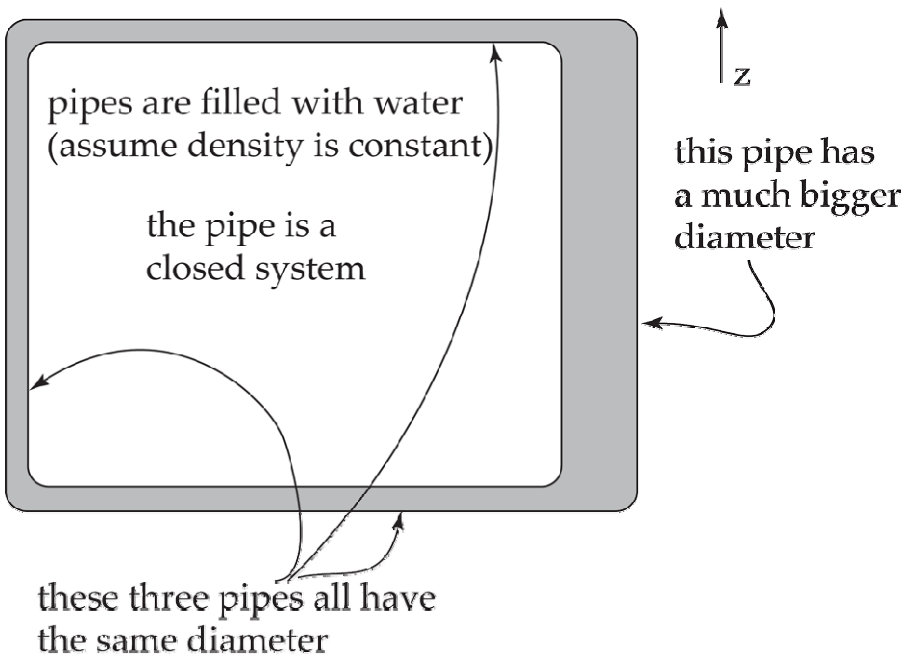
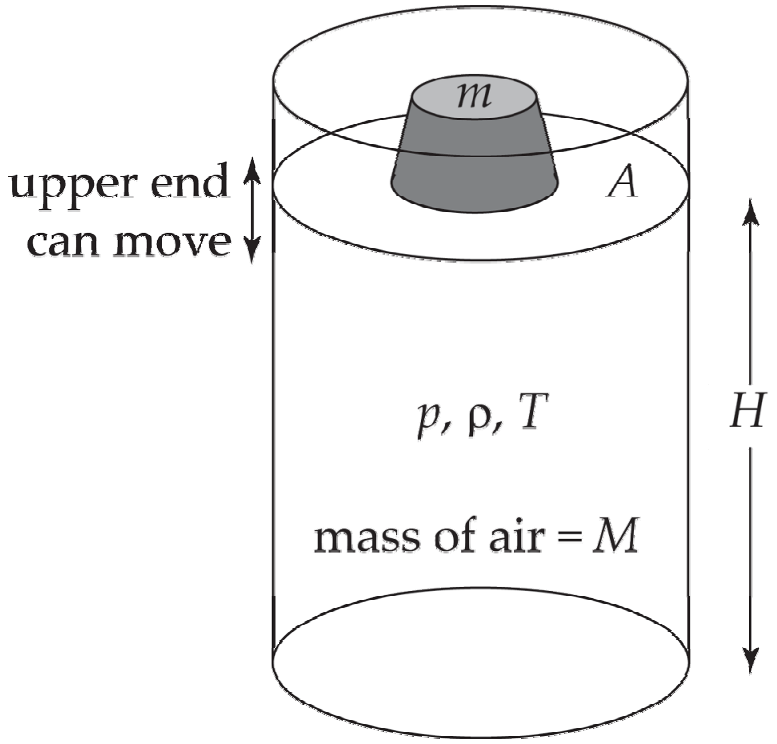
Introduction to Fluid Dynamics
Problem Set 1, 10/5/2007, due at the start of class 10/12/2007

1. A Boeing 747 airliner in flight typically has a mass of 400,000 kg. Its wing area looking down from the top is 525 m^2.
[3] What is the average pressure difference, Δp, between the bottom and top faces of the wing?
[2] What fraction is Δp of typical sea level atmospheric pressure?

2. Consider a pipe filled with water that looks like the figure shown below.
[10] Under the influence of gravity, an optimistic inventor might expect that the water in the pipe would develop a clockwise circulation because the weight of water in the pipe on the right is so great. Will this perpetual motion machine work? Use integrals of the hydrostatic balance to support your answer. Be explicit about your assumption of what the pressure at the top of the top pipe is.





3. Consider a cylinder filled with dry air, whose top surface can move. It has temperature $T_1 = 20°\text{C}$ (NOTE: K = °C + 273.15). There is a weight of mass $m = 10^4\,\text{kg}$ on the top, which has area $A = 1\text{m}^2$. The cylinder walls are insulating, and you may ignore the effect of atmospheric pressure.

[5] What are the pressure, p_1, and density, ρ_1, of the initial state, assuming the usual value for gravity?

[5] What is the total mass, *M*, of air if the initial height of the cylinder is 10 m?

[5] Would we be justified in neglecting the hydrostatic change in pressure over the height of the cylinder?

Now we add 10^5 Joules of heat to the air in the cylinder.

*[3] Was the change to the system adiabatic? Was the work done by the moving end reversible? Was the change to the system isentropic?

*[10] What will the new gas state, p_2, ρ_2, and T_2, be?

*[2] How far did the top end of the cylinder move, and in which direction?

*[5] What is the ratio of the work done by the moving end of the cylinder to the change of internal energy of the system? Be explicit about the *signs* of energy change.

[15] Answer the four questions (*) above for the case where instead of adding heat to the system we double the mass on top, $m \to 2m$.