Name: ______________________________________ Date: ________________________

Student Exploration: Air Track

Vocabulary: air track, approach velocity, conservation of energy, conservation of momentum, elasticity, kinetic energy, momentum, separation velocity, velocity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
Imagine going to a bowling alley with a bowling ball and a ping pong ball.

1. Why is a bowling ball better for knocking down pins than a ping pong ball? ______________

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2. Which do you think would knock down more pins, a bowling ball moving 10 meters per

   second or a bowling ball moving 10 centimeters per second? ________________________

3. What *two* factors seem to most affect the amount of damage that occurs in a collision?

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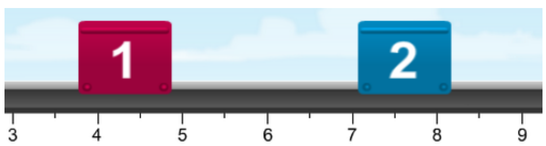
Gizmo Warm-up
An **air track** is a device that helps scientists study motion. Air comes out of holes in the track, allowing the gliders to move with minimal friction.



1. On the *Air Track* Gizmo™, click **Play** ( ) to view a collision between the two gliders.

   What do you see? ____

2. Click **Reset** ( ). The **velocity** (*v*) of an object describes its speed and direction. The velocity of each glider is indicated next to the v_1 and v_2 sliders. Click **Play,** and then click **Pause** ( ) just before the collision.

   A. What is the velocity of **Glider 1**? ____

   B. In which direction does **Glider 1** move? ____

   C. What is the velocity of **Glider 2**? ____

   D. In which direction does **Glider 2** move? ____

Activity A: **Momentum**	Get the Gizmo ready: • Click **Reset**.

Question: How does an object's momentum change when it collides with another object?

1. Explore: The Gizmo allows you to adjust the mass and initial velocity of each glider. Set up each of the following scenarios, and describe what happens when the gliders collide.

   A. The gliders have the same mass but different velocities. ______________________

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   B. The gliders have the same mass and one glider is stationary. __________________

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   C. The gliders have the same velocity (but in opposite directions) and different masses.

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2. Calculate: An object's **momentum** (p) describes how hard it is to stop. Momentum is equal to the product of mass and velocity: $p = mv$. If mass is measured in kilograms and velocity in meters per second, the unit of momentum is kilograms-meters per second, or kg•m/s.

   A. What is the momentum if the mass is 1.5 kg and the velocity is 4 m/s? ___________

   Turn on **Show numerical data** and use the Gizmo to check your answer.

   B. How could you use the Gizmo to increase a glider's momentum? _______________

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3. Gather data: Click **Reset**. Set m_1 to 3.0 kg and v_1 to 2.0 m/s. Set m_2 to 2.0 kg and v_2 to -4.0 m/s. Fill in the left table, run the collision, and then fill in the right table.

Before collision

Glider	Glider 1	Glider 2
Mass	3.0 kg	2.0 kg
Velocity	2.0 m/s	-4.0 m/s
Momentum		

After collision

Glider	Glider 1	Glider 2
Mass		
Velocity		
Momentum		

(Activity A continued on next page)

Activity A (continued from previous page)

4. Calculate: To find the total momentum, add up the momentum of each glider. (Note: Pay attention to signs.)

   A. What was the total momentum of the two gliders before the collision? _____________

   B. What was the total momentum of the two gliders after the collision? ______________

   Turn on **Show total momentum** to check your answers.

5. Experiment: Click **Reset**. Set up three collisions using any combination of masses and velocities you like. (The only rule is that the gliders must collide.) Record the mass, velocity, and momentum of each glider before and after the collision. Then, find the total momentum. Remember to include units.

	Glider 1			**Glider 2**			**Total momentum**
	m	***v***	***p***	***m***	***v***	***p***	
Before collision							
After collision							
Before collision							
After collision							
Before collision							
After collision							

6. Analyze: What do you notice about the total momentum of the two gliders? ______________

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7. Draw conclusions: The principle of **conservation of momentum** states that, in a closed system, the total momentum of all of the objects will remain constant. How do your experiments demonstrate conservation of momentum?

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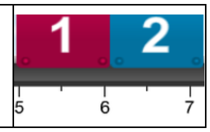
Activity B: Velocity	Get the Gizmo ready: • Click **Reset**. • Check that the **Elasticity** is set to 1.0.	

Introduction: When two gliders are moving toward each other, the relative speed they are moving together before the collision is called the **approach velocity**. Similarly, the speed at which the gliders are moving apart after the collision is described by the **separation velocity**. Each is equal to the difference in the gliders' velocities:

$$v_{(approach)} = v_1 - v_2 \qquad v_{(separation)} = v_2' - v_1'$$

Question: What rule governs the velocities of two colliding objects?

1. Calculate: Set $\boldsymbol{m_1}$ to 3.0 kg and $\boldsymbol{m_2}$ to 1.5 kg. Set $\boldsymbol{v_1}$ to 4.0 m/s and $\boldsymbol{v_2}$ to -6.0 m/s. Pay attention to the signs of the velocities as you calculate them.

   A. What is the approach velocity of the two gliders? _______________

   B. Click **Play** and then **Pause** after the collision. What is the velocity of each glider?

   Glider 1 velocity: _______________ Glider 2 velocity: _______________

   C. What is the separation velocity of the two gliders? _______________

   D. What do you notice? ____

2. Experiment: Click **Reset**. Set up two collisions using any combination of masses and velocities you like. Calculate the approach velocity and separation velocity for each collision. Remember to include units.

	Glider 1		**Glider 2**		$\boldsymbol{v_{(approach)}}$	$\boldsymbol{v_{(separation)}}$
	m	***v***	***m***	***v***		
Before collision						
After collision						
Before collision						
After collision						

3. Analyze: So far, you have found that momentum is conserved in a collision. What else appears to be conserved? Explain your answer.

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(Activity B continued on next page)

Activity B (continued from previous page)

[Note: The following extension is designed as a challenge.]

4. Challenge: So far, you have found two rules that govern the behavior of the gliders before and after a collision. These two rules are expressed by the equations below. (Note: In each equation, a prime symbol (′) indicates "after the collision.")

	Before collision		After collision
Conservation of momentum:	$m_1v_1 + m_2v_2$	=	$m_1v_1' + m_2v_2'$
Approach velocity = separation velocity:	$v_1 – v_2$	=	$v_2' – v_1'$

If you are given the initial masses and velocities of the objects, you can use these two equations to solve for the two unknowns: v_1' and v_2'. Try this in the space below. (Hint: Solve the second equation for v_2', and then substitute this expression into the first equation.)

5. Solve: For each of the situations given below, determine the final velocity of each glider. Use the Gizmo to check your answers. (The Gizmo cannot be used to solve the last problem.)

   A. **Glider 1** has a mass of 2.0 kg and a velocity of 2.6 m/s. **Glider 2** has a mass of 3.0 kg and an initial velocity of -4.4 m/s.

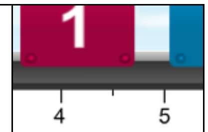
   v_1' ________________ v_2' ________________

   B. **Glider 1** has a mass of 0.5 kg and a velocity of 9.0 m/s. **Glider 2** has a mass of 1.0 kg and an initial velocity of -9.0 m/s.

   v_1' ________________ v_2' ________________

   C. **Glider 1** has a mass of 5.0 kg and a velocity of 15.0 m/s. **Glider 2** has a mass of 6.0 kg and a velocity of -12.0 m/s.

   v_1' ________________ v_2' ________________

Activity C: Kinetic energy and elasticity	Get the Gizmo ready: • Click **Reset**. • Check that the **Elasticity** is set to 1.0. • Turn off **Show numerical data** for both gliders.	

Introduction: The **kinetic energy** (*KE*) of an object is a measure of its energy of motion, measured in joules (J). Kinetic energy depends on both the mass and velocity of the object:

$$KE = mv^2 / 2$$

Question: What happens to the kinetic energy of a system during a collision?

1. Calculate: Set $\boldsymbol{m_1}$ to 3.0 kg and $\boldsymbol{v_1}$ to 2.0 m/s. Set $\boldsymbol{m_2}$ to 1.5 kg and $\boldsymbol{v_2}$ to -6.0 m/s.

   A. What is the kinetic energy of **Glider 1**? _____________ **Glider 2**? _____________

   B. What is the total kinetic energy of both gliders? ______________________

2. Run Gizmo: Turn on **Show numerical data**. Click **Play** and then **Pause** after the collision.

   A. What is the kinetic energy of **Glider 1**? _____________ **Glider 2**? _____________

   B. What is the total kinetic energy now? _____________

3. Experiment: Click **Reset**. Set up two collisions using any combination of masses and velocities. Calculate the kinetic energy of each glider and the total kinetic energy. Remember to include units.

	Glider 1			Glider 2			Total *KE*
	m	***v***	***KE***	***m***	***v***	***KE***	
Before collision							
After collision							
Before collision							
After collision							

4. Summarize: The principle of **conservation of energy** states that in a closed system the total energy remains constant. How do your experiments demonstrate this principle?

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(Activity C continued on next page)

Activity C (continued from previous page)

5. Experiment: If the colliding objects are deformed in the collision, some of the kinetic energy is converted to heat and/or sound. The **elasticity** of a collision is related to the kinetic energy that is preserved in a collision.

   Set the **Elasticity** to a value less than 1.00 and run an experiment with any combination of masses and velocities. Record the results below. Remember to include units.

	Glider 1			**Glider 2**			**Total *KE***
	m	***v***	***KE***	***m***	***v***	***KE***	
Before collision							
After collision							

6. Calculate: Elasticity is also related to the approach velocity and the separation velocity.

   A. What is the approach velocity in the example above? ______________________

   B. What is the separation velocity in the example above? ______________________

   C. What is the ratio of the separation velocity to the approach velocity? _____________

   D. How does the elasticity of the collision relate to this ratio? ______________________

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7. Gather data: Repeat your experiment with several different values of **Elasticity**. In each experiment, record the approach velocity, separation velocity, and the ratio of the separation velocity to the approach velocity. Remember to include units.

Trial	**Elasticity**	$v_{(approach)}$	$v_{(separation)}$	$\frac{v_{(separation)}}{v_{(approach)}}$
1	0.2			
2	0.8			
3	0.6			

8. Make a rule: Based on your table, how could you calculate the elasticity of a collision if you know the approach velocity and separation velocity of the colliding objects?

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