Circular Motion and Simple Harmonic Motion PH1140

Overview

Do you believe that circular motion is a combination of two linear motions? To be precise, circular motion is the superposition of two linear, independent, perpendicular simple harmonic motions (SHMs). That is a mouthful, but the idea is really very simple. The relationship between circular motion and simple harmonic motion is one of nature's gems. From this relationship, we can immediately derive the sinusoidal solutions of the equation of motion of a simple harmonic oscillator (SHO), and obtain the simple picture of a rotating arrow, which we call a phasor, to mathematically describe the state of a SHO. In this first lab, we suspend a ball from four identical elastic strings and create circular motion in the horizontal plane by applying two initial conditions, chosen to create two independent and perpendicular simple harmonic motions. Similarly, we create circular motion with a pendulum.

Setup

As shown in the figure, attach the four strings to the ball, attach two of the strings to adjoining bench stands, mount two force sensors to the other bench stands and attach the remaining two strings to the sensors. The strings should have equal tensions, and the ball should be centered. Run Logger Pro, and with the ball in its equilibrium position, zero the force sensors.

Also hang the pendulum as shown in the figure.

(W1) What are the state variables of the ball and pendulum?

(W2) List several possible sets of initial conditions of the ball and pendulum.

Informal Procedure

Play around with horizontal motions of the ball. Spend a few minutes before moving on to the formal procedure, and try to create as many different motions as you can by varying the initial conditions. Create elliptical motions, and linear motions in various directions.

(W3) Sketch some of the motions you created, and indicate the initial conditions used to produce the motions.

Repeat for the pendulum.

Formal Procedure

Displace the ball horizontally from its equilibrium position along the line of one pair of strings, start data collection, then release the ball and observe the motion.

(W4) Is the first free (hands off) cycle of motion 1D or 2D? How many cycles does it last?

(R1) Does the first cycle of force data suggest simple harmonic motion? Explain.

(R2) Sketch the motion and briefly describe its evolution in time.

With the ball in its equilibrium position, start data collection. Then slap the ball, that is, apply an impulse to impart a velocity along the line of one pair of strings.

(W5) Is the first free cycle of motion 1D or 2D? How many cycles does it last?

(R3) Does the first cycle of force data suggest simple harmonic motion? Explain.

(R4) Sketch the motion and briefly describe its evolution in time.

Start data collection and apply a combination of initial displacement and velocity to produce circular motion of the ball in the horizontal plane.

(W6) Sketch the motion of the ball during its first free cycle, and indicate initial conditions.

(R5) Does the force data suggest <u>two</u> independent simple harmonic motions? Explain.

(R6) In words and formulas, describe how to create circular motion of the ball.

You may have noticed "beats", alternate shrinking and swelling of the two force sinusoids over time. These are the result of coupling between two oscillation modes, a subject we explore later in the course.

(R7) Option: offer an explanation of the beat phenomena.

Open the xyforce.cmbl template, zero the sensors, start data collection, and again impart circular motion to the ball.

(R8) Explain why the XY force plot is circular.

Repeat with linear motions of the ball in several different directions.

(R8) Relate the directions of the induced motions to the slopes of the plots.

Apply a combination of initial displacement and velocity to the pendulum to produce circular motion.

(W7) Sketch the motion of the pendulum, and indicate initial conditions.

(R9) In words and formulas, describe how to create circular motion of the pendulum.

Lab Worksheet for: Circular Motion and Simple Harmonic Motion **PH1140**

Name: **Section:**

(W1) What are the state variables of the ball and pendulum?

(W2) List several possible sets of initial conditions of the ball and pendulum.

(W3) Sketch some of the motions you created, and indicate the initial conditions used to produce the motions.

(W4) An Initial displacement: Is the first free cycle of motion 1D or 2D? How many cycles does it last?

(W5) An initial velocity: Is the first free cycle of motion 1D or 2D? How many cycles does it last?

(W6) Sketch the motion of the ball during its first free cycle, and indicate initial conditions.

(W7) Sketch the motion of the pendulum, and indicate initial conditions.