PENDULUM MOTION:
MOVING AWAY FROM SIMPLE MOTION

Objective: • Determine how the period of a pendulum depends on amplitude.

To Do Before Lab: • Read this handout.

Apparatus: Stopwatch, string, mass, clamp, meter sticks, protractor

Introduction: A *simple pendulum* is an idealization consisting of a point mass, swinging at the end of a massless string. In class you have learned that for small angles of swing, the period of a simple pendulum is *approximately* given by the formula

$$T = 2\pi\sqrt{\frac{\ell}{g}}\ , \qquad (1)$$

where ℓ is the length of the string and g is the acceleration of gravity. As the amplitude of oscillation approaches 0, the period of a simple pendulum approaches the value given by eq. 1. In this lab we will investigate what happens to the period when the small angle approximation is not valid.

Procedure:
Given the tools available, design an experiment that will allow you to determine the period T as a function of angular amplitude θ_m, with minimal uncertainty in each quantity. To determine θ_m, you may use the protractor or trigonometry. Measure the period of the pendulum for as broad a range of angular amplitudes as practical. Plot T vs. θ_m including error bars for both T and θ_m. Be sure to explain your methods, including estimates of error bars, in your notebook.

Later in your physics education you may be lucky enough to derive the relation $T = T_0 \cdot Q(\theta_m)$ where T_0 is the value given by eq. 1 and $Q(\theta_m)$ is the amplitude correction. The function $Q(\theta_m)$ can be written as a power series in θ_m ,

$$Q(\theta_m) = 1 + a_1\theta_m + a_2\theta_m^2 + a_3\theta_m^3 + ...$$

Note that some of the a_i may be zero. If θ_m is not too large ($\theta_{radians} \leq 1$), the higher order terms in the power series become progressively smaller very quickly and only the first non-zero term after the 1 is important. Determine the power of the first non-zero term after the 1 by plotting your data in such a way that it will give a straight line if the first term is of order θ_m, $\theta_m^{\ 2}$, or $\theta_m^{\ 3}$. See if you can convince your instructor that the correction term is linear, quadratic, or cubic using your data. Determine the value of the leading non-zero coefficient, (a_1, a_2, or a_3) and its uncertainty. You get a **bonus point** if you can measure a value for 'a' (within 20% of the right value and with a relative uncertainty of less than 20%. Two **bonus points** are available for 'a' within 2% and with an uncertainty of less than 2%.