Collisions

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Introduction

Both Galileo Galilei and Isaac Newton described a quantity of motion which was the product of an object's mass and its velocity. Newton's description of this quantity, momentum, was actually tied to his statement of his second law. While we are used to writing it as follows:

1) $$\sum F = m a$$

Newton's expression of this law was more like this:

2) $$\sum F = \frac{\Delta p}{\Delta t}$$

where Δp is the change in momentum of a system due to the net force on the left hand side of equation 2). When the net force is zero as in an idealized system with no friction, air resistance (or other forces), equation 2) simplifies to give us a statement of momentum conservation:

3) $$\Delta p = 0$$

This should be taken to mean that in the absence of external forces acting on a system, momentum is conserved.

As applied to collisions in an ideal environment, one would expect that the total momentum before a collision, p, is the same as the total momentum after the collision, p'.

4) $$p = m_1 v_1 + m_2 v_2$$

5) $$p' = m_1 v_1' + m_2 v_2'$$

In elastic collisions, the kinetic energy, K, before the collision is the same as the kinetic energy after the collision, K':

6) $$K = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$$

7) $$K' = \frac{1}{2} m_1 v_1'^2 + \frac{1}{2} m_2 v_2'^2$$

In inelastic collisions, momentum is conserved, but kinetic energy is not. In this case, kinetic energy is lost to deformation or other sources. In this lab we shall investigate whether the principle of conservation of momentum holds within our ability to measure, and presuming that we can negate the effects of outside forces. Additionally, we shall confirm that conservation of kinetic energy applies for elastic collisions, but not for inelastic collisions.

Procedure

Set up the air track as indicated by your instructor. Mass the carts. Level the air tracks so that when turned on, the air carts don't drift. Set up the photo gate timers to measure velocity. You will need to measure the flag length and enter it into Data Studio so that your velocities are accurate. Make the following measurements indicated by the tables below. Be certain to estimate uncertainties in mass, velocity, momentum, and kinetic energy.

Elastic Collision 1: v_1 positive, v_2 negative, $m_1 = m_2$

$m_1 = m_2 =$ _______________

v_1	v_2	p	K	v_1'	v_2'	p'	K'	p - p'	K - K'
δv_1	δv_2	δp	δK	$\delta v_1'$	$\delta v_2'$	$\delta p'$	$\delta K'$	$\delta p + \delta p'$	$\delta K + \delta K'$

Elastic Collision 2: v_1 positive, v_2 positive , $m_1 = m_2$

$m_1 = m_2 =$ _______________

v_1	v_2	p	K	v_1'	v_2'	p'	K'	p - p'	K - K'
δv_1	δv_2	δp	δK	$\delta v_1'$	$\delta v_2'$	$\delta p'$	$\delta K'$	$\delta p + \delta p'$	$\delta K + \delta K'$

Elastic Collision 3: v_1 positive, $v_2 = 0$, $m_1 = m_2$

$m_1 = m_2 =$ _______________

v_1	v_2	p	K	v_1'	v_2'	p'	K'	p - p'	K - K'
δv_1	δv_2	δp	δK	$\delta v_1'$	$\delta v_2'$	$\delta p'$	$\delta K'$	$\delta p + \delta p'$	$\delta K + \delta K'$

Elastic Collision 4: v_1 positive, v_2 negative, $m_1 \neq m_2$

$m_1 =$ _______________ $m_2 =$ _______________

v_1	v_2	p	K	v_1'	v_2'	p'	K'	p - p'	K - K'
δv_1	δv_2	δp	δK	$\delta v_1'$	$\delta v_2'$	$\delta p'$	$\delta K'$	$\delta p + \delta p'$	$\delta K + \delta K'$

Elastic Collision 5: v_1 positive, v_2 positive, $m_1 \neq m_2$

$m_1 =$ _______________ $m_2 =$ _______________

v_1	v_2	p	K	v_1'	v_2'	p'	K'	p - p'	K - K'
δv_1	δv_2	δp	δK	$\delta v_1'$	$\delta v_2'$	$\delta p'$	$\delta K'$	$\delta p + \delta p'$	$\delta K + \delta K'$

Elastic Collision 6: v_1 positive, $v_2 = 0$, $m_1 \neq m_2$

m_1 = ______________ m_2 = ______________

v_1	v_2	p	K	v_1'	v_2'	p'	K'	p - p'	K - K'
δv_1	δv_2	δp	δK	$\delta v_1'$	$\delta v_2'$	$\delta p'$	$\delta K'$	$\delta p + \delta p'$	$\delta K + \delta K'$

Inelastic Collision 1: v_1 positive, v_2 negative, $m_1 = m_2$

$m_1 = m_2$ = ______________

v_1	v_2	p	K	v_1'	v_2'	p'	K'	p - p'	K - K'
δv_1	δv_2	δp	δK	$\delta v_1'$	$\delta v_2'$	$\delta p'$	$\delta K'$	$\delta p + \delta p'$	$\delta K + \delta K'$

Inelastic Collision 2: v_1 positive, v_2 positive , $m_1 = m_2$

$m_1 = m_2$ = ______________

v_1	v_2	p	K	v_1'	v_2'	p'	K'	p - p'	K - K'
δv_1	δv_2	δp	δK	$\delta v_1'$	$\delta v_2'$	$\delta p'$	$\delta K'$	$\delta p + \delta p'$	$\delta K + \delta K'$

Inelastic Collision 3: v_1 positive, $v_2 = 0$, $m_1 = m_2$

$m_1 = m_2$ = ______________

v_1	v_2	p	K	v_1'	v_2'	p'	K'	p - p'	K - K'
δv_1	δv_2	δp	δK	$\delta v_1'$	$\delta v_2'$	$\delta p'$	$\delta K'$	$\delta p + \delta p'$	$\delta K + \delta K'$

Inelastic Collision 4: v_1 positive, v_2 negative, $m_1 \neq m_2$

m_1 = ______________ m_2 = ______________

v_1	v_2	p	K	v_1'	v_2'	p'	K'	p - p'	K - K'
δv_1	δv_2	δp	δK	$\delta v_1'$	$\delta v_2'$	$\delta p'$	$\delta K'$	$\delta p + \delta p'$	$\delta K + \delta K'$

Inelastic Collision 5: v_1 positive, v_2 positive, $m_1 \neq m_2$

m_1 = _______________ m_2 = _______________

v_1	v_2	p	K	v_1'	v_2'	p'	K'	p - p'	K - K'
δv_1	δv_2	δp	δK	δv_1'	δv_2'	δp'	δK'	δp + δp'	δK + δK'

Inelastic Collision 6: v_1 positive, v_2 = 0, $m_1 \neq m_2$

m_1 = _______________ m_2 = _______________

v_1	v_2	p	K	v_1'	v_2'	p'	K'	p - p'	K - K'
δv_1	δv_2	δp	δK	δv_1'	δv_2'	δp'	δK'	δp + δp'	δK + δK'

Analysis

Calculate the pre- and post collision momentum and kinetic energy for each collision. Remember that the sign of the velocity is important in calculating momentum! Determine the change in momentum (p-p') and the change in kinetic energy (K-K') for each collision. Calculate the uncertainties in momentum:

8) $$\delta p = p\sqrt{\left(\frac{\delta m}{m}\right)^2 + \left(\frac{\delta v}{v}\right)^2}$$

and kinetic energy:

9) $$\delta K = K\sqrt{\left(\frac{\delta m}{m}\right)^2 + 2\left(\frac{\delta v}{v}\right)^2}$$

Compare the measured changes in kinetic energy and momentum to the total uncertainty of each quantity. If the difference from pre- to post collision is less than the total uncertainty, what can you say. What if the difference is larger that the total uncertainty? What sources of uncertainty are there in this experiment? Are you able to account for all of them? What is the point of using an air track? In the case of inelastic collisions, why is energy not conserved (there's no deformation, right?) Did the results match what was expected?