EXPERIMENT M6

LINEAR DYNAMICS

Objectives

- Observe completely inelastic collisions between two gliders, testing for the conservation of momentum.
- Measure energy changes during completely inelastic collisions.

Background

When objects collide, whether locomotives, shopping carts, or your foot and the path, the results can be complicated. Yet even in the most chaotic of collisions, as long as there are no external forces acting on the colliding objects, one principle always holds and provides an excellent tool for understanding the dynamics of the collision. That principle is called the conservation of momentum.

The collision of two gliders on a track can be described in terms of momentum conservation and, in some cases, energy conservation. If there is no net external force experienced by the system of two gliders, then we expect the total momentum of the system to be conserved. This is true regardless of the force acting between the gliders. In contrast, energy is only conserved when certain types of forces are exerted between the gliders.

Collisions are classified as *elastic* (kinetic energy is conserved), *inelastic* (kinetic energy is lost) or *completely inelastic* (the objects stick together after collision). Sometimes collisions are described as *super-elastic*, if kinetic energy is gained. In this experiment you can observe completely inelastic collisions and test for the conservation of momentum and energy.

Now answer questions A1 to A2 on the answer sheet

Experimental set-up:

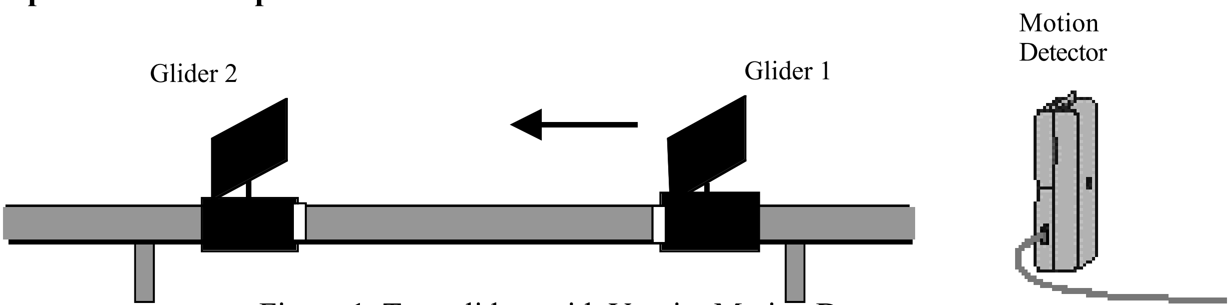

Figure 1. Two gliders with Vernier Motion Detector.

Apparatus

LabPro or CBL 2 interface
TI Graphing Calculator
Retort Stand
Two gliders

Vernier Motion Detector
Air track system
Masses
Variable Air Compressor

Procedure:

This is a Calculator Based Laboratory (CBL) experiment. It will take you some time to get to know the calculator functions and capabilities, but once you have mastered those, you will obtain your data within a few minutes.

Technical note: The motion sensor sends out pulses of ultrasound, and measures how long it takes to come back when they reflect back off an object. The distance to the object is then worked out by multiplying this time by the speed of sound in air.

Preparation:

1) Verify that the motion sensor is connected to the digital input port (labelled DIG/SONIC) of the CBL.
2) Switch on the calculator. If there is anything on the screen, ignore it – press the APPS button and select DATAMATE.
3) The CBL will now scan all its input ports for detectors, and will detect the motion sensor after a short while.
4) Select SETUP, and select DIGITAL MOTION. A screen will appear with a choice of measuring motion in feet or meters. Select measurements in meters.
5) Now select MODE, and select TIME GRAPH.
6) Choose 2 to enter the time between successive measurements of the distance between the sensor and the gliders, and the number of measurements you make (called "number of samples"). At this point it is not important to get these values "right": you will find out by experimenting which settings work best. For a start, try something like 0.1 s and 100 data points, i.e. a measuring time of 10 s. (A maximum of 1024 data points can be recorded and the time interval should not be less than 0.01 s).
7) Select OK to enter these data, then select OK again to return to the main screen. You are now ready to make the measurements!
8) Fix the motion sensor in the retort stand so that its position remains fixed while you're making measurements. Place the Motion Detector at the glider 1 end of the track, allowing for the 0.4 m minimum distance between detector and glider. Always roll glider 1 from this end of the track.

Starting Up:

9) Measure the masses of your gliders and record them in Table A3. Label the gliders as glider1 and glider 2.
10) Set up the track so that it is horizontal. Test this by releasing a glider on the track from rest. The glider should not move.
11) Adjust the variable control of the air compressor so the gliders roll smoothly.
12) Practice creating gentle collisions by placing cart 2 at rest in the middle of the track and release glider 1 so it rolls toward the first glider, Velcro bumper toward Velcro bumper. The gliders should stick together after the collision and roll smoothly away from the collision site.

Making Measurements:

13) Select START to begin taking data. Repeat the collision you practiced above. Make sure you keep your hands out of the way of the Motion Detector after you push the glider.
14) Press ENTER to view the distance graph. Use this graph to verify that the Motion Detector can track the glider properly throughout the entire range of motion. You may need to adjust the position of the Motion Detector. If necessary, press ENTER and return to the previous step.
15) Press ENTER to return to the graph selection screen. Press ▼ and press ENTER to display the VELOCITY graph. From the velocity graph you can determine an average velocity before and after the collision for each glider. You should see two approximately constant regions in your velocity graph, corresponding to the glider speed before the collision and then the speed of the two gliders together after the collision. If you cannot see two such regions, repeat your data collection. To repeat, press ENTER and select MAIN SCREEN. Then return to Step 13.
16) To measure the average velocity during the time interval before the collision,
   a. Press ENTER to return to the graph selection screen.
   b. Select MAIN SCREEN.
   c. Select ANALYZE from the main screen.
   d. Select STATISTICS from ANALYZE OPTIONS.
   e. Select VELOCITY from SELECT GRAPH. The velocity graph will be displayed.
   f. Using the ◄ and ► cursor keys move the lower bound to the left edge of the first constant-velocity region.
   g. Press ENTER to set the left bound.
   h. Using the cursor keys, move the upper bound to the right edge of the first constant-velocity region.
   i. Press ENTER to set the right bound. The calculator will display the mean velocity during the time interval. Record this as the initial velocity in your Data Table.
   j. Press ENTER to return to ANALYZE OPTIONS.

17) In the same way, measure the average velocity of the gliders after the collision and enter the value in the Data Table. Note that the gliders have the same velocity after collision since they are stuck together. When you are done, select RETURN TO MAIN SCREEN to prepare for further data collection.
18) Repeat the collision two more times for a total of three runs. (Runs 1-3 in A3)
19) Increase the mass on glider 1only (i.e. $mass_{glider1} > mass_{glider2}$) and repeat the collision between glider 1 and glider 2 three times. (Runs 4-6 in A3)
20) Increase the mass on glider 2 only (i.e. $mass_{glider2} > mass_{glider1}$) and repeat the collision between glider 1 and glider 2 three times. (Runs 7-9 in A3)

Data Manipulation:

21) For each run number 1-9 in A3 compute the momentum of each glider before and after the collision.

Now answer questions A4 to A8 on the answer sheet

22) For each run number 1-9 in A3 compute the kinetic energy of each glider before and after the collision.

Now answer questions A9 to A14 on the answer sheet

You have now successfully completed the prescribed part of the experiment. Feel free to explore other options that the calculator or the experiment gives you.

Analysis

Conservation of Momentum

For a two-object in-line collision, momentum conservation is easily stated mathematically by the equation:

$$p_1 = m_A v_{A1} + m_B v_{B1}$$
$$= m_A v_{A2} + m_B v_{B2} = p_2$$

m_A and m_B are the masses of the two objects,
v_{A1} and v_{B1} are the initial velocities of the objects (before the collision),
v_{A2} and v_{B2} are the final velocities of the objects,
and p_1 and p_2 are the combined momenta of the objects, before and after the collision.

Kinetic Energy

In the air track glider collisions you will be investigating, the total energy before the collision is simply the kinetic energy of the gliders:

$$K = \frac{1}{2} m v_A^2 + \frac{1}{2} m v_B^2$$

Reference Giancoli, Physics, Fifth Edition, Chapter 6.
Young and Freedman, University Physics, Ed. 9, Chapter 8.