EXPERIMENT 6a
Inelastic One-dimensional Collisions

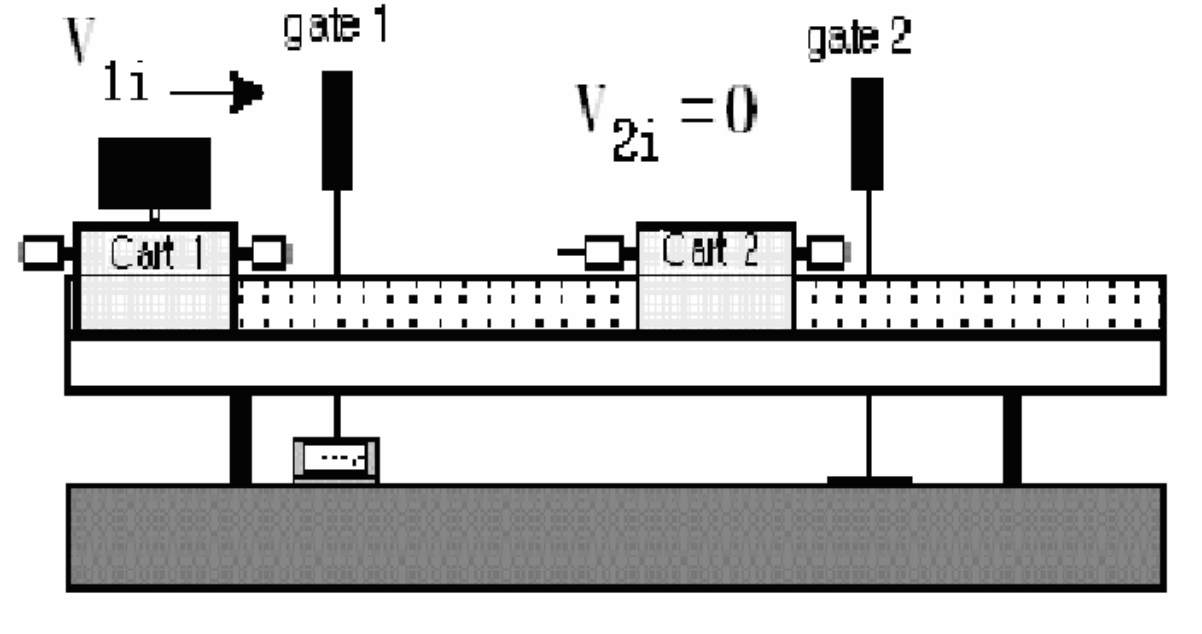
Objectives

- to measure the momentum and kinetic energy of two objects before and after a completely inelastic one-dimensional collision
- to observe that the concept of **conservation of momentum** is independent of **conservation of energy**, that is, the total momentum remains constant in an inelastic collisions while the kinetic energy changes
- to calculate the percentage of KE which will be lost (converted to other forms of energy, notably heat) in a completely inelastic collision between an initially stationary mass and an initially moving mass; and to compare this calculation with the result of the elastic collision

Procedure

In this and the next experiment we will analyze collisions between two carts of varying masses in the case where one of the carts is initially at rest. The carts move on an air track. Therefore, in order to insure that no energy due to the gravitational potential is created, you should first make sure that your track is level.

In this lab we study the totally inelastic collision, by arranging that when two carts collide they will stick together and move with some final velocity common to both masses. Thus, we have only to measure the velocity of Cart 1 before the collision and the common velocity of the carts after the collision, since of course the velocity of Cart 2 is zero before the collision. For this purpose, we use two photogates (see Figure 1). Each of them allows us to measure the time it takes for the cart or carts to go through it. The photogates record times by sensing the fins attached to the tops of the carts while they are moving through the photogates' light beams. Therefore the velocities for these labs are calculated by dividing the length of the fin (NOT the length of the cart) by the time measured by the photogate (speed = length/time).



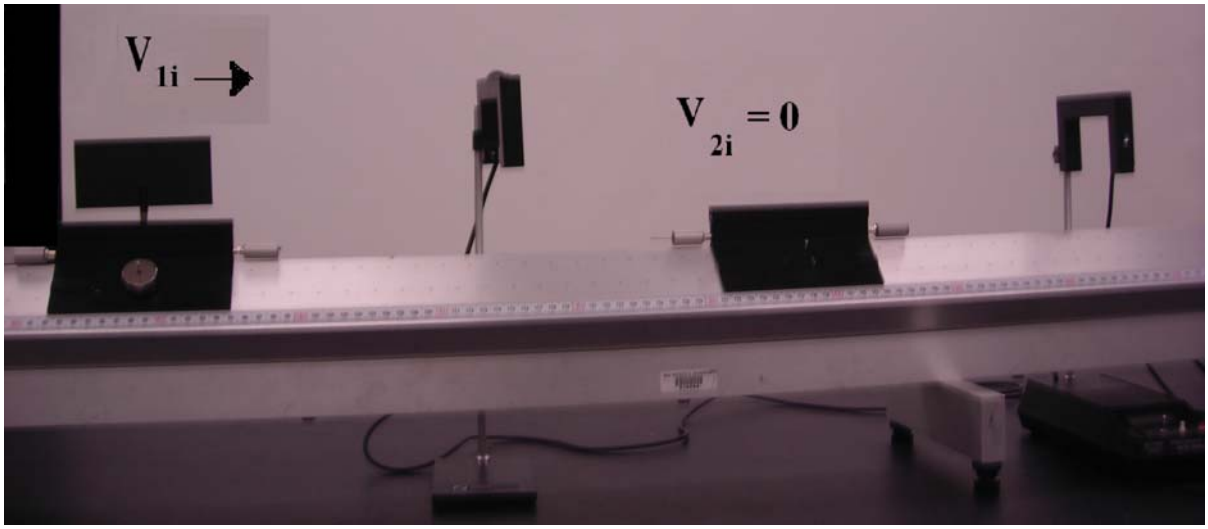


Figure 1: The Initial State of the Carts Before the Collision

In these instructions Gate 1 has the controllers on it and Gate 2 does not. Cart 1 has the fin on it and Cart 2 does not. Cart 2 is initially stationary. Position Cart 2 close to Gate 2. Set the photogate timer to the "GATE" mode and the memory switch to the "ON" position. In this mode the photogate display unit will ALWAYS display the FIRST time interval measured. Subsequent measurements will NOT be immediately displayed, but the times are added in the memory. By pushing the "READ" switch you can display the memory contents, which is the SUM OF ALL THE MEASUREMENTS.

Example: The initial reading for Cart 1 (the time that it took to pass through Gate 1) is 0.300 seconds. This time will be displayed on the photogate. Cart 1 collides with Cart 2 and they go together through Gate 2 (Figure 2). Suppose it takes them 0.513 seconds to go through

Gate 2 together. The display will remain at "0.300," but the memory will contain 0.300 + 0.513 = 0.813 seconds. To find the second time, you have to subtract the first time from the contents of the memory that you can obtain by pushing the "READ" switch. Try this out by moving the cart through the gate by hand a few times.

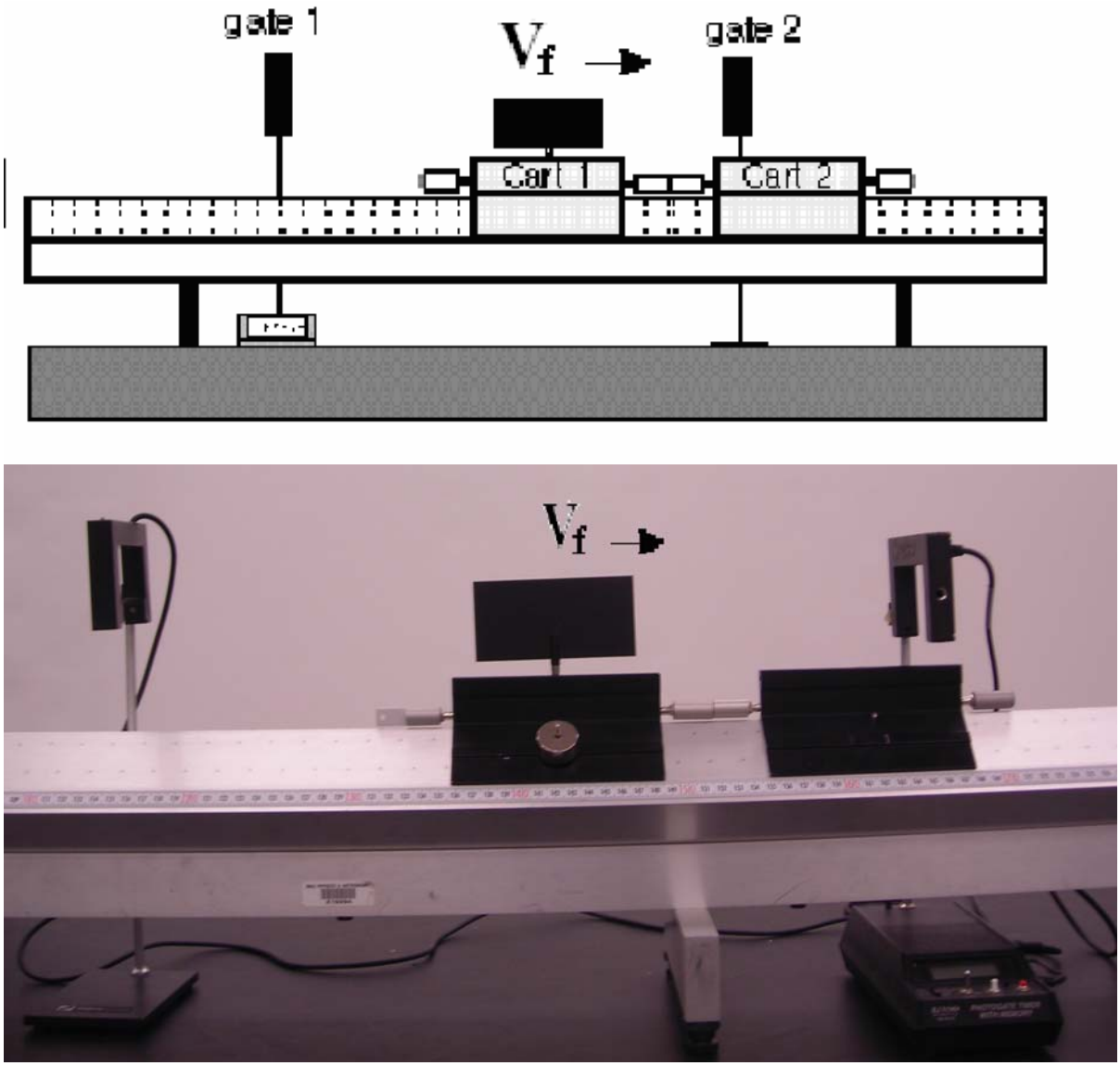


Figure 2: The Final State of the Carts After the Collision

The masses of the carts can be varied by adding weights (which in this case are small metal disks) to them. Remember that the experiment is done with Cart 2 initially at rest. So in the initial state we have

Initial state: Cart1: has a mass m_1 and initial velocity v_{1i}
Cart 2: has mass m_2 and is at rest, so v = 0 cm/s

After the collision (final state): the two carts will stick together
the total mass of the carts is (m_1+m_2)
the velocity is v_f

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

Trials 1 & 2: no mass disks on Cart 1, 4 mass disks on Cart 2

Trials 3 & 4: 2 mass disks on Cart 1, 2 mass disk on Cart 2

Trails 5 & 6: 2 mass disks on Cart 1, no mass disks on Cart 2

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. However, you should include with your lab report manual calculations for all of the cells highlighted in blue on the spreadsheet.

Start with Trial 1, enter your measurements into your spreadsheet and check the spreadsheet to see if the change in momentum is less than 5%. If it is not, you should repeat Trial 1 before proceeding to the other trials. If the change in momentum 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, Carts 1 and 2 both must include a counterbalance on the side opposite the putty or needle accessory (see Figure 3). In addition, all of these accessories must be placed in the lower holes on Carts 1 and 2. When doing each of the trials Cart 2 must be at rest prior to the collision, the fin on top of Cart 1 must be completely through gate 1 before the collision and the fin cannot enter gate 2 until after the collision is complete.

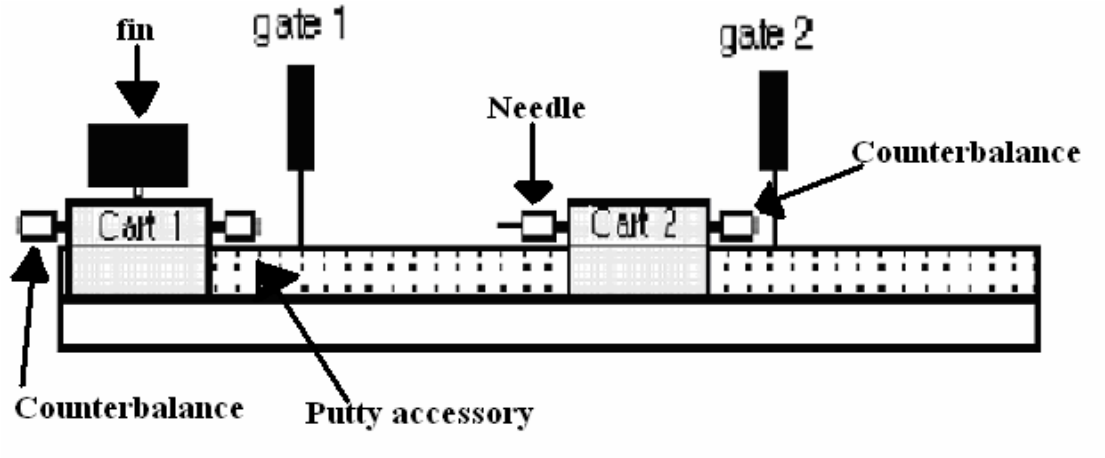


Figure 3

It is possible to calculate the percentage of the kinetic energy lost in a completely inelastic collision; you will find that this percentage depends only on the masses of the carts used in the collision, if one of the carts starts from rest.

The initial KE is given by:

$$KE_i = \frac{m_1 v_{1i}^2}{2} + \frac{m2 v_{2i}^2}{2} \text{ but since } v_{2i} = 0$$

$$KE_i = \frac{m_1 v_{1i}^2}{2} \tag{7}$$

The final KE is given by:

$$KE_f = \frac{m_1 + m_2}{2} v_f^2 \tag{8}$$

Where, v_f is the common final velocity of the two carts $v_f = v_{f1} = v_{f2}$.

From conservation of momentum

$$m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f \quad \text{or, since } v2 = 0$$

$$m_1 v_{1i} = (m_1 + m_2) v_f \tag{9}$$

Show that equations (7), (8), and (9) can be combined to obtain the following expression for KE_f in terms of KE_i.

$$KE_f = \left(\frac{m_1}{m_1 + m_2} \right) KE_i \tag{10}$$

Compare this result with the results of the experiment. Do they agree (see question #3)?

QUESTIONS

1. For which of your trials was momentum conserved? The scientific way to address this question is to ask, for which of your trials is P_{diff} compatible with zero?

2. Was kinetic energy conserved for any of your trials?

3. Combine equations (7), (8) and (9) to obtain the expression in equation (10). Hint: solve equation (9) for v_f, then substitute this into equation (8). Compare this result with the results of the experiment for at least one of your trials. Do they agree?

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: $KE_i = \frac{m_1 v_{1i}^2}{2}$

Final state:

Measure the photogate time t_3, calculate v_f and the error in v_f (called δv_f on the spreadsheet)*

Momentum: $P_f = (m_1 + m_2)v_f$ and kinetic energy: $KE_f = \frac{(m_1 + m_2)v_f^2}{`2}$

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: $\delta P = P\frac{\delta v}{v}$

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

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

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

WORKSHEET
Inelastic Collisions

Tabulate the results of the measurements on this sheet.

Carts' masses, grams

	Cart 1	Cart 2
No mass disks		
2 mass disks		
4 mass disks		

Length of the fin _____ cm

Measured times, sec

Trial #	t_{1i}	memory	t_f	Comments
1				**0 disks on Cart 1**
2				**4 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**