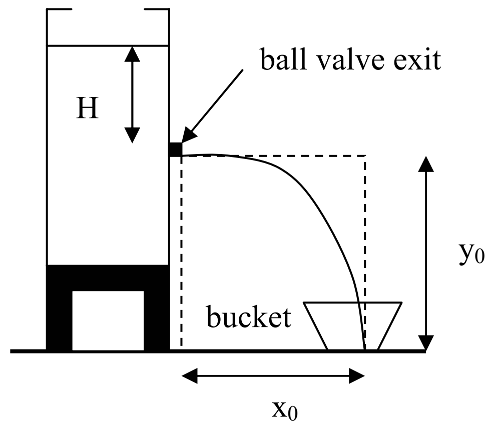
Torricellis Experiment using the Hydrostatic Pressure Column:

Basic Equations for flow from an orifice in the side of a tank:

$$
\begin{aligned}
Q &= A_{vc}V_{act} \\
&= \left(C_c A_{exit}\right)\left(C_v V_{ideal}\right) \\
&= \left(C_c C_v\right)\left(A_{exit} V_{ideal}\right) \\
&= C_d A_{exit} V_{ideal} \\
&= C_d A_{exit} \sqrt{2gH}
\end{aligned}
$$



where Q = volumetric flow rate

A_{vc} = actual flow area, i.e. area of vena contracta

V_{act} = actual velocity at vena contracta (includes friction losses)

A_{exit} = measurable flow area of valve outlet (0.077 in^2)

V_{ideal} = $(2gH)^{1/2}$,the velocity at vena contracta assuming no losses.

g = the acceleration of gravity ($g = 32.174\ ft/s^2 = 386.0\ in/s^2$)

H = the depth of the orifice below the free surface

C_v = V_{act}/V_{ideal} , the **velocity coefficient**

C_c = A_{vc}/A_{exit} , the **contraction coefficient**

C_d = $Q_{actual}/(A_{exit}V_{ideal}) = C_v \cdot C_c$, the **discharge coefficient**

BASIC MEASUREMENTS: Record H, t, and x_o for three different runs.

where H = height of water free surface *above* orifice centerline, in inches.
Δt = time for water level to drop one inch, in seconds.
x_o = *throw* of the water jet, i.e. horizontal distance to point where jet hits floor, in inches.

Run #	H (inches)	Δt (seconds)	x_o (inches)
1			
2			
3			

DISCHARGE COEFFICIENT Calculations: Shaded columns are measured data copied from previous table: (A_{exit} = 0.077 in^2)

Run #	H (inches)	V_{ideal} =$(2gH)^{1/2}$ (in/s)	$A_{exit}V_{ideal}$ (in^3/s)	Δt (seconds)	Q =(75 in^3)/ Δt (in^3/s)	Discharge Coefficient $C_d = Q/(A_{exit}V_{ideal})$
1						
2						
3						
Average Discharge Coefficient						

VELOCITY COEFFICIENT Calculations: Shaded data copied from basic measurements. (y_o = 40.7 inches, g = 386.0 in/s^2)

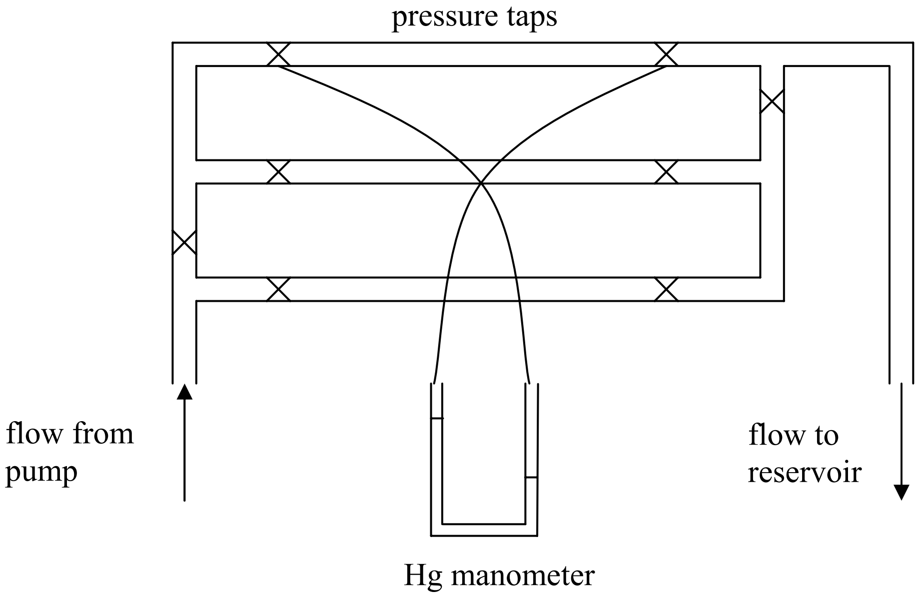
Run #	Throw x_o (inches)	Actual Velocity $V_{act} = \frac{x_o}{\sqrt{2y_o/g}}$ (in/s)	Ideal Velocity V_{ideal} =$(2gH)^{1/2}$ (in/s)	Velocity Coefficient $C_v = V_{actual}/V_{ideal}$
1				
2				
3				
Average Velocity Coefficient				

CONTRACTION COEFFICIENT and VENA CONTRACTA AREA Calculations:

Run #	Discharge Coefficient C_d	Velocity Coefficient C_v	Contraction Coefficient $C_c = C_d / C_v$	Vena Contracta Area $A_{vc} = C_c A_{exit}$
1				
2				
3				
Average Area of Vena Contracta				

Pipe Friction:

The apparatus shown below is designed to study head (pressure) loss due to pipe friction and fittings. In particular, we will be calculating friction factor and will plot our results against Reynolds number. (These results will be compared with values from the Colebrook equation found in your text.)



When starting the apparatus please follow the following procedure.

1. Verify that the valve by the pump is closed and the valve in the flexible pipe to the reservoir (tank) is open.
2. Verify that plastic tubing connects each side of the manometer to one of the pressure taps of the top pipe on the wall.
3. Verify that the mercury in the U-tube manometer reads zero on scale. **If mercury is observed outside the manometer, notify your instructor immediately.**
4. Start the pump then open the valve by the pump slowly until it is fully open.
5. Wait one minute to allow air to escape the pipe network before taking data.

Data are desired over a range of flow rates (say from 0.2 to 0.5 gal/s). Perform the following procedure for each datum.

1. Adjust the valve by the pump to provide a new flow rate. This will require one person reading the manometer and another adjusting the valve. Try to achieve a Δz that is +/- 0.1 inch of the target value. **If the pump starts to make popping sounds** open the valve slightly and try again.
2. Record the actual Δz.
3. Measure and record the time in seconds [s] that it takes for one revolution of needle on the flow meter (accumulator). Calibration tests indicate that each tick on the dial is actually 1.08 gallons [gal] and a full revolution is 10.8 gallons.
4. Repeat the procedure for the next data point.

After all the data have been taken, close the valve by the pump, and turn off the pump.

Pipe Friction Data and Calculation Sheet:

Target Δz (in Hg)	Actual Δz (in Hg)	Measured Pressure Drop ΔP (psi)	Measured Δt for 10.8 gal (seconds)	Measured Flow Rate Q (gal/s)	Average Velocity V (ft/s)	Reynolds Number Re_D	Measured Friction Factor f	Predicted Friction Factor f Colebrook Value
4.0								
3.7								
3.3								
3.0								
2.7								
2.3								
2.0								
1.7								
1.3								

where the following equations have been developed using appropriate fluid and equipment parameters:

$$\Delta P = \left(\rho_{Hg} - \rho_{water}\right) g \Delta z = \left(0.4533 \frac{psi}{in}\right) \Delta z$$

$$\mathrm{Re}_D = \frac{\rho V D}{\mu} = \frac{VD}{\nu} = \left(\frac{8.67 \times 10^3}{ft/s}\right) V$$

$$V = \frac{Q}{A} = \left(24.5 \frac{ft/s}{gal/s}\right) Q$$

$$\Delta P = f \frac{L}{D} \rho \frac{V^2}{2} \rightarrow f = \frac{D}{L} \frac{\Delta P}{\rho \frac{V^2}{2}} = \left[1.59 \frac{(ft/s)^2}{psi}\right] \left(\frac{\Delta P}{V^2}\right)$$

Plot the measured friction factor and the Colebrook (or Haaland) value versus the Reynolds number and comment on it.