PHY 221 LAB 08-1: Center of Mass

Objective: To analyze the motion of the center of mass of a system and its motion relative to the center of mass.

Data

The toy spring "popper" that you will analyze in this experiment has three parts: (1) the top end (which is less massive), (2) the bottom end (which is more massive), and (3) the spring.

1. more massive end 3.8 g
2. less massive end 1.96 g
3. spring 6.30 g

Its total mass is 12.06 g.

Write an equation for the center of mass of the popper in terms of its three components and their positions: $\vec{r}_1$, $\vec{r}_1$, $\vec{r}_3$.

Experiment

1. Download the video `08-1-toy-popper` from our course web site.
2. Open Logger Pro and insert the video. Save your file in your folder on your computer.
3. Calibrate the video using the meterstick shown in the first frame.
4. Set the origin of the coordinate system at any point. The center of the bottom part of the popper is one possible choice for the origin, but any point will be fine.
5. Advance the video to the first frame after the popper leaves the table.
6. Click the Add Point icon, and mark the center of the bottom piece of the popper in all subsequent frames of the video. Be precise in your measurements.
7. Click `Add point series` , and mark the center of the top piece of the popper. Again, be precise in your measurements.
8. Go to `Data→New Calculated Column` to calculate the y-component of the geometric center of the pieces. This will be the y-position of the center of the spring. Name it `y_geom` with units of m. Its formula will be the arithmetic mean of the positions of the top and bottom pieces of the popper, $y_{geom} = 1/2(y_1 + y_2)$.
9. Go to `Data→New Calculated Column` to calculate the y-component of the center of mass of the system. Name it `y_cm` . Type the necessary formula to calculate the y-component of the center of mass of the toy.
10. Graph y_{cm} vs. t and you will notice that it is slightly curved, with a downward concavity, as expected for a projectile.

11. Fit a quadratic function to the graph.

Record the best-fit function for the graph.

Use the curve-fit to determine the y-acceleration of the center of mass.

Determine the % error from the theoretical value of the y-acceleration of the center of mass.

12. Create a new calculated column and calculate the position of the top piece of the popper relative to the center of mass. (Note: $y_{top,rel} = y_{top} - y_{cm}$.)
13. Graph the relative position of the top piece of the popper as a function of time.
14. Fit a curve to the graph that is of the form $Asin(Bt + C) + D$. You will likely have to do a manual fit to the data. Adjust the parameters until the RMSE is as low as you can get it. Adjust delta for each variable to make it quicker and easier to change the values of the variables.

Record the best-fit curve for $y_{top,rel}$.

15. Create a new calculated column and calculate the position of the bottom piece of the popper relative to the center of mass. (Note: $y_{bot,rel} = y_{bottom} - y_{cm}$.)
16. Fit a curve to the graph that is of the form $Asin(Bt + C) + D$. You will likely have to do a manual fit to the data just as you've done before.
17. Record the best-fit curve for $y_{bottom,rel}$.