Name: ______________________________________ Date: ________________________

# Gizmo Activity: Impulse and Momentum

*[Note: This activity requires you to use the* 2-D Collisions *Gizmo™.]*

**Learning goals**
After completing this activity, you will be able to …

- Relate Newton's laws of motion to collisions and the conservation of momentum.
- Describe parallels between momentum and mass with respect to Newton's second law.
- Calculate the impulse in a collision.

**Vocabulary:** impulse

**Warm-up question**
Newton's second law is often written $F = ma$, where *F* is the force exerted on an object, *m* is its mass, and *a* is the acceleration the force causes. Based on this equation, complete the sentence below. (Put the same word in both blanks.)

*An object with less _______ will have its velocity changed more than an object with greater*

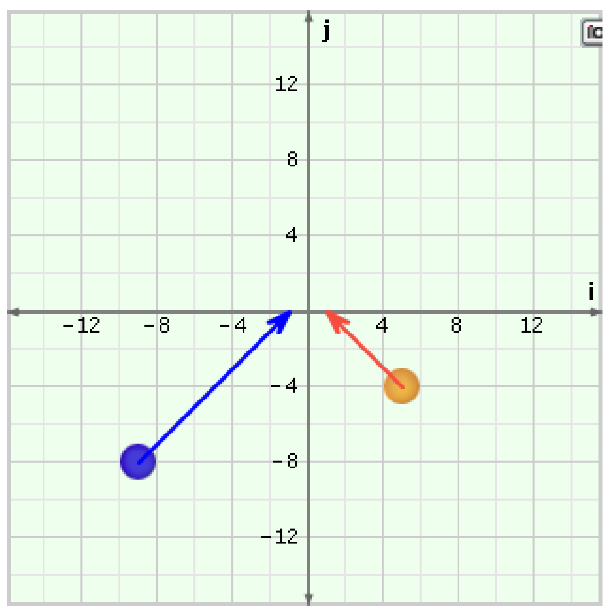
*_______ if the same force acts on each.*

**Setting up the Gizmo**
In this activity you will use the *2D-Collisions* Gizmo™ to investigate impulse and the application of Newton's laws to collisions.

After opening the Gizmo, move the gold puck to the point (5, -4) and set its velocity to -4.00**i** + 4.00**j**. (You can change the velocity of the pucks by dragging the arrow tips.) Move the blue puck to (-9, -8) and set its velocity to 8.00**i** + 8.00**j**.

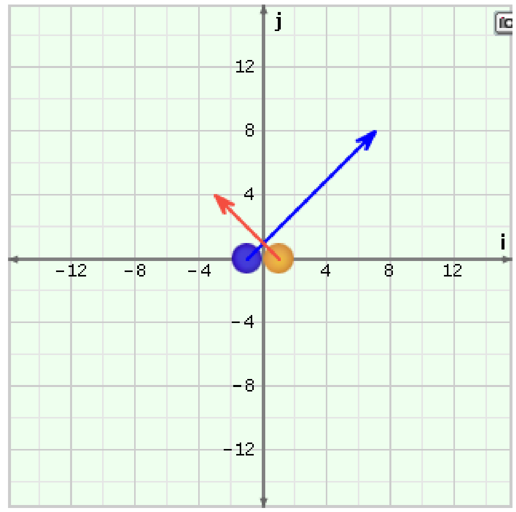
The simulation panel of your screen should match the illustration shown to the right.

Set the mass of both pucks to 5 kg by using the sliders. Set **Elasticity** to 0.5. Select the box next to **Puck trails**.



1. The gold puck's velocity is set to -4.00**i** + 4.00**j**, so after 1 second it will be at (1, 0). The blue puck's velocity is set to 8.00**i** + 8.00**j**, so it will be at (-1, 0) after 1 second. A picture showing the pucks as they collide is shown at the right.

   When the pucks collide, each puck exerts a force on the other.




   A. According to Newton's third law, how does the force the gold puck applies to the blue one compare to the force the blue puck exerts on the gold?

   _________________________________

   _________________________________

   B. When the pucks hit each other, they are exactly side-by-side. This means that, even though the gold puck is moving forward, it exerts a force only in the leftward direction on the blue puck (not counting friction). Similarly, the blue puck can only exert a rightward force on the gold puck.

   On the graph above, draw two arrows representing these two forces. The arrow representing the force the gold puck exerts on the blue should start at the center of the blue puck. The arrow representing the force the blue puck exerts on the gold puck should start at the center of the gold puck.

   Since the angle made by these lines and the velocity vectors are the same for each puck, they are said to be "hitting each other at equal angles." In this case each is pushing the other in a direction 135° away from its original velocity.

2. Press **Play** ( ). Compare each puck's original direction of motion to the direction it traveled after the collision.

   A. Which puck was deflected more, or were they deflected equally? ________________

   _____________________________________________________________________

   B. The pucks have equal mass, they hit each other at equal angles, and they exert equal forces on each other, so it might seem strange that they were not deflected by the same amount. Suggest a reason why one puck deflected more from its original course than the other even though equal forces were applied to both.

   _____________________________________________________________________

   _____________________________________________________________________

   _____________________________________________________________________

3. Click the TABLE tab, and compare the $V_{before}$ to the $V_{after}$.

   A. What was the change in velocity for the gold puck? _____ **i** + ______ **j** (m/s)

   B. Assume the pucks are in contact for 0.1 seconds. What was the average acceleration during this time period? ______ **i** + _____ **j** (m/s$^2$)

   C. Use Newton's second law to calculate the average force the blue puck exerted on the gold puck during the collision: ______ **i** + _____ **j** (N)

The **impulse** one object applies to another describes the amount of force applied *over time*. If an object applies a force of (20**i** + 30**j)** newtons for 3 seconds, the impulse applied is (60**i** + 90**j**) N-s. In general, $I = F \times \Delta t$, where *I* is the impulse, *F* is the average force, and Δ*t* is the time over which the force is applied.

4. Based on your answer to part C of question 3, what was the impulse exerted on the gold puck by the blue puck? ________ **i** + _______ **j** (N-s)

5. Select the CALCULATION tab. How does the impulse compare to the change in momentum (*p*) experienced by the gold puck? _____________________________________________

6. Make a rule about impulse and momentum from your responses to question 5.

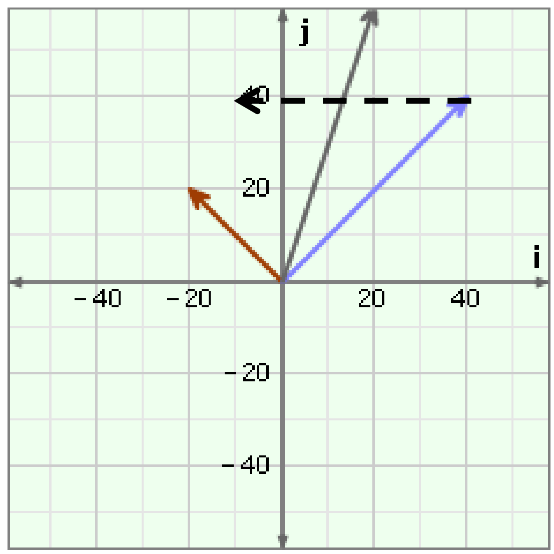
   ________________________________________________________________________

7. It is not hard to prove the rule above. Below is a short proof. Give a short explanation for why each step is justified:

| Statement | Justification |
|---|---|
| Impulse = *F* x *(Δt)* | |
| Impulse = *m x a x (Δt)* | |
| Impulse = m x (Δv) | |
| Impulse = change in momentum | |

8. In the space below, show that Newton's third law leads to the conservation of momentum. You will need to use the statement you proved above.

9. You can also use your rule to explain how the pucks can deflect different amounts even though they are the same mass and exert equal and opposite forces on one another. At the right is a graph showing the momentum of the two pucks right as the hit, before they have exerted force on one another. In question 4, you found the impulse the gold puck exerted on the blue puck. That impulse is drawn as a dotted arrow beginning at the tip of the blue puck's momentum vector.




   A. The pucks exert equal and opposite impulses on each other. Draw your own dotted arrow starting at the tip of the gold puck's momentum vector equal and opposite to the impulse the blue puck exerts on the gold puck.

   B. Select the MOMENTUM tab. The arrows there show the momentum vectors before and after the collision. Draw those vectors on the image as well using solid arrows. This should form two triangles. What do the sides of each triangle represent?

   ___________________________________________________________________________

   ___________________________________________________________________________

   C. Why does it make sense that the dotted impulse vectors form the far edge of these triangles? (Hint: Remember the rule you made in question 6 and proved in 7.)

   ___________________________________________________________________________

   ___________________________________________________________________________

   ___________________________________________________________________________

10. Look again at the image in the last question:

A. How do the angles formed by the before and after momentum vectors for the blue puck relate to the change in direction of the puck? (Hint: remember that momentum is mass times velocity.)

_______________________________________________________________________

B. How do the triangles help explain why the blue puck deflected less than the gold puck even though they were the same mass and exerted equal forces (and equal impulses) on one another?

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

C. Explain in your own words why the following definition for momentum is reasonable: "Momentum determines how hard it is to change the direction of an object in motion."

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

11. Complete the statement below about mass similar to the following: "Momentum is a measure of the tendency for an object to move in a straight line."

*Mass determines how hard it is to change the ____________ of an object in motion.*