LAB 08: CENTRIPETAL ACCELERATION

The Objectives

We will be using Newton's laws and the concepts of angular motion to answer the question:

What is the elastic constant (stiffness) of a spring?

Specifically:

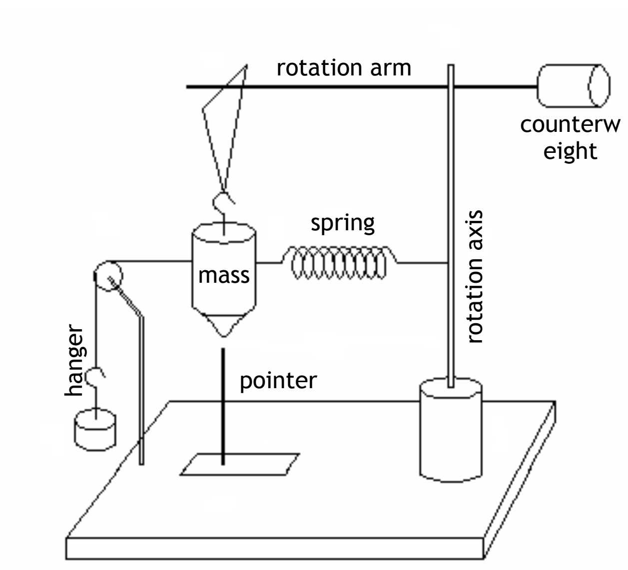
- Use Newton #2 to describe the forces acting on an object in equilibrium
- Observe and measure the period of circular motion
- Determine the centripetal acceleration of a moving object
- Analyze circular motion in terms of applied forces
- Compare methods for determining the constant of a spring
- Examine experimental equipment and techniques for sources of error
- Perform error analysis to determine the accuracy of the results

The Procedure

The apparatus shown can be used in two different ways to determine the constant of the spring. As shown, the pendulum is in static equilibrium. The cord on the right (passing over the pulley, attached to the mass hanger) can be detached, which permits the central vertical axis to spin freely.

The Data

Measure and record the unstretched length of the spring. Measure and record the mass of the pendulum. Measure the reaction times of the timers using the stopwatches. These remain constant for both methods. Watch your units: mass in kg, length in m, time in s.

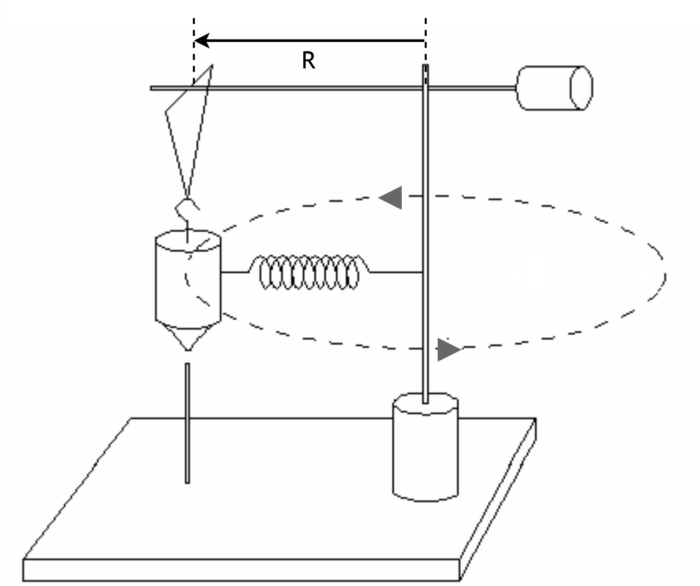


Static Method

As shown on the sketch, alignment is critical. The pendulum mass should be hanging vertically. Without either the spring or the cord attached, allow the pendulum to hang. Align the pointer directly underneath. Re-attach the spring and cord. Add mass to the hanger until the pendulum is again hanging in the vertical position (as marked by the pointer).

Record the total mass added to the hanger. Measure and record the amount by which the spring has been stretched.

Sketch a force diagram of the stationary pendulum in equilibrium when the spring is attached. Use this to determine the spring constant k. Show your work.



Dynamic Method

For the dynamic method, measure and record the radius of the circular motion as shown. Detach the cord and the hanger, and spin the rotation axis. Spin up to speed, when the pendulum is properly aligned with the pointer. Again, alignment is very important. Keep the axis spinning at the rate which maintains the alignment. Notice that, because the pendulum is aligned exactly as before, the amount by which the spring stretches is also the same (and does not need to be remeasured).

Record the period of motion for each trial. You should measure the amount of time it takes for some whole number of complete revolutions (5? 10? 100?), and you should have each timer record multiple measurements (3? 5? 100?).

Dynamic Reduction

1. For each dynamic time trial, calculate the period of the motion:

$$T = \frac{t}{n}$$

   where T is the period of one complete revolution, t is the total measured time interval, and n is the number of complete revolutions observed.
2. Calculate the average period of motion over all trials.
3. Sketch the free body equation of the pendulum in motion. Use it to write Newton #2 for the pendulum, and calculate the spring constant. Show your work.

The Analysis

Error Propagation

4. Determine the experimental uncertainty (based on the known uncertainties in the measured values used to make the calculation) in the value of k for the static trial.
5. For the uncertainty in the period, take the average reaction time as the absolute uncertainty in the average total time. Then the absolute uncertainty δT in one period is

$$\delta T = \frac{(\text{average reaction time})}{n}$$

   where n is the total number of revolutions measured.
6. For the dynamic trial, determine the experimental uncertainty (based on the known uncertainties in the measured values used to make the calculation) in the value of k.

Random Error

Identify the sources of error in the experiment, and discuss how they effect the results. Which method results in a more accurate and reliable spring constant? Explain.

Systematic Error

Do you have any reason to think that your results are subject to systematic error?

The Conclusions

Comment on the overall success of the experiment. If you have not already, suggest how the experiment could be modified to improve the results.