5.1: Forces and Conservation Laws in Two Dimensions

Name: ____

Date: ________________________

Partners:____

Equipment

- *Movie* software file
- *PuckCollision* movie
- *StandingJump* movie
- *LabPro* interface
- Force Plate
- *BigForce* software file
- *FrontalCrash* movie

I. Two Dimensional Collision

Open *Movie* and select **Insert/Movie**. Find the movie *PuckCollision* and open it. Play the movie. The movie shows two pucks colliding on an air table. Return the movie to the first frame.

Scale the movie and extract position vs. time data for both pucks.

A. Momentum

To examine the collision in terms of momentum, rather than velocity, *LoggerPro* must be "taught" how to measure momentum.

To determine the x-momentum of puck1:

- Select **Data/New Calculated Column** and enter the appropriate name and units.
- In the equation box, enter the product of the mass of puck1 and its x-velocity. Use the **Variables** pull-down menu to select the appropriate variable for your equation. In this example, the equation should read: 0.050*"X Velocity". (You can set both puck masses to 50 g since the error introduced by this simplification is much less than the error inherent in selecting pixel locations for the two pucks.)

Use this technique to create columns for:

- the x-momentum of each puck,
- the y-momentum of each puck,
- the total x-momentum in the system of the two pucks,
- and the total y-momentum in the system of the two pucks,

Create a graph of the x-momentum of each puck and the total x-momentum vs. time. Print, label, and attach this graph.

Extract data from this graph to complete the first row of the following table.

	before collision	**after collision**
Total x-momentum	±	±
Total y-momentum	±	±

Create a graph of the y-momentum of each puck and the total y-momentum vs. time. Print, label, and attach this graph. Complete the above table.

Question: Which, if either, of the momentum defined above appear to be conserved in the collision? Which, if either, of the momentum *should* be conserved in a collision of this type? Explain.

B. Energy

Using **Data/New Calculated Column** create columns for:

- the kinetic energy of each puck,
- and the total kinetic energy in the system of the two pucks,

Create a graph of kinetic energy of each puck and the total kinetic energy vs. time. Print, label, and attach this graph.

Extract data to complete the following table.

	before collision	**after collision**
Total kinetic energy	±	±

Question: Does the kinetic energy defined above appear to be conserved in the collision? *Should* the kinetic energy be conserved in a collision of this type? Explain.

Question: Carefully watch the two pucks before and after the collision. Can you see where some of the initial kinetic energy in the system is "hiding" after the collision?

II. Vertical Leap

Open the movie *StandingJump*. Play the movie. The movie shows a man (5'8" tall and 160 lbs) performing a standing, vertical jump.

It is quite complicated to accurately analyze this motion. Since his arms and legs move relative to his torso, his center-of-mass is not at a constant location on his body. However, we can approximate the complicated motion of this man by a single point particle, located at his hip, and determine rough answers to a series of interesting questions.

Scale the movie and extract position vs. time data.

As a test of the accuracy of your "clicking" (and a test of the validity of our approximation of a person by a point), fit the appropriate function to the appropriate portion of the y-position vs. time graph to determine the acceleration of the man while he's in the air. Print this graph with the region selected and best-fit function displayed and attach it to the end of this activity.

Question: Based on your best-fit function, what is the acceleration of the man, with uncertainty and units, while he is in the air?

If your result above is reasonable, continue your analysis to answer the following questions. For each question, fit the appropriate function to the appropriate portion of the y-position vs. time graph to answer each question. Print each graph with the region selected and best-fit function displayed and attach it to the end of this activity. Show your work in answering each question. Remember, ***every*** value generated from experimental data has an associated uncertainty!

Question: What is the vertical speed of the man when he leaves the ground?

Question: What is his acceleration during lift-off? What is the force exerted by his legs on the ground during lift-off?

Question: What is his acceleration during landing? What is the force exerted by his legs on the ground during landing?

Use **Data/New Calculated Column** to calculate the man's total energy vs. time. Create a graph of total energy vs. time.

Question: How much energy does the man "create" during lift-off? Where does this energy come from?

Question: How much energy does the man "lose" during landing? Where does this energy go?

Question: Comment on the effectiveness of your analysis. What could you have done to improve your analysis? Do you feel your results are accurate?

III. Live Vertical Leap

Attach the force plate to the *LabPro* interface and open the file *BigForce*.

Rather than watch a video of a person jumping, you are going to perform a vertical jump on top of the force plate. Select your lab group's strongest jumper and collect force vs. time data for a complete lift-off and landing. Print and attach your graph. Use your data to answer the following questions:

Question: What are the maximum force and the average force exerted by your legs during lift-off?

Question: What the maximum force and the average force exerted by your legs during landing?

Question: How do the force exerted by your legs compare to the values calculated for the “professional” jumper?

IV. Car Crash

Open the movie *FrontalCrash.* Play the movie. The movie shows a driver’s-side frontal crash test.

This is even more complicated to analyze than the vertical jump! The car is marked by several cross-hairs that can be tracked to gather kinematic data on different parts of the car. For your initial collection of data, extract position vs. time data for the crosshair located slightly in front of where the driver’s head would be.

To scale the movie you will have to do a little detective work. Once you figure out the make and model of the car involved in the test, I’d turn Google loose. Once you’ve scaled the movie, create a graph of x- and y-position vs. time.

As a test of the accuracy of your “clicking” (and your ability to read small print), fit the appropriate function to the appropriate portion of the graph to determine the speed of the car before the crash. Print this graph with the region selected and best-fit function displayed and attach it to the end of this activity.

Question: Based on your best-fit function, what is the speed of the car before the crash, with uncertainty and units? (This crash test was done at 40 mph. If your answer is not within a reasonable uncertainty to 40 mph, you have made a mistake in scaling or analyzing the movie.)

If your result above is reasonable, continue your analysis to answer the following questions. For each question, fit the appropriate function to the appropriate portion of the graph to answer each question. Print each graph with the region selected and best-fit function displayed and attach it to the end of this activity. Show your work in answering each question.

Question: What are the x-, y-, and total acceleration of the crosshair above the driver’s head during the collision? How many “g’s” of acceleration does this correspond to?

Question: What are the x-, y-, and total acceleration of the crosshair located near the center of the hood of the car? Compare these accelerations to the accelerations of the point near the driver’s head. How does the “crumple zone” of the car effect the relative accelerations of these two points?

Use **Data/New Calculated Column** to calculate the car’s kinetic energy vs. time. Create a graph of kinetic energy vs. time.

Question: How much energy does the car “lose” during the collision? Where does this energy go?

Question: Comment on the effectiveness of your analysis. What could you have done to improve your analysis? Do you feel your results are accurate?