Name: ______________________________________ **Period:** _____ **Due Date:** ___________
Lab Partners: ____

CONSERVATION OF LINEAR MOMENTUM in ONE-DIMENSIONAL COLLISIONS - WebAssign

Purpose: To observe and then analyze a variety of two-body collisions, ranging from the nearly elastic to the totally inelastic, in order to ascertain the conditions under which a) total linear momentum is conserved, b) total kinetic energy is conserved, or c) both momentum and kinetic energy are conserved.

Equipment: Air Track, two gliders, four 50g disk weights, a set of rubber-band bumpers for the elastic collisions, a set of pin/wax attachments for the totally inelastic collisions. Digital interface with two photogates. LoggerPro software for controlling the photogates. Excel spreadsheet template for recording times and calculating **total momentum** before and after each collision.

Preliminary Procedure: A blank copy of the Excel spreadsheet template appears on the last two pages of this handout. Manually enter the following data in the appropriate spaces near the top of that printout. A scale is available in the lab for determining the masses.

Preliminary Data:

Post-it note width = ______________ m Mass of four disk weights = _____________ kg

Mass of glider **A** = ______________kg (*with pin connector and rubber-band bumper installed*.)

Mass of glider **B** = ______________kg (*with wax connector and rubber-band bumper installed*)

Make the initial handwritten records of the masses and timing data on the printed data table. Record the timing information as described in the **General Procedures** below and in the specific procedures describing each collision scenario. Later you will reenter the timing data into a spreadsheet template. The layout of the template will allow you to create equations to calculate the velocities and momenta of the gliders before and after the collision investigated in each trial.

There are 10 different collision scenarios for you to investigate. Complete the first four of these using the pin/wax attachments according to the instructor's directions. These are the totally inelastic collisions and the two gliders must stick together after each collision. The last six are all "nearly elastic" collisions using the rubber band bumpers. These collisions are most nearly elastic at medium to slow speeds.

If the gliders clank or bounce during the collision, you are launching them too fast, or the rubber bands are too tight or too loose. The collision must occur smoothly. Speeds that are too slow also lead to high relative %errors. Use good technique. Gate times between 0.035 and 0.300 sec seem to work best. Keep the two photogates as close together as practicable (*to minimize the effects of track friction and track-leveling errors*); but not too close together. B*oth flags must fit between the photogates for the duration of the entire collision, i.e. as long at the velocities are changing*.

General Procedures:

You will be colliding two gliders in these experiments. It is not necessary to collide them at high velocity. Do not let the gliders hit the end-stops of the air tracks. You will need two photogates. Make sure they are hooked up properly. Typically, glider **A** will move through photogate#1 into the region between the photogates. Glider **B** will either be sitting motionless between the photogates or move through photogate#2 into the region between the photogates. The gliders must collide while both flags are between the photogates. One or both of the gliders must exit the collision region through the same or different photogates. The specific scenario will be described in each case. When one glider stops between the photogates, its final velocity will be taken as zero (*even if it is moving slightly due to imperfections in the experimental set-up*).

1) Level the air track carefully. The force of gravity must be eliminated as a source of acceleration during the collision. We need constant speeds for both gliders prior to and after the collision. (*The track is level when the gliders do not move unless pushed*.)

2) Measure the mass of each glider with its pin/wax connector on one end and its rubber band bumper on the other end. There is a table below for recording these masses.

3) Mark the glider flags **A** and **B** so that they can be easily distinguished.

4) Start the LoggerPro software and open the file named **CnsrvMom** in the **NewLabs** folder.

5) Use the pin attachment for inelastic collisions and the rubber band bumpers for elastic or nearly elastic collisions. Use the four disk weights, when needed, to add weight to one glider.

6) Use post-it notes as flags on both gliders to trigger the photogates. The velocity of each glider will be equal to the post-it width (*in meters*) divided by the photogate time (*in seconds*). Times between the photogates are not measured. Only times in the photogates appear on the LoggerPro screen.

7) Record the times on your printed data sheet. (*Later you will enter your times into an Excel spreadsheet to perform the calculations. Formulas are provided in some parts of that spreadsheet for you. You will be responsible for creating other formulas in the spreadsheet. You must create the formulas to calculate the velocity and momentum of each glider*.)
A copy of the Student spreadsheet will be uploaded into the VcDistribution folder on your H:\ drive. Use **File : Save-as** to save it the root directory of your **H:** drive.

8) When you turn in the completed lab write-up, you must attach both the hand-written copy of the data table containing the times recorded in the laboratory session, and a printout of your final spreadsheet data tables showing all the data and competed calculations. You must keep a copy of your spreadsheet file on your **H:** drive. Its name will be

Lab-11-(Conservation of Linear Momentum)2005.xls

This is the same name given to it when it was uploaded to your **H:** drive. Do not change its name. Be sure to save it in the root directory of your **H:** drive.

Specific Goals of Each Collision

Trials #1, #2, and #3 – Goals: These are all nearly identical. The only differences among them are the initial locations of the extra weights and the velocities of glider **A**. Try to include a range of initial velocities without going too fast. At high speeds the gliders do not consistently stick together. If the gliders do not stick together you must redo that trial. Three times will be recorded. Only the first two are needed to complete your calculations. (*When gliders stick together, both necessarily have the same final velocity. Right?*)

Photogate#1 : time of glider **A** before the collision (*positive velocity*).
Photogate#2: time of glider **B** after the collision (*positive velocity*) [Use this time for both final velocities]
time of glider **A** after the collision (*positive velocity*) [Don't use this number]

<u>#1 Instructions</u> - (**Totally inelastic: pin and wax**) Place glider **B** at rest between the photogates. Send glider **A** through photogate#1. Both gliders must stick together and pass through photogate#2 after the collision. (*Use the time for the first glider through photogate#2 to calculate both final velocities. The gliders must stick together after the collision. See your instructor for advice if they do not.*)

<u>#2 Instructions</u> - (**Totally inelastic: pin and wax**) Place glider **B**, with four 50g weights attached, at rest between the photogates. Send glider **A** through photogate#1. Both must pass through photogate#2. (*Use the time for the first glider through photogate#2 to calculate both final velocities. The gliders must stick together after the collision. See you instructor for advice if they do not.*)

<u>#3 Instructions</u> - (**Totally inelastic: pin and wax**) Place glider **B** at rest between the photogates. Send glider **A**, with four 50g weights attached, through photogate#1. Both gliders must pass through photogate#2. (*Use the time for the first glider through photogate#2 to calculate both final velocities. The gliders must stick together after the collision. See you instructor for advice if they do not.*)

Trial #4 – Goals: This is a variation on the first three. This time both gliders will be moving toward each other with no added weights. Make sure that the collision takes place between the photogates. You must experiment with different relative speeds for the two gliders. Practice with two people controlling the gliders until you can get them to stick together and both move through the second photogate after the collision. Four times will be recorded. Only the first three are required to complete the calculations.

If both gliders happen to have the same initial speed, what would you expect to observe after the collision?

Photogate#1 : time of glider **A** before the collision (*positive velocity*).
Photogate#2: time of glider **B** before the collision (*negative velocity*)
time of glider **B** after the collision (*positive velocity*) [Use this time to calculate the velocities of both gliders after the collision.]
time of glider **A** after the collision (*positive velocity*) [Don't use this time.]

<u>#4 Instructions</u> - (**Totally inelastic: pin and wax**) Both gliders are moving toward each other, but glider **A** must move faster than glider **B**. Let the slow moving glider **B** enter the collision region first. Then fling glider **A** into the collision. They must collide between the photogates. After the collision, both must pass through photogate#2. There will be four times recorded by the digital interface. (*Use the first three as described above. The gliders must stick together following the collision. See your instructor for advice if they do not.*)

Trials #5 through #9 and #10 – Goals: All of these collisions use the elastic bumpers. It is necessary to complete them in the order given here. The times through the photogates must be recorded carefully. It is up to you to keep track of which time refers to which glider passing through each photogate. It may take a little experimenting to get some collisions to work the way they are described. Trial #10 is a little different in that you will lift one end of the rail and include gravity as an outside force effecting the collision.

<u>#5 Instructions</u> - (**Elastic: bumpers**) Place glider **B** at rest between the photogates. Send glider **A** through photogate#1. Glider **A** must stop between the photogates after hitting glider **B**. Glider **B** must pass forward through photogate#2. Two times will be recorded.

Photogate#1: time of glider **A** before the collision (*positive velocity*).
Photogate#2: time of glider **B** after the collision (*positive velocity*).

<u>#6 Instructions</u> - (**Elastic: bumpers**) Place glider **B**, with four 50g weights attached, at rest between the gates. Send glider **A** through photogate#1. Glider **A** must bounce back through photogate#1. Glider **B** must pass forward through photogate#2. Three times will be recorded.

Photogate#1: time of glider **A** before the collision (*positive velocity*).
time of glider **A** after the collision (*negative velocity*).
Photogate#2: time of glider **B** after the collision (*positive velocity*).

<u>#7 Instructions</u> - (**Elastic: bumpers**) Place glider **B** at rest between the gates. Send glider **A**, with four 50g weights attached, through photogate#1. Glider **B** must pass forward through photogate#2. Glider **A** must also pass forward through photogate#2. Three times will be recorded.

Photogate#1 : time of glider **A** before the collision (*positive velocity*).
Photogate#2: time of glider **B** after the collision (*positive velocity*).
time of glider **A** after the collision (*positive velocity*).

<u>#8 Instructions</u> - (**Elastic: bumpers**) Both gliders are moving toward each other, but glider **A** must be moving faster than glider **B**, which has four 50g weights attached. They must collide between the photogates. The gliders must each reverse direction and pass back through their respective initial photogates. Four times will be recorded.

Photogate#1: time of glider **A** before the collision (*positive velocity*)
time of glider **A** returning after the collision (*negative velocity*)
Photogate#2: time of glider **B** before the collision (*negative velocity*)
time of glider **B** returning after the collision (*positive velocity*)

<u>#9 Instructions</u> - (**Elastic: bumpers**) Both gliders are moving toward each other, but glider **A**, with four 50g weights attached, must be moving at the higher speed. They must collide between the photogates. Both gliders must then pass separately through photogate#2 after the collision. Four times will be measured. .

Photogate#1: time of glider **A** before the collision (*positive velocity*)
Photogate#2: time of glider **B** before the collision (*negative velocity*)
time of glider **B** returning after the collision (*positive velocity*)
time of glider **A** continuing forward after the collision (*positive velocity*)

#10 Instructions - (**Elastic: bumpers**) Introduce the force of gravity along the track (mg sinθ) by tilting the track just a little (*about one 1 inch of elevation*) on the side where photogate#1 is located. Reset the photogate heights so they register times properly. Now repeat the procedure for trial #8. Glider **B** should be moving uphill, with four 50g weights attached, and enter the collision region through photogate #2. Glider **A** must be moving downhill, without any extra weights attached, and enter the collision region through photogate#1. They must collide between the photogates. The gliders must each reverse direction and pass back through their respective initial photogates. Four times will be recorded. Catch glider **A** as soon as it leaves the collision region so that it does not accidentally reenter the collision region. Glider **A** may be moving rather fast after the collision. Do not let either glider hit the end-stop at the end of the air track. Practice this collision to make sure it works before trying to measure the times. Your instructor can give you some pointers if you have trouble figuring this one out.

To minimize the time during which gravity can effect the velocity measurements, it is essential to keep the two photogates as close together as possible; but not too close. Make sure the collision is over before the either flag reenters its photogate.

Photogate#1: time of glider **A** moving downhill before the collision (*positive velocity*)
time of glider **A** returning uphill after the collision (*negative velocity*)
Photogate#2: time of glider **B** moving uphill before the collision (*negative velocity*)
time of glider **B** returning downhill after the collision (*positive velocity*)

#11 Instructions - (**Extra Credit**) Design your own collision. Use additional sheets of paper if necessary. This collision must be different in a measurable fashion from the first 10 collision already measured. Start by describing your proposed collision in detail, including how it is different from the ones already studied. Your instructor must approve this proposal before you continue any further with this extra credit project.

If approval is granted, your instructor will arrange a separate time for the two of you to try this collision. For complete credit the collision must work as described and you must complete the same complete analysis on this collision as you are performing on the other ten collisions.

Analysis:

1. If any momentum was lost in the inelastic collisions, there must have been an outside force acting on the gliders, slowing them. This force could have nothing to do with the pin, the wax, or the rubber bands because these are all internal to the system. Suggest 2 or 3 outside forces that might affect the results of your measurements?

2. If the track is not level, gravity will act as an outside force to add or subtract momentum from the system. If the track is tilting down so that glider **A** is accelerated and **B** is decelerated as they enter the collision region through the photogates, the gravity will add *(circle one)* [**POSITIVE** / **NEGATIVE**] momentum to the system. Explain why this gravitational effect does or does not cancel out in this case.

3. A general principle of elastic collisions involving equal masses is that they will exchange velocities. Which trials should have demonstrated this principle? ______________________(*list trial numbers*). Were the velocities traded? ____ (***yes** or **no** for each case*). Explain how to predict this result using conservation of energy, conservation of momentum, and a little algebra. (*Use a separate sheet of paper. You'll need more room for this one*.)

4. Analysis of kinetic energy. ($K = \frac{1}{2}mv^2$)

   In **all** collisions momentum is conserved. In **nearly elastic** collisions the gliders bounce off each other with only a small loss of kinetic energy. In **perfectly elastic** collisions, kinetic energy and momentum are both conserved. In **totally inelastic** collisions, a large amount of kinetic energy is lost to heat and other vibrations of the objects, but not all. Fill out the **Table of Kinetic Energies** on the following page (use a spreadsheet, if you wish). Based on those results, answer these questions:

   Which collisions were **totally inelastic**? ________________________________(*list trial numbers*)

   Which trials were nearly **elastic** collisions? ____________________________(*list trial numbers*)

   In your **totally inelastic** collisions, what was the average kinetic energy loss? _______________J

   In your **elastic** collisions, what was the average kinetic energy loss? _________________J

   Which of your **elastic** collisions were **perfectly elastic**? ___________ (*list trial numbers*)

Note: You may use a spreadsheet of your own creation to perform the kinetic energy calculations for the table on the next page. Make sure the printout has the same arrangement as the table on page 7. Be sure to attach the printout of your kinetic energy spreadsheet, if you chose to make one, along with the two printed pages from the student template.

Table of Kinetic Energies

KE Before the collision			KE After the Collision		Change in KE (J)
Trial #	KE Glider **A** (J)	KE Glider **B** (J)	KE Glider **A** (J)	KE Glider **B** (J)	$KE_{after} - KE_{before}$
1	________	________	________	________	
KE_{Total} before = ________			KE_{Total} after = ________		ΔKE_T = ________
2	________	________	________	________	
KE_{Total} before = ________			KE_{Total} after = ________		ΔKE_T = ________
3	________	________	________	________	
KE_{Total} before = ________			KE_{Total} after = ________		ΔKE_T = ________
4	________	________	________	________	
KE_{Total} before = ________			KE_{Total} after = ________		ΔKE_T = ________
5	________	________	________	________	
KE_{Total} before = ________			KE_{Total} after = ________		ΔKE_T = ________
6	________	________	________	________	
KE_{Total} before = ________			KE_{Total} after = ________		ΔKE_T = ________
7	________	________	________	________	
KE_{Total} before = ________			KE_{Total} after = ________		ΔKE_T = ________
8	________	________	________	________	
KE_{Total} before = ________			KE_{Total} after = ________		ΔKE_T = ________
9	________	________	________	________	
KE_{Total} before = ________			KE_{Total} after = ________		ΔKE_T = ________
10	________	________	________	________	
KE_{Total} before = ________			KE_{Total} after = ________		ΔKE_T = ________

If you use a spreadsheet to compete your kinetic energy calculations, you do not need to fill-in this table by hand. Be sure to attach a print-out of the spreadsheet table to the lab write-up, however.