Collisions in One Dimension – ID: 8879

By Charles W. Eaker

Time required
45 minutes

Topic: Momentum and Collisions

- *Compare kinetic energy and momentum.*
- *Classify collisions as elastic or inelastic.*
- *Compare the momentums of two objects before and after inelastic collisions.*

Activity Overview

In this activity, students will use the law of conservation of momentum to determine the momentums and velocities of objects involved in perfectly inelastic collisions. They will use a simulation to model a snowball being tossed from one skater to another. This simulation will allow them to explore conservation of momentum in one-dimensional collisions.

Materials

To complete this activity, each student will require the following:

- *TI-Nspire™ technology*
- *pen or pencil*
- *blank sheet of paper*

TI-Nspire Applications

Graphs & Geometry, Notes, Lists & Spreadsheet, Data & Statistics

Teacher Preparation

Before carrying out this activity, review the calculation of momentum and the law of conservation of momentum. Discuss with students the differences between elastic, inelastic, and perfectly inelastic collisions. Review the calculation of the kinetic energy of a moving object.

- *The screenshots on pages 2–5 demonstrate expected student results. Refer to the screenshots on pages 6–7 for a preview of the student TI-Nspire document (.tns file).*
- ***To download the .tns file, go to education.ti.com/exchange and enter "8879" in the search box.***

Classroom Management

- *This activity is designed to be **teacher-led** with students following along on their handhelds. You may use the following pages to present the material to the class and encourage discussion. Note that the majority of the ideas and concepts are presented only in **this** document, so you should make sure to cover all the material necessary for students to comprehend the concepts.*
- *Students may answer the questions posed in the .tns file using the Notes application or on blank paper.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*

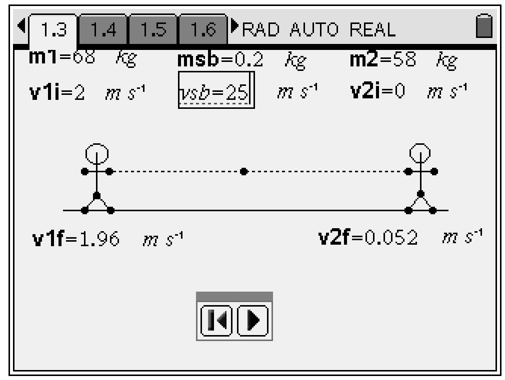
The following questions will guide student exploration in this activity:

- What happens to total momentum during a one-dimensional collision?
- Is kinetic energy conserved in a perfectly inelastic collision?

Students will explore the motion of a snowball tossed between two skaters. They will graphically determine the velocities of the two skaters from distance and time data, use the law of conservation of momentum to account for the final velocities of the skaters, and calculate the kinetic energy before and after the snowball is caught.

Part 1 – Relationship between distance, time, velocity, and momentum

Step 1: Students should open the file **PhyAct_8879_1Dcollisions.tns** and read the first two pages. On page 1.3, students will observe a simulation of a snowball being tossed from a moving skater to a stationary skater. Students should vary the velocity of the snowball (**vsb**) and observe the effects on the final velocities (**v1f** and **v2f**) of the two skaters.



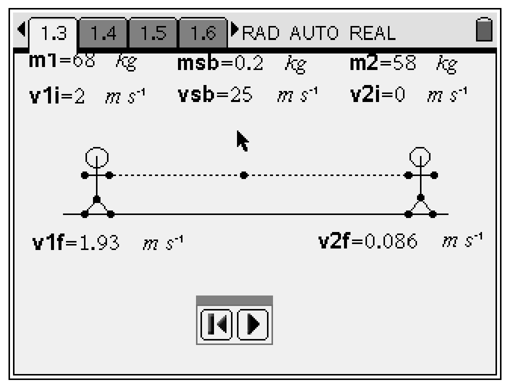
Step 2: Next, students should answer questions 1 and 2 on page 1.4.

Q1. How does changing the velocity of the snowball affect **v2f**?

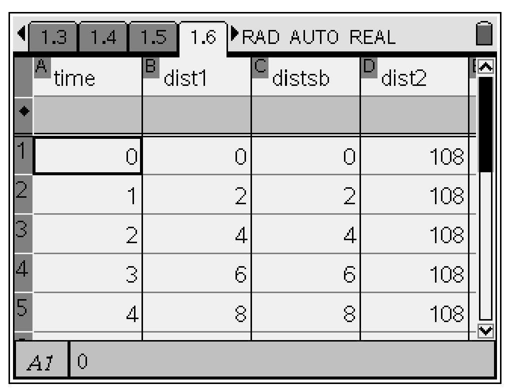
A. *As **vsb** increases, **v2f** increases. As **vsb** decreases, **v2f** decreases.*

Q2. How does changing the velocity of the snowball affect **v1f**?

A. *As **vsb** increases, **v1f** decreases. As **vsb** decreases, **v1f** increases.*

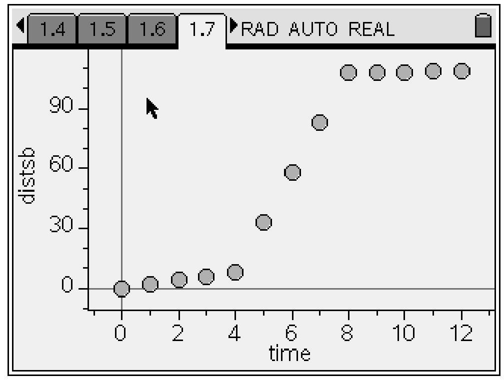


Step 3: Next, students determine the velocity of the snowball as it is thrown from one skater to the other. They assume a scenario in which skater 1 holds the snowball for 4 seconds, then throws it to skater 2, who catches it 4 seconds later. The spreadsheet on page 1.6 gives the position in meters of skater 1, the snowball, and skater 2 at different times. The spreadsheet will automatically update as students vary the velocity of the snowball. You may wish to assign different groups of students to use different values for **vsb**, and then compare the groups' results.

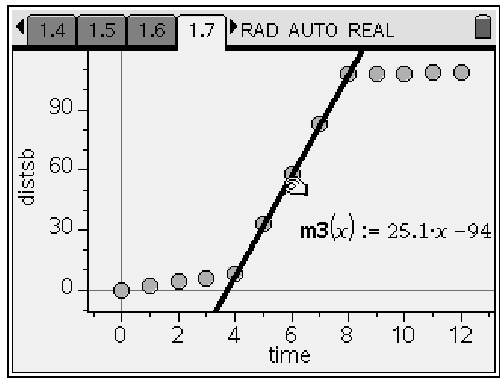


	A time	B dist1	C distsb	D dist2
1	0	0	0	108
2	1	2	2	108
3	2	4	4	108
4	3	6	6	108
5	4	8	8	108

Step 4: Students should use the *Data & Statistics* application on page 1.7 to plot the position of the snowball (**distsb**) vs. **time**. Discuss the shape of the graph with students.



Step 5: Next, students should use the **Movable Line** tool (**Menu > Analyze > Add Movable Line**) to identify the relationship between distance, time, and velocity for the snowball in each of the three regions (0–4 sec, 4–8 sec, and 8–12 sec). Then, students should answer questions 3–10 on pages 1.8–1.11.



Q3. What is the significance of the slope of the best-fit line through the data points from 0 sec to 4 sec?

A. *It is equal to the magnitude of the initial velocity of skater 1.*

Q4. What is the significance of the slope of the best-fit line through the data points from 4 sec to 8 sec?

A. *It is equal to the magnitude of the velocity of tossed snowball.*

Q5. What is the significance of the slope of the best-fit line through the data points from 8 sec to 12 sec?

A. *It is equal to the magnitude of the final velocity of skater 2.*

Q6. If the mass of the snowball is 0.20 kg and its velocity is 12. m s^{-1} east, what is the momentum of the snowball? Show your work.

A.

$$momentum = mass \bullet velocity$$

$$momentum_{snowball} = (0.20\ kg)(12.\ m/s\ east)$$

$$momentum_{snowball} = 2.4\ kg \bullet m/s\ east$$

Q7. What is the momentum of skater 2 and the snowball after skater 2 catches the snowball? Explain your answer.

A. *Skater 2 has no initial momentum. Momentum is conserved during a completely inelastic collision. Therefore, when skater 2 catches the snowball, the total momentum of the skater and the snowball will be equal to the momentum of the snowball before the skater catches it: 2.4 kg·m/s east.*

Q8. Write an equation for **v2f** in terms of **msb**, **vsb**, and **m2** (assume **v2i** is zero).

A.

$$\textit{final momentum} = \textit{initial momentum}$$

$$(\mathbf{m2} + \mathbf{msb})(\mathbf{v2f}) = (\mathbf{msb})(\mathbf{vsb})$$

$$\mathbf{v2f} = \frac{(\mathbf{msb})(\mathbf{vsb})}{\mathbf{m2} + \mathbf{msb}}$$

Q9. What law did you use to write the equation for **v2f**?

A. *the law of conservation of momentum*

Q10. Apply this same law to write an equation for **v1f** in terms of **msb**, **vsb**, **m1**, and **v1i**.

A.

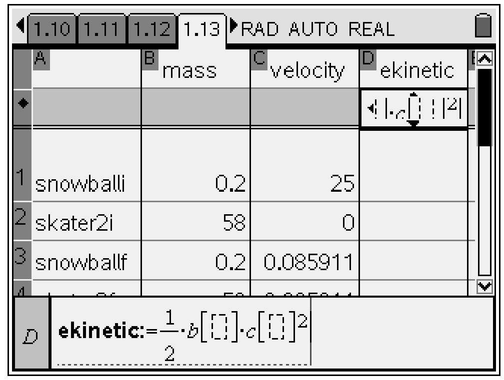
$$\textit{final momentum} = \textit{initial momentum}$$

$$(\mathbf{m1})(\mathbf{v1f}) + (\mathbf{msb})(\mathbf{vsb}) = (\mathbf{m1} + \mathbf{msb})(\mathbf{v1i})$$

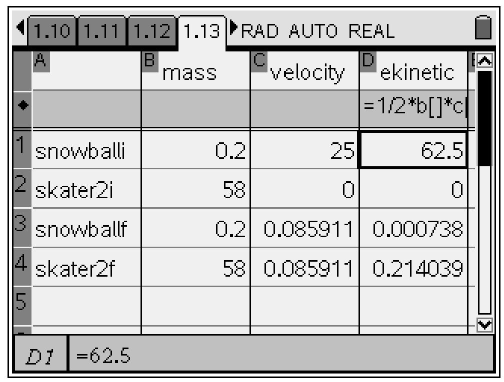
$$(\mathbf{m1})(\mathbf{v1f}) = (\mathbf{m1} + \mathbf{msb})(\mathbf{v1i}) - (\mathbf{msb})(\mathbf{vsb})$$

$$\mathbf{v1f} = \frac{(\mathbf{m1} + \mathbf{msb})(\mathbf{v1i}) - (\mathbf{msb})(\mathbf{vsb})}{\mathbf{m1}}$$

Part 2 – Calculating kinetic energy



Step 1: Page 1.13 contains a spreadsheet with the mass and velocity of the snowball and skater 2 before and after the snowball is caught. Students should enter the equation for kinetic energy, $K_E = \frac{1}{2}mv^2$, in the formula cell of Column D.



Step 2: Finally, students should answer questions 11 and 12 on page 1.14.

Q11. What is the total kinetic energy of the system before and after the snowball is caught?

A. *Students' answers will vary depending on the value of **vsb** they enter. For **vsb** = 12. m/s east, the initial total kinetic energy of the system is 14.4 J, and the final total kinetic energy of the system is 0.049 J.*

Q12. Is kinetic energy conserved in the "collision" of the snowball with skater 2? Explain your answer.

A. *Kinetic energy is not conserved during the collision. During a completely inelastic collision, momentum is conserved, but kinetic energy is not. Students may conclude that this violates the law of conservation of energy. Remind them that the law of conservation of energy applies to the total energy of the system, not to only kinetic energy.*

Collisions in One Dimension – ID: 8879

(Student)TI-Nspire File: *PhyAct_8879_1Dcollisions.tns*

1.1 RAD AUTO REAL

COLLISIONS IN ONE DIMENSION

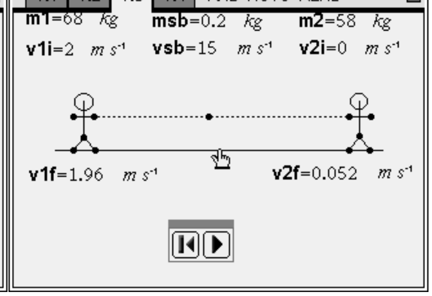
Physics

Momentum and Collisions

1.2 RAD AUTO REAL

The diagram on page 1.3 shows two skaters. Skater 1 has mass **m1** and is initially moving with velocity **v1i** east. Skater 2 has mass **m2** and is initally not moving (**v2i** = 0). Skater 1 throws a snowball of mass **msb** to skater 2. The velocity of the snowball is **vsb** east. The final velocities of the skaters are **v1f** and **v2f** east, respectively.

1.3 RAD AUTO REAL



1.4 RAD AUTO REAL

1. How does changing the velocity of the snowball affect **v2f**?

2. How does changing the velocity of the snowball affect **v1f**?

1.5 RAD AUTO REAL

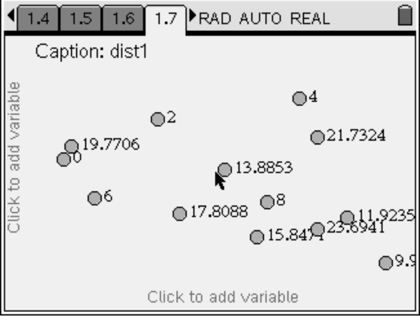
Suppose skater 1 throws the snowball after gliding for 4 seconds, and skater 2 catches the snowball 4 seconds later. The spreadsheet on the next page gives the position in meters of skater 1, the snowball, and skater 2 at different times. Make a plot of the position of the snowball (**distsb**) vs. **time** on page 1.7.

1.6 RAD AUTO REAL

	A time	B dist1	C distsb	D dist2
◆				
1	0	0	0	68
2	1	2	2	68
3	2	4	4	68
4	3	6	6	68
5	4	8	8	68

A1 0

1.7 RAD AUTO REAL



1.8 RAD AUTO REAL

3. What is the significance of the slope of the best-fit line through the data points from 0 sec to 4 sec?

4. What is the significance of the slope of the best-fit line through the data points from 4 sec to 8 sec?

1.9 RAD AUTO REAL

5. What is the significance of the slope of the best-fit line through the data points from 8 sec to 12 sec?

6. If the mass of the snowball is 0.20 kg and its velocity is 12. m s^{-1} east, what is the momentum of the snowball? Show your work.

1.10 RAD AUTO REAL

7. What is the momentum of skater 2 and the snowball after skater 2 catches the snowball? Explain your answer.

8. Write an equation for **v2f** in terms of **msb, vsb**, and **m2** (assume **v2i** is zero).

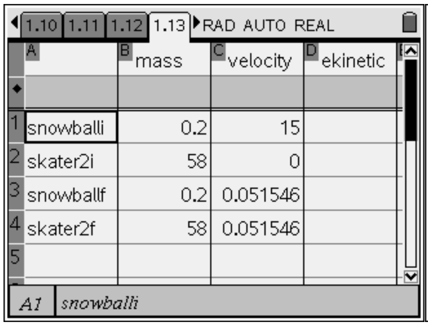
1.11 RAD AUTO REAL

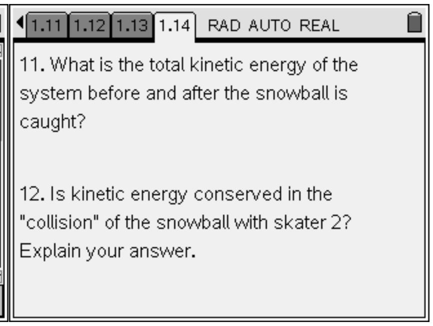
9. What law did you use to write the equation for **v2f**?

10. Apply this same law to write an equation for **v1f** in terms of **msb, vsb, m1**, and **v1i.**

1.12 RAD AUTO REAL

The next page contains a spreadsheet with the mass and velocity of the snowball and skater 2 before and after the snowball is caught. Enter the equation for kinetic energy (**ekinetic**) in the formula cell of column D.


1.10 1.11 1.12 1.13 RAD AUTO REAL
A
B mass
C velocity
D ekinetic
1 snowballi 0.2 15
2 skater2i 58 0
3 snowballf 0.2 0.051546
4 skater2f 58 0.051546
5
A1 snowballi


1.11 1.12 1.13 1.14 RAD AUTO REAL
11. What is the total kinetic energy of the system before and after the snowball is caught?
12. Is kinetic energy conserved in the "collision" of the snowball with skater 2? Explain your answer.