PHYS 232C Lab 2. Bernoulli's law

Theory

Begin by using Bernoulli's law to show that the height of the top surface of a fluid, y, draining from a container with circular cross section of diameter D from a circular hole of diameter d a height H below the initial level, y_0, of the surface is given by

$$y = y_2 + \frac{1}{2}a_0(\Delta t - T)^2,$$

where

$$\begin{aligned}
\Delta t &= t - t_0 && (t_0\text{, start time}) \\
T &= \sqrt{\frac{2H}{a_0}} = \sqrt{\frac{2H}{g}\left(\left(\frac{D}{d}\right)^4 - 1\right)} && \text{(total drain time)} \\
y_2 &= y_0 - H && \text{(location of outlet)} \\
a_0 &= \frac{g}{1-(d/D)^4}\left(\frac{d}{D}\right)^4 .
\end{aligned}$$

Thus, the top surface of the fluid undergoes constant accelerated motion. (Note that the direction of the acceleration is upwards.) In this lab we will examine the dependence of the drain time and acceleration of the top surface of the fluid on the outlet diameter, d.

I. Drain time and outlet diameter

Choose one of the outlet diameters. Measure H, D, and d. Note that the different reservoirs should have the same H and D, but different values of d.

Set up the equipment as shown in the figure below. Be careful to tighten all clamps so that the bottle is secure when filled with water. Using the motion sensor, measure the height of the water as a function of time as the water drains fully. Be sure to let the water settle before beginning and to collect data before the bottle starts to drain so that an estimate of y_0 and t_0 may be made. Fit this curve to a function of the form

$$y = y_0 - H + \frac{1}{2}a_0(t - t_0 - T)^2.$$

January 31, 2020

Use the curve fit editor to lock the values of y_0, H, and t_0. Thus, the fit will find an estimate of T and a_0. Repeat with the three other outlet sizes.

When $d \ll D$, $T \approx \left(\frac{D}{d}\right)^2 \sqrt{\frac{2H}{g}}$. Plot T vs. $1/d^2$. The graph should be linear. Fit the data to a linear function. Compare the measured slope and intercept to the theoretical prediction.

II. Acceleration and outlet diameter

When $d \ll D$, $a_0 \approx g \left(\frac{d}{D}\right)^4$. Plot $a_0^{1/4}$ vs. d. Again the graph should be linear. Fit the data to a linear function. Compare the measured slope and intercept to the theoretical prediction.

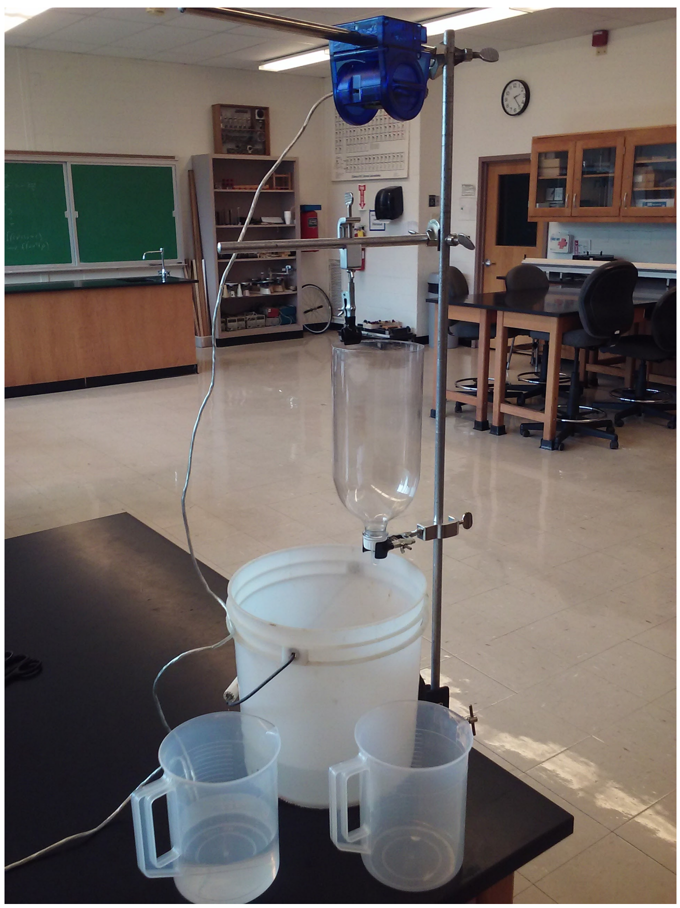

Figure 1: Experimental setup.