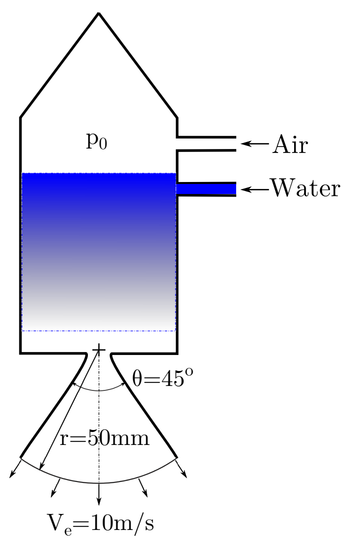
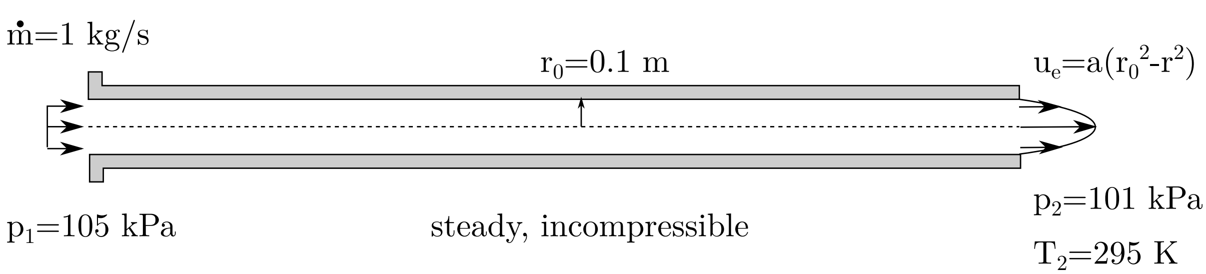
ENAE311H Homework 3

Due: Thursday, October 17th by 5pm

1. Consider a water rocket on a test stand as shown below, where thrust is produced by forcing water from a high-pressure reservoir (p_0) through a two-dimensional (planar) diverging nozzle of depth 10 mm. The flow at the exit can be considered to be directed radially outwards from a point (actually a line into the page) upstream near the nozzle throat as shown, and the exit pressure can be assumed atmospheric. The rocket is connected from the side to two large reservoirs, one to keep the water level constant, the other to maintain the pressure at p_0. Calculate the vertical thrust produced by the rocket, assuming steady flow and that the effects of gravity are negligible.



2. Consider the viscous fluid flow of air through a long, circular pipe. At the entrance to the pipe, the fluid velocity is uniform and the mass flux is 1 kg/s. Because of viscous effects, the velocity profile at the exit is parabolic, of the form $u_e(r) = a(r_0^2 - r^2)$, where r is the radial distance from the pipe center, $r_0 = 0.1\,\text{m}$ is the pipe radius, and a is a constant. Assume the flow is steady and incompressible. The pressure across the inlet and exit are constant (but different values as indicated in the figure), and the exit temperature is 295 K. Determine the viscous force exerted on the pipe by the fluid flow.



3. Consider the flow through a scramjet combustor as shown below. Hydrogen fuel is added to an air inflow and the two are fully mixed (without combusting) by position 1, where the the conditions are uniform with the following values: ρ_1=0.3 kg/m^3, u_1=1500 m/s, and T_1=1000 K. Chemical reactions then occur between position 1 and 2, releasing energy into the flow. At the outlet (position 2), the flow is again uniform with u_2=1700 m/s, T_2=1200 K. The respective cross-sectional areas are A_1=750 mm^2 and A_2=1500 mm^2. Assuming steady, inviscid flow with no heat losses at the walls, calculate the rate of heat release from the chemical reactions, $\dot{Q}$. Treat the gas mixture as a perfect gas with c_p=1150 J/kgK.