

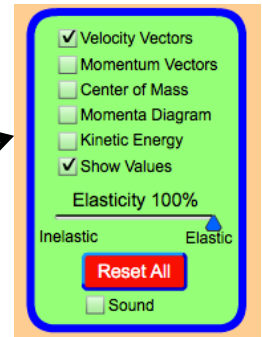
Experiments in Physics

Lab: Conservation of Momentum

Name _____ Score _____

Introduction:

Collisions occur in all different forms in our world when two or more objects strike each changing their momentum. Some of the most familiar collisions are a result of car accidents. Other types of collisions involve less noticeable forms such as bouncing a ball or hitting a baseball. Name another real life occurrence of a collision between two or more objects _____. Collisions also occur at the atomic level. An important law of physics involves the relationship between the total momentum of objects before and after a collision. *The purpose of this lab is to determine the relationship between the total momentum of objects before and after a collision. In addition, students will distinguish the difference between elastic and inelastic collisions. Note: the symbol u represents the initial velocity of an object and the symbol v represents the final velocity of the object.*



Part I – The Conservation of Momentum

- (1) Open the PhET simulation entitled “Collision Lab”.
- (2) Check the box “Show Values” and “Velocity Vectors.”
- (3) By changing the various settings for the two masses, complete the table below.
Hint: Slide the velocity vectors to change the velocities. Start the collision by hitting the play button. Be careful to get the sign correct on your velocities.

m_1/kg	m_2/kg	u_1/ms^{-1}	u_2/ms^{-1}	Momentum before/ kgms^{-1}		v_1/ms^{-1}	v_2/ms^{-1}	Momentum after/ kgms^{-1}		Total Momentum before $\rho_1 + \rho_2$	Total Momentum after $\rho'_1 + \rho'_2$
				ρ_1	ρ_2			ρ'_1	ρ'_2		
0.5	1.5	1.00	0.00								
0.5	1.5	1.00	-0.44								
2.6	1.5	3.25	0.48								
2.6	1.2	1.39	-3.43								
2.6	2.6	1.20	-2.37								

(4) The velocity vectors pointing left are negative. What does the negative sign represent?

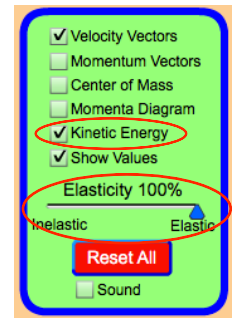
(5) What do you notice about the total momentum before and the total momentum after?

(6) Write a statement for the conservation of momentum. Verify your statement by researching the conservation of momentum on the internet, textbook, or by asking your instructor.

(7) A 3 kg ball traveling to the left at a velocity of 2.3 m/s collides with another 0.5 kg ball traveling to the left at 0.3 m/s. As a result of the collision, the 3 kg ball moves to the left with a velocity of 1.73 m/s. Using the conservation of momentum calculate the velocity of the 0.5 kg ball after the collision. Show all your work. Use the simulation to verify your answer.

Part II: Elastic and Inelastic collisions

- (1) Check the box labeled “Kinetic Energy”. The simulation provides a number at the top that represents the total kinetic energy of the two balls before and after the collision. The slider labeled “Elasticity” is set a 100% as the default setting. Keep the setting. At 100% elasticity a collision is considered “elastic”. Try numerous types of collisions by changing the parameters for both balls. What can you conclude about the total kinetic energy before and after the collisions?

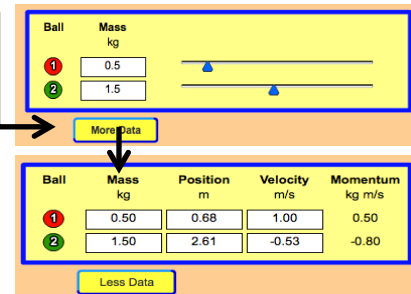


- (2) Draw a conclusion concerning elastic collisions with regards to the conservation of momentum and the conservation of energy. In other words, define an elastic collision.

- (3) Using the slider, change the Elasticity to 0% such that the arrow is directly over the word “inelastic”.

- Click on the “More Data” button.
- Manipulate the objects mass, position, and velocity vectors to match the data below.

Ball	Mass kg	Position m	Velocity m/s	Momentum kg m/s
1	0.50	0.70	1.00	0.50
2	1.50	2.60	-0.53	-0.80



- Calculate the total momentum before the collision (include a proper unit). _____
 - What is the total kinetic energy before the collision (include a proper unit)? _____
 - Press the play button and pause the simulation after the collision. Calculate the total momentum after the collision (include a proper unit). _____
 - What is the total kinetic energy after the collision (include a proper unit)? _____
- (4) What can you conclude about the law of conservation of momentum for elastic and inelastic collisions?

- (5) What can you conclude about the law of conservation of energy for elastic and inelastic collisions?

- (6) Try various other inelastic (< 100% Elasticity) collisions by manipulating the parameters. Based upon your observations, define inelastic collisions.

- (7) A 50% inelastic collision occurs between a 0.7 kg ball moving to the left with a velocity of 1.8 m/s and a 1.6 kg ball moving to the right at 0.5 m/s. After the collision, the 1.6 kg ball moves to the left with a velocity of 0.55 m/s. The formula for kinetic energy of an object is given by: $E_K = \frac{1}{2}mv^2$.

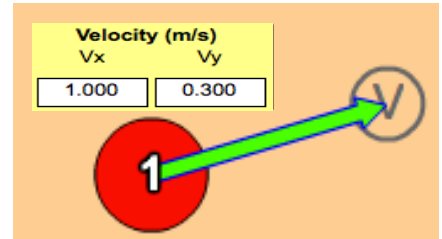
- Calculate the kinetic energy for each ball before the collision. Show all your work.

- Determine the total kinetic energy **before** the collision (include a proper unit). _____
- Calculate the kinetic energy of each ball after the collision. Show all your work.

- Determine the total kinetic energy **after** the collision (include a proper unit). _____
- Calculate the change in kinetic energy during the collision (ΔE_K). _____
- Suggest a reason for why the total kinetic energy before and after an inelastic collision is not the same. _____

Part III – Two-dimensional collisions

- Two-dimensional collisions occur at various angles. As a result, proper analysis of such collisions must consider the horizontal and vertical components of the motion of the object. Draw the right triangle for the angled velocity vector for the red ball in the picture to the right. Label the horizontal component and vertical components.
- Show by calculation that the resultant velocity is 1.04 m/s.



- If the mass of the red ball is 0.5 kg, calculate the horizontal momentum (ρ_x) and the vertical momentum (ρ_y). Show all your work.

- Select the “Advanced” tab at the top of the simulation. Match the settings in the picture below. Use the data in the yellow box to verify your calculations for item (3).

Ball	Mass (kg)	Position (m)		Velocity (m/s)		Momentum (kg m/s)	
		x	y	Vx	Vy	Px	Py
1	0.500	1.000	0.000	1.000	0.300	0.500	0.150
2	1.500	2.000	0.500	-0.500	-0.500	-0.750	-0.750

- Change the parameters for position and velocity by typing in the values in the simulation. Complete the table below by using the “Play and Pause” buttons. Show your work for all calculations.

Collision parameters		BEFORE the collision		AFTER the collision																																
		Total ρ_x	Total ρ_y	Total ρ_x	Total ρ_y																															
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Ball</th> <th>Mass (kg)</th> <th colspan="2">Position (m)</th> <th colspan="2">Velocity (m/s)</th> <th colspan="2">Momentum (kg m/s)</th> </tr> <tr> <th></th> <th></th> <th>x</th> <th>y</th> <th>Vx</th> <th>Vy</th> <th>Px</th> <th>Py</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0.500</td> <td>1.000</td> <td>0.000</td> <td>1.000</td> <td>0.300</td> <td>0.500</td> <td>0.150</td> </tr> <tr> <td>2</td> <td>1.500</td> <td>2.000</td> <td>0.500</td> <td>-0.500</td> <td>-0.500</td> <td>-0.750</td> <td>-0.750</td> </tr> </tbody> </table>	Ball	Mass (kg)	Position (m)		Velocity (m/s)		Momentum (kg m/s)				x	y	Vx	Vy	Px	Py	1	0.500	1.000	0.000	1.000	0.300	0.500	0.150	2	1.500	2.000	0.500	-0.500	-0.500	-0.750	-0.750				
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- Draw a conclusion concerning the conservation of momentum involving two-dimensional collisions based upon the calculated values in the table.

Part IV – The Wall

- (1) A common problem in physics is when a ball bounces off a wall. Using the advanced tab, match the settings for the picture below and to the right. Play the simulation and pause the simulation after the ball bounces off the right wall. Observe what happens before and after the collision for ρ_y . “Restart” the simulation if needed. Calculate $\Delta\rho_y$ for the ball bouncing off the wall?

Add Ball

Ball	Mass (kg)	Position (m)		Velocity (m/s)		Momentum (kg m/s)	
		x	y	Vx	Vy	Px	Py
1	0.500	2.066	0.484	1.208	-0.323	0.604	-0.162

Less Data

1 Dimension
 2 Dimensions

- Velocity Vectors
- Momentum Vectors
- Center of Mass
- Reflecting Border
- Momenta Diagram
- Kinetic Energy
- Show Paths
- Show Values

Elasticity 100%

InelasticElastic

Reset All

Sound

- (2) Try bouncing the ball at various angles. What can you conclude about $\Delta\rho_y$ for a ball bouncing off a wall at any angle? _____
- (3) Try bouncing the ball at various angles again. Observe what happens to ρ_x . In general, what can you conclude about the magnitude of ρ_x before and after the ball bounces of the wall?

- (4) Based upon your observations for item (3), determine an expression in terms of ρ_x for $\Delta\rho_x$.

- (5) Write the expression for $\Delta\rho_x$ in terms of m , the mass of the ball, and v_x .

- (6) Write the expression for $\Delta\rho_x$ in terms of m , the mass of the ball, v , the velocity of the ball, and θ , the angle measured from the normal to the wall at which the ball strikes the wall.

- (7) A 0.06 kg tennis ball moving at a velocity of 23 m/s strikes a wall at an angle of 30 degrees measured from the normal to the wall. Calculate the total change in momentum for the tennis ball. Show all your work.