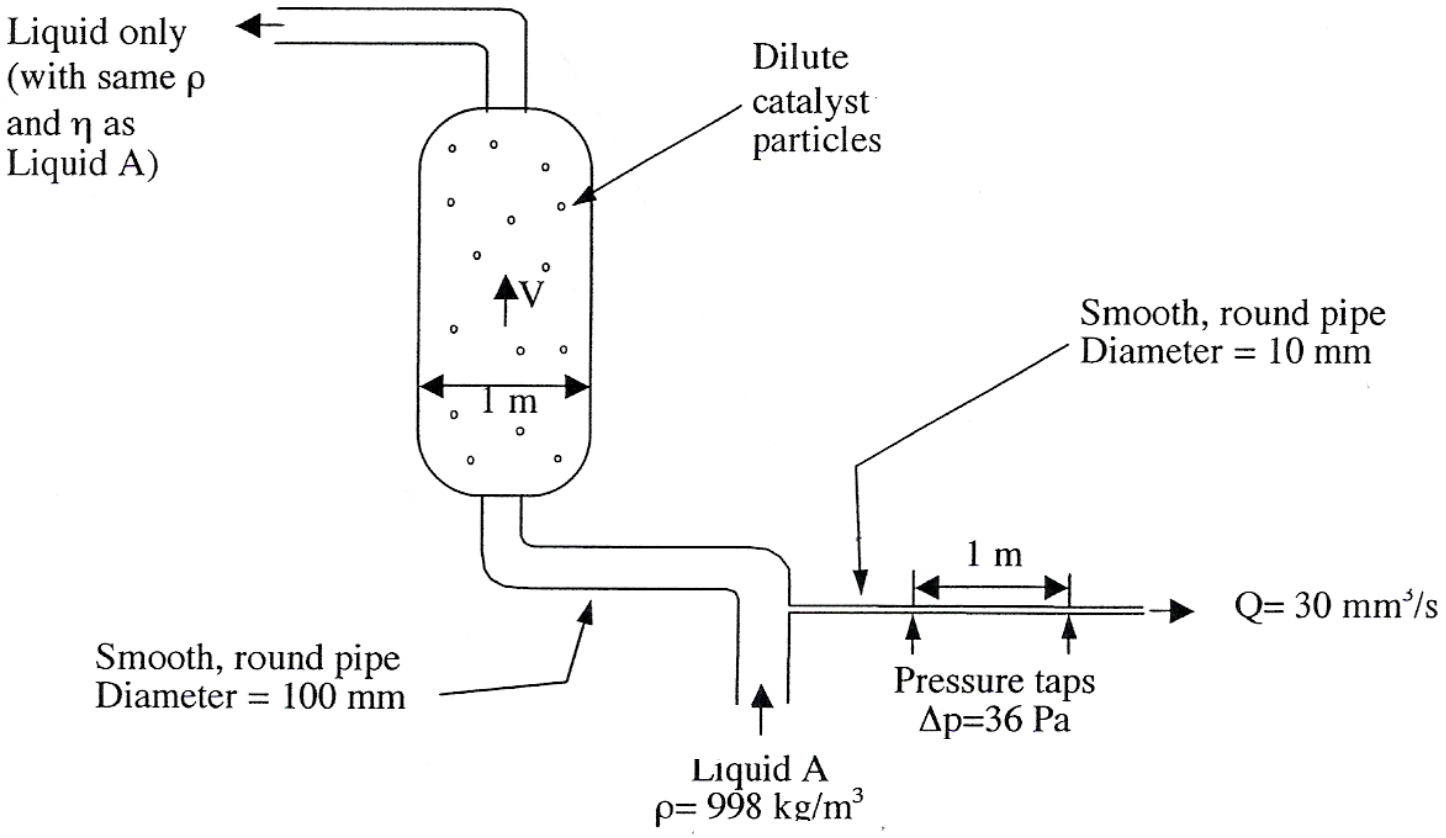
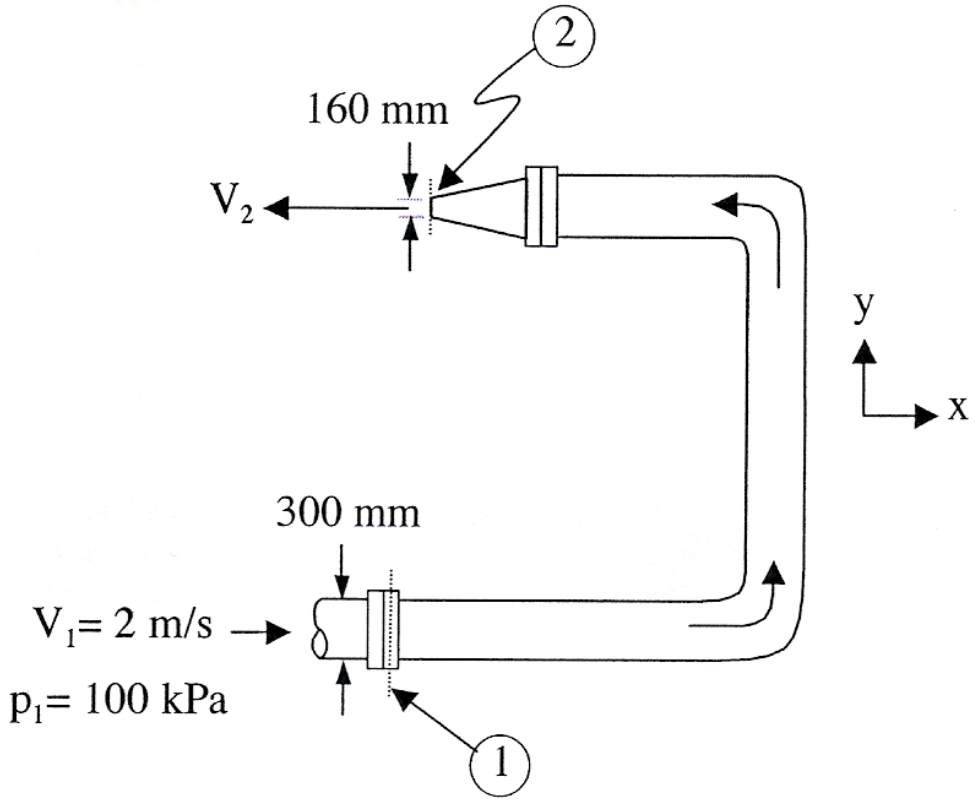
1. (40 pts) Part of a complex processing operation includes the streams indicated in the figure below. A stream of liquid reactant A is split into a main stream which flows into a reactor where it contacts spherical catalyst particles and a second, smaller stream which is monitored for quality control purposes. The catalyst particles are very dilute in the reactor, and the catalyst particles all have a diameter of 3 mm and a density of 1.9×10^3 kg/m^3. If the density and viscosity of liquid A are unchanged during this process, what is the maximum velocity V of liquid A in the reactor that can be used if the particles are to be kept in the reactor rather than carried off in the stream of liquid?



2. (40 pts total)

a) Determine the magnitude and direction of the x and y components of reaction force exerted on the flowing water by the ***horizontal*** elbow and nozzle combination shown in the figure below. Atmospheric pressure is 100 kPa. The gage pressure at section 1 is 100 kPa. At section 2, the water exits to the atmosphere.



b) What additional information would you need in order to determine the z-component of the force needed to anchor this elbow and nozzle combination in place? Be specific. Describe in words or using an equation (with clearly defined symbols) what this z-component of force is equal to.

3. (20 points)

a) Equation K on the equations sheet attached to this exam describes the conservation of some quantity. Name the quantity:

b) Also with regard to equation K, what does F represent (in words)? Be specific.

c) What is w_1 in equation K? What are it's dimensions?

d) In the movies we watched in class, we saw fluid contained in a cylinder, with a drop of colored fluid added. The cylinder was then rotated about it's axis. Briefly describe what happens to the drop of colored fluid when the cylinder rotation is stopped at low Re and at high Re.

e) In the conduit shown below, the velocity is independent of y, but depends on x as indicated. What is the average velocity $\langle v_z \rangle$?

$v_z = 1\,m/s \quad for \quad 0 < x < 1$

$v_z = 5\,m/s \quad for \quad 1 < x < 2$

$v_z = 2\,m/s \quad for \quad 2 < x < 4$