

Bell Ringer: Momentum in Two Dimensions –

ID: 13584

Time required
15 minutes

Topic: Momentum and Collisions

- Explore how momentum can be resolved into horizontal and vertical components.
- Calculate the total momentum of a system of objects in two dimensions.

Activity Overview

In this activity, students explore a simulation of two masses traveling in two dimensions prior to a collision. Students vary the mass, velocity, and angle at which the objects are traveling to understand how these variables affect the horizontal and vertical components of momentum. Students resolve momentum vectors into their components to calculate the total momentum of the system in the horizontal and vertical directions.

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

Teacher Preparation

Before carrying out this activity, review with students how to calculate the total momentum in a system. Also, review resolving vectors into their components.

- *The screenshots on pages 2–5 demonstrate expected student results. Refer to the screenshots on page 6 for a preview of the student TI-Nspire document (.tns file). The solution .tns file contains sample responses to the questions posed in the student .tns file.*
- ***To download the student .tns file and solution .tns file, go to education.ti.com/exchange and enter “13584” in the search box.***
- *This activity is related to activity 9678: Two-Dimensional Collisions. If you wish, you may extend this bell-ringer activity with the longer activity. You can download the files for activity 9678 at education.ti.com/exchange.*

Classroom Management

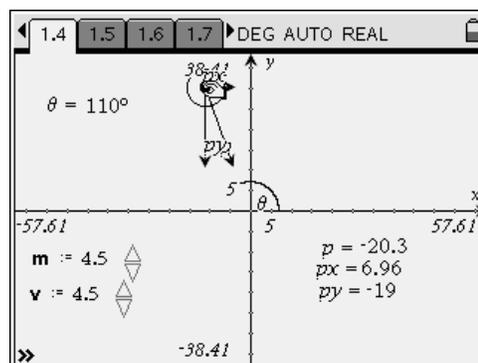
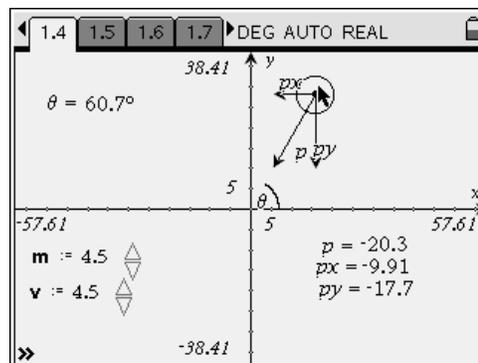
- *This activity is designed to be **teacher-led**, with students following along on their handhelds. You may use the following pages to present the material to the class and encourage discussion. Note that the majority of the ideas and concepts are presented only in **this** document, so you should make sure to cover all the material necessary for students to comprehend the concepts.*
- *If you wish, you may modify this document for use as a student instruction sheet. You may also wish to use an overhead projector and TI-Nspire computer software to demonstrate the use of the TI-Nspire to students.*
- *If students do not have sufficient time to complete the main questions, they may also be completed as homework.*
- *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 during this activity:

- How can you represent momentum with a vector?
- How do you resolve a vector into its components?
- How do you determine the total momentum of a system in the horizontal and vertical directions?

The purpose of this activity is for students to gain a visual understanding of how two-dimensional momentum vectors are resolved into their components and added to determine the total momentum in a system. Students vary the mass, velocity, and angle at which a mass is traveling to observe how these variables affect the components of momentum.

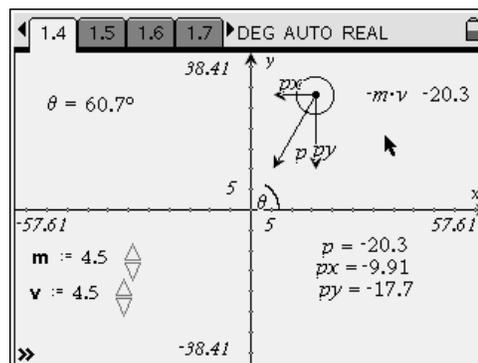
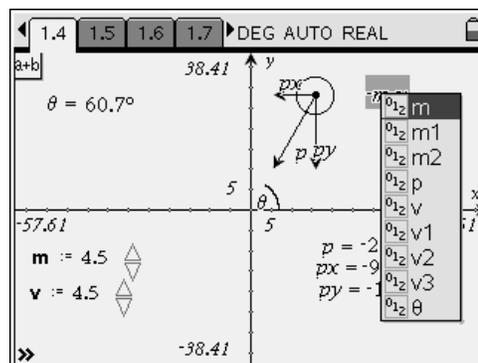
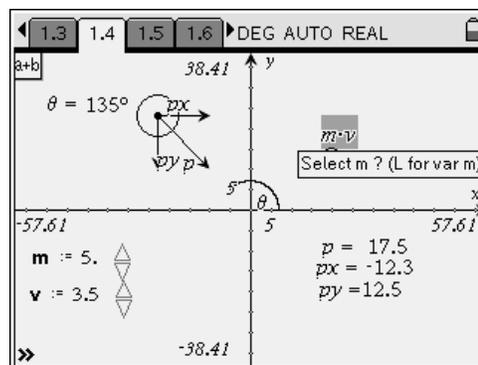
Step 1: Students should open the file **PhysBR_week16_2dmomentum.tns** and read the first three pages. Page 1.4 shows a simulation of a circular object with mass m and velocity v traveling in two dimensions at an angle θ to the horizontal axis. The total momentum of the object is given by the vector p , and the horizontal and vertical components of momentum are given by vectors p_x and p_y , respectively. Students can vary the mass and velocity of the object using the NavPad to move the cursor to the up and down arrows located to the right of each variable. They can press \odot to change the values. The mass of the object ranges from 3 to 5, and the velocity ranges from 0 to 5. Students can drag the object along a circular arc through the first two quadrants of the screen. (To drag the object, students should use the NavPad to move the cursor to the point at the center of the circle. The cursor should change to an open hand. Students should press and hold \odot until the cursor changes to a closed hand. They can then use the NavPad to drag the point. To release the point, students should press \odot again.) Students should observe how the momentum vector and the components of momentum change as the mass, velocity, and angle change.



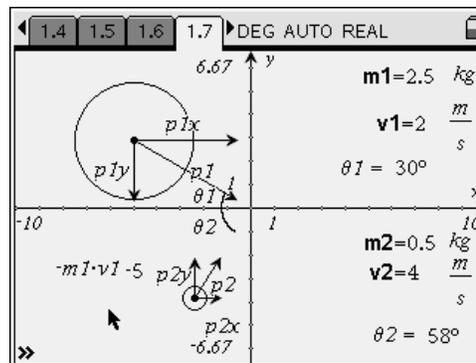
Step 2: Next, students should answer question 1 on page 1.5.

Q1. Verify the values of p , p_x , and p_y on page 1.4 by calculating the values directly.

- A.** Students should recall that the momentum of an object is the product of the object's mass and velocity ($p = mv$). The horizontal components of momentum are given by $p_x = mv \cos \theta$ and $p_y = mv \sin \theta$. To calculate the momentum of the object using the handheld device, students should return to page 1.4 and select the **Text** tool (**Menu > Actions > Text**). They should then click once (press Ⓢ) on an empty area of page 1.4 to place a text box. After entering the expression in the text box, students should use the **Calculate** tool (**Menu > Actions > Calculate**) to determine the value of the expression. After they select the **Calculate** tool, they should click on the expression they entered for momentum. They will be prompted to select values for m and v . They should press Ⓢ to see a drop-down list of different variables. Students can use the NavPad to select the appropriate value for each variable. After students have selected the value for each variable, they should click on a blank spot on the page to place the calculated value of momentum in that location. Students should use negative values to correctly account for direction (i.e., to ensure that left- and down-pointing vectors are negative).

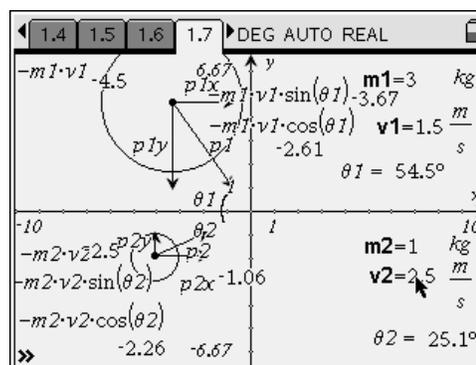


Step 3: Next, students should read page 1.6. Page 1.7 shows a simulation of two circular objects with masses m_1 and m_2 and velocities v_1 and v_2 traveling at angles θ_1 and θ_2 , respectively. Vectors p_1 , p_{1x} , and p_{1y} represent the total momentum, horizontal momentum, and vertical momentum, respectively, of mass 1. Similarly, vectors p_2 , p_{2x} , and p_{2y} represent the respective total momentum, horizontal momentum, and vertical momentum of mass 2. Students should study page 1.7 and then answer questions 2 and 3.



- Q2.** Calculate the values of p , p_x , and p_y for both masses on page 1.7.
- A.** To calculate the desired values, students should follow the same process that was performed in question 1. The values are $p_1 = -5$, $p_2 = -2$, $p_{1x} = -4.33$, $p_{2x} = -1.06$, $p_{1y} = -2.5$, and $p_{2y} = -1.7$.
- Q3.** Calculate the total horizontal and vertical momentum in the system on page 1.7 by adding the components of momentum for each mass.
- A.** Students should recall that the total momentum in a system is the sum of the momentums of the objects in that system. Similarly, the total horizontal momentum is the sum of all the horizontal components in the system, and the same principle applies to vertical momentum. Thus, the total horizontal momentum (p_x) is $p_x = p_{1x} + p_{2x}$, and the total vertical momentum (p_y) is $p_y = p_{1y} + p_{2y}$. The values are $p_x = -5.39$ and $p_y = -4.19$.

Step 4: Next, students should read question 4 on page 1.9 and then proceed to change the values on page 1.7. Students can change the angle of each mass by clicking on the point at the center of the circular object and dragging the point to the left or right. To change the mass and velocity of each object, students should move the NavPad so that the cursor is over the text for each variable. The cursor will change to an open hand. Students should press $\text{2nd} + \text{enter}$ twice. Then they can type the new value directly into the text box.



Q4. Change the variables on page 1.7 such that $m_1 = 3$ kg; $v_1 = 1.5$ m/s; $\theta_1 = 55^\circ$; $m_2 = 1$ kg; $v_2 = 2.5$ m/s; and $\theta_2 = 25^\circ$.

- a. Determine the total vertical and horizontal momentum in this system.
- b. If these objects collide and then bounce away from each other, what will be the values of the total vertical and horizontal momentum in the system? (Ignore any external forces.)

A. *Students should adjust the points so that the angles are as close as possible to the specified values.*

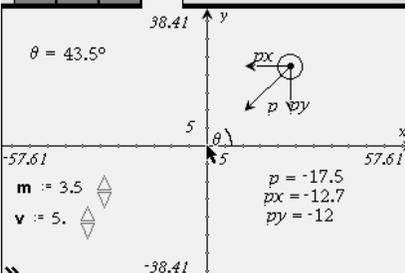
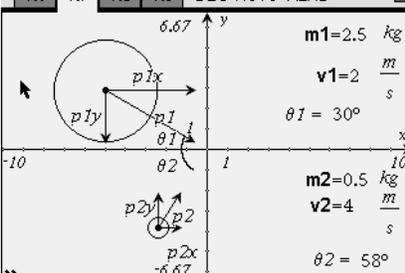
a. When students change the variables on page 1.7, the calculated values from question 3 will also change. Students can observe that the new values are $p_x = -4.85$ and $p_y = -4.74$.

b. According to the law of conservation of momentum, the total horizontal and vertical momentum after the collision will be the same as the total values before the collision. So, the momentum will be $p_x = -4.85$ and $p_y = -4.74$.

Suggestions for Extension Activities: If you wish, you may have students verify that the components of momentum on page 1.7 combine to yield the total momentum of the system using the Pythagorean theorem: $p_x^2 + p_y^2 = p^2$.

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(Student)TI-Nspire File: *PhysBR_week16_2d_momentum.tns*

<p>1.1 1.2 1.3 1.4 DEG AUTO REAL</p> <p>MOMENTUM IN TWO DIMENSIONS</p> <p>Physics</p> <p>Momentum and Collisions</p>	<p>1.1 1.2 1.3 1.4 DEG AUTO REAL</p> <p>Recall that an object traveling in two dimensions has both a horizontal and vertical component of velocity. Because momentum is the product of an object's mass and velocity, momentum also has horizontal and vertical components.</p>	<p>1.1 1.2 1.3 1.4 DEG AUTO REAL</p> <p>On page 1.4, an object with mass m is traveling at velocity v at an angle θ to the horizontal axis. Its momentum is represented by the vector p. The components of momentum are represented by p_x and p_y. Change the mass, velocity, and angle of the object to observe how the momentum vectors change.</p>
<p>1.1 1.2 1.3 1.4 DEG AUTO REAL</p>  <p>$\theta = 43.5^\circ$</p> <p>$m := 3.5$</p> <p>$v := 5$</p> <p>$p = -17.5$ $p_x = -12.7$ $p_y = -12$</p>	<p>1.2 1.3 1.4 1.5 DEG AUTO REAL</p> <p>1. Verify the values of p, p_x, and p_y on page 1.4 by calculating the values directly.</p>	<p>1.3 1.4 1.5 1.6 DEG AUTO REAL</p> <p>On page 1.7, two masses, m_1 and m_2, are traveling toward one another with velocities v_1 and v_2, respectively. Mass m_1 travels at an angle θ_1 to the horizontal axis, and m_2 travels at an angle θ_2 to the horizontal axis.</p>
<p>1.6 1.7 1.8 1.9 DEG AUTO REAL</p>  <p>$m_1 = 2.5 \frac{\text{kg}}{\text{s}}$</p> <p>$v_1 = 2 \frac{\text{m}}{\text{s}}$</p> <p>$\theta_1 = 30^\circ$</p> <p>$m_2 = 0.5 \frac{\text{kg}}{\text{m}}$</p> <p>$v_2 = 4 \frac{\text{m}}{\text{s}}$</p> <p>$\theta_2 = 58^\circ$</p>	<p>1.5 1.6 1.7 1.8 DEG AUTO REAL</p> <p>2. Calculate the values of p, p_x, and p_y for both masses on page 1.7.</p> <p>3. Calculate the total horizontal and vertical momentum in the system on page 1.7 by adding the components of momentum for each mass.</p>	<p>1.6 1.7 1.8 1.9 DEG AUTO REAL</p> <p>4. Change the variables on page 1.7 such that $m_1 = 3 \text{ kg}$; $v_1 = 1.5 \text{ m/s}$; $\theta_1 = 55^\circ$; $m_2 = 1 \text{ kg}$; $v_2 = 2.5 \text{ m/s}$; and $\theta_2 = 25^\circ$.</p> <p>a. Determine the total vertical and horizontal momentum in this system.</p> <p>b. If these objects collide and then bounce away from each other, what will be the values of the total vertical and horizontal momentum in the system? (Ignore any external forces.)</p>