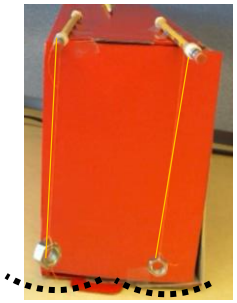
Hang In There!

1. Cut two pieces of thin string of equal length and tie a different weight (bob) to each.
2. Secure each string to a rigid rod.
3. On a shoebox or other horizontal support, tape one of the rods so that the hanging bob swings freely.
4. Keeping the string taut, lift the bob horizontally to one side, a small amount (about 5 degrees from vertical), and release.
5. Use a stopwatch to determine the period of one complete vibration.
6. Repeat the process for the second rod.
7. On a shoebox or other common horizontal support, tape both rods so that the bobs swing freely.
8. Keeping the string taut, lift one bob horizontally to one side, a small amount (about 5 degrees from vertical), and release. Do not vibrate the second bob.
9. Find or make a uniform rod that is the same length as your string.
10. On a shoebox or other horizontal support, tape a pencil so that the eraser side faces out.
11. Using a pushpin, attach the rod to the pencil eraser, assuring that the rod rotates easily and freely.
12. Lift the bottom of the rod horizontally to one side, a small amount (about 5 degrees from vertical), and release.
13. Use a stopwatch to determine the period of one complete vibration.



Physical Pendulum

A **physical pendulum** is a system in which a rod with significant mass (with a regular or irregular shape) swings about a pivot point. In a physical pendulum, the rod has a **moment of inertia** relative to the pivot point. For a uniform rod that pivots around one fixed end, the **center of mass** is at the center of the rod, and the period is given by:

$T = 2\pi\sqrt{\frac{2l}{3g}}$. This means that the period of a physical pendulum is faster than that of a simple pendulum of equal length.

Simple Pendulum

A **simple pendulum** is a system in which a point-mass is suspended from a string or rod of negligible mass. The weight, or bob, moves along an arc in simple periodic motion. It is driven from rest at one end of its path, accelerates downward by the force of gravity until it reaches its maximum velocity at the center of its path, and continues to the end of its arc with decreasing velocity until it momentarily stops and starts along the same arc in the opposite direction. If the angle of swing is small (less than 5^0), the **period**, T, is given by:

$T = 2\pi\sqrt{\frac{l}{g}}$ where l is the length of the string and g is the acceleration due to gravity. The period does not depend on the mass of the bob, so pendulums of equal length with different masses have the same period. If two simple pendulums are supported by the same structure and one is oscillating, the other pendulum will couple out of phase, with the same period but opposite motion (**coupled oscillator**). This property makes the simple pendulum useful as a seismometer, since it will couple with the earth's motions.

NAVY NOTES

Feedback control loops use error values between a desired set point and measured value to apply correction factors that improve accuracy. The Whitehead torpedo used a pendulum-and-hydrostat control mechanism to maintain both depth control (hydrostat) and fore-aft stability (pendulum) in its feedback loop.