Timing oscillations of a mass spring

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OSCILLATION

Timing oscillations of a mass spring

The determination of the force constant k of a coil spring is a classical experiment in an introductory physics laboratory. Usually this determination is made by measuring the period T of an oscillating mass–spring system. Typical values of k and T are in the ranges 1–5 N m^{-1} and 0.2–1.5 s, respectively. Because T is so small, a stopwatch is used to determine the time t for a number n of complete oscillations, so that $T = t/n$. Increasing n improves the precision in the measurement of T. Two usual procedures are ~5–10 experiments with $n \sim 10$–30 (T is obtained by the mean value) or one experiment with $n \sim 100$. Commercial ultrasonic motion sensors and photogate detectors are also used for measuring the oscillation period T. Here we propose an alternative procedure to determine T by means of a small cylindrical neodymium magnet (1.2 cm diameter, 0.5 cm thickness and 4.1 g weight), a coil of enamelled copper wire connected to a laptop and standard sound analysis software. We recall here that the use of sound-card software is a useful and powerful timing technique in a physics laboratory that has been suggested in recent pedagogical works [1–5].

Figure 1. *The experimental set-up used to analyse the timing of a mass–spring oscillator. The magnet (not visible) is located under the hanger.*

Figure 1 shows the experimental set-up. A coil spring is hung over a clamp and stretched with a (non-magnetic) mass hanger and slotted masses. The magnet is glued in the low end of the hanger. A coil of 15 turns of enamelled copper wire (0.01 cm diameter) is wound around a plastic tube 2 cm long, with an inner diameter of 4.9 cm and a thickness of 0.15 cm. The plastic tube is horizontally clamped with an aluminum alloy pincer so that the magnet is located in the coil centre. The coil ends are connected to the audio input of a laptop. A free software for recording and editing sounds is installed on the laptop [6, 7].

Once the mass–spring system is made to oscillate vertically, the recording button is activated. According to Faraday's law of magnetic induction, the oscillation of the magnet through the coil generates a periodic electric signal that is recorded by the laptop. A typical recording time is around 30 s. The recorded signal is very weak and must be amplified using the facilities of the program. Figure 2 shows a typical recorded signal. The period of the oscillating mass–spring system is given by the time between two alternate peaks (i and $i+2$): $T = t_{i+2} - t_i$. This is because the magnet passes through the coil 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 exact location of the peak). The sound card of the laptop works with a sampling rate of 44 100 Hz and, therefore, the times t_i are measured with a maximum uncertainty of 2.3×10^{-5} s. In order to increase the precision associated with the location of the peaks, it is advisable to perform the measurement of the times of the peaks i and $i+20$, so that $T = (t_{i+20} - t_i)/10$. The determination of the force constant k is made from a linear regression analysis of the square of the periods obtained for different loading masses [8].

To conclude, we have proposed a method to determine the period of an oscillating mass–spring system. The method consists of attaching a small magnet to the mass hanger that oscillates inside a copper coil connected to the audio input of a laptop. The electric signal generated is recorded by using standard software for the computer sound card. The method is faster and more accurate than the traditional one based on the use of a stopwatch. Furthermore, the use of a laptop allows you to project the recorded signal onto a screen making the experiment appropriate for a classroom demonstration.

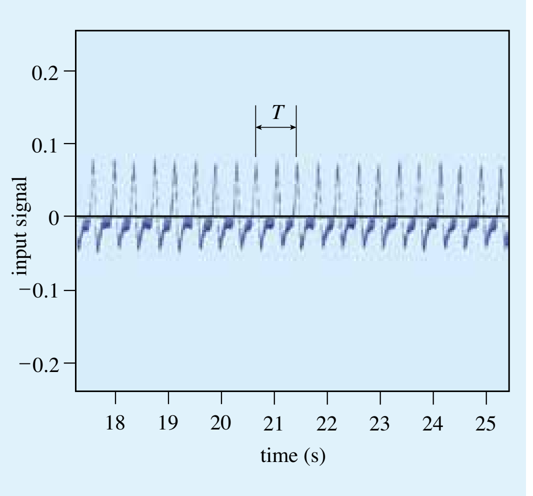

Figure 2. *The electrical signal generated by the oscillating magnet inside the copper coil. The period is obtained by selecting the times of the centre of the marked peaks.*

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References

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[6] 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/)

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