Experiment 9

Bessel's Pendulum

This is an alternative method to determine the local value of g, so most of the theoretical considerations are identical to that of Experiment 8. This particular design is due to Bessel, and a slightly enhanced version[a] of such a pendulum is capable of measurements with precision of 1 part in 10,000!

[a]D. Candela, K. M. Martini, R. V. Krotkov, and K. H. Langley, 2001. Bessel's improved Kater pendulum in the teaching lab. *Am. J. Physics* **69**:714. doi: 10.1119/1.1349544

9.1 The apparatus

The Bessel's Pendulum procedure is similar to that used with Kater's pendulum, but there is only one point of intersection used to determine a value for g, the local acceleration due to gravity. Details of the theory and analysis can be found in `https://www.physics.brocku.ca/Courses/2P20/lab-manual/BesselsPendulum/218100_AE.pdf`. In summary, the local acceleration due to gravity g is given by

$$g = \Delta x * \omega^2,$$

where Δx is the distance between the pendulum pivot points and ω is the frequency where the two curves $(x_n, \omega_{1,n})$ and $(x_n, \omega_{2,n})$ intersect.

Here are a few suggestions for a successful measurement:

- the pendulum is made out of a piece of steel strapping which bends easily; be sure to completely straighten it before you start;
- secure the utility knife (used as the pendulum pivot point) to a lab stand, knife edge pointing up. Using a clamp if available will help to keep the knife edge stable;

Exercise caution: the exposed knife edge is sharp and can injure!

- check that two aluminum discs, labelled **A**, are attached at one end of the pendulum and that two steel discs, labelled **S**, are attached at the other end, creating an asymmetric mass distribution, and that the sensing magnet is located at the physical centre of the pendulum strap, equidistant from the two pivot notches and the discs;
- carefully measure the distance Δx between pivot notches with the digital calipers;

- determine the spacing between the holes of the strapping, then the step by which the separation between trimmer bolts is changing is $x_n = n \times (2d)$. Describe in your report the method that you used to verify d;
- place the trimming bolts symmetrically about the midpoint of the pendulum and tighten the nuts.
- using 3–5 nuts on trimmer bolts, perform trials to check that the two sets of measurements of the period of oscillations as a function of x_n include the intersection point where the periods are the same. With trimmer bolts symmetrically closest to the center, it is expected that the period of "steel disks down" will be shorter than the period of "Al disks down"; when trimmer bolts are far apart, the opposite should be true.

  Removing one nut from both trimmer bolts will move the intersection point toward the smaller values of x_n.

9.2 Experimental procedure

A short slideshow illustrating the experimental setup is available at `https://www.physics.brocku.ca/Courses/2P20/lab-manual/BesselsPendulum/`, feel free to consult it in parallel with this manual. In the images of the slideshow, the Al disks are coloured red, for clarity.

(!) Install the trimmer bolts and selected number of nuts symmetrically into the two holes closest to the magnet at the centre of the pendulum.

(!) Seat the pendulum pivot slot closest to the aluminum discs on the knife edge, then setup the iOLab so that the magnetometer (marked M on the face of the iOLab, next to the microphone) is centered along the pendulum trajectory.

(!) Start the pendulum and wait until all stray oscillations have disappeared. Keep the oscillations *very small*, less than 0.5 cm. At this amplitude the pendulum should oscillate for at least 5-10 minutes, giving you plenty of time to acquire some five clean data sets of 5-10 s each trial.

Monitor the y-axis magnetometer value and adjust the iOLab position to get a smooth sinusoidal variation of magnetic field with pendulum motion.

(!) Acquire five trial traces of 5–10 oscillations, fitting each to a sine function to get a set of ω values and from these determine precisely the period and the experimental error for this pendulum configuration.

(!) Seat the pendulum pivot slot closest to the steel discs on the knife edge and repeat the data acquisition steps.

(!) Move the trimmer bolts symmetrically one hole farther from the centre of the pendulum and repeat the above steps.

(!) Repeat the above step, moving the trimmer bolts sequentially out from the centre of the pendulum. There are seven pairs of holes.

Use eXtrema to plot the resulting graph and determine a value for g from the point of intersection. It may help to smooth your data sets.

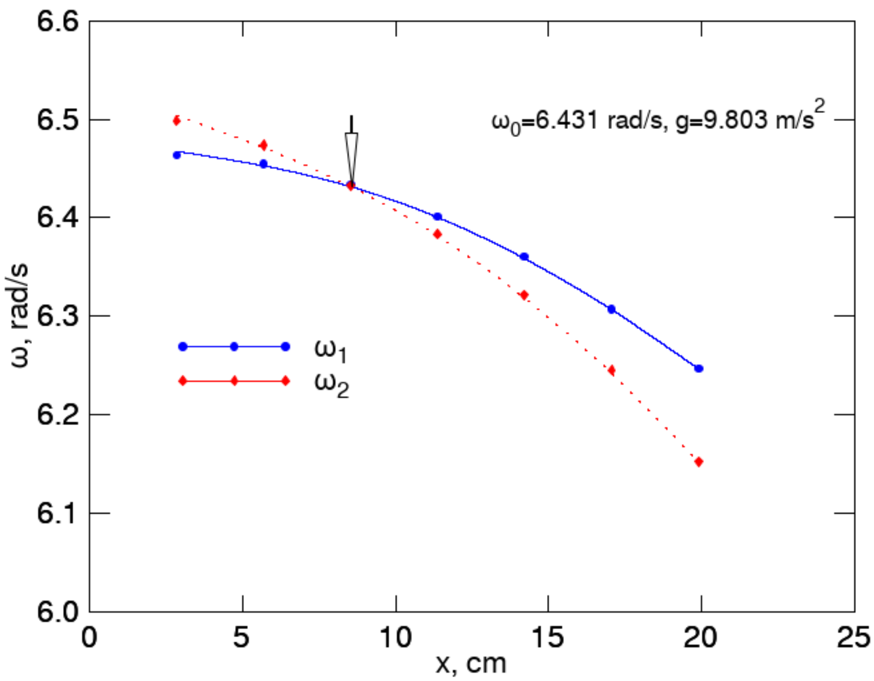

Figure 9.1: Representative graph of a Bessel's pendulum experiment.