Homework #4

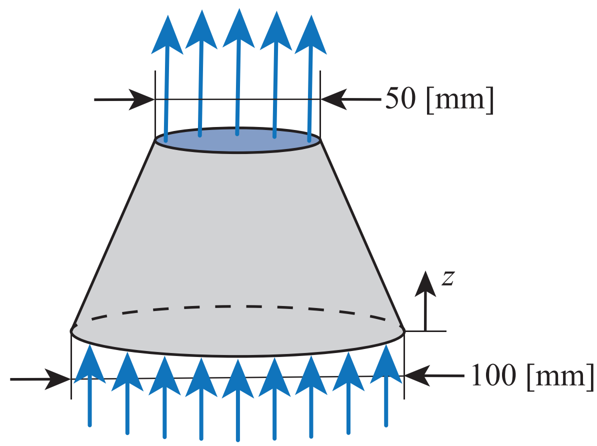
MEMS 0071 - Introduction to Fluid Mechanics

Assigned: October 12$^{\text{th}}$, 2019
Due: October 18$^{\text{th}}$, 2019

Problem #1

Water enters a nozzle with a velocity of 1.5 [m/s]. Determine:

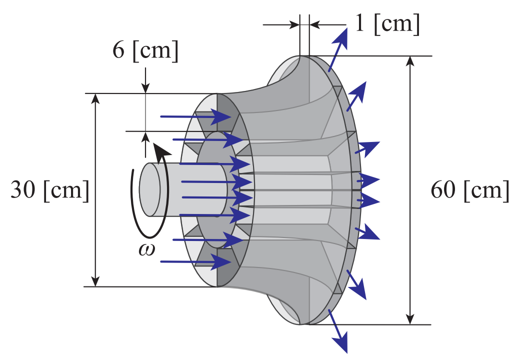
a) the exit velocity;
b) the force in the z-direction required to hold the nozzle into position.



Problem #2

The impeller of a centrifugal blower has a diameter of 30 [cm] and a blade width of 6 [cm] at the inlet, and a diameter of 60 [cm] and a blade with of 1 [cm] at the outlet. The blower increases the pressure of atmospheric air by 125 [kPa], whereas the temperature can be assumed invariant at 20°C. Disregarding mechanical losses, and assuming the air velocity at the inlet and outlet are equal to the impeller velocities at the inlet and outlet, determine:

1. The volumetric flow rate of when when the impeller is operated at 3,000 rpm and the power consumption of the blower is 450 [W].
2. The normal component of velocity at the inlet and outlet of the impeller.



Problem #3

A sprinkler is depicted in the figure below. Water enters the bottom of the sprinkler with a pressure of 20 [kPa] gage with a volumetric flow rate of 12.5 [L/min]. The sprinkler rotates at 60 [rpm]. Given that the diameter of the sprinkler nozzle is 4 [mm], and the nozzle is oriented 45° above the horizontal plane, calculate the jet speed *relative* to the nozzle. That is, the water exiting the nozzle should have a greater speed that what the sprinkler rotates at. Also determine the total torque, $\vec{T}$, that the sprinkler produces under steady-state operation.

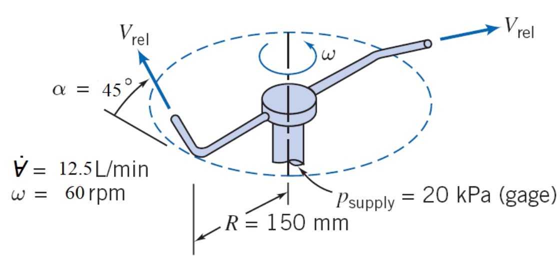
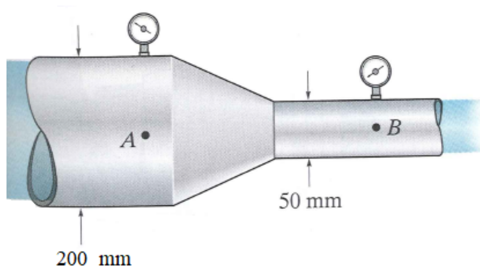


Figure 1: Schematic for Problem #4.

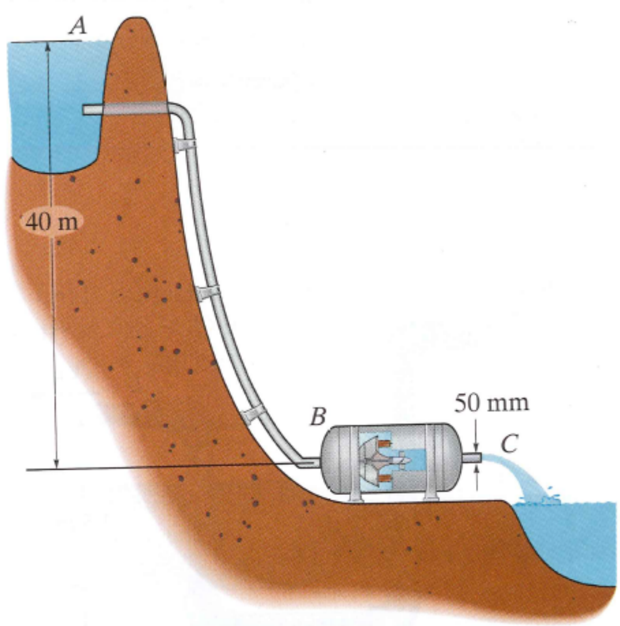
Problem #4

Air enters A with a velocity of 6.5 [m/s], a pressure of 32 [kPa] gage and a temperature of 40 °C. Determine the pressure of the fluid at B.



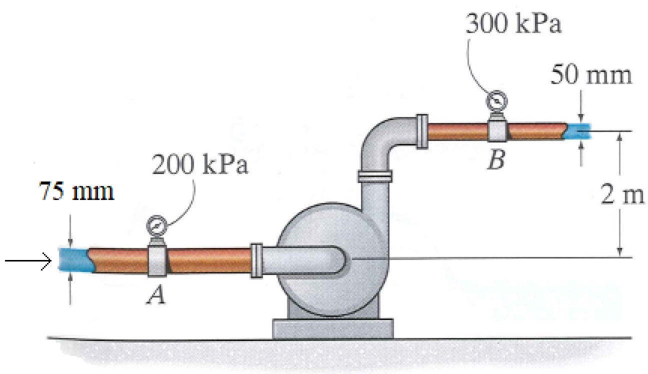
Problem #5

Water from the upper reservoir flows through a 75 [m] long, 50 [mm] diameter pipe into the turbine at B. If the head loss is 0.1 [m] per 100 [m] of length, and the water exits the turbine at C with a velocity of 10 [m/s], determine the power output of the turbine assuming η=0.80.



Problem #6

Given the water pressures at the inlet and exit of the pump as shown in the figure below, assuming the volumetric flow rate is 0.1 [m^3/s], determine the required pumping power.



Problem #7

There is a large tank, with the (1) open to atmosphere, that is filled with water to a height of h, from the center of the the outlet pipe (2). The valve on the outlet pipe is opened, allowing the water to flow out. Assume (2) is exposed to atmospheric pressure. Using the Bernoulli equation, derive the Toricelli equation, i.e. the expression for the outlet velocity as a function of height.

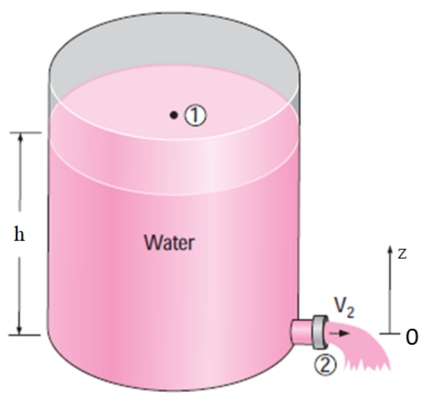


Figure 2: Schematic for Problem #1.

Problem #8

In Figure 2 provided below, the fountains at the Bellagio can shoot water as high as 140 [m] (distance between 1 and 2). The fountains uses pumps that pressurize the water to 250 [psi] (1,723.7 [kPa]) which is *then* sent through a nozzle with an exit diameter of 6.35 [cm]. Determine the exit velocity of the water from the nozzle at 1. Hint: be very discerning about the location of where you apply the pressure.

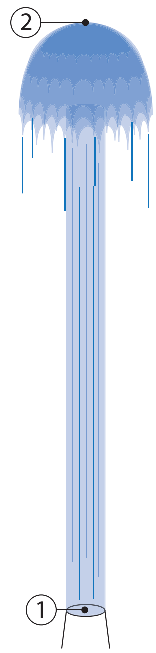


Figure 3: Schematic for Problem #2.

Problem #9

In Figure 3 provided below, a nozzle forces air into the compressor of a jet engine. The jet is flying at 200 [m/s], which is the velocity that enters the engine at 1. The ratio of inlet to exit area of the inlet nozzle is 1.65. Determine the velocity of the air entering the compressor at location 2. If the mass flow rate through the jet engine is 192 [kg/s], and the ratio of nozzle inlet area 1 to nozzle exit area 3 is 2.875, assuming the density of air is still 1.225 [kg/m^3], determine the velocity and pressure at 3, as well as the pressures at 1 and 2. Hint: apply 0 at a location with known pressure and velocity.

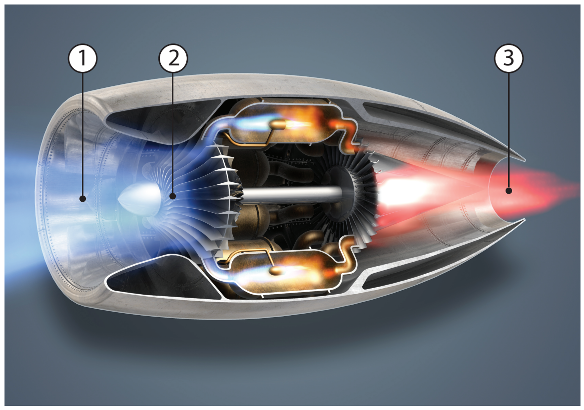


Figure 4: Schematic for Problem #3.