

# Collisions and Momentum in 1D

## Teacher's Guide

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### 1.0 Summary

*Collisions and Momentum in 1D* is the sixth activity in the Dynamica sequence. This activity should be done after *Force in 2D* and it should take students approximately 20 minutes. This is a fairly basic activity that only includes collisions on the x-dimension. The activity gives students a solid foundation for *Advanced Collisions*, the next activity in the sequence.

### 2.0 Learning Goals

**Driving Question:** When two items collide, what happens to their velocities?

This activity presents a model of two balls colliding and asks students to figure out the rules for what happens to the ball's respective velocities when they collide.

Step One: **Balls of the Same Mass** introduces students to collisions by observing collisions of pool balls of the same mass. Students are introduced to linear momentum and the equation  $p=mv$ .

Step Two: **Balls of Different Masses** encourages students to predict what different masses do when they collide. This section also allows students to discover the rules for final velocities when each ball has a different mass.

Step Three: **The Law of Conservation of Momentum** introduces students to this law. Students learn how to calculate the total momentum for a system both before and after a collision. Then, students are given various experiments to test the law.

Step Four: **The Mystery Ball** section has one ball colliding with a mystery ball. Students must observe the collision, look at a data table and draw conclusions about the mass of the hidden ball.

Step Five: **Quiz** contains three questions meant to ensure that students understand the basic concepts of collisions.

#### Additional Teacher Background

This activity is somewhat abstract. The few situations in the visible world where objects collide and neatly exchange velocities may seem contrived. But it's a worthwhile exploration for a number of reasons:

- Students get used to noticing the conditions before and after an event.
- Students do math involving both positive and negative velocity.
- The activity leads toward momentum and how it enables one to deal with different masses.

- The notion of a *conservation law*, where some quantity (in this case velocity) is the same before and after an event, is a very important tool in physics. Understanding the conservation of energy (see the *Energy* activity) is especially valuable.
- The use of a law (such as exchange of velocities) is often used to infer a quantity that cannot be measured directly - in this case, the velocity of a hidden ball.

### Additional Activities

*Collisions:* Use two sonar rangers to explore the before-and-after velocities of low-friction carts. If the masses are equal, do they exchange velocities? If not, can you explain why not?

## 3.0 Standards Alignment

### Alignment to National Math and Science Standards (NCTM or NSES)

Objective	Standards
<b>Students will discover rules for collisions by doing experiments.</b>	<ul style="list-style-type: none"> <li>• Students should draw reasonable conclusions about a situation being modeled.</li> <li>• Students should use the language of mathematics to express mathematical ideas precisely.</li> <li>• Students should recognize and apply mathematics in contexts outside of mathematics.</li> </ul>
<b>Students will understand the meaning of positive and negative velocity.</b>	<ul style="list-style-type: none"> <li>• Students should use the language of mathematics to express mathematical ideas precisely.</li> </ul>
<b>Students will use the conservation of velocity rule in collisions of equal masses.</b>	<ul style="list-style-type: none"> <li>• Students should draw reasonable conclusions about a situation being modeled.</li> <li>• Students should make and investigate mathematical conjectures.</li> </ul>

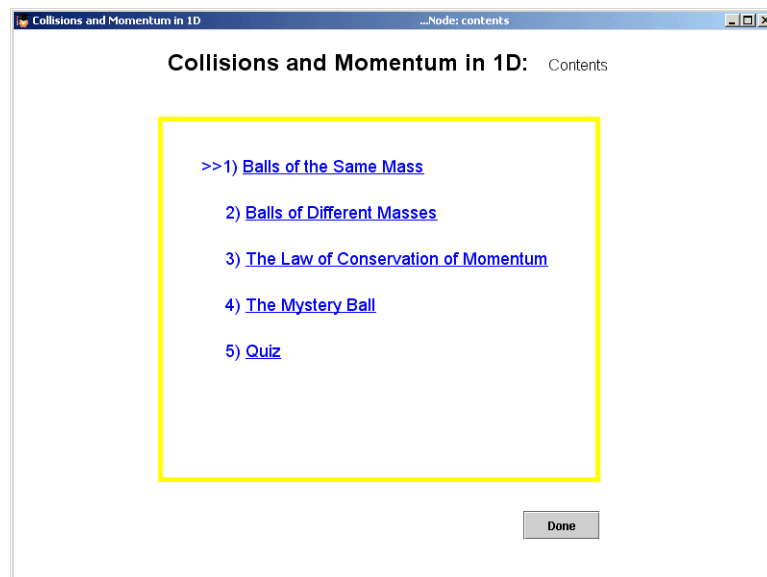


Opening screen

## 4.0 Activity Sections

### 4.1 Table of Contents

This activity has 7 sections. The required sections of this activity are sections 1 through 6. The last section is a "Lab" within which teachers may assign students custom experiments.



### 4.2 1) Balls of the Same Mass

In this section, students run models and observe that when two objects of the same mass collide, they exchange velocities. Of course, the model depicts a frictionless environment.

Collisions and Momentum in 1D ...Node: Same\_Mass\_02

1 square = 1 meter

Run the model again.

1. Fill in the values for the initial velocity for each ball.

Green  m/s

Yellow  m/s

2. Fill in the values for the final velocity for each ball.

Green  m/s

Yellow  m/s

**Submit Answer(s)**

Correct! Go on.

4 m/s ← **6** 5 kg      **1** 5 kg → 1 m/s

**2** Seconds

**Pause** **Reset**

Model showing the exchange of velocities

Collisions and Momentum in 1D ...Node: Same\_Mass\_03

1 square = 1 meter

Now, one of the balls is at rest. Before you run the model, answer the following question.

3. In the last model, both balls were moving. Now, one ball isn't moving. What do you think will happen now?

**Submit Answer(s)**

**6** 5 kg → 2 m/s      **1** 5 kg

**0** Seconds

**Run** **Reset**

Students are asked to predict what will happen with one ball at rest.

Collisions and Momentum in 1D ...Node: Same\_Mass\_05

1 square = 1 meter

The arrows attached to the balls represent the horizontal velocity of each ball ( $v_x$ ). The length of the arrow is how far the ball will go in one second.

You can set the velocity by using the slider below the model. Choose a velocity for each ball using the sliders and observe the length of the arrows change.

Run the model a few times, using different velocities. Try both positive and negative velocities.

0 Seconds

Run Reset

Green Yellow

-4 -2 0 2 4 m/s -4 -2 0 2 4 m/s

Students experiment with initial velocities.

Collisions and Momentum in 1D ...Node: Same\_Mass\_07

An Introduction to Linear Momentum

When any mass is moving, with a positive or negative velocity, the mass is said to have momentum. Momentum is denoted by the letter "p" and is a vector quantity, which means that momentum has both a magnitude and a direction. The momentum of an object can be found by multiplying its mass by its velocity.

$$p = m \cdot v$$

6. Consider the following scenario. Calculate the momentum of each ball in the system. The balls are both 1 kg.

Green 0 kg\*m/s ✓ Check it!

Yellow -6 kg\*m/s ✓ Check it!

Later on in this activity, you will learn how momentum is conserved during collisions.

Correct! Go on.

Introduction to linear momentum

## 4.3 2) Balls of Different Masses

In this section, students run models of collisions with two balls of different mass. First, they are asked to predict what will happen after the collision. Then, they are guided through various scenarios.

Collisions and Momentum in 1D ...Node: Different\_Masses\_01

1 square = 1 meter

**Demonstration 2**

In this model, the mass of the blue ball is 4 kg and the mass of the orange ball is 1 kg.

7. How do you think the different masses of the balls will affect their final velocities after the collision?

Not sure.

Submit Answer(s)

Run the model and test your prediction.

0 Seconds

4 m/s

4 kg

1 kg

Run Reset

Run the model and examine the graphs.

Collisions and Momentum in 1D ...Node: Different\_Masses\_02

1 square = 1 meter

In this model, the mass of the blue ball is 8 kg and the mass of the orange ball is 1 kg.

8. What will happen to the blue ball when the balls collide?

The blue ball will stop.

The blue ball will bounce back.

The blue ball will follow the orange.

Submit Answer(s)

After you submit your answer, run the model to test your prediction.

0 Seconds

3 m/s

8 kg

1 kg

Run Reset

The student is asked to predict the result of this collision.

### 4.4 3) The Law of the Conservation of Momentum

This section helps students better understand the Law of Conservation of Momentum. In this section, students learn to calculate the total momentum of a system both before and after a collision. Then, they are given three experiments to conduct that “test” this law.

**Collisions and Momentum in 1D** ...Node: Test\_Law\_01

### The Conservation of Linear Momentum

As you have observed, when objects of the same mass collide they "transfer" velocities. During any collision, even with objects of different masses, momentum is conserved. This means that the total momentum before a collision is always equal to the total momentum after a collision. This law is called the The Conservation of Linear Momentum. In the example below, the total momentum (p) both before and after the collision is -1kg(m/s).

Before Collision	After Collision
$p_1 = 1\text{kg} * 2\text{m/s} = 2\text{kg(m/s)}$ $p_2 = 1\text{kg} * -3\text{m/s} = -3\text{kg(m/s)}$ $p_{\text{total}} = p_1 + p_2 = 2\text{kg(m/s)} + -3\text{kg(m/s)}$ <b><math>p_{\text{total}} = -1\text{kg(m/s)}</math></b>	$p_1 = 1\text{kg} * -3\text{m/s} = -3\text{kg(m/s)}$ $p_2 = 1\text{kg} * 2\text{m/s} = 2\text{kg(m/s)}$ $p_{\text{total}} = p_1 + p_2 = -3\text{kg(m/s)} + 2\text{kg(m/s)}$ <b><math>p_{\text{total}} = -1\text{kg(m/s)}</math></b>

When the masses are unequal, the velocities are also transferred but the magnitude of the velocities is dependent on the mass of each of the objects.

The law as applied to objects of the same mass

**Collisions and Momentum in 1D** ...Node: Test\_Law\_02

### The Conservation of Linear Momentum

Here is an example of a collision with two balls of different mass. The green ball is 6kg and the yellow ball is now 2kg. As mentioned earlier, momentum is conserved in this collision; therefore,  $p_{\text{total}}$  before the collision is equal to  $p_{\text{total}}$  after the collision.

Before Collision	After Collision
$p_1 = 6\text{kg} * 4\text{m/s} = 24\text{kg(m/s)}$ $p_2 = 1\text{kg} * 0\text{m/s} = 0\text{kg(m/s)}$ $p_{\text{total}} = p_1 + p_2 = 24\text{kg(m/s)} + 0\text{kg(m/s)}$ <b><math>p_{\text{total}} = 24\text{kg(m/s)}</math></b>	$p_1 = 6\text{kg} * 2\text{m/s} = 12\text{kg(m/s)}$ $p_2 = 2\text{kg} * 6\text{m/s} = 12\text{kg(m/s)}$ $p_{\text{total}} = p_1 + p_2 = 12\text{kg(m/s)} + 12\text{kg(m/s)}$ <b><math>p_{\text{total}} = 24\text{kg(m/s)}</math></b>

This simple law may seem too good to be true. Go on to conduct a few experiments to test this law and prove to yourself that it works with different masses.

The law as applied to objects of different mass

Collisions and Momentum in 1D ...Node: Test\_Law\_03

1 square = 1 meter

0 Seconds

Now, you can run your own experiments to test the law of conservation. Try to change the settings such that the blue ball completely stops. Then, answer the question below.

**Experiment 1**

10. What must be true in order for the blue ball to completely stop?

Submit Answer(s)

After you submit your answer, go on to the next experiment.

	Blue	Orange
Mass	2	5
Initial Velocities	4	0
Final Velocities	0	0
Momentum	8	0

Experiment 1

Collisions and Momentum in 1D ...Node: Test\_Law\_05

1 square = 1 meter

0 Seconds

Adjust the settings such that you give the orange ball the greatest possible velocity.

**Experiment 2**

11. What settings give the greatest possible velocity to the orange ball?

Submit Answer(s)

After you submit your answer, go on to the next experiment.

	Blue	Orange
Mass	2	5
Initial Velocities	4	0
Final Velocities	0	0
Momentum	8	0

Experiment 2



Collisions and Momentum in 1D ...Node: Test\_Law\_06

1 square = 1 meter

Adjust the settings such that you give the orange ball the greatest possible velocity.

**Experiment 3**

12. Is there a setting where the blue ball bounces back with the same velocity it started with (4m/s)?

Yes

No

Explain why and why not?

**Submit Answer(s)**

After you submit your answer, go on.

0 Seconds

4 m/s

2 kg

5 kg

**Run Reset**

	Blue	Orange
Mass	2	5
Initial Velocities	4	0
Final Velocities	0	0
Momentum	8	0

Experiment 3

#### 4.5 4) The Mystery Ball

Now, students observe a collision with a hidden ball. Students are asked to run the model and, based on their observations, determine the mass of the hidden ball.

Collisions and Momentum in 1D ...Node: Mystery\_01

1 square = 1 meter

**The Mystery Ball**

This section presents a new challenge. There is now a hidden ball and the blue ball will hit it when you run the model.

13. Compared to the blue ball, the mystery ball's mass is:

greater

less

the same

**Submit Answer(s)**

0 Seconds

2 m/s

2 kg

**Run Reset**

	Blue	Orange
Mass	2	?
Initial Velocities	2	0
Final Velocities	0	0
Momentum	4	0

First scenario- the hidden ball's mass is less than the blue ball.

Collisions and Momentum in 1D ...Node: Mystery\_02

1 square = 1 meter

**The Mystery Ball**

Now, the mystery ball has changed its mass. The hidden ball is initially at rest. Run the model before you answer the question.

14. Compared to the blue ball, the mystery ball's mass is:

greater

less

the same

Submit Answer(s)

Run Reset

0 Seconds

2 m/s

2 kg

	Blue	Orange
Mass	2	?
Initial Velocities	2	0
Final Velocities	0	0
Momentum	4	0

Second scenario- the hidden ball's mass is greater than the blue ball.

Collisions and Momentum in 1D ...Node: Mystery\_03

1 square = 1 meter

**The Mystery Ball**

The mystery ball has changed mass once again. The hidden ball is initially at rest. The hidden ball is initially at rest. Run the model before you answer the question.

What is the mass of the mystery ball:

m/s

Submit Answer(s)

Run Reset

0 Seconds

2 m/s

2 kg

	Blue	Orange
Mass	2	?
Initial Velocities	2	0
Final Velocities	0	0
Momentum	4	0

Third scenario- the hidden ball's mass is equal (2kg) to the blue ball.

## 4.6 5) Quiz

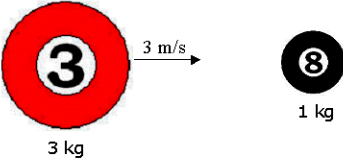
This assessment contains three questions. At the end of the quiz, students will see their total score. In addition, they will be able to review the questions and see the correct answers to any question that they may have answered incorrectly.

Correct answers: 1-C 2-D 3-C

Collisions and Momentum in 1D ...Node: quiz1

**Quiz time!**

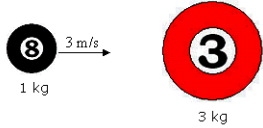
1. The red ball is moving to the right at 3 m/s and hits the black ball that is not moving. After the collision, the **red** ball will have a velocity to the right that is:



A) equal to 3 m/s.  
 B) faster than 3 m/s.  
 C) slower than 3 m/s.

Collisions and Momentum in 1D ...Node: quiz2

Suppose the situation is reversed. The black ball is moving to the right at 3 m/s and hits the red ball that is not moving.



2. After the collision, the **black** ball will:

A) keep going at 3 m/s.  
 B) keep going but more slowly.  
 C) come to a stop.  
 D) bounce back.

3. After the collision, the **red** ball will have a velocity to the right that is:

A) equal to 3 m/s.  
 B) faster than 3 m/s.  
 C) slower than 3 m/s.


Collisions and Momentum in 1D

**Congratulations!** You have completed the quiz at the end of the Collisions and Momentum in 1D activity. You will need the graph interpreting skills you learned here in the remaining Dynamica activities.

**Your score:**  
3/3

**Excellent work!**

Click on the question number below to see the correct answer for each question.



#	Answer	Correct
<a href="#">1</a>	C	✓
<a href="#">2</a>	D	✓
<a href="#">3</a>	C	✓

Done

Students can review correct answers by clicking on the question numbers.

## 5.0 Student Reports

Your students' work with the *Collisions and Momentum in 1D* activity is logged and viewable on the MAC Project Web Portal at <http://mac.concord.org>. For each student, you can view a report containing questions and student answers.

The next activity in the sequence should be *Advanced Collisions*.