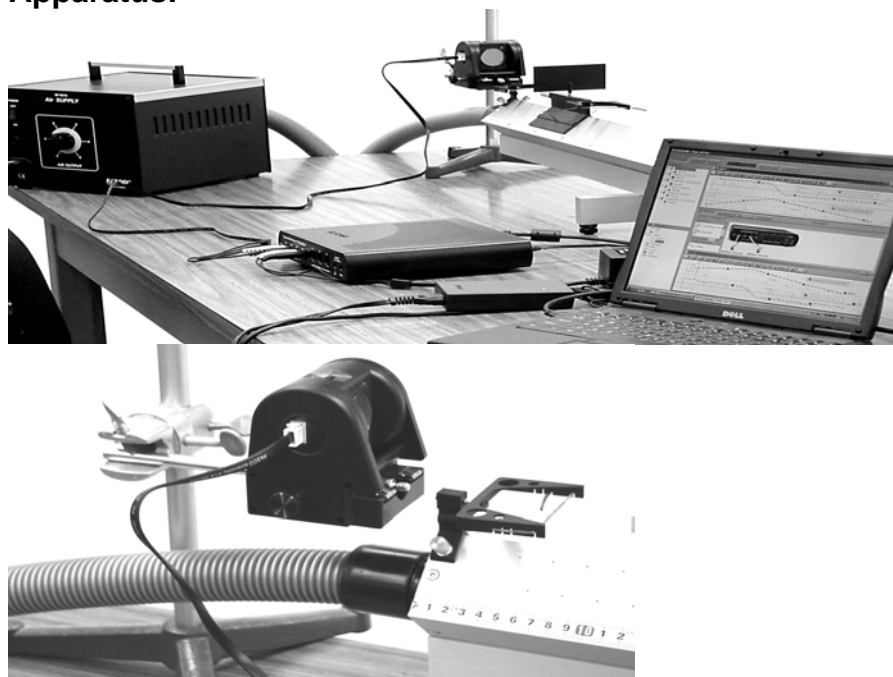


CONSERVATION OF ENERGY AND MOMENTUM

Prepared by Katherine Meyer (adapted from Dr. M. Haeri and Dr. W. Hubbard's version)

Purpose: To examine basic elastic collisions and verify the laws of conservation of momentum and kinetic energy.

Apparatus:



Equipment: Air track, 2 motion sensors, 750 Interface Box (PASCO), air supply with hose, 2 carts with bumpers and fins, laptop computer with Data Studio Software, Data Studio Instruction Sheet, two stands, two clamps, two small rods

Theory:

Whenever two (or more) objects collide, certain conservation laws apply provided certain conditions are satisfied:

- If there are no external forces acting on the colliding objects, the total momentum is conserved. That is, the total momentum of the objects after the collision is equal to that of the objects before the collision.
- If there are no non-conservative forces (internal or external) involved, the total kinetic energy of the objects is conserved.

These two conservation laws can be expressed mathematically for two colliding objects as follows:

Conservation of momentum:
$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

Conservation of kinetic energy:
$$\frac{1}{2} m_1 v_{1i}^2 + \frac{1}{2} m_2 v_{2i}^2 = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2$$

Here the subscripts *1* and *2* signify *object 1* and *2* respectively and the subscripts *i* and *f* signify *before* and *after* the collision respectively.

Procedure:

1. Dust the carts and airtrack.
2. Carefully level the airtrack.
3. Measure the mass (m) of each cart.
4. Set up the air track and motion sensors as shown, using bumpers on the carts to provide an approximately elastic collision. Place a black flag into the top of each cart and align the motion sensors so that the sound waves emitted by the sensors will bounce off the flags. Set the range button on the top of the motion sensor to narrow range.
5. Obtain a laptop computer and a PASCO 750 Interface. Place the yellow leads on each motion sensor in digital channels 1 & 3 of the Interface and put the black leads of the motion sensors into the remaining digital channels. **BEFORE TURNING THE LAPTOP ON, YOU MUST PLUG IN AND TURN (switch is on back) ON THE 750 INTERFACE WITH THE CHANNELS CONNECTED TO THE SENSORS TO BE USED.** Otherwise the computer does not recognize that the sensors are connected. **NOW TURN ON THE LAPTOP!!**
6. Open Data Studio and click on “Create Experiment”
7. Open “Setup” and search the menu for the type of sensor(s) you are using. Click and hold on the type of sensor then drag the icon to the appropriate (i.e. make sure the actual interface connections exactly match those on the computer image of the interface) channel on the 750 Interface image. You should see the sensor become “plugged in” or installed into the appropriate channel on the computer image of the interface.
8. Go to the “Display” menu on the left side and double click on any display icon you want to see (usually you will use *Graph*, *Table* or *Digit*). A window of Data Sources will open from which you choose what data to display. [EXAMPLE: Say a motion sensor is being used and a graph display is chosen to represent the position of a cart.] *The **instructions below** will allow you to put several types of data together on the same graph window, keeping the same horizontal (time) axis scale but having different vertical axes & scales:*
Go to the left side of the Data Studio Window under the Data menu and click & hold on the Data Run icon you want to add to the graph then drag it to the previously opened graph in which you want to display it. Make sure that the gliders have spring bumpers on the surfaces, which will collide. Make sure that there is no Velcro or other material, which will cause the gliders to stick together upon collision.
9. Measure and record the masses M_1 and M_2 of the two gliders to be used in the collision. Don't forget to record the possible error along with the value
10. For the first trial place **m1 at rest** in the center of the air track, start **m2** at the end of the track and (**hit START on Data Studio now** to begin recording data) give **m2** a quick, gentle push toward **m1**. After the two carts have collided and before they collide with the ends of the track, **hit STOP on Data Studio**.
11. On the graphs of velocity vs. time for each motion sensor highlight as many data points as possible in a region where the velocity of the cart is approximately constant. Your instructor will show you how to do this and take the average of these velocities.
12. Record the average velocities initially (before collision) and finally (after collision) for each cart in the table below.

Procedure (continued)

13. **Be sure to record the sign of the average velocity for each cart before and after the collision. (Note: You must determine which direction the cart is moving relative to its motion sensor for the cart to have a negative or positive velocity.)**
14. A total of 10 trials (collisions) will be completed in the manner described above however you must use several different initial arrangements and velocities for the carts. Notice: You will use these same average velocities to verify Conservation of Kinetic Energy.
15. Perform the calculations on an excel spreadsheet using the laptops.

****COMPLETE THE ANALYSIS OF TRIAL 1 BEFORE PROCEEDING TO TRIAL 2.**

****PERFORM THE ANALYSIS USING AN EXCEL SPREADSHEET**

Data:

Conservation of Linear Momentum & Kinetic Energy

Trial #	mass 1 (kg)	mass 2 (kg)	v 1 initial (m/s)	v 1 final (m/s)	v 2 initial (m/s)	v 2 final (m/s)	P initial System (kgm/s)	P final System (kgm/s)	% diff in P	K initial System (J)	K final System (J)	% diff in K
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Optional Analysis with Error Propagation: (*at professor's discretion*)

- Construct an “Analysis Table” similar to the “Data Table” you constructed to record your data. Using the “trial number” from the data table, record the results of each of the calculations in this table. You will need columns for the trial number, the velocity of each cart both before and after the collision, the momentum of each cart before and after the collision and the kinetic energy of each cart before and after the collision (13 columns total).
- Construct an “Error Table” identical to the “Analysis Table” to record the possible errors in each of the quantities calculated in the “Analysis Table” Leave room to record both absolute and percent error in each cell of the table.
- Create yet one more table the “Results Table” with columns for the total momentum and total kinetic energy both before and after the collisions along with their possible errors. (5 columns with cells big enough for both the value and the error.) Calculate the total momentum and kinetic energy of the two gliders before and after the collision. And record these values in the “Results Table”
- Calculate the possible error in each calculated value of momentum and kinetic energy and record these values in the “Results Table” along with the corresponding values.
- Compare the “before” and after “values” of momentum and kinetic energy, do they agree to within your estimated possible error?