Impulse and Momentum

Momentum is a vector defined as the product of an object’s mass $m$ and velocity $\vec{v}$,

$$\vec{p} = m\vec{v}.$$ 

The units of momentum are $kg\ m/s$. Momentum has the same direction as the velocity.

Impulse is very closely related to momentum. Impulse is a vector, $\vec{J}$, defined as the change in the momentum of an object:

$$\vec{J} = \Delta\vec{p}$$

$$= \vec{p}_f - \vec{p}_i$$

where $\vec{p}_f$ and $\vec{p}_i$ are the final and initial momentum respectively. It can be shown that impulse is the average force, $F_{avg}$, multiplied by the change in time $\Delta t$;

$$\vec{J} = F_{avg}\Delta t.$$ 

Note: Since this experiment only involves one dimension, the sign of the impulse and momentum vectors will indicate direction.

To talk about momentum conservation and impulse on a group of objects we need to first mention two concepts;

1. System,
2. External Force.

The system is the set of objects or single object that we are considering. For example if we have two cars colliding we can consider the two cars as our system. Alternatively we could consider one of the two cars as our system.

An external force is defined using the idea of a system. It is any force that is applied on the system from outside the system. For example, if our two cars collide and we choose our system to be the two cars, there is no external force (the force between them is internal because it is between two objects in the system). If we choose our system to be one car on the other hand, there will be an external force since the other car is outside the system and it provides a force.
The momentum of a system is defined as the sum of all the momenta of all the objects in the system:

\[ \vec{p}_{sys} = \sum_i \vec{p}_i = \vec{p}_1 + \vec{p}_2 + \ldots \]

The next two statements are the most important for this lab and you should refer back to them throughout the lab.

If a system has no net external force, then momentum is conserved, \( \vec{p}_{sys_i} = \vec{p}_{sys_f} \).
If a system has a net external force, then momentum is not conserved, \( \vec{p}_{sys_i} \neq \vec{p}_{sys_f} \).
Prelab Questions

These questions need to be completed before entering the lab. Please show all workings.

Marker’s Initials

Prelab 1

If the mass of an object is 0.412 kg and its velocity is 0.436 m/s right, what is the momentum? Note: Consider the positive x axis to be to the right. Give your answer in unit vector notation.

Prelab 2

If the mass of an object is 0.412 kg and its velocity is 0.436 m/s left, what is the momentum? Give your answer in unit vector notation.

Prelab 3

The mass of an object is (0.412 +/- 0.009) kg and its velocity is (0.436 +/- 0.008) m/s left. What is the magnitude of the momentum and its uncertainty?
Laboratory Worksheet:

Name and Student Number: _____________________________
Partner’s Name: _____________________________
Date: _____________________________

QUESTION 1:

Table 1:

<table>
<thead>
<tr>
<th>Value</th>
<th>Uncertainty</th>
<th>Cart Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_1$ [kg]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m_2$ [kg]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$v_{1i}$ [m/s]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$v_{2i}$ [m/s]</td>
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</tr>
<tr>
<td>$v_{1f}$ [m/s]</td>
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<td></td>
</tr>
<tr>
<td>$v_{2f}$ [m/s]</td>
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<td></td>
</tr>
</tbody>
</table>

CHECKPOINT: Instructor Initial
QUESTION 2:

QUESTION 3:

\[ p_i = \]

QUESTION 4:

\[ p_i = \]
QUESTION 5:

\[ p_f = \]

QUESTION 6:

\[ p_f = \]

QUESTION 7:

QUESTION 8:
QUESTION 9:

QUESTION 10:

QUESTION 11:

QUESTION 12:
QUESTION 13: 

QUESTION 14: 

QUESTION 15: 

QUESTION 16: