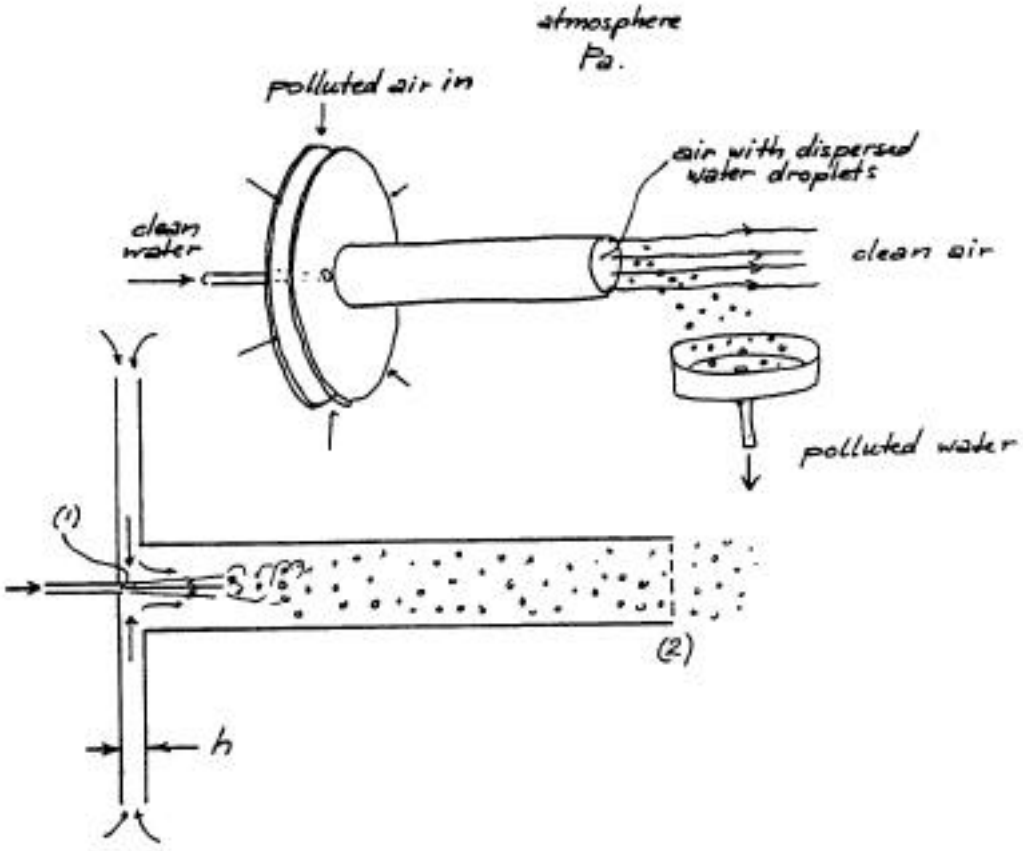
Problem 5.9

Scrubber



A scrubber is a device that removes pollutants from air by allowing the air to come in contact with a spray of water droplets. The pollutants are absorbed by the droplets, and the air that passes through is clean. The polluted droplets are collected and processed.

An inventor seeks a patent on a scrubber with the novel inlet region shown in the sketch, which, he claims, has the advantage that no fan is needed to move the air. A high-speed water jet (speed V_j and mass flow rate $\dot{m}_w$) enters at (1) and quickly breaks up into droplets which become dispersed as they move through the tube. By station (2), friction between the water droplets and the air has brought the two phases to essentially the same (and approximately uniform) speed V_e. The device automatically draws in atmospheric air via the streamlined, cymbal-shaped entrance, whose radius is large and separation *h* is small compared with the radius *R* of the mixing tube.

We shall assume that the system is so designed that the water spray fills the entire cross-section at (2) uniformly, but does not at any point hit the side walls of the tube. Simplify your analysis by also assuming that $V_e << V_j$, and $\dot{m}_w V_j >> \dot{m}_{air} V_e$, where $\dot{m}_{air}$ is the mass flow rate of air drawn in.

Derive an expression for the mass flow rate $\dot{m}_{air}$ of air drawn through the device, expressed in terms of V_j, $\dot{m}_w$, R, h, and the densities if air and water.

HINT HINT 2 HINT 3 HINT 4 ANSWER