speeds up as the force is applied).

This law explains that the force required to accelerate an object depends on both the mass of the object and the acceleration. In the context of the marshmallow launcher:

- When you increase the air pressure, you increase the force exerted on the marshmallow. According to Newton's Second Law, a greater force results in a greater acceleration, causing the marshmallow to travel farther and faster.

Now, we bring in the concept of pipe length. The length of the PVC pipe influences how long the marshmallow is subjected to the force of the air pressure before it exits the launcher.

- Short Pipe: In a shorter pipe, the marshmallow travels a shorter distance before exiting the launcher. This means the marshmallow has less time to accelerate as it moves through the pipe, so it may exit the pipe faster but with less acceleration compared to a longer pipe. The shorter the pipe, the quicker the release of pressure, and the marshmallow might not achieve the same speed or distance as in a longer pipe.
- Long Pipe: A longer pipe gives the marshmallow more time to accelerate before it exits the launcher. As the marshmallow moves through the longer pipe, it continues to be acted on by the force of the compressed air for a longer duration, which leads to greater acceleration. Therefore, the marshmallow is likely to exit the pipe with more speed, potentially traveling farther than it would from a shorter pipe.

The difference in acceleration between a short and long pipe demonstrates how distance and time play a role in the motion of objects, and how air pressure can be manipulated to affect the velocity and distance of the marshmallow.

Air Pressure, Newton's Second Law, and Pipe Length:

By adjusting the air pressure and varying the length of the PVC pipe, students can observe how these factors work together to determine the marshmallow's acceleration, speed, and distance traveled.

- Greater Air Pressure = More force = More acceleration (greater speed and distance).
- Shorter Pipe = Less time for the marshmallow to accelerate = Less distance traveled.
- Longer Pipe = More time for the marshmallow to accelerate = Greater distance traveled.

This allows students to directly see how force and acceleration are interconnected and how the mass of the marshmallow and the time it is in the pipe contribute to its overall motion.

Introduction (5 minutes)

"Good afternoon, everyone! Today, we're going to explore the fascinating world of ***air pressure*** *and* ***Newton's Second Law of Motion*** *by launching marshmallows using a specially designed*

launcher! Yes, you heard that right — we'll be using an air compressor to fire marshmallows, and we'll learn how air pressure and physics come together to make them fly!"

*"First, let's talk about **air pressure**. Air pressure is the force exerted by the air molecules around us. Normally, we don't notice it because the air pressure inside our bodies is balanced with the air pressure outside. But when we use an air compressor, we can **compress the air** inside a tube and make it much higher than the air pressure around us. When we release that air, it creates a **force** that pushes objects, like our marshmallows, out of the tube."*

"Here's where **Newton's Second Law of Motion** *comes into play. This law says that **force equals mass times acceleration**. In simpler terms: when you apply force to something, it will accelerate. How much it accelerates depends on its **mass** — heavier objects need more force to accelerate at the same rate. So, when we apply force to our marshmallow using compressed air, we make it accelerate out of the tube. The more air pressure we use, the more force we can apply, and the faster and farther the marshmallow will travel!"*

*"But that's not all. We're going to experiment with **different lengths of pipe** today. We'll use short, medium, and long pipes, and observe how the length affects the marshmallow's flight. The longer the pipe, the more time the air has to push the marshmallow, so it will likely travel farther. The shorter the pipe gives the marshmallow less time to accelerate, so it may not travel as far or as fast."*

*"So, in a moment, you'll work in teams to launch marshmallows and see how **air pressure**, **pipe length**, and **mass** all affect how far and fast your marshmallow travels. We'll measure the distance and time it takes to see how the marshmallow performs under different conditions. You'll also be testing Newton's Second Law of Motion to understand how **force** and **acceleration** are related in real-world situations."*

"Before we start, remember to be safe. Always handle the launcher carefully and make sure no one is standing in front of the launcher when it's ready. Also, make sure to keep your marshmallow inside the pipe until it's time to launch!"

"Are you ready to launch some marshmallows and explore the science behind it? Let's get started!"

Procedure (15 minutes)

Prior to the start of the activity set up a launch range. Extend a 100-foot tape measure and place distance markers at ten-foot intervals all the way to 200 feet. Ensure that students can determine the distance their marshmallow flies without having to go out onto the launch range.

Assign students to equal numbered teams based on number of launchers.

Step 1: Set the Air Pressure

- **Task:** Set the air compressor to a consistent pressure. Start with **20 PSI** for a moderate launch.
- **Discussion:** Explain that the air pressure will apply a **force** on the marshmallow, launching it out of the pipe. Higher pressure leads to greater force and potentially greater acceleration.

Step 2: Insert the Marshmallow

- **Task:** Insert a **marshmallow** into the pipe. Use a smaller diameter pvc pipe to push the marshmallow into the pipe. Make sure it's snug but not stuck. Use the cooking spray for lubrication if necessary.
- **Discussion:** The marshmallow should move easily but not fall out on its own.

Step 3: Launch the Marshmallow

- **Task:** Aim the launcher toward the range and squeeze the trigger to release the compressed air, launching the marshmallow out of the pipe.
- **Measurement:** Take note of the **distance** traveled by the marshmallow after it exits the launcher.

Step 4: Record Results

- **Task:** Record the distance the marshmallow travels and any relevant observations.
- **Repeat:** For each pipe length (short, medium, long), launch **2-3 marshmallows** to get an average distance for each pipe length.

Step 5: Experiment with Different Pipe Lengths

- **Task:** Repeat the launch process for each **pipe length**: short (6"), medium (12"), and long (18").
    - For **each length**:
        1. Insert a marshmallow. Use a ruler to determine the distance in the pipe.
        2. Launch the marshmallow.
        3. Measure and record the distance traveled.
        4. Record observations.

- **Discussion:** Students will observe how the **length of the pipe** affects the marshmallow's speed, distance, and acceleration.
    - **Short pipe**: Less time for the air pressure to push the marshmallow, resulting in a shorter distance.
    - **Long pipe**: More time for the air to apply force, resulting in a longer distance.

Step 6: Vary Air Pressure

- **Task:** If time permits, you can vary the **air pressure** for each pipe length.
    - Start with **low pressure (20 PSI)**, then gradually increase to **medium pressure (40 PSI)** and **high pressure (60 PSI)**.
- **Discussion:** As the air pressure increases, the **force** on the marshmallow increases, causing it to accelerate more and travel farther. Students will observe how **increased force** leads to increased **acceleration** and **distance**.

Step 7: Data Analysis and Group Discussion

- **Task:** Have students compare their results across the different pipe lengths.
    - Which pipe length caused the marshmallow to travel the farthest? Why?
    - How did the marshmallow's **speed** and **distance** change with pipe length?
    - Discuss how **force** (from air pressure) and **time in the pipe** affected **acceleration**.

Discussion (5 minutes)

How did increasing the **pipe length** affect the marshmallow's travel distance? (The longer the pipe, the more time the marshmallow had to accelerate.)

What role does **air pressure** play in the distance and speed of the marshmallow? (Higher pressure = more force = more acceleration.)

How did the **mass** of the marshmallow affect its travel? (Heavier marshmallows may travel less far, requiring more force to accelerate.)

Can you apply Newton's Second Law of Motion (**F = ma**) to explain the results? (Higher force or longer acceleration time results in greater acceleration.)

Task: Have students reflect on what they learned about the relationship between **force**, **acceleration**, and **distance**.

Extension: Encourage them to predict how **mass** and **air resistance** might influence the marshmallow's flight if they were to test different types of marshmallows or launch from different angles.

"Great job today, everyone! Through this experiment, you explored how **air pressure**, **force**, **mass**, and **acceleration** influence the motion of objects—concepts that are critical not only in your daily life but also in industries like **aerospace**. In the aerospace industry, engineers use similar principles to design and launch **rockets**, **spacecraft**, and even *airplanes*.

Just like we saw with the marshmallow launcher, in aerospace applications, **compressed air** or **propellants** create **forces** that propel objects at high speeds. In a rocket launch, for example, **air pressure** and **propellant force** push the rocket upward against gravity, causing it to accelerate rapidly into space. Engineers also carefully calculate how much force is needed to lift different objects into the sky, taking into account the **mass** of the rocket and its cargo, much like we considered how the mass of the marshmallow affects its flight.

Additionally, in the design of **airplanes** or **spacecraft**, engineers account for factors like **air resistance**, **acceleration**, and **time** spent in the air (or in flight) to ensure that the vehicle reaches its destination efficiently. Just as we experimented with **different pipe lengths** to observe how they affect the marshmallow's speed and distance, aerospace engineers adjust the **size of rocket engines**, **fuel capacity**, and **shape** of the vehicle to maximize performance, reduce drag, and improve fuel efficiency.

In short, the very principles you applied today are foundational to the design, testing, and optimization of vehicles that travel at high speeds and even into space. Understanding these forces helps engineers make critical decisions that impact the safety and efficiency of aerospace missions."

Marshmallow Mayhem Data Results

Pressure	6" Pipe	12" Pipe	18" Pipe	Observations
Trial 1 20 psi				
Trial 2 20 psi				
Trial 3 20 psi				
Trial 1 40 psi				
Trial 2 40 psi				
Trial 3 40 psi				
Trial 1 60 psi				
Trial 2 60 psi				
Trial 3 60 psi				

Conclusions: