Drexel-SDP GK-12 ACTIVITY

Science

Variables

Pendulums

Grade Level 5

Lesson # 1 of 1

Lesson Dependency

Time Required 1 Day

Summary

- In this lesson, students will explore the theory behind pendulums and observe that pendulums can be used to mark time, such as the Foucault Pendulum at the Franklin Institute. Students will learn how and why this is possible, construct a pendulum that can be used to mark relative time, and then modify that pendulum to keep accurate time (i.e. have a period of exactly one second).

  If you have ever looked at a grandfather clock or the Foucault Pendulum, you know that it operates based on a swinging weight from a rod. But how does it keep such accurate time? The period, or time to make one complete revolution (swing back and forth) dictates the accuracy at which the pendulum will mark time. If our period is one second exactly, the pendulum will swing back and forth at just the right time, like a grandfather clock. The Foucault Pendulum actually has a period of ten seconds, but the pins are arranged so that a ten second period will accurately mark time.

  Now what if we decide to swing our pendulum from a shorter distance? Or from a shorter rod? Will either or both of these things affect the period of the pendulum? You will find out in your experiment.

Keywords

- Pendulum, Variables, Time, Period

Educational Standards: 2.3.5, 2.5.5, 2.6.5

Learning Objectives

- Discuss, observe and/or predict the behavior of the Foucault Pendulum
- Create and measure the period of a simple pendulum
- Determine the variable that actually modifies the period of the pendulum, and manipulate that variable to attain a period of 1 second.

Procedure

- Pendulum clocks have been used to keep time since 1656, and they have not changed dramatically since then. Pendulum clocks were the first clocks made to have any sort of accuracy. When you look at a pendulum clock from the outside, you notice several different parts that are important to the mechanism of all pendulum clocks:

  There is the face of the clock, with its hour and minute hand (and sometimes even a "moon phase" dial).

  There are one or more weights (or, if the clock is more modern, a keyhole used to wind a spring inside the clock -- we will stick with weight-driven clocks in this article).

  And, of course, there is the pendulum itself.

  In most wall clocks that use a pendulum, the pendulum swings once per second. In small cuckoo clocks the pendulum might swing twice a second. In large grandfather clocks, the pendulum swings once every two seconds. So, how do these parts work together to keep the clock ticking and the time accurate? The idea behind the weight is to act as an energy storage device so that the clock can run for relatively long periods of time unattended. When you "wind" a weight-driven clock, you pull on a cord that lifts the weight. That gives the weight "potential energy" in the Earth's gravitational field. As we will see in a moment, the clock uses that potential energy as the weight falls to drive the clock's mechanism. We want to use a falling weight to create the simplest possible clock -- a clock that has just a second hand on it. We want the second hand on this simple clock to work like a normal second hand on any clock, making one complete revolution every 60 seconds.

  We might try to do that, as shown in the figure on the right, simply by attaching the weight's cord to a drum and then attaching a second hand to the drum as well. This, of course, would not work. In this simple mechanism, releasing the weight would cause it to fall as fast as it could, spinning the drum at about 1,000 rpm until the weight clattered on the floor.

  Still, it's headed in the right direction. Let's say we put some kind of friction device on the drum -- some sort of brake pad or something that would slow the drum down. This might work. We would certainly be able to devise some scheme based on friction to get the second hand to make approximately one revolution per minute. But it would only be approximate. As the temperature and the humidity in the air changed, the friction in the device would change. Thus our second hand would not keep very good time.

  So, back in the 1600s, people who wanted to create accurate clocks were trying to solve the problem of how to cause the second hand to make exactly one revolution per minute. The Dutch astronomer Christiaan Huygens is credited with first suggesting the use of a pendulum.

Pendulums are useful because they have an extremely interesting property: The period (the amount of time it takes for a pendulum to go back and forth once) of a pendulum's swing is related only to the length of the pendulum and the force of gravity. Since gravity is constant at any given spot on the planet, the only thing that affects the period of a pendulum is the length of the pendulum. The amount of weight does not matter. Nor does the length of the arc that the pendulum swings through. Only the length of the pendulum matters.

A simple pendulum consists of a mass (called the bob) attached to the end of a thin cord and attached at a fixed point. When the mass is drawn upwards and let go, the force of gravity accelerates it back to the original position. The momentum built up by the acceleration of gravity causes the mass to then swing in the opposite direction to an equal height as the original position. This force is known as inertia.

- Methods and Procedure:
    - Build your pendulum by attaching the string to the wood base (or tie it around the wood)
    - Attach a weight to the other end of your string
    - Pull the string back about a foot, and time it for 60 seconds. Count the number of complete swings back-and-forth that the pendulum makes during this time.
    - Compute the period of the pendulum -- the number of seconds per swing. What is the math expression for this problem?
    - Repeat steps 3-4, but this time only pull the string back a half foot (much less than before).
    - How does the period change when you change the length of the pull?
    - Modify your pendulum so that it has a one second period. In other words, so that it takes one second exactly to swing back and forth.
    - **Check your work by pulling the string back and timing the pendulum for 60 seconds. Count the number of swings -- is it 60? If so, your period is one second. Show the math expression for this as you did in step 4.**

References

Background material drawn from:
http://www.nc4h.org/greenlight/afterschool/Pendulum_Clocks.pdf

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