PHYSICS 125 EXPERIMENT NO. 5
THE CONICAL PENDULUM: A STUDY OF UNIFORM CIRCULAR MOTION

In this laboratory exercise, we will determine g, the acceleration due to gravity, by studying the dynamics of a conical pendulum. See University Physics, pp. 128-129.

As shown in Fig. 1, the apparatus consists of a pendulum attached to the shaft of a synchronous clock-motor, whose rotational speed is determined by the frequency of the AC current driving it. A variable frequency oscillator and an audio power amplifier provide the driving current. The angle of the rotating pendulum is measured by a protractor on which the pendulum's shadow is projected.

In your text, it is shown that the period of rotation T of a conical pendulum of length, L, is given by

$$T = 2\pi\sqrt{\frac{L\cos(\theta)}{g}},$$

where θ is the angle the pendulum makes with the vertical and g is the acceleration due to gravity. Solving for $\cos(\theta)$, we get

$$\cos(\theta) = \frac{gT^2}{4\pi^2 L} \quad \text{or,} \quad 4\pi^2 L\cos(\theta) = gT \; .$$

<u>Procedure</u>

1. Adjust the projection lamp so that the hinge of the pendulum coincides with the index mark (arrow) of the protractor.
2. Measure the length L of the pendulum as precisely as you can.
3. Turn on the oscillator and set it to a low frequency so that the angle θ is about 30^{o} (see Figure 1). Wait several minutes for the pendulum to reach equilibrium. The angle should be about the same on both sides and should not vary with time.

4. Measure the angle θ by placing a piece of paper against the protractor so that the shadow of the pendulum just grazes the edge of the paper. Record the angle of the shadow of each side of the protractor and take the average value as your measured θ. Remember, the angle that the arm makes **with the vertical** should be recorded.

5. Record also, the frequency f of the driving current as measured on the counter. The motor is constructed so that this frequency is equal to the rotational speed in RPM (revolutions per minute). To measure the frequency precisely, switch the electronic counter to the "count" (rather than "frequency") position and set it to a count interval of 10 seconds. In this method, the counter reading divided by 600 (60 for conversion from minutes to seconds; 10 for the 10 second counting interval) yields the frequency of rotation in revolutions per second. Check your reading by visually counting how many revolutions the pendulum makes in one minute.

Q1. How is the frequency f related to the period T?

6. Repeat the above measurements for other values of θ between 20° and 70°. Make changes in frequency slowly and gradually, or the motor might slip. Always wait for the system to come to equilibrium when you have made changes. BE CAREFUL WITH THE EQUIPMENT! It is capable of very precise results, but only if you treat it carefully and use it intelligently.

ANALYSIS

Using your measured values of θ and f, draw a graph to analyze your data. Plot the quantity $4\pi^2 L\cos(\theta)$ on the y-axis and T^2 on the x-axis. If eq. (2) is correct, this procedure should yield a straight line of slope g. (Be sure you plot your graph neatly and on a large enough scale to be able to see the scatter of the data points.) Determine your value of g and compare it with the accepted value. Include appropriate error bars.

Q2. Derive eq. (1)

Q3. Do you think parallax is a source of error in this experiment?

Q4. Eqs. (1) and (2) assume that the support rod has zero mass. In actual fact, the rod's mass (m) is 1.25g and the bob's mass (M) is 9.0 g. A more precise theory gives

$$4\pi^2 L\cos(\theta) = g\frac{(M + m/2)}{(M + m/3)}T^2$$

Is this more correct equation necessary for your experiment? Explain.

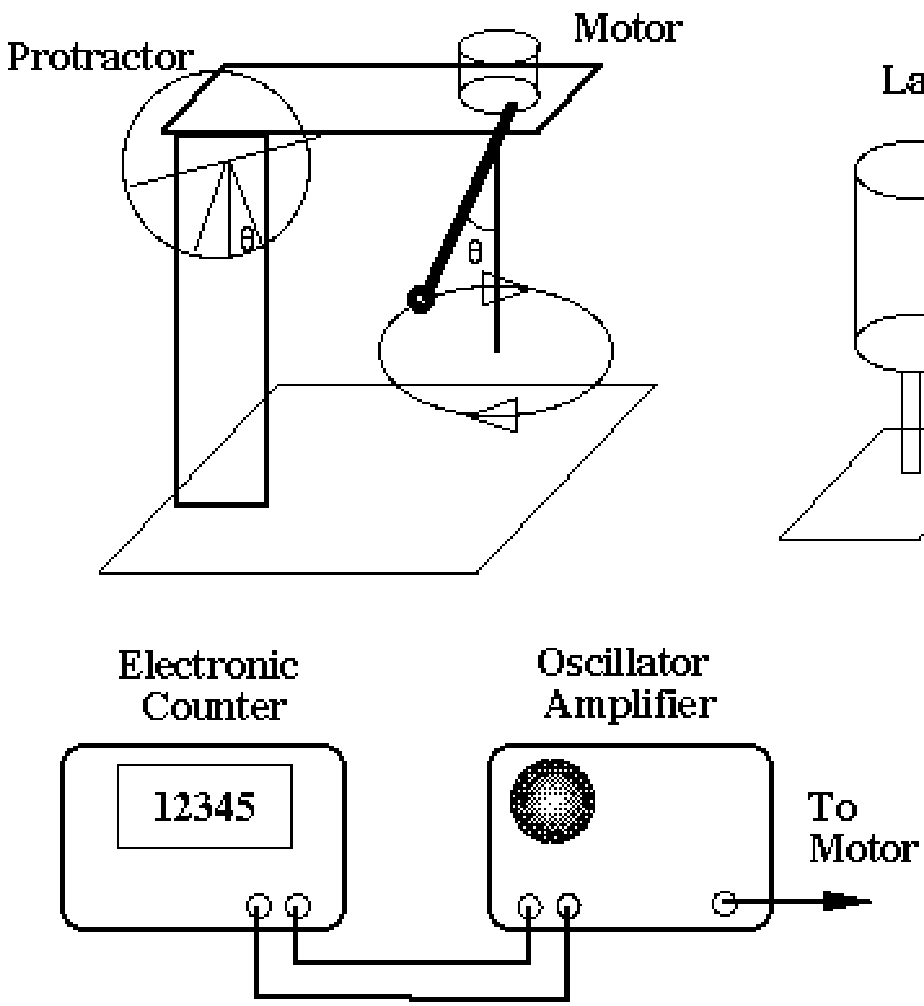

Figure 1