

## Exercises #4

due: Monday, February 16

## Reading Assignment:

For additional information on this week's material, please review *Simple Harmonic Motion* in your Elementary Classical Physics text and read Sections 2.4 to 2.5 in Giordano.

To prepare for next week, please review *Damped and Driven Harmonic Motion* in your Elementary Classical Physics text and read Sections 3.1 to 3.3 in Giordano.

## 1. Motion of balls with spin

- (a) Open the files *odespin.m* and *spinu.m* in the editor, familiarize yourself with their contents, and run the program. The graphs show the trajectories of a baseball in the  $y-x$  and  $z-x$  planes. As you can see, with the given initial conditions the ball is not going to make it to home plate at  $x = 18.44$  m and  $-0.216 \text{ m} \leq z \leq 0.216 \text{ m}$ . Leaving the initial velocity of the ball in the  $x$ -direction at  $v_{x0} = 30$  m/s (about 70 mph) modify the initial vertical velocity  $v_{y0}$  so that the ball passes over home plate at a height between 0.5 m and 1.2 m.
- (b) Now add spin to the ball by giving the angular velocity  $\omega_y$  a non-zero value. How much spin do you need to have the ball come in right at the edge of home plate?
- (c) Modify the initial horizontal velocity to correspond to a fast ball  $v_{x0} = 42$  m/s (about 95 mph) and find appropriate parameters as in (a) and (b) above. Is the effect of spin larger or smaller than for the slower ball?
- (d) Write a program that describes the motion of a golf ball. Use the information on pp. 39–41 in Giordano along with information about actual golf balls to reproduce the “no-spin”, “normal drive”, and “extra backspin” curves of Fig. 2.13

## 2. Simple harmonic motion:

- (a) Open the files *odeharmonic.m* and *harmonic.m* in the editor and familiarize yourself with their contents. To obtain the graphs for the undamped harmonic oscillator discussed in class, please set the parameters and initial values to

$$\omega_{\text{nat}} \equiv \Omega = 1, \quad \gamma = 0, \quad x_0 = -1, \quad v_0 = 0 \quad (1)$$

Please note: it will be easier to compare the results for the phase space plots in this and the following parts if you include the statement:

```
axis equal
```

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below the line title([' Phase space plot']) .
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Run the program and confirm that your results are as expected. Please write down the value of the total energy and the lengths of the semi axes of the ellipse.

- (b) On paper:  
Calculate the total energy for the case

$$\omega_{\text{nat}} \equiv \Omega = 1, \quad \gamma = 0, \quad x_0 = 0, \quad v_0 = 2 * \Omega \quad (2)$$

Is it higher or lower than in (a)? In phase space, the system should again trace out an ellipse. Predict the values of the semi axes and compare with (a).

- (c) Change the parameters in the program to those of Eq. (2). Run the program and determine the total value of the energy and the axes of the ellipse. Does the result agree with your calculation?
- (d) Now include damping: reset the parameters  $\Omega$ ,  $x_0$ , and  $v_0$  to

$$\omega_{\text{nat}} \equiv \Omega = 1, \quad x_0 = -1, \quad v_0 = 0 \quad (3)$$

Which value of  $\gamma$  leads to critical damping for this value of  $\Omega$ ? Run the program three times, once each for the overdamped, the underdamped, and the critically damped case. Compare the graphs ( $x(t)$ ,  $v(t)$ , phase-space plot, and energy plots) with each other and the undamped case.