EXPERIMENT 6b
Elastic One-dimensional Collisions

Objectives

- to measure the momentum and kinetic energy of two objects before and after a one-dimensional collision

- to try to account for any change in KE in the nearly elastic collision

- compare and contrast the results obtained from the inelastic collision experiment with the results obtained from this experiment

Apparatus

The same apparatus used in the inelastic experiment will be used in this experiment. However, one of the carts will use an elastic bumper (see Figure 1 below). The second cart will be fitted with a bumper blade which will make contact with the elastic bumper on the first cart during the collision. A bumper blade is on the left hand side of the cart shown in Figure 1 and the elastic bumper is on the right hand side of the cart.
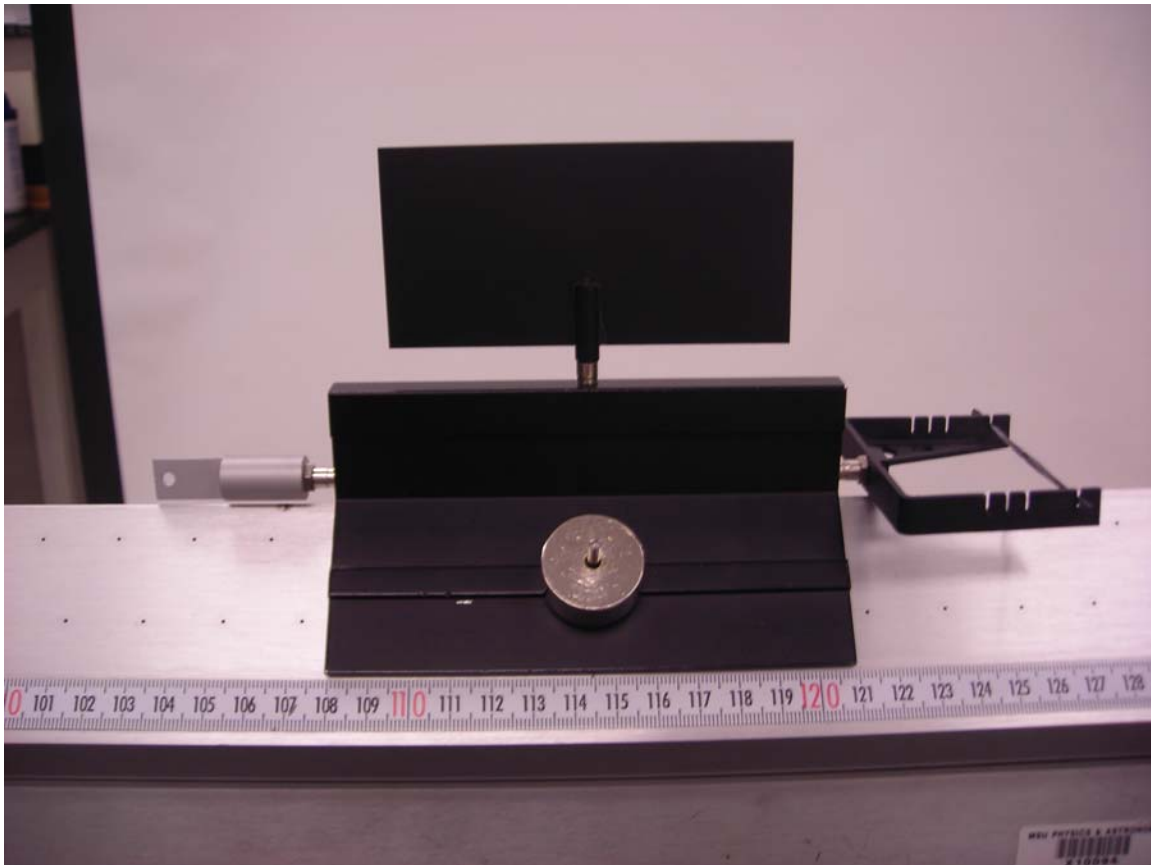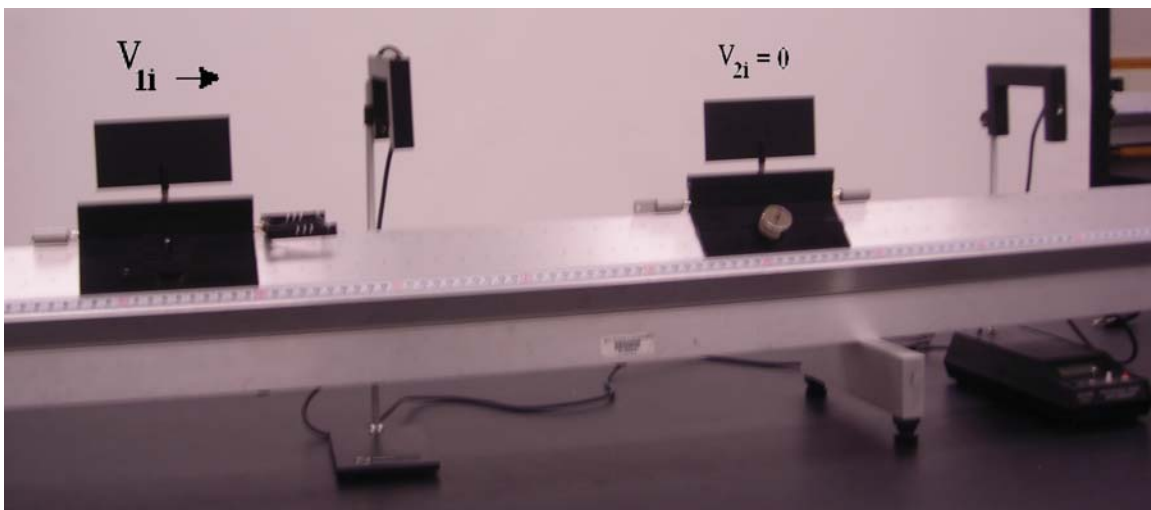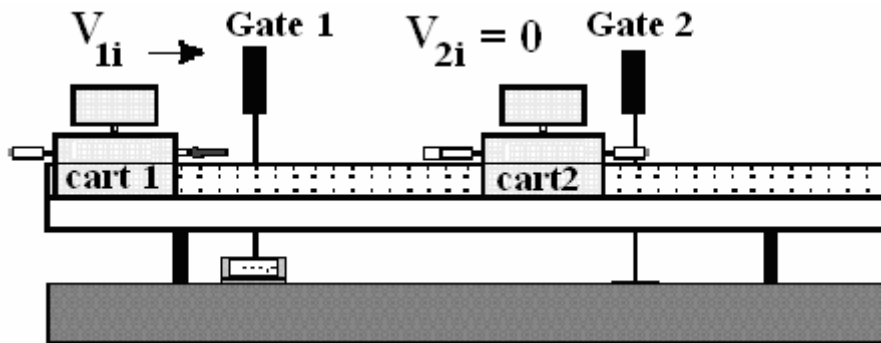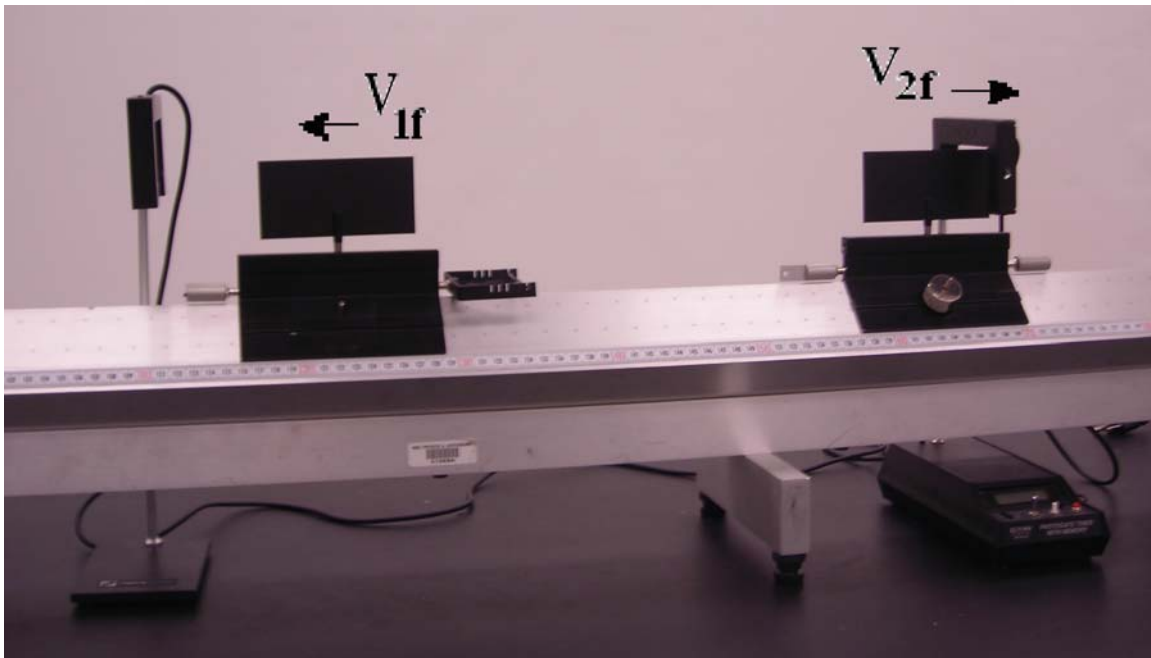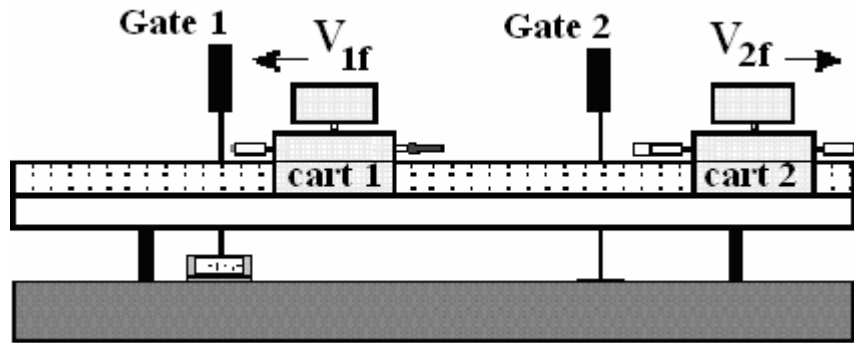

Figure 1

Procedure

In this experiment we will try to obtain an almost elastic collision of two carts on the air track. The main difference from the previous lab is that the carts will now move separately after the collision. The elastic bumper allows the carts to bounce off of each other with almost no conversion of kinetic energy into other forms of energy.

As before, Cart 2 is initially at rest. Before the collision we have to measure only the velocity of Cart 1, v_{1i} (Figure 1). However, after the collision we have to measure the velocities of <u>both</u> carts, v_{1f} and v_{2f} (Figure 2). Thus, in all we have to measure <u>three</u> times (t_{1i}, t_{1f}, and t_{2f}), while the photogate system allows us to simultaneously measure only <u>two</u> of them.

We can get out of this situation if <u>after</u> the measurement of the initial time t_1, but <u>before</u> the collision of the two carts, we reset the timer. You will probably have to make several practice trials to learn to quickly remember and reset the contents of the timer before the carts collide. Then, we can again use the contents of the timer display and the memory to find t_{1f} and t_{2f}.

Figure 2: The Initial State of the Carts Before the Collision

Figure 3: The Final State of the Carts After the Collision

The fins on two carts have the same length. Verify this by measuring these lengths L_1 and L_2. Again the masses of the carts can be varied by adding the metal disks, or weights, to them.

Remember, the experiment will be done with Cart 2 initially at rest. So in the initial state we have

Initial state: Cart 1:   has a mass m_1 and initial velocity v_1
                   Cart 2:   has mass m_2 and is at rest, so $v = 0$ cm/s

After the collision (final state):   the two carts will be moving independently
                                          the speeds of the carts will be v_{1f} for m_1 and v_{2f} for m_2

You will do 6 trials with the following m_1 and m_2 choices:

Trials 1 & 2:   no mass disks on Cart 1, 2 mass disks on Cart 2; measure v_{1i}, v_{1f} and v_{2f}
Trials 3 & 4:   2 mass disks on Cart 1, 2 mass disk on Cart 2; measure v_{1i}, v_{1f} and v_{2f}
Trails 5 & 6:   2 mass disks on Cart 1, no mass disks on Cart 2; measure v_{1i}, v_{1f} and v_{2f}

To measure these speeds you measure the times t_1, t_{1f}, and t_{2f}. Enter the data into the spreadsheet and have *Excel* calculate the momenta and kinetic energies before and after the collisions, as well as the percent change in the <u>total</u> momentum and in the kinetic energy. Due to the large number of equations involved in this experiment, all of the *Excel* formulae have been programmed in for you for this lab except for the formula for the final velocity of cart 1. Velocity is a vector quantity and in one dimension, its direction is indicated by its sign. For this experiment, the positive direction is defined as the direction of the INITIAL velocity of cart 1. In each of your trials you will need to in a formula for v_{1f} – make sure you include the observed direction of this vector in your formulae!

Although almost all of the formulae are programmed into *Excel* for you, you need to include manual calculations for all of the cells highlighted in blue. The only formulae you will need to enter are the formula for the velocities. Remember, velocity (like momentum) is a vector and in one dimension its direction is indicated by its sign. Assign the initial direction of Cart 1 as the positive direction.

Start with Trial 1, enter your measurements into your spreadsheet and check the spreadsheet to see if the change in momentum and the change in kinetic energy is less than 5%. If either is not, you should repeat Trial 1 before proceeding to the other trials. If the either change is greater than 5% you should verify that the air track is level before redoing the trial. When running your trials, it is very important that both carts are balanced. That is, a counter balance is attached to both Carts 1 and 2. In addition, all of these accessories must be placed in the lower holes on Carts 1 and 2. Furthermore, Cart 2 must be at rest prior to the collision, Cart 1 must have passed through the first photogate before the collision; you must have read the first time from the photogate timer and pressed the reset button before the fin on top of either cart enters one of the photogates.

After the collision, it is important that both carts are NOT passing through different photogates simultaneously.   Since the spreadsheet is set up it is easy to see whether momentum and/or energy are better conserved with every trial you do.

For some of your trials, one of the carts may be stationary after the collision. What does this mean? Answer: Its velocity is zero. What time must you use in your spreadsheet in order to simulate/approximate this final velocity (you will need to enter a numerical value)?

QUESTIONS

1. For which of your trials was momentum conserved? Justify your response.

2. For which of your runs was kinetic energy conserved? Justify your response.

3. Qualitatively compare the results of the elastic and inelastic collision experiments (i.e. what was conserved and what was not).

4. Where did the kinetic energy go that was lost in the inelastic collisions you performed in the previous experiment?

Summary of formulae for momentum and kinetic energy

Initial state:

Measure photogate time t_1, calculate v_1 and the error in v_{1i} (called δv_{1i} on the spreadsheet)*

Momentum: $P_i = m_1 v_1$ and kinetic energy: $KE_i = \dfrac{m_1 v_{1i}^2}{2}$

Final state:

Measure the photogate times t_{1f} and t_{2f}, calculate v_{1f}, v_{2f} and the error in the final velocities (called δv_{1f} and δv_{2f} on the spreadsheet)*

Momentum: $P_f = m_1 v_{1f} + m_2\ v_{2f}$ and kinetic energy: $KE_f = \dfrac{m_1 v_{1f}^2 + m_2 v_{2f}^2}{`2}$

Note: Momentum is a vector quantity i.e. in one dimension it has a sign.

The difference between the final state and the initial state is:

Momentum: $P_{diff} = P_f - P_i$ which is called Pdiff in the spreadsheet

Kinetic energy: $KE_{diff} = KE_f - KE_i$ which is called KEdiff in the spreadsheet

*Summary of uncertainties

You have to determine (this means choose) the uncertainties in the length measurement (δL) and your time measurement (δt). There is a brief discussion on estimating uncertainties in part 2 of Course Supplement A.

Here we will neglect the uncertainty in the mass measurement. The uncertainty in the velocity is given by:

$$\frac{\delta v}{v} = \frac{\delta L}{L} + \frac{\delta t}{t} \text{ resulting in } \delta v = v\left(\frac{\delta L}{L} + \frac{\delta t}{t}\right)$$

The uncertainty in momentum is: $\delta P = P\dfrac{\delta v}{v}$

and the uncertainty in kinetic energy is: $\delta KE = 2\dfrac{\delta v}{v}$

The uncertainties in the differences for the momenta and kinetic energies are then:

$$\delta P_{diff} = \delta P_f + \delta P_i \quad \text{and} \quad \delta KE_{diff} = \delta KE_f + \delta KE_i$$

Tabulate the results of the measurements on this sheet.

Carts' masses, grams

	Cart 1	Cart 2
No mass disks		
2 mass disks		

Length of the fin on cart 1 _____ cm

Length of the fin on cart 2 _____ cm

Measured times, sec

Trial #	$t_{1initial}$	t_{2final}	memory	t_{1final}	Comments
1					**0 disks on Cart 1**
2					**2 disks on Cart 2**
3					**2 disks on Cart 1**
4					**2 disks on Cart 2**
5					**2 disks on Cart 1**
6					**0 disks on Cart 2**