ES 204
Mechanical Systems Swinging Pendulum Lab

Objective
Experimentally determine the best location of the moveable mass for the fastest swing from horizontal to vertical. You will collect data from an actual swinging pendulum with moveable mass, and compare to your theoretical result from the homework.

The system
The ME and ECE departments share the dynamic systems and controls lab in room C-116. This equipment is precisely instrumented, and includes real-time interface through desktop PCs running Simulink with Real Time Workshop. For this experiment, we will be using the ECP Rectilinear system with inverted pendulum accessory. By mounting the pendulum accessory to cart 3, and adding an extension to the damper attachment arm on cart 1, we have devised a configuration such that the pendulum can be released from a position slightly above the horizontal.

The software is configured to automatically release the pendulum at approximately t=1 seconds into the simulation. It will then record the precise time the pendulum reaches horizontal, and the time it reaches vertical. Since the release point is slightly above horizontal, the angular speed when crossing horzontal is small and we will consider it to be negligible. The overall system is depicted in Figure 1 below.

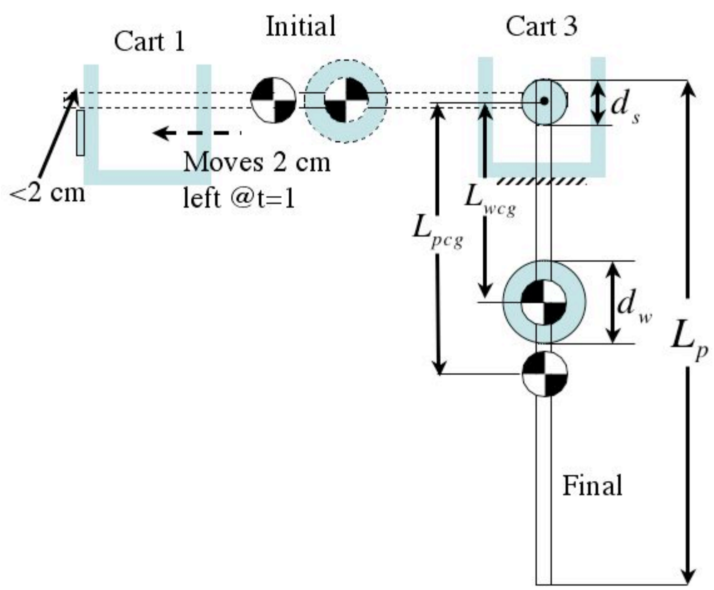

Figure 1: System Schematic

The system nominal dimensions are shown below:

pendulum mass................ m_p = 68.5 g
moveable weight............. m_{add} = 88 g
pendulum length............. L_p = 43.2 cm
Sensor diameter................ d_s = 2.5 cm
moveable weight diameter.. d_w = 5 cm

Note that the pivot axis goes through the center of the sensor, so the pendulum rod cg is located at a distance $(L_p - d_s)/2$ from the pivot. During the lab, test the configurations 1 through 7 shown in the figure below. (I'm showing the pendulum in its initial horizontal position for the sake of space). The added mass cg is depicted only for configuration one. Noting the dimensions above, the minimum distance from pivot to added mass cg is $L_{cg\min} = d_s/2 + d_w/2$. The seven suggested configurations have a distance from pivot to added mass of

$$L_{wcg} = d_s/2 + (n - 1/2)d_w\,, \quad n = 1, 2, \ldots, 7$$

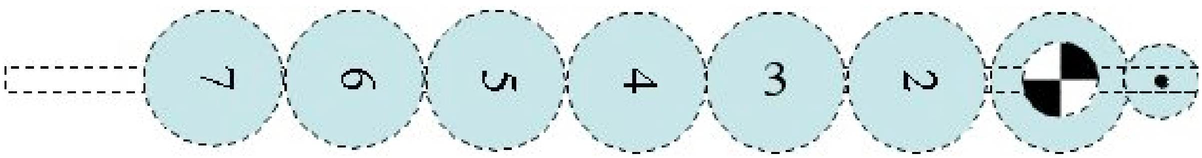

Figure 2: Experimental configurations

It may help to mark lightly in pencil the location of the bottom edge of the moveable weight for case *i* in order to precisely position it for case *i* + 1. Tables are provided at the back of the handout for recording your experimental data.

The process

For each experimental configuration, record the times crossing horizontal and vertical for three swings since there may be some experimental scatter. For each swing, you need to do the following.

1. With the pendulum at rest in the **vertical** position, and cart one at approximately zero, run the simulink file 'ecpdspresetmdl', a picture is shown below. Click the 'connect to target' button. The 'play' button should turn black--click the play button and wait about two seconds. You have just reset the system encoders. This is an important step in getting a precise measurement of when the pendulum crosses horizontal and vertical

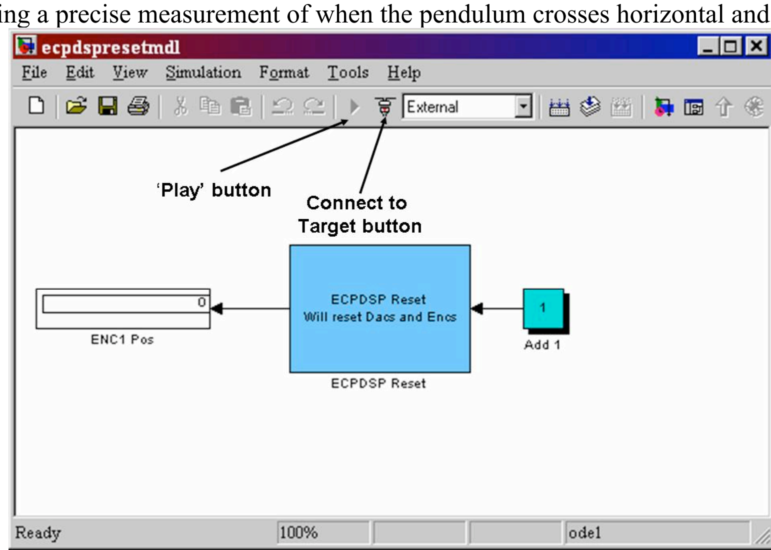

Figure 3: ecpdspresetmdl.

2. Push the black button on the big interface box which connects the computer to the device.

3. Now, swing the pendulum up to horizontal, and move the cart to the right, so the trip arm supports the pendulum and is within 2 cm of the end of the pendulum.

4. Find the simulink file 'final_four', a picture is shown below.

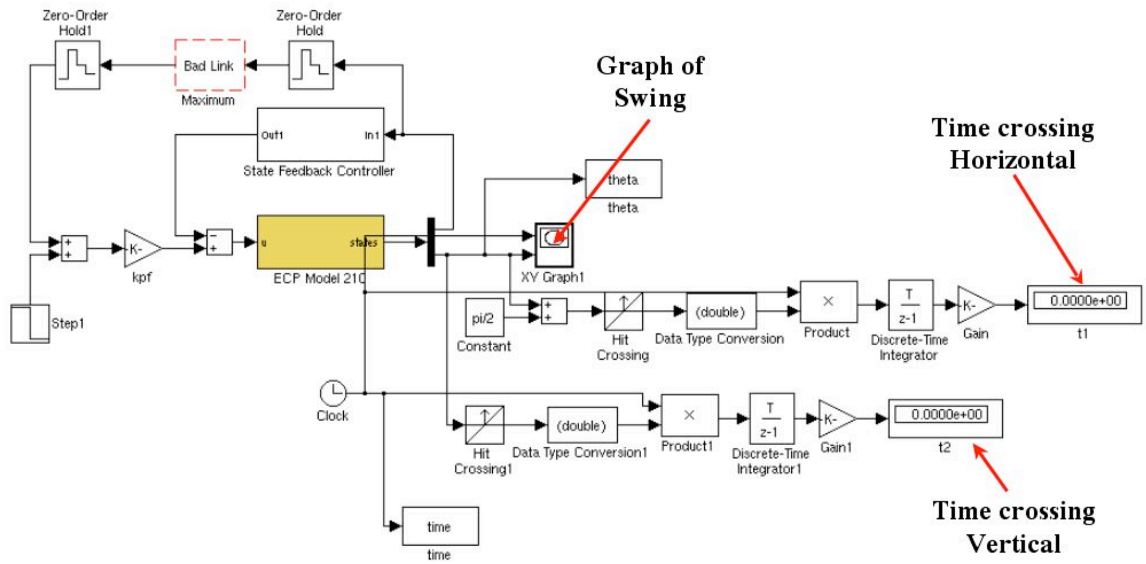

Figure 4: final_four simulink

5. Push the 'connect to target' button--the play button should turn black. If you get 'internal error', just ignore it, push close and try again. Push the play button and watch the pendulum. The times crossing horizontal and vertical will be recorded as t1 and t2 respectively. Record these numbers.

6. Repeat the steps 1-5 three times for each configuration. Now you are ready to move the weight to the next configuration and repeat steps 1-5. A worksheet is provided on the next page for recording your calculations. Finally, try configuring the system according to your theoretical prediction of the optimal location. Record the time of swing at the end of the worksheet.

7. Turn in the provided worksheet with observations, or an Excel spreadsheet with the same information (Your instructor may provide a template). Attach an Excel scatter plot of average Δt as a function of L_{wcg}. Use the 'Scatter with data points connected by smoothed Lines.' option when plotting in Excel.

Important Note: If cart one rams into a limit switch, or in any way appears unstable, reset the system using the steps below. Note that we are using a feedback controller to precisely move the cart 2cm left and release the pendulum. This system is very dependent on reliable measurements from the sensors, so if something isn't properly reset, it could result in damage to the equipment

Quit Matlab.
Start the ECP32 program found under Start->Programs->ECP->ECP32.
Download the controller personality file by selecting Utility->Download Controller Personality File
Navigate to c:\Program Files\ECP Systems\cn\m210_rtwt3.pmc and click Open
Close the ECP32 software.
Restart Matlab.
Navigate to the Desktop\ES204 directory. Open the simluink files and rebuild final_four.mdl.
Now try again.