Galileo and the Pendulum

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Figure 1: Pendulum Clock

In Aristotelian physics, which was still the predominant way to explain the behavior of bodies near the Earth, a heavy body (that is, one in which the element earth predominated) sought its natural place, the center of the universe. The back and forth motion of a heavy body suspended from a rope was therefore not a phenomenon that could explain or illustrate much. It was outside the paradigm.

Galileo was taught Aristotelian physics at the university of Pisa. But he quickly began questioning this approach. Where Aristotle had taken a qualitative and verbal approach, Galileo developed a quantitative and mathematical approach. Where the Aristotelians argued that heavier bodies fell faster than lighter ones in the same medium, Galileo, early in his career, came to believe that the difference in speed depended on the
densities of the bodies. Where Aristotelians maintained that in the absence of the resisting force of a medium a body would travel infinitely fast and that a vacuum was therefore impossible, Galileo eventually came to believe that in a vacuum all bodies would fall with the same speed, and that this speed was proportional to the time of fall.

Because of his mathematical approach to motion, Galileo was intrigued by the back and forth motion of a suspended weight. His earliest considerations of this phenomenon must be dated to his days before he accepted a teaching position at the university of Pisa. His first biographer, Vincenzo Viviani, states that he began his study of pendulums after he watched a suspended lamp swing back and forth in the cathedral of Pisa when he was still a student there. Galileo’s first notes on the subject date from 1588, but he did not begin serious investigations until 1602.

Galileo’s discovery was that the period of swing of a pendulum is independent of its amplitude—the arc of the swing—the isochronism of the pendulum. Now this discovery had important implications for the measurement of time intervals. In 1602 he explained the isochronism of long pendulums in a letter to a friend, and a year later another friend, Santorio Santorio, a physician in Venice, began using a short pendulum, which he called "pulsilogium," to measure the pulse of his patients. The study of the pendulum, the first harmonic oscillator, date from this period.

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The motion of the pendulum bob posed interesting problems. What was the fastest motion from a higher to a lower point, along a circular arc like a pendulum bob or along a straight line like on an inclined plane? Does the weight of the bob have an effect on the period? What is the relationship between the length and the period? Throughout his experimental work, the pendulum was never very far from Galileo’s thought. But there was also the question of its practical use.

A pendulum could be used for timing pulses or acting as a metronome for students of music: its swings measured out equal time intervals. Could the device also be used to improve clocks? The mechanical clock, using a heavy weight to provide the motive power, began displacing the much older water clock in the High Middle Ages. By incremental improvement, the device had become smaller and more reliable. But the

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1 Strictly speaking, a simple pendulum is not isochronous; the period does vary somewhat with the amplitude of the swing. This was shown by Christian Huygens, in the 1650s. Huygens installed cycloidal “cheeks” near the suspension point of his pendulums and showed that as a result the bob now described a cycloidal arc. And he proved that when this is the case the pendulum is truly isochronous. In practice, the swing of the bob was kept very small and the amplitude as constant as possible, as in the long-case clock or our familiar grandfather clock. Under these conditions the simple pendulum is isochronous for all practical purposes.
accuracy of the best clocks was still so low that they were, for instance, useless for astronomical purposes. Not only did they gain or lose time, but they did so in an irregular and unpredictable manner. Could a pendulum be hooked up to the escape mechanism of a clock so as to regulate it?

In 1641, at the age of 77, totally blind, Galileo turned his attention to this problem. Vincenzo Viviani describes the events as follows, as translated by Stillman Drake [3]:

One day in 1641, while I was living with him at his villa in Arcetri, I remember that the idea occurred to him that the pendulum could be adapted to clocks with weights or springs, serving in place of the usual tempo, he hoping that the very even and natural motions of the pendulum would correct all the defects in the art of clocks. But because his being deprived of sight prevented his making drawings and models to the desired effect, and his son Vincenzio coming one day from Florence to Arcetri, Galileo told him his idea and several discussions followed. Finally they decided on the scheme shown in the accompanying drawing, to be put in practice to learn the fact of those difficulties in machines which are usually not foreseen in simple theorizing.

Viviani wrote this in 1659, seventeen years after Galileo’s death and two years after the publication of Christiaan Huygens’s *Horologium*, in which Huygens described his pendulum clock. It is from Huygens’s construction that we date the practical development of the device.

**Glossary**

**Definition 2: isochronous**
Equal or uniform in time

**Definition 2: harmonic oscillator**
Each oscillation has a frequency that is an integer multiple of the same basic frequency

**References**


