# Investigate Forces and Motion

**Hands-On Activity: Investigation**

## Activity Overview

**Grades: 6–8** **Suggested Duration: 45–60 minutes**

This *Expedition: Learn!* activity provides opportunities for students to apply and extend what they learned in the "Forces and Motion" lesson. Working in groups, students plan and conduct an investigation using dynamic carts, masses (weights), and a ramp to provide evidence that the change in the motion of an object subjected to unbalanced forces depends on the mass of the object and the size of the net force. Students observe that the greater the object's mass, the greater the force needed to change its motion, and the greater the net force acting on an object of consistent mass, the greater the change in motion.

## National Standards Related to This Activity

**NGSS MS-PS2-2:** Plan and conduct an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

- **DCI: PS2.A:** Forces and Motion
  - The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
  - All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.
- **SEP:** Planning and Carrying Out Investigations
- **CCC:** Stability and Change

## Materials

- Balances or scales (3 or 4 for the class)
- Dynamics carts with bumpers (2 per group)
- Masking tape (1 roll per group)
- Masses (8 per group)
- Meter sticks (2 or 3 per group)
- "Motion of a Bicycle" video (found in the Learn More section of the "Forces and Motion" lesson)
- Protractor (1 per group)
- Ramps (1 per group)
- Student activity sheet (digital or physical, 1 per student)

### Teaching Tips

Large washers with a mass of about 30 grams that fit inside the dynamic carts work well for this investigation. The ramp can be made using various materials, such as large pieces of cardboard or dry-erase boards and books. The ideal length is 1 meter.

## Preparation

- Gather and organize materials.
- Assign students to collaborative groups of three to five students.
- Prepare printed or editable digital copies of the student activity sheet.

## Teaching Tips

Decide in advance whether you will assign half the groups to each investigation question or allow them to choose which question to investigate. If it becomes logistically challenging for students to share their work with a group that researched the other question, it is recommended that a whole-class discussion be conducted during the closure to facilitate this exchange.

## Safety

- No special safety equipment or procedures are required.

# Introduction

1. Show the "Motion of a Bicycle" video found in the Learn More section at the end of the "Forces and Motion" lesson.
2. Invite students to share their knowledge and wonderings about the forces and motion of stationary and moving objects.
3. Inform students that they will plan and conduct an investigation to provide evidence that the change in an object's motion when subjected to unbalanced forces depends on the object's mass and the size of the net force. Some groups will investigate how changing the mass of a stationary cart affects the distance it travels when pushed. Other groups will investigate how changing the angle of a ramp, which directly relates to the cart's acceleration and the force applied, affects the distance a second stationary cart travels when pushed.
4. Discuss fair testing procedures, the types of data students might gather, the tools they might need to collect the data, how measurements might be recorded, and the amount of data required to produce reliable measurements.

# Procedure

1. Review the student activity sheet with students.
2. As necessary, provide additional instructions for gathering materials, safety, and working in groups.
3. Assign the remainder of the activity.
4. Ensure students have correctly followed the initial setup instructions.
5. Provide appropriate scaffolding based on student experience with planning and conducting investigations.

## Teaching Tips

For students testing the ramp angle, it is recommended to add two to four masses to cart B so that it does not travel as far, thereby making it easier to conduct the trials and accurately measure its distance.

# Closure

1. Instruct student groups to communicate their findings with a group that researched the same question and with a group that investigated the alternate question.
2. As a class, discuss and account for the similarities and differences in their investigations and results.
3. Review the analysis questions with students and evaluate student understanding of the following:
    - An object's motion is its change in position over time.
    - There are forces acting on all objects, whether they are moving or not. The combination of forces acting on an object determines its motion.
    - If those combined forces total zero, an object's motion remains unchanged. If the combined forces do not equal zero, there will be a change in the speed or direction of the object's motion.
    - The size, or magnitude, of combined forces determines how much the object's motion changes.

## Check for Understanding

**Use the questions below as a formative assessment at the end of the activity. Suggested formats include individual or group exit tickets or small-group or whole-class discussions.**

How are mass and acceleration related to force? [DOK: 2; DCI: PS2.A; CCC: Stability and Change]

**The greater the mass of the object, the greater the force needed to achieve the same acceleration as that of an object with a lower mass. For any given object, a larger force causes a larger acceleration.**

Why do unbalanced forces acting on an object cause a change in motion? [DOK: 2; DCI: PS2.A; CCC: Stability and Change]

**Unbalanced forces cause a change in motion because the motion of an object is determined by the sum of the forces acting on it. So, if the sum is not zero, the forces are unbalanced, and the object's motion will change.**

# Investigate Forces and Motion

**Hands-On Activity: Investigation (Answer Key)**

## Activity Overview

This *Expedition: Learn!* activity provides a hands-on opportunity to plan and conduct an investigation to provide evidence that the change in the motion of an object acted on by unbalanced forces depends on the mass of the object and the size of the net force. You will conduct one of two possible investigations.

| Investigation Question | In this investigation you will: |
|---|---|
| *Mass Investigation*<br>How does changing the mass of cart B affect how much its motion changes when acted on by an unbalanced force? | 1) observe the motion of cart B after it is pushed by cart A traveling down a ramp<br>2) examine how changing the mass of cart B changes its motion |
| *Angle Investigation*<br>How does changing the size of the net force acting on cart B affect how much its motion changes? | 1) observe the motion of cart B after it is pushed by cart A traveling down a ramp<br>2) examine how changing the angle of the ramp, which determines the force applied by cart A, changes the motion of cart B |

## Materials

- Balance or scale (for mass investigation)
- Dynamics carts with bumpers (2 per group)
- Masking tape (1 roll per group)
- Masses (8 per group)
- Meter sticks (2 or 3 per group)
- Protractor (1 per group)
- Ramp (1 per group)

## Safety

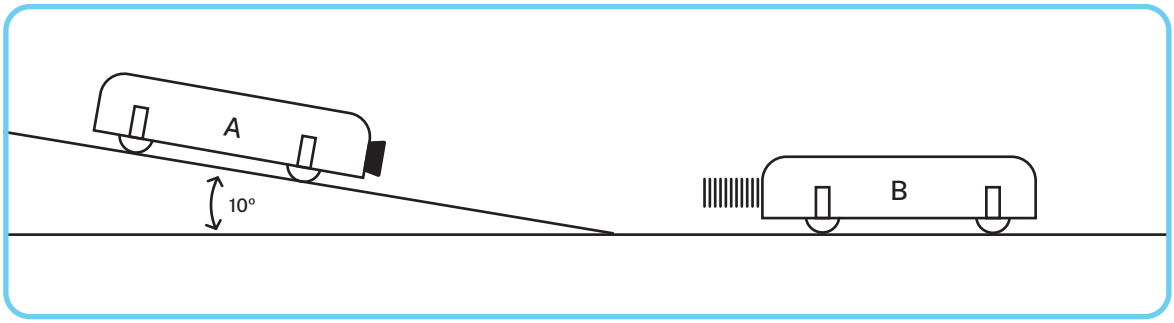
- Follow classroom rules for engaging in hands-on group activities.

# Procedure

## Initial Setup

1. Set up the ramp with an angle of about 10°.
2. Use the meter sticks and masking tape to create a track for the carts.
3. Attach a rubber bumper to one cart and a metal spring bumper to the other.
4. Use the diagram below to help plan the remainder of the setup based on the research question you are investigating. In the investigation, cart A will be released from a designated starting position on the ramp, while cart B will be at rest a specified distance from the bottom of the ramp.




## Plan Your Investigation

**[DOK: 4; DCI: PS2.A; SEP: Planning and Carrying Out Investigations; CCC: Stability and Change]**

**Research Question** (circle one)

**Mass investigation:** How does changing the mass of cart B affect how much its motion changes when acted on by an unbalanced force?

**Angle investigation:** How does changing the size of the net force acting on cart B affect how much its motion changes?

| Cause (Independent Variable) | Mechanism (Science Ideas) | Effect (Dependent Variable) |
|---|---|---|
| **Mass of cart B**<br>**Angle of the ramp** | *The change in an object's motion depends on the sum of the forces on the object and the mass of the object.* | **Motion of cart B (distance traveled)** |

**Hypothesis**

**For mass investigation:** We believe that cart B will **travel less distance** (describe its motion) when the **mass of cart B** (independent variable) is **increased**/decreased (circle one).

**For angle investigation:** We believe that cart B will **travel more distance** (describe its motion) when the **angle of the ramp** (independent variable) is **increased**/decreased (circle one).

**Procedure** (the steps you will take to investigate the research question)

**Sample student procedures. Student responses will vary.**

**For mass investigation:**

1. **Record the mass of each cart.**
2. **Mark the starting positions of both carts using tape.**
3. **Release cart A from the top of the ramp.**
4. **Record the distance cart B moves.**
5. **Repeat two times.**
6. **Add two masses to cart B and repeat steps 1–5.**
7. **Add four masses to cart B and repeat steps 1–5.**

**For angle investigation:**

1. **Mark the starting positions of both carts using tape.**
2. **Add four masses to cart B.**
3. **Release cart A from the top of the ramp.**
4. **Record the distance cart B moves.**
5. **Repeat two times.**
6. **Double the angle of the ramp and repeat steps 1–5.**
7. **Double the angle of the ramp and repeat steps 1–5.**

**Constants** (what you will keep the same during every trial)

- **The starting locations**
- **The carts used for A and B**
- **The number of trials**
- **The angle of the ramp (for mass investigation)**
- **The mass in the cart (for angle investigation)**

**Data Table** (number of trials, type of data you will collect, and measurements you will use)

**Sample tables with examples of student data. Student responses will vary.**

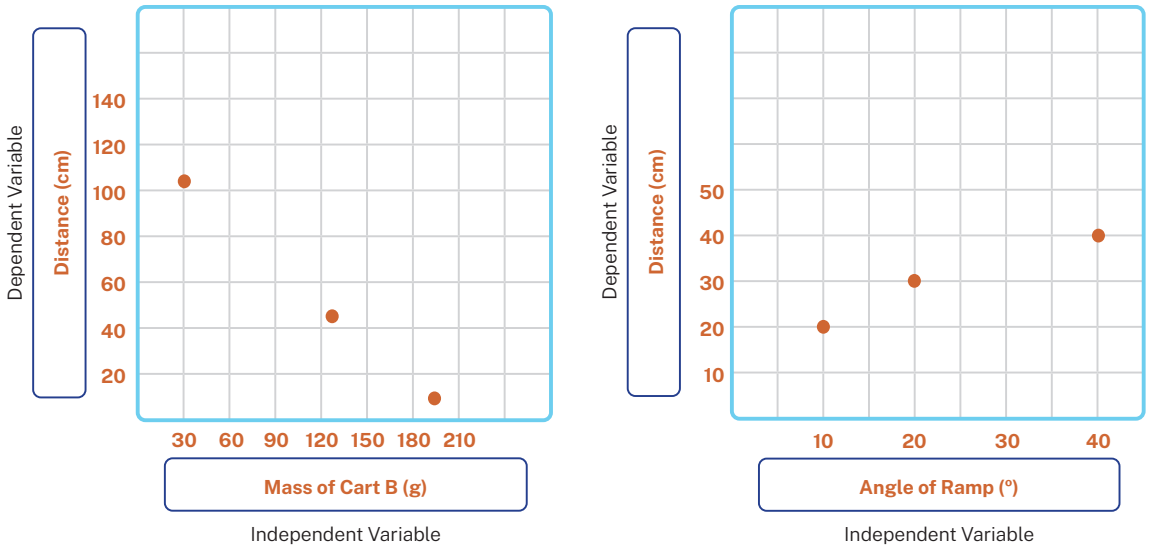
| Trial | Cart A Mass (g) | Cart B Mass (g) | Distance Cart B Moves (cm) |
|---|---|---|---|
| 1 | 63 | 63 | 103 |
| 2 | 63 | 63 | 110 |
| 3 | 63 | 63 | 104 |
| 4 | 63 | 127 | 48 |

| Trial | Ramp Angle | Distance Cart B Moves (cm) |
|---|---|---|
| 1 | 10° | 10 |
| 2 | 10° | 12 |
| 3 | 10° | 11 |
| 4 | 20° | 20 |

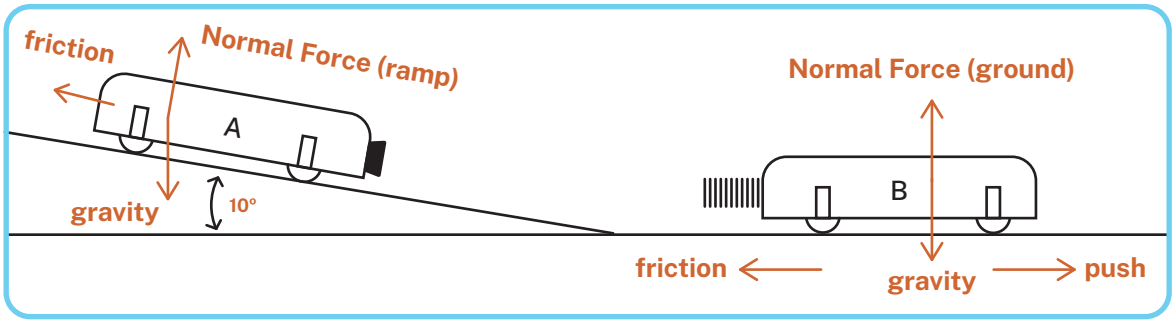
**Graph** (the averaged data for each test of the independent variable)

**Sample graphs with examples of student data. Student responses will vary.**




## Analysis

Draw and label a force diagram for your investigation. **[DOK: 3; DCI: PS2.A; SEP: Planning and Carrying Out Investigations; CCC: Stability and Change]**



**Research Question: How does changing the mass of cart B affect how much its motion changes when acted on by an unbalanced force?**

1. How did the mass of cart B affect its motion after the collision? **[DOK: 2; DCI: PS2.A; SEP: Planning and Carrying Out Investigations; CCC: Stability and Change]**
   **As the mass of cart B increased, the distance it traveled after the collision decreased.**

2. Why did the mass of cart B affect its motion after the collision? **[DOK: 3; DCI: PS2.A; SEP: Planning and Carrying Out Investigations; CCC: Stability and Change]**
   **A larger mass requires more force to achieve the same change in motion.**

3. How might you increase the distance cart B travels? **[DOK: 3; DCI: PS2.A; SEP: Planning and Carrying Out Investigations; CCC: Stability and Change]**
   **To make cart B travel farther, I would add masses to cart A to provide a larger force or push.**

**Research Question: How does changing the size of the net force acting on cart B affect how much its motion changes?**

1. How did changing the angle of the ramp (acceleration) affect the motion of cart B? **[DOK: 2; DCI: PS2.A; SEP: Planning and Carrying Out Investigations; CCC: Stability and Change]**
   **The larger the angle of the ramp, the farther cart B traveled after the collision.**

2. Why did changing the angle of the ramp (acceleration) affect the motion of cart B? **[DOK: 3; DCI: PS2.A; SEP: Planning and Carrying Out Investigations; CCC: Stability and Change]**
   **A steeper ramp causes cart A to have a greater acceleration, which is directly proportional to force ($F = ma$). A larger force pushes the second cart farther in a collision.**

3. How might you decrease the distance cart B travels? **[DOK: 3; DCI: PS2.A; SEP: Planning and Carrying Out Investigations; CCC: Stability and Change]**
   **I would have the smallest angle for the ramp that still allows cart A to travel down and bump cart B. Adding masses to cart B would also prevent it from traveling as far.**

| Name: | Date: |
|---|---|

# Investigate Forces and Motion

**Hands-On Activity: Investigation (Student Activity Sheet)**

## Activity Overview

This *Expedition: Learn!* activity provides a hands-on opportunity to plan and conduct an investigation to provide evidence that the change in the motion of an object acted on by unbalanced forces depends on the mass of the object and the size of the net force. You will conduct one of two possible investigations.

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| *Angle Investigation*<br>How does changing the size of the net force acting on cart B affect how much its motion changes? | 1) observe the motion of cart B after it is pushed by cart A traveling down a ramp<br>2) examine how changing the angle of the ramp, which determines the force applied by cart A, changes the motion of cart B |

## Materials

- Balance or scale (for mass investigation)
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- Protractor (1 per group)
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## Safety

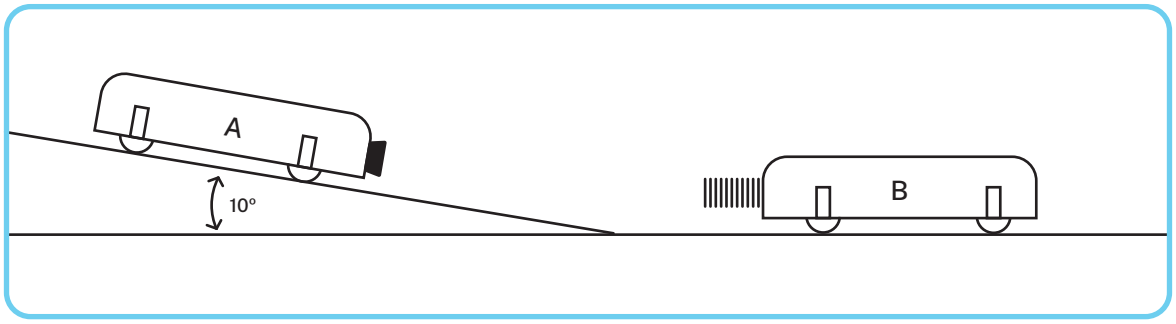
- Follow classroom rules for engaging in hands-on group activities.

# Procedure

## Initial Setup

1. Set up the ramp with an angle of about 10°.
2. Use the meter sticks and masking tape to create a track for the carts.
3. Attach a rubber bumper to one cart and a metal spring bumper to the other.
4. Use the diagram below to help plan the remainder of the setup based on the research question you are investigating. In the investigation, cart A will be released from a designated starting position on the ramp, while cart B will be at rest a specified distance from the bottom of the ramp.




## Plan Your Investigation

**Research Question** (circle one)

**Mass investigation:** How does changing the mass of cart B affect how much its motion changes when acted on by an unbalanced force?

**Angle investigation:** How does changing the size of the net force acting on cart B affect how much its motion changes?

| Cause (Independent Variable) | Mechanism (Science Ideas) | Effect (Dependent Variable) |
|---|---|---|
| | *The change in an object's motion depends on the sum of the forces on the object and the mass of the object.* | |

**Hypothesis**

We believe that cart B will _____ (describe its motion) when the

_____ (independent variable) is increased/decreased (circle one).

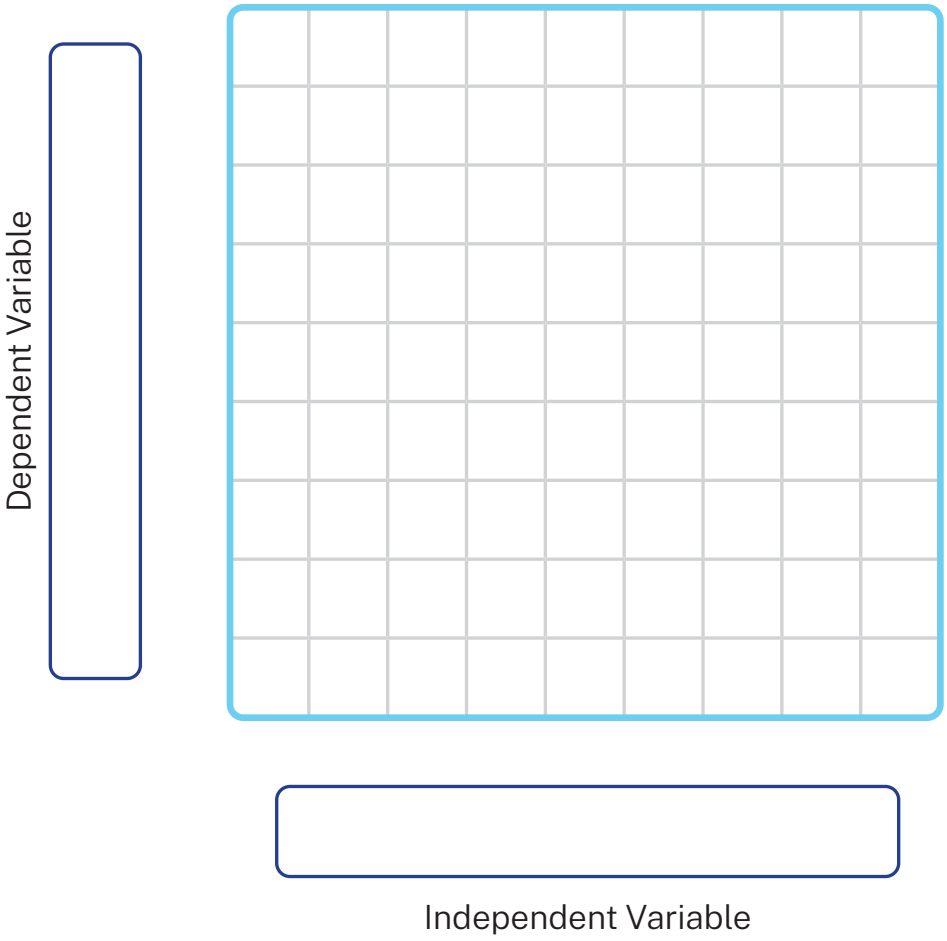
**Procedure** (the steps you will take to investigate the research question)

**Constants** (what you will keep the same during every trial)

**Data Table** (number of trials, type of data you will collect, and measurements you will use)

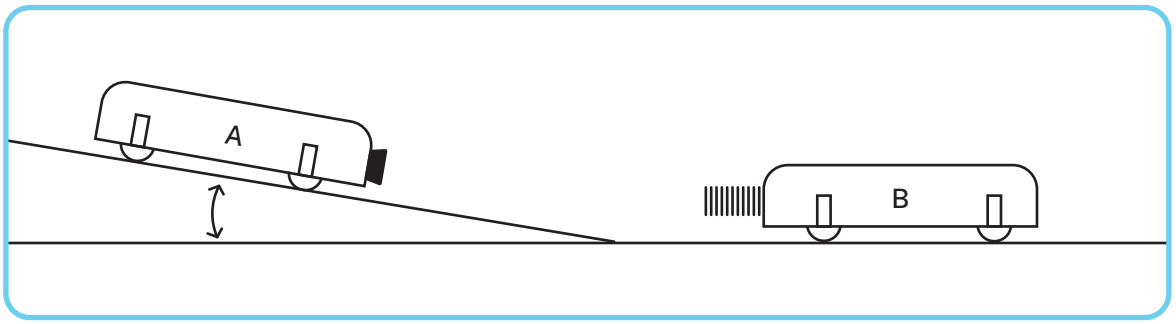
 

**Graph** (the averaged data for each test of the independent variable)



# Analysis

Draw and label a force diagram for your investigation.




**Research Question: How does changing the mass of cart B affect how much its motion changes when acted on by an unbalanced force?**

1. How did the mass of cart B affect its motion after the collision?

2. Why did the mass of cart B affect its motion after the collision?

3. How might you increase the distance cart B travels?

**Research Question: How does changing the size of the net force acting on cart B affect how much its motion changes?**

1. How did changing the angle of the ramp (acceleration) affect the motion of cart B?

2. Why did changing the angle of the ramp (acceleration) affect the motion of cart B?

3. How might you decrease the distance cart B travels?