CONSERVATION OF ENERGY

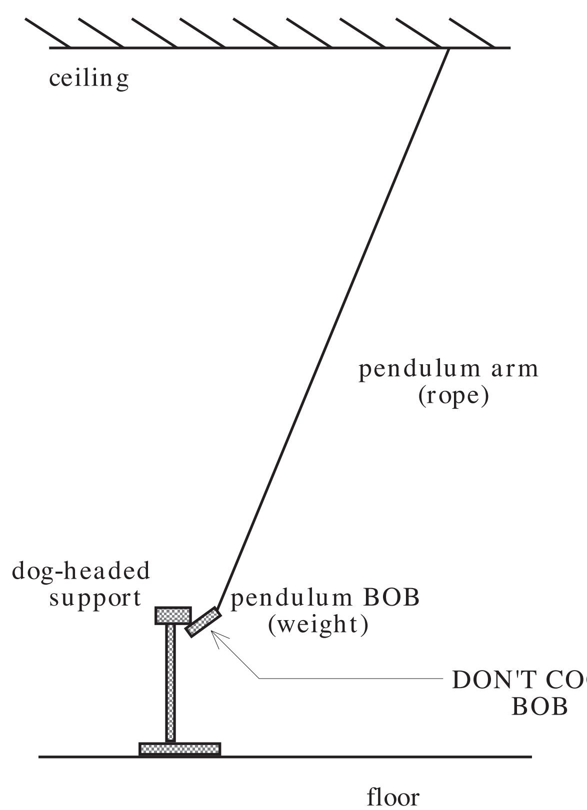
(L-11)

Pendulum motion normally dampens out very slowly because its major sources of energy loss--resistance due to air friction and frictional heating at the support--don't remove energy very quickly. It is, therefore, an ideal system from which to take a close look at the consequences of energy conservation.

PROCEDURE--DATA

Part A: (one-swing energy loss)

a.) Measure and record the pendulum BOB'S mass and diameter (although your meter stick will be in centimeters, use MKS throughout the lab).



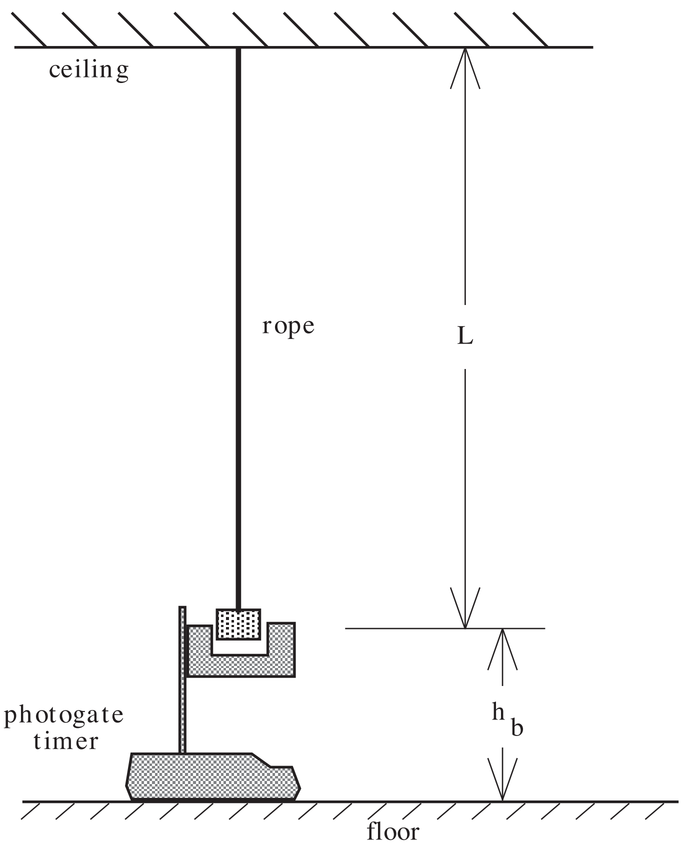
b.) You will find at the front of the room a peculiar looking *stand* consisting of a long piece of vertical wood with what appears to be a stylized, miniature dog's head at the top. The structure is a support. Attach a meter stick to the side of the support.

Pull the BOB to the side until its *center of mass* is 90 centimeters above the ground (make sure the string and the BOB'S central axis are aligned--that is, don't cock the mass as shown in the sketch). Position the support so that the individual releasing the BOB can rest his or her hand comfortably on the dog's head while holding the BOB snugly against the support at the required height.

When in position, release the BOB and allow it to swing out into the room, then back to the support. At least five people should eyeball the returning BOB, using the meter stick to visually approximate the final height of the BOB'S *center of mass* at the end of its back swing (due to parallax, everyone should be level with the BOB'S final height). Average the values for all the observers and record that average.

You will make *five* such runs. The BOB must always be released from the same place. Record your data as outlined above, then calculate and record the average of your averages. Call this h_{avg}.

Part B: (top versus bottom energy)



c.) We would like to know how much energy the BOB has at the bottom of its arc. With the BOB hanging stationary in the vertical:

i.) Measure the distance h_b between the BOB'S *center of mass* and the floor (we'll be using the floor as *zero potential energy level* in this lab);

ii.) Measure the length L of the pendulum arm (the wire's length from its attachment at the ceiling to the BOB'S center of mass) . . . and don't break your neck doing it;

iii.) Position the jaws of a PHOTOGATE TIMER so that the BOB will pass through the opening when at the bottom of its arc (see sketch to the right).

d.) With everything appropriately positioned, pull the BOB back to the dog-face support (exactly 90 centimeters above the floor) and let it go just as you did in *Part A*. As it passes through the bottom of its arc, it will engage the photogate for as long as the photogate's beam is disrupted. Knowing that time and the diameter of the BOB, you can determine the BOB'S velocity at the bottom of its arc.

Assuming you have a steady-fingered person releasing the BOB (see *Note 1* below), make two runs and average the times recorded (if there is considerable disparity between the runs, do it a third time).

Note 1: Whoever releases the BOB, it is imperative that you let it go cleanly. If you inadvertently give it a nudge one way or the other, the BOB will not fall through the true bottom of its arc and will, instead, veer sideways *hitting the photogate* . . . a definite no-no.

Note 2: Someone must catch the BOB after it has passed through the photogate's jaws.

CALCULATIONS

Part A: (energy loss through one complete swing cycle)

1.) Showing formula(s), etc.:

a.) Calculate the *initial* energy E_o of the BOB before release (assume the *zero potential energy level* is at the floor). (Don't make this hard. All you are doing is calculating how much potential energy, relative to the floor, the BOB has when at the release point!)

b.) Calculate he *final* energy E_f of the BOB after one, full, round-trip swing.

2.) Determine the % of energy lost during the first full swing.

3.) For the first full swing:

a.) Where in the system was the energy lost (just a few words describing how energy was extracted during the swing)?

b.) Where did the energy go (that is, what happened to it)?

c.) To a good approximation, can we assume that energy is conserved through one swing of this system? (No BS—tell it like it is!)

Part B: (energy at top versus bottom of arc)

4.) Ignoring the energy loss due to friction, use *conservation of energy* to determine the BOB'S theoretical velocity v_{theo} as it passed through the bottom of its arc during its first swing.

5.) Using the data you took from the photogate and your knowledge of the BOB'S diameter, calculate the experimental velocity v_{exp} of the BOB at the bottom of its arc during its first swing.

6.) Do a % comparison between the experimental and theoretical velocities.

7.) Does the *conservation of energy* appear to hold here?

QUESTIONS

I.) In our set-up, the BOB started out 90 centimeters above the ground. At the bottom of its arc, the BOB was approximately 30 centimeters above the ground. In other words, the BOB started its first swing approximately 60 centimeters above the lowest point in its arc. If, after one swing, the BOB came back to a position 57 centimeters above the lowest point in its arc, it would have lost 5% of its initial energy during that first swing.

Assume that that *rate of energy loss* is characteristic of all of the BOB'S swings (i.e., assume the BOB loses 5% of however much energy it has at the beginning of *any* given swing), how many swings will the BOB execute before getting down to just 2% of its initial energy?

Extra Credit: The first time I tried this lab, my data was as follows:

--the initial height of the BOB was $h_1 = .90$ meters;
--the low-point height of the BOB was $h_2 = .30$ meters;
--the diameter of the BOB was d = .038 meters;
--the time during which the photogate ran was t = .0100 seconds.

Having accumulated all of this information, I proceeded to do the write-up. I used *conservation of energy* to calculate the BOB's theoretical velocity at the bottom of the arc and got $v = 3.43\ m/s$. I used the experimental data and the equation $v = d/t$ to calculate the BOB's experimentally determined velocity at the bottom of its arc and got $v = 3.8\ m/s$.

There is something spectacularly wrong with these velocities. What is it?