Physics 105, Spring 2021, Reinsch

Homework Assignment 9

Due Thursday, April 15, 11:59 pm

Problem 1

In this problem we will do calculations similar to those in Section 11.2, which starts on page 421. We use the values $k_1 = k_3 = k$ and $k_2 = k/2$ for the spring constants and $m_1 = 2m$ and $m_2 = 5m$ for the masses.

(a) Repeat all of the calculations on pages 421-425.

(b) At $t = 0$, we have $x_1 = 0$, $\dot{x}_1 = v_{10}$, $x_2 = x_{20}$ and $\dot{x}_2 = 0$. Find x_1 and x_2 as functions of time.

Problem 2

In this problem we will do calculations similar to those in the section "The Double Pendulum," which starts on page 431. Rather than massless rods, we will assume a constant linear mass density μ. The values of the point masses are not changed.

(a) Calculate the exact Lagrangian.

(b) Calculate the new matrices in Eq. (11.44).

(c) For the case of equal lengths and masses (which refers to the point masses), repeat the calculations on pages 435 and 436. Use the value $\mu = m/(2L)$.

Problem 3

A thin uniform rod of length $5b$ has total mass m. There are two strings attached to the rod, one at each end. The length of one string is $3b$ and the length of the other string is $6b$. The strings are attached to two points on the ceiling that are a distance $4b$ apart. Thus, the strings are vertical in equilibrium. We use g for the familiar acceleration due to the Earth's gravitational field.

With this set-up, proceed as in Problem 11.20. Please do not hand in a solution to the original unchanged Problem 11.20.

Problem 4

This problem is similar to the previous problem, except the strings are replaced with springs. For simplicity, we will assume that the unstretched lengths of the springs are both zero.

(a) Find the spring constants so that the equilibrium position of the rod is the same as in the previous problem.

(b) Now proceed as in Problem 11.29. You do not have to use the hint given there.

Problem 5

Using an object such as a pencil and two pieces of thread (dental floss, etc), set up an experiment for Problem 3 and measure the frequencies of the three modes. Something like a door frame or piece of furniture can be used to provide points of suspension. In the photo "HW9_Prob3_FrequencyMeasurements.jpg" a stand-alone frame has been built, but this requires more effort. A socket wrench extension bar was used because it is much more massive than the strings. However, it is not ideal because it is not a perfectly uniform rod and the thickness is nonzero.

You should report the value of b for your apparatus (one-fifth the length of the bar) and calculate the expected frequencies in cycles per second ($\frac{\omega}{2\pi}$).

For your timing experiments you should practice launching the bar in such a way that a pure mode is excited and then timing 10 cycles of the motion.

If you want to get really fancy, launch the bar with random initial conditions and use a method of automated data acquisition to measure the sum of the x and y coordinates of one end of the bar as a function of time. (This can be done with a laptop webcam.) Then Fourier transform and you should see three spikes in frequency space.

Problem 6

For this problem, programming is not required, but you should make an effort to run the Python code provided, and answer the questions below. The Python code is in an ipynb file in the Homework 9 folder on bCourses. (Recall that on bCourses, under Files, we have a folder called "Python" which contains a Quick Start guide.)

Please respond to each item below. You will get full credit for each attempt.

(a) I could log into datahub.berkeley.edu

(b) I could open the ipynb notebook and see the animation at the top.

(c) I could evaluate the next few cells, and produce an animation window (embedded in the Python notebook) with animation controls below the window.

(d) I could start and stop the animation.

(e) Some of the Python code is highly technical, for producing animations, etc. Other parts of the code contain the physics explained in our textbook. The physics part of the code was clear to me.

(f) For each of the two modes, six phase space plots are created at the end of the notebook, looking at two-dimensional subspaces. I understand the behavior shown in these plots, and can identify the corresponding modes in our textbook.