**Introduction**

**Purpose** To investigate conservation of momentum in a system of two colliding motion carts.

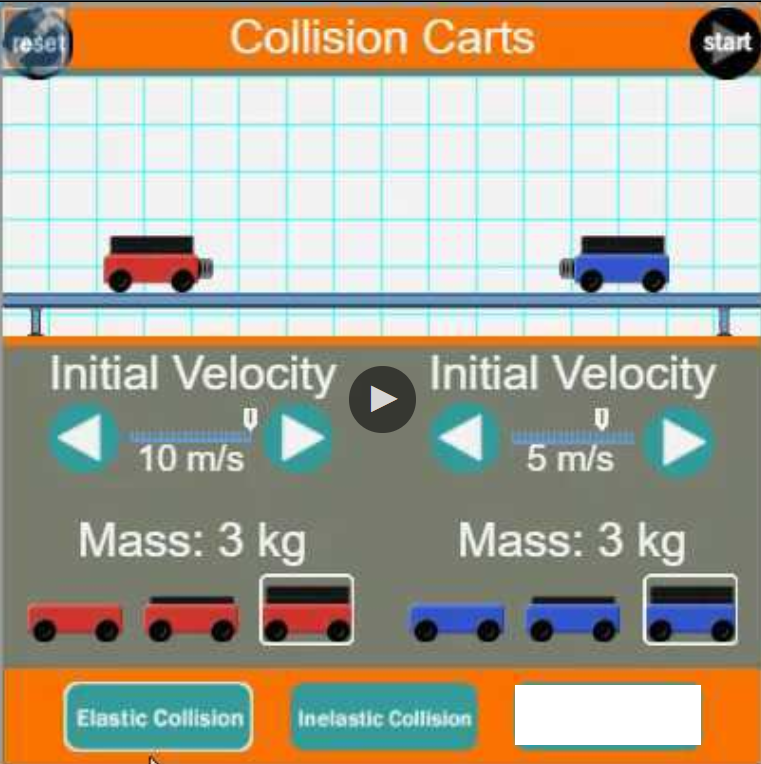
**Background Information**

Momentum is the product of an object’s mass and its velocity (p = mv). The direction of the motion is all important. Momentum is usually understood in the context of collisions, which follows the study of Newton’s third law of motion: whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first object.

The objects involved in a collision are often considered as a system. Provided that the system of two objects is not experiencing a net external impulse, there would be no change in momentum of the system. If one object within the system loses momentum, it is gained by the other object within the system. The combined momentum of both objects would be conserved.

Under certain conditions, collisions obey the law of conservation of momentum, meaning that momentum does not increase or decrease overall in a system. Objects in a system (motion carts in this lab) can exert forces on one another, but the total momentum does not change. One can observe conservation of momentum experimentally by looking at:

∆ Momentum = (│Before – After│).



∆ means “change” (*usually the final minus initial momentums, and use the absolute value of the difference of momentum from before and after a collision in this lab*). So, the momentum before a collision and after a collision should be the same if momentum is conserved.

An important ingredient to the conservation of momentum are elastic collisions. An **elastic collision** is a collision in which there is no net loss in kinetic energy in the system as a result of the collision. Both momentum and kinetic energy are conserved quantities in elastic collisions. An **inelastic collision** is a collision in which there is a loss of kinetic energy. While momentum of the system is conserved in an inelastic collision, kinetic energy is not. This type of collision is perfectly inelastic because the maximum possible kinetic energy has been lost.

**Hypothesis**

If collisions between two objects occur in a closed system, then momentum will be conserved.

**Procedures**

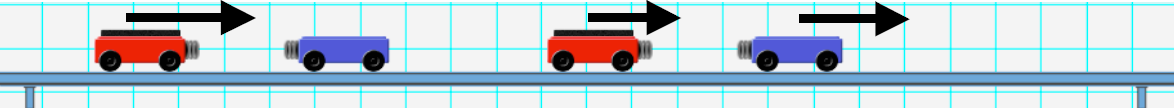
1. Complete the worksheet using the following video link: [**http://somup.com/cYfTYHiyN0**](http://somup.com/cYfTYHiyN0) .

2. For further optional investigation, use the following link to experiment on your own:

<https://www.physicsclassroom.com/Physics-Interactives/Momentum-and-Collisions/Collision-Carts/Collision-Carts-Interactive> .

## **Calculations and Data**

**COLLISION 1 ELASTIC COLLISION**

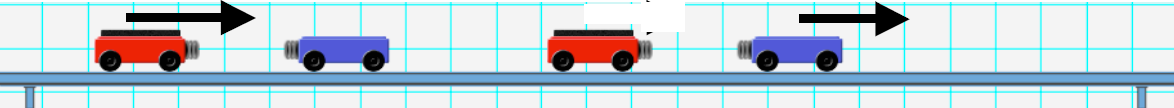
 **m Red = \_\_\_ kg** **m Blue = \_\_\_ kg**

BEFORE Collision **V Red = \_\_\_ m/s** **V Blue = \_\_\_ m/s**

AFTER Collision **V Red = \_\_\_ m/s** **V Blue = \_\_\_ m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s + \_\_ kg∙m/s** |
| AFTER Collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **\_\_ kg∙m/s - \_\_ kg∙m/s = \_\_ kg∙m/s** | |  |

**COLLISION 2 ELASTIC COLLISION**

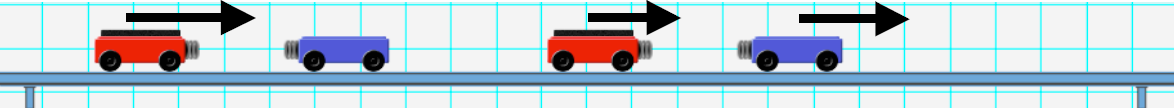
 **m Red = 3 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = 0 m/s**

AFTER Collision **V Red = 0 m/s** **V Blue = 10 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s + \_\_ kg∙m/s** |
| AFTER Collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **\_\_ kg∙m/s - \_\_ kg∙m/s = \_\_ kg∙m/s** | |  |

**COLLISION 3 INELASTIC COLLISION**

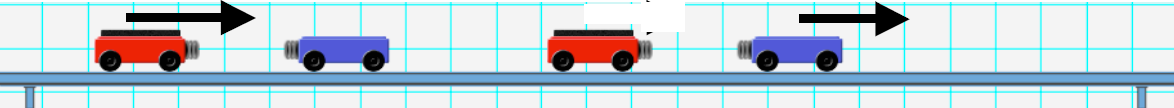
 **m Red = 3 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = 0 m/s**

AFTER Collision **V Red = 5 m/s** **V Blue = 5 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s + \_\_ kg∙m/s** |
| AFTER Collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **\_\_ kg∙m/s - \_\_ kg∙m/s = \_\_ kg∙m/s** | |  |

**COLLISION 4 ELASTIC COLLISION**

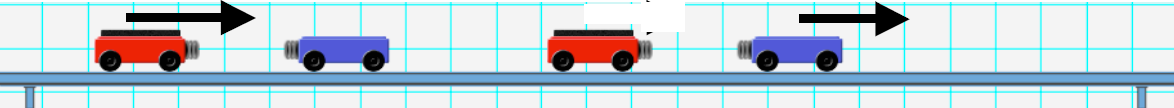
 **m Red = 3 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = -5 m/s**

AFTER Collision **V Red = -5 m/s** **V Blue = 10 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s + \_\_ kg∙m/s** |
| AFTER Collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **\_\_ kg∙m/s - \_\_ kg∙m/s = \_\_ kg∙m/s** | |  |

**COLLISION 5 ELASTIC COLLISION**

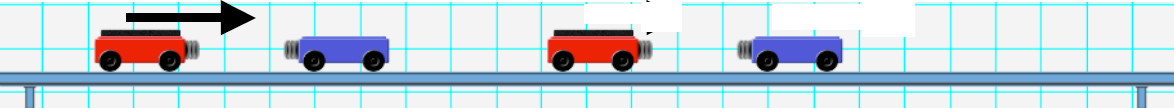
 **m Red = 3 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = -10 m/s**

AFTER Collision **V Red = -10 m/s** **V Blue = 10 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s + \_\_ kg∙m/s** |
| AFTER Collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **\_\_ kg∙m/s - \_\_ kg∙m/s = \_\_ kg∙m/s** | |  |

**COLLISION 6 ELASTIC COLLISION**

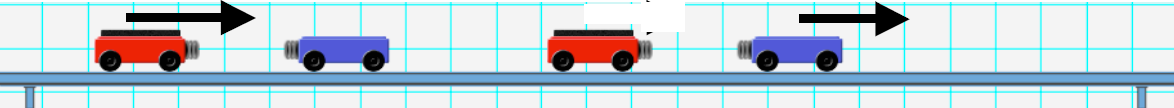
 **m Red = 1 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = -10 m/s**

AFTER Collision **V Red = -20 m/s** **V Blue = 0 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s + \_\_ kg∙m/s** |
| AFTER Collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **\_\_ kg∙m/s - \_\_ kg∙m/s = \_\_ kg∙m/s** | |  |

**COLLISION 7 ELASTIC COLLISION**

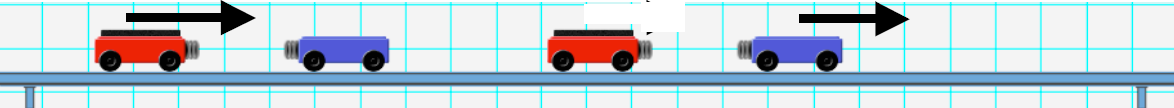
 **m Red = 1 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = 0 m/s**

AFTER Collision **V Red = -5 m/s** **V Blue = 5 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s + \_\_ kg∙m/s** |
| AFTER Collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **\_\_ kg∙m/s - \_\_ kg∙m/s = \_\_ kg∙m/s** | |  |

**COLLISION 8 INELASTIC COLLISION**

 **m Red = 1 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = 0 m/s**

AFTER Collision **V Red = 2.5 m/s** **V Blue = 2.5 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s + \_\_ kg∙m/s** |
| AFTER Collision | **\_\_\_ kg x \_\_\_ m/s**  **= \_\_\_ kg∙m/s** | | **\_\_ kg x \_\_ m/s**  **= \_\_\_ kg∙m/s** | **\_\_ kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **\_\_ kg∙m/s - \_\_ kg∙m/s = \_\_ kg∙m/s** | |  |

**Conclusions and Questions**

1. Did the 8 different collisions demonstrate the law of conservation of momentum? (Give at least one example of supporting evidence.)

2. Which has more momentum:

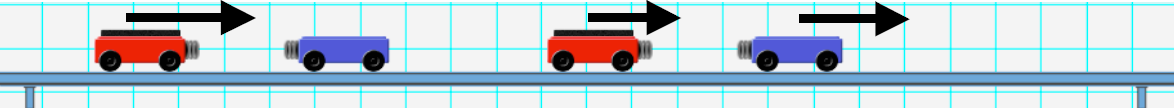
a. A skateboarding moving down the sidewalk or a parked car?

b. A 0.046 kg golf ball rolling at 60.0 m/s or a 7.0 kg bowling ball rolling at 6.0 m/s?

## **ANSWERS**

## **Calculations and Data**

**COLLISION 1 ELASTIC COLLISION**

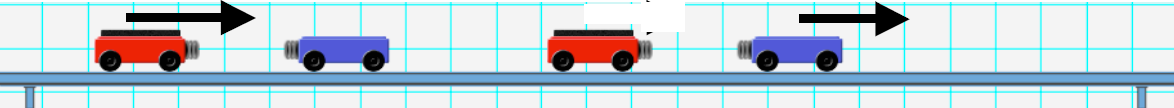
 **m Red = 3 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = 5 m/s**

AFTER Collision **V Red = 5 m/s** **V Blue = 10 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **3 kg x 10 m/s**  **= 30 kg∙m/s** | | **3 kg x 5 m/s**  **= 15 kg∙m/s** | **30 kg∙m/s + 15 kg∙m/s**  **45 kg∙m/s** |
| AFTER Collision | **3 kg x 5 m/s**  **= 15 kg∙m/s** | | **3 kg x 10 m/s**  **= 30 kg∙m/s** | **15 kg∙m/s + 30 kg∙m/s**  **45 kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **45 kg∙m/s - 45 kg∙m/s = 0 kg∙m/s** | |  |

**COLLISION 2 ELASTIC COLLISION**

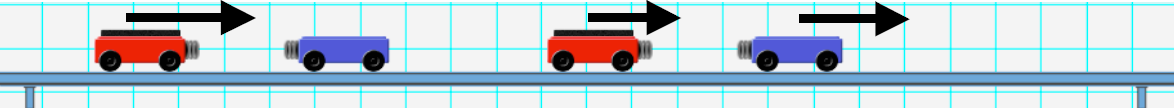
 **m Red = 3 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = 0 m/s**

AFTER Collision **V Red = 0 m/s** **V Blue = 10 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **3 kg x 10 m/s**  **= 30 kg∙m/s** | | **3 kg x 0 m/s**  **= 0 kg∙m/s** | **30 kg∙m/s + 0 kg∙m/s**  **30 kg∙m/s** |
| AFTER Collision | **3 kg x 0 m/s**  **= 0 kg∙m/s** | | **3 kg x 10 m/s**  **= 30 kg∙m/s** | **0 kg∙m/s + 30 kg∙m/s**  **30 kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **30 kg∙m/s - 30 kg∙m/s = 0 kg∙m/s** | |  |

**COLLISION 3 INELASTIC COLLISION**

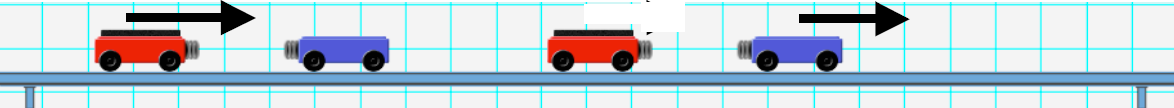
 **m Red = 3 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = 0 m/s**

AFTER Collision **V Red = 5 m/s** **V Blue = 5 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **3 kg x 10 m/s**  **= 30 kg∙m/s** | | **3 kg x 0 m/s**  **= 0 kg∙m/s** | **30 kg∙m/s + 0 kg∙m/s**  **30 kg∙m/s** |
| AFTER Collision | **3 kg x 5 m/s**  **= 15 kg∙m/s** | | **3 kg x 5 m/s**  **= 15 kg∙m/s** | **15 kg∙m/s + 15 kg∙m/s**  **30 kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **30 kg∙m/s - 30 kg∙m/s = 0 kg∙m/s** | |  |

**COLLISION 4 ELASTIC COLLISION**

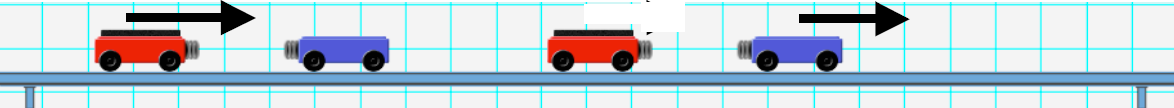
 **m Red = 3 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = -5 m/s**

AFTER Collision **V Red = -5 m/s** **V Blue = 10 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **3 kg x 10 m/s**  **= 30 kg∙m/s** | | **3 kg x -5 m/s**  **= -15 kg∙m/s** | **30 kg∙m/s + -15 kg∙m/s**  **15 kg∙m/s** |
| AFTER Collision | **3 kg x -5 m/s**  **= -15 kg∙m/s** | | **3 kg x 10 m/s**  **= 30 kg∙m/s** | **-15 kg∙m/s + 30 kg∙m/s**  **15 kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **15 kg∙m/s - 15 kg∙m/s = 0 kg∙m/s** | |  |

**COLLISION 5 ELASTIC COLLISION**

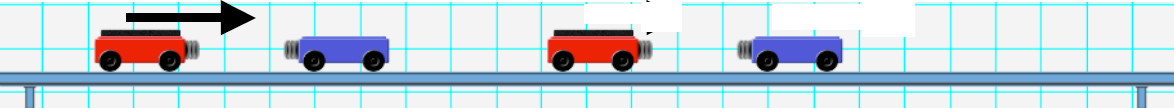
 **m Red = 3 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = -10 m/s**

AFTER Collision **V Red = -10 m/s** **V Blue = 10 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **3 kg x 10 m/s**  **= 30 kg∙m/s** | | **3 kg x -10 m/s**  **= -30 kg∙m/s** | **30 kg∙m/s + -30 kg∙m/s**  **0 kg∙m/s** |
| AFTER Collision | **3 kg x -10 m/s**  **= -30 kg∙m/s** | | **3 kg x 10 m/s**  **= 30 kg∙m/s** | **-30 kg∙m/s + 30 kg∙m/s**  **0 kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **0 kg∙m/s - 0 kg∙m/s = 0 kg∙m/s** | |  |

**COLLISION 6 ELASTIC COLLISION**

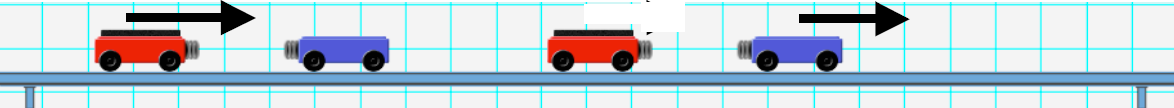
 **m Red = 1 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = -10 m/s**

AFTER Collision **V Red = -20 m/s** **V Blue = 0 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **1 kg x 10 m/s**  **= 10 kg∙m/s** | | **3 kg x -10 m/s**  **= -30 kg∙m/s** | **10 kg∙m/s + -30 kg∙m/s**  **-20 kg∙m/s** |
| AFTER Collision | **1 kg x -20 m/s**  **= -20 kg∙m/s** | | **3 kg x 0 m/s**  **= 0 kg∙m/s** | **-20 kg∙m/s + 0 kg∙m/s**  **-20 kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **-20 kg∙m/s – (-20 kg∙m/s) = 0 kg∙m/s** | |  |

**COLLISION 7 ELASTIC COLLISION**

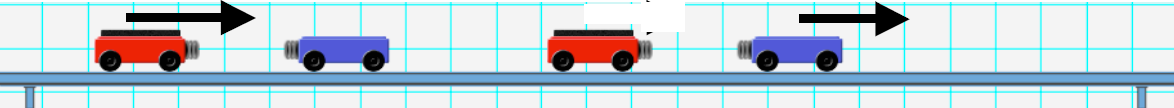
 **m Red = 1 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = 0 m/s**

AFTER Collision **V Red = -5 m/s** **V Blue = 5 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **1 kg x 10 m/s**  **= 10 kg∙m/s** | | **3 kg x 0 m/s**  **= 0 kg∙m/s** | **10 kg∙m/s + 0 kg∙m/s**  **10 kg∙m/s** |
| AFTER Collision | **1 kg x -5 m/s**  **= -5 kg∙m/s** | | **3 kg x 5 m/s**  **= 15 kg∙m/s** | **-5 kg∙m/s + 15 kg∙m/s**  **10 kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **10 kg∙m/s - 10 kg∙m/s = 0 kg∙m/s** | |  |

**COLLISION 8 INELASTIC COLLISION**

 **m Red = 1 kg** **m Blue = 3 kg**

BEFORE Collision **V Red = 10 m/s** **V Blue = 0 m/s**

AFTER Collision **V Red = 2.5 m/s** **V Blue = 2.5 m/s**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Red Cart** | | **Blue Cart** | Total Momentum  (Red + Blue) |
| BEFORE collision | **1 kg x 10 m/s**  **= 10 kg∙m/s** | | **3 kg x 0 m/s**  **= 0 kg∙m/s** | **10 kg∙m/s + 0 kg∙m/s**  **10 kg∙m/s** |
| AFTER Collision | **1 kg x 2.5 m/s**  **= 2.5 kg∙m/s** | | **3 kg x 2.5 m/s**  **= 7.5 kg∙m/s** | **2.5 kg∙m/s + 7.5 kg∙m/s**  **10 kg∙m/s** |
| ∆ Momentum  (│Before – After│) | | **10 kg∙m/s - 10 kg∙m/s = 0 kg∙m/s** | |  |

**Conclusions and Questions**

1. Did the 8 different collisions demonstrate the law of conservation of momentum? (Give at least one example with supporting evidence.)

*All 8 collisions demonstrated the law of conservation of momentum, meaning that the change in momentum was 0 kg∙m/s.*

2. Which has more momentum:

a. A skateboarding moving down the sidewalk or a parked car?

*P = mv … since the parked car has a v= 0 m/s, the skateboarder has more momentum.*

b. A 0.046 kg golf ball rolling at 60.0 m/s or a 7.0 kg bowling ball rolling at 6.0 m/s?

*P golf ball = mv 0.046 kg x 60.0 m/s = 2.8 kg∙m/s*

*P bowling ball = mv 7.0 kg x 6.0 m/s = 42.0 kg∙m/s*

*The bowling ball has much more momentum than the golf ball.*