Names: ______________________________, ____________________________________

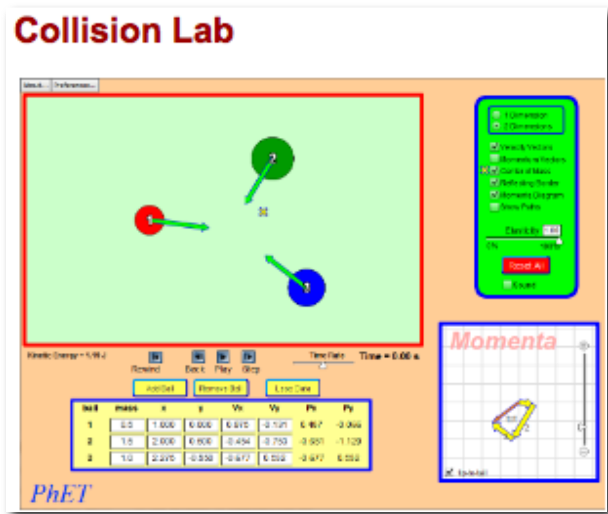
Computer Simulation

Computer Simulation: Collisions in Two Dimensions

In this experiment you will be using the *PHET* simulation *Collision Lab* to explore the relationships between the momentum, impulse, and kinetic energies during two-dimensional collisions.

Objectives:

- add momentum vectors – by components and by vector addition
- apply the Law of Conservation of Momentum
- determine the impulse on an object involved in a collision
- determine the role of elasticity on the outcome of collisions



Description

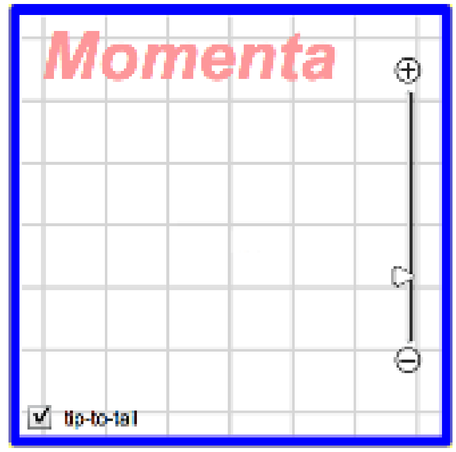
The simulation consists allows you to change the velocity and mass of up to five balls that will collide in two dimensional collisions. When you open the simulation make the following setting changes:

- activate *velocity* and *momentum* vectors
- activate the *momenta diagram* and *show paths*
- deactivate the *reflecting border*

PreRequisite Skills: *Momentum and Impulse*

- Newton's third law can also be phrased in terms of momentum: for any closed system of objects, the total momentum remains ____________________. Note that momentum *can* be exchanged between objects in a closed system. However, the magnitude of the change in momentum for one object must be ________________ to the magnitude of the change in momentum of the other object.
- A change in momentum for an object is also referred to as an ____________________________.
- Fill in the appropriate units for each quantity: momentum: ___________ impulse: ____________

Exploration:



1. Begin with two balls with masses of 2kg and 3 kg. Change the velocity of each ball (by dragging on the velocity vector) until the total momentum is close to zero. Adjust the scale on the *Momenta Diagram* until it just fits inside the grid, then copy the vector diagram in the space to the right.

2. Set the Elasticity to 0.0, then run the simulation. Describe what happens to the motions of the balls after the collision; how does this relate to the motion of the center of mass?

____

____

____

____

____

3. Rewind, set the Elasticity to 50%, and run the simulation again. Record the total initial and final kinetic energies of the system in the spaces below.

$E_{k_i} =$ __________ J $\qquad$ $E_{k_f} =$ __________ J

Rewind, set the Elasticity to 100%, and run the simulation again. Record the total initial and final kinetic energies of the system in the spaces below.

$E_{k_i} =$ __________ J $\qquad$ $E_{k_f} =$ __________ J

Describe the effect the elasticity had on the motions of the balls after the collision.

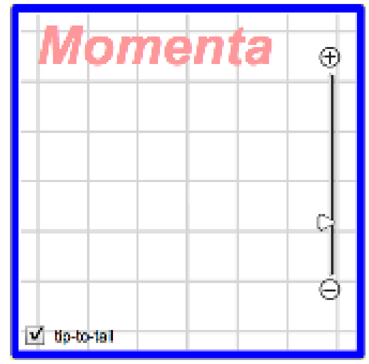
____

____

____

Did the elasticity affect the total momentum of the balls after the collision? ____________

Analysis: Two Dimensional Collisions



1. Use two balls, with masses of 2kg and 3 kg. Change the velocity of each ball (by dragging on the velocity vector) such that there is a significant, ***non-zero***, total momentum, and that their initial directions are not along either axis (not purely east/west or north/south). Arrange the initial locations of the balls so that will collide ***obliquely***!

Adjust the scale on the *Momenta Diagram* until it just fits inside the grid, then copy the vector diagram in the space to the right.

2. Activate the *more data* button, set the *elasticity* to 70%, and run the simulation. Transfer the data into the table below then calculate the total momentum *and* direction of each ball.

	Before the Collision			
	2 kg Ball		**3 kg Ball**	
Component Velocities	$\mathbf{v}_x$ (m/s)	$\mathbf{v}_y$ (m/s)	$\mathbf{v}_x$ (m/s)	$\mathbf{v}_y$ (m/s)
Component Momenta	$\mathbf{p}_x$ (kgm/s)	$\mathbf{p}_y$ (kgm/s)	$\mathbf{p}_x$ (kgm/s)	$\mathbf{p}_y$ (kgm/s)
Total Momentum	*calculation:*		*calculation:*	
Direction (°)	*calculation:*		*calculation:*	

	After the Collision			
	2 kg Ball		**3 kg Ball**	
Component Velocities	$\mathbf{v}_x$ (m/s)	$\mathbf{v}_y$ (m/s)	$\mathbf{v}_x$ (m/s)	$\mathbf{v}_y$ (m/s)
Component Momenta	$\mathbf{p}_x$ (kgm/s)	$\mathbf{p}_y$ (kgm/s)	$\mathbf{p}_x$ (kgm/s)	$\mathbf{p}_y$ (kgm/s)
Total Momentum	*calculation:*		*calculation:*	
Direction (°)	*calculation:*		*calculation:*	

3. Verify the Elasticity of the Collision

$$Elasticity = \frac{E_{k_f}}{E_{k_i}} = \frac{\frac{1}{2}(\_\_\_\_\_\ kg)(\_\_\_\_\_\ \tfrac{m}{s})^2 + \frac{1}{2}(\_\_\_\_\_\ kg)(\_\_\_\_\_\ \tfrac{m}{s})^2}{\frac{1}{2}(\_\_\_\_\_\ kg)(\_\_\_\_\_\ \tfrac{m}{s})^2 + \frac{1}{2}(\_\_\_\_\_\ kg)(\_\_\_\_\_\ \tfrac{m}{s})^2} = \frac{(\_\_\_\_\_\_\_\_\ J)}{(\_\_\_\_\_\_\_\_\ J)} = \_\_\_\_\_\_\_\_\ \%$$

How does this compare to the elasticity set in the simulation? ________________________________

4. Apply the Law of Conservation of Momentum to analyze the collision in two ways: 1) by components, and 2) using a vector diagram.

Component Method

$p_{i_x} = p_{f_x}$	$p_{i_y} = p_{f_y}$

Was momentum conserved in both component directions? ________________________________

Vector Addition: $\vec{p}_{2kg} + \vec{p}_{3kg} = \vec{p}_{total}$

Total Initial Momentum (vector diagram)	Total Final Momentum (vector diagram)
Calculation – magnitude *and* direction (sine or cosine law)	Calculation – magnitude *and* direction (sine or cosine law)

Was momentum conserved within the limits of accuracy in the simulation? ______________

5. Calculate the magnitude and direction of the impulse on the 2 kg ball. $I = \vec{p}_f - \vec{p}_i$

vector diagram

calculation (magnitude *and* direction)

6. Calculate the magnitude and direction of the impulse on the 3 kg ball.

vector diagram

calculation (magnitude *and* direction)

7. Compare the magnitude and direction of the impulse on each ball during the collision. How do the impulses relate to Newton's 3rd Law?

Conclusion:

Summarize, in a brief paragraph, what relationships you have learned from this simulation. Ensure that you address each of the objectives from page 1.