OSCILLATION

Timing the oscillations of a pendulum

The determination of the acceleration due to gravity from the measurement of the period T of a pendulum is a traditional experiment in an introductory physics laboratory. In this experiment, typical values of T are in the range 1–2 s. When using a stopwatch for determining T, in order to reduce errors associated with our reflexes (~0.2 s), the time t for n cycles (~10–30) is measured so that $T = t/n$. Modern laboratories have improved the measurement of T by using a photogate connected to a digital timer. A lot of photogates and timers are available commercially and used in physics labs. Here we propose substituting the photogate timer set by an optocoupler connected to the audio input of a laptop and by using a standard sound analysis software program [1]. The use of sound card software as a useful and powerful timing technique in a physics laboratory has been suggested in recent pedagogical articles [2–5].

We use a U-shaped optocoupler, which has a transmitter and receiver together, recycled from a computer mechanical mouse (you can buy a suitable optocoupler for ~1€). The optocoupler operates with a standard 1.5 V battery. A steel ball is suspended by a thread. The optocoupler is positioned 7 or 8 cm below the pivot point and held with a clamp. The thread crosses the centre of the optocoupler so that the pendulum oscillates perpendicular to the bottom of the 'U'. The experimental set-up is shown in figure 1. Once the ball is set to oscillate (very small oscillations can be detected), the recording button is activated. As the thread cuts through the optocoupler beam, the output signal of the optocoupler changes. A typical recording time is around 40 s. It may be necessary to attenuate the optocoupler signal to match the microphone input level signal. In many situations, the desired level signal can be simply obtained via software by means of the microphone level control. Figure 2 shows a typical recorded signal. The period of the pendulum is given by the time between two alternate peaks (i and $i + 2$): $T = t_{i+2} - t_i$. This is because the thread passes through the beam twice in one cycle. The time of a peak is measured by placing the cursor in the peak (a horizontal zoom of the signal can be useful to determine the location of the peak). The sound card of the laptop works with a sampling rate of 44 100 Hz and, therefore, the time t_i is measured with a maximum uncertainty of 2.3×10^{-5} s, much smaller than that of standard digital timers. The main source of uncertainty in the measurement of T arises from the location of the peaks. Thus, it is more convenient to

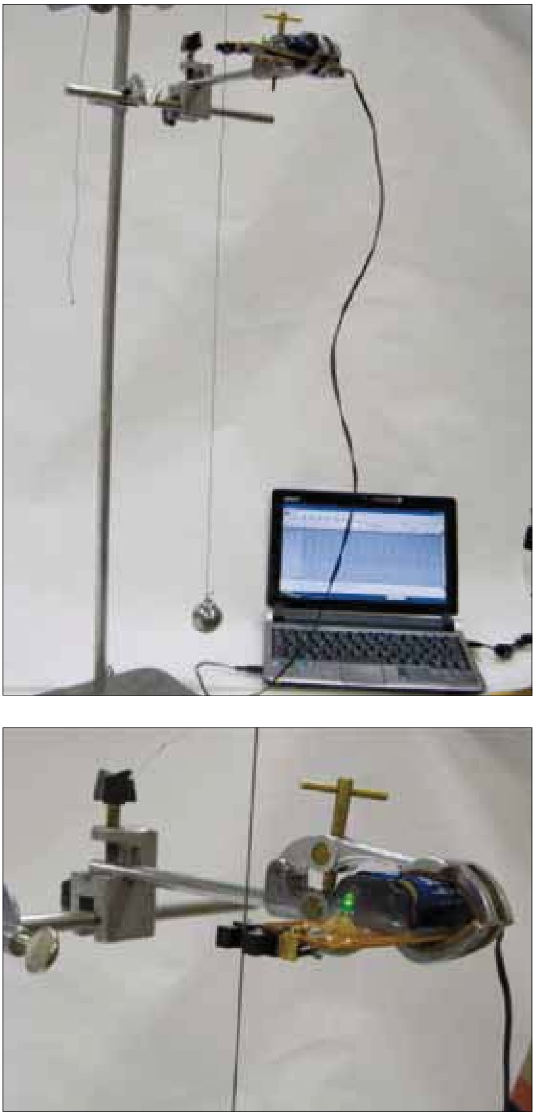

Figure 1. *Images of the experimental set-up.*

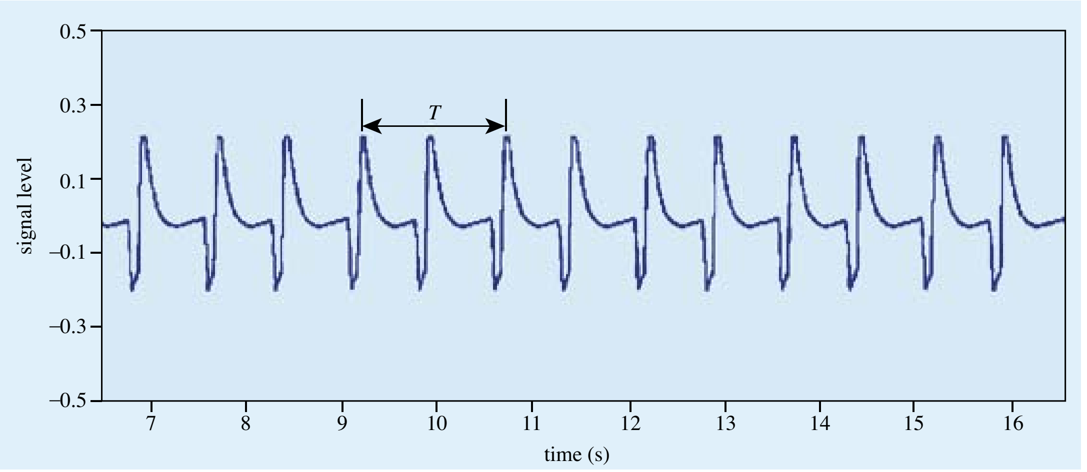

Figure 2. *The electric signal generated by the oscillations of a pendulum through an optocoupler. The period is obtained by selecting the times of the centre of the marked peaks.*

measure the times of the peaks i and $i+20$, so that $T = (t_{i+20} - t_i)/10$.

To conclude, we have proposed a method to determine the period of a pendulum by using a U-shaped optocoupler connected to the audio input of a laptop. The generated electric signal is recorded by using standard software for the sound card. The method is more accurate than using digital timers. Furthermore, the use of a laptop allows us to project the timing procedure onto a screen, making the experiment appropriate for a classroom demonstration.

Acknowledgements

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References

[1] Many software programs for recording and editing sounds can be found on the world wide web. An excellent free program is provided by Audacity http://audacity.sourceforge.net/

[2] Dwayne R 2005 An inexpensive computer-controlled photogate *Phys. Teach.* **43** 169

[3] Ganci S 2007 Quantitative measurements of acoustical beats by means of the ‘improper’ use of sound card software *Eur. J. Phys.* **28** L45

[4] White J A, Román F L, Medina A and Velasco S 2007 A measurement of *g* listening to falling balls *Phys. Teach.* **45** 175

[5] Ganci S 2008 Measurement of *g* by means of the ‘improper’ use of sound card software: a multipurpose experiment *Phys. Educ.* **43** 297

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