COLLISIONS *Fall 2016*

I. PURPOSE

In this experiment you will examine both elastic and inelastic collisions in one dimension. After you finish the experiment you should understand:

- the differences between elastic and inelastic collisions
- how momentum and energy apply to collisions
- what part mass plays in a collision

II. THEORY

(This material is covered in chapter 9 of the PHYS 1111 textbook, *Physics*, 4th ed., by James S. Walker; and in chapters 9 & 10 of the PHYS 1211 textbook, Physics for Scientistists and Engineeers, 3rd ed., by Randall D. Knight.) In this experiment two objects will collide and we will assume that the net external force is either negligible or zero.

A. In an **inelastic collision** momentum is conserved, but kinetic energy is not.

$\mathbf{p}_i = \mathbf{p}_f$ and $K_i \neq K_f$

where i = initial (before the collision) and f = final (after the collision)

Some of the kinetic energy is lost by being converted to other forms of energy associated with sound, heat, deformation, etc. In this experiment we will examine the special case of an inelastic collision in one-dimension in which an object that is moving collides with an object at rest and the two "stick" together after the collision.

For this case **the momentum equations** are:

Before the collision: $\mathbf{p}_i = m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i}$, but since $\mathbf{v}_{2i}$ is zero… $\mathbf{p}_i = m_1\mathbf{v}_{1i}$

After the collision: $\mathbf{p}_f = m_1\mathbf{v}_{1f} + m_2\mathbf{v}_{2f}$, but since the objects stick together they have the same velocity, $\mathbf{v}_f$, so $\mathbf{p}_f = (m_1 + m_2)\,\mathbf{v}_f$

$\mathbf{p}_i = \mathbf{p}_f$ so $m_1\mathbf{v}_{1i} = (m_1 + m_2)\,\mathbf{v}_f$ or more simply $m_1\mathbf{v}_i = (m_1 + m_2)\,\mathbf{v}_f$ (1)

If the masses of the two objects are equal then $\mathbf{v}_i = 2\,\mathbf{v}_f$ (2)

The **kinetic energy equations** are:

Before the collision: $K_i = ½\ m_1v^2_{1i} + ½\ m_2v^2_{2i}$, but again v_{2i} is zero so… $K_i = ½\ m_1v^2_{1i}$

or more simply $K_i = ½\ m_1v^2_i$ (3)

After the collision: $K_f = ½\ (m_1 + m_2)v^2_f$ (4)

Again, if the two masses are equal then $K_i = 2K_f$ (5)

B. In an **elastic collision** both momentum and kinetic energy are conserved.

$\mathbf{p}_i = \mathbf{p}_f$ and $K_i = K_f$

The momentum equation is: $m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = m_1\mathbf{v}_{1f} + m_2\mathbf{v}_{2f}$ (6)

The kinetic energy equation is: $½\ m_1v^2_{1i} + ½\ m_2v^2_{2i} = ½\ m_1v^2_{1f} + ½\ m_2v^2_{2f}$ (7)

If the second object is again at rest before the collision these reduce to:

$m_1\mathbf{v}_i = m_1\mathbf{v}_{1f} + m_2\mathbf{v}_{2f}$ and,

$½\ m_1v^2_i = ½\ m_1v^2_{1f} + ½\ m_2v^2_{2f}$

Using these two equations to solve for the final velocities of each object yields:

$v_{1f} = ((m_1 - m_2)/(m_1 + m_2))v_i$ (8)

$v_{2f} = ((2m_1)/(m_1 + m_2))v_i$ (9)

Notice that the final velocity of object two is always positive, but the final velocity of object one is positive if it has a larger mass than object two, negative if it has a smaller mass than object two and zero if it has the same mass as object two.

III. APPARATUS

You will be using the linear air track again in this experiment but this time you will be using two gliders and the track now has ultrasonic motion detectors at each end. Each detector will record the motion of the glider nearest to it and these motions will be displayed independently on the same graph. Notice that each glider has a bumper at one end and a Velcro clip at the other end.

IV. PROCEDURE

Preparation (Note: The equipment used in the Science Learning Center (SLC) lab room is slightly different from that used in the Physics building. The instructions in bold are for the SLC equipment.)

1. Log in to the computer and initiate the software. You should see a displacement vs. time graph and a velocity vs. time graph. You will only be using the displacement vs. time graph so you may delete the other graph and expand the displacement vs. time graph to fill the screen.
2. Measure the masses of the two red (**black**) gliders <u>only</u> and record them on the worksheet.
3. Place the two red (**black**)gliders on the track with their bumpers facing each other.
4. You must now set the "zero" reference for the displacement readings:
   a. Move the glider on the left up against the air track bumper on the left and the glider on the right up against the air track bumper on the right.
   b. From the **Menu** choose **Experiment** and click on **Zero.** In the window that appears you should see both detectors selected. If they are not, select them. Click **OK**.
5. With only one glider on the track, turn on the blower and **level the air track** as you have done in previous air track experiments--this step is very important in this experiment <u>and remember to tighten the wing nut on the leveling leg when you are done.</u>
6. Put both red (**black**) gliders on the track with their bumpers facing each other.
7. Click the <u>*arrow button*</u> to start a data run. You should see two graphs being generated—one for each glider. Note which glider corresponds to which graph. Adjust the angle of the motion detectors if necessary to get "clean" graphs. Gently push the gliders to see how the graphs display the interactions between them.

Inelastic Collision

1. Turn the red (**black**) gliders around so that the Velcro clips are facing each other.
2. Place the left bottom edge of the glider on the right at roughly the center of the track—the 75 cm and 80 cm marks are good numbers to use—and hold it there. Place the other glider near the left end of the track.
3. Hit the *arrow button* to start collecting data and push the left-hand glider towards the right-hand glider. Just before the gliders collide remove your hand from the right-hand glider. The reason for holding the right–hand glider still is that you want it to start from rest. (You may want to practice this a few times.)
4. When you are ready, perform your first data run.
5. Select a region of the graph for the left-hand glider just before the collision and apply a linear fit on this. Record this as v_i on the data table. Select a region of the graph of the right-hand glider just after the collision and apply another linear fit. This is v_f.
6. Repeat this procedure two more times and record the data.
7. When both groups using the same air track blower are done collecting the data—TURN OFF THE BLOWER. Calculate all of the other items in the table using the appropriate equations and answer the questions related to inelastic collisions.

Elastic Collision

1. Still using the red (**black**) gliders, turn them around so that the bumpers are facing each other.
2. Again hold the right-hand glider still at the center of the track and place the left-hand glider near the left end of the track.
3. Start the data collection and push the left-hand glider toward the right-hand glider. Just before they collide, release the right-hand glider.
4. Notice what happens to each glider after the collision (see Question 1 for elastic collisions).
5. Apply the linear fits to the appropriate regions of the graphs as before and record the data.
6. Perform one more trial.
7. When both groups using the same air track blower are done collecting the data—TURN OFF THE BLOWER. Calculate all of the items in the table using the appropriate equations and answer the questions related to elastic collisions.

Unknown Mass

1. Remove the right-hand glider and put the smaller gold glider in its place.

(1. Add the unknown mass to the black glider on the left. It screws into the top of the glider; your TA will show you how. Add it to the right of the reflector so that it does not interfere with the motion detector.)

2. Hold the glider on the right at rest and repeat the experiment. Notice what happens to both gliders after the collision (see Questions 1 and 2 for unknown mass.)
3. Apply the linear fits to the appropriate regions of the graphs as before and record the data**.** This time you will also apply a linear fit to the region of the graph of the more massive glider just after the collision; this will be v_{1f}.
4. Perform one more trial.
5. When both groups using the same air track blower are done collecting the data—TURN OFF THE BLOWER. You now need to figure out how to compute the unknown mass of the gold glider (**unknown mass attached to black glider**) using what you have learned in the experiment (see Question 3 for unknown mass).

Smaller Mass Hitting a Larger Mass That is at Rest

1. With the more massive glider still on the left, hold it still at the center of the track and put the less massive glider at the right end of the track.
2. Start the data collection and push the less massive glider into the more massive glider, again releasing the more massive glider just before the collision.
3. **Describe** what you observe regarding speeds and directions of each glider before and after the collision.

Name_______________________________ Day/Time____________________

Lab Partner_________________________ Instructor_____________________

COLLISIONS

Mass of Glider 1 (Left-hand glider) = ____________ kg
Mass of Glider 2 (Right-hand glider) = ____________ kg

Inelastic Collision

Trial	v_i (m/s)	v_f (m/s)	$2v_f$ (m/s)	%Diff.	K_i (J)	K_f (J)	$2K_f$ (J)	%Diff.
1								
2								
3								

1. For the special case of an inelastic collision between objects of equal mass, one object being at rest, $v_i = 2\ v_f$ and $K_i = 2\ K_f$. Do your data show this? If not, why not?

Elastic Collision

Trial	v_{1i} (m/s)	v_{1f} (m/s)	v_{2i} (m/s)	v_{2f} (m/s)
1				
2				

Trial	p_i (kg m/s)	p_f (kg m/s)	%Diff.	K_i (J)	K_f (J)	%Diff.
1						
2						

1. What happened to the left-hand glider after the collision? Why?

2. Was this an elastic collision? Why or why not?

Unknown Mass

Trial	v_{1i} (m/s)	v_{1f} (m/s)	v_{2f} (m/s)	Unknown Mass (kg)
1				
2				

1. After the collision what happened to the speed of the more massive glider?

2. After the collision is the speed of the less massive glider larger or smaller than the initial speed of the more massive glider?

3. Show how you determined the value of the unknown mass. Include all equations used and show calculations using the values for just one trial.

Measured value of unknown mass = __________ kg

Trial	%Error
1	
2	

4. What may have caused errors in the experimental determination of the unknown mass?

Smaller Mass Hitting a Larger Mass That is at Rest

1. Describe what you observe regarding speeds and directions of each glider before and after the collision.