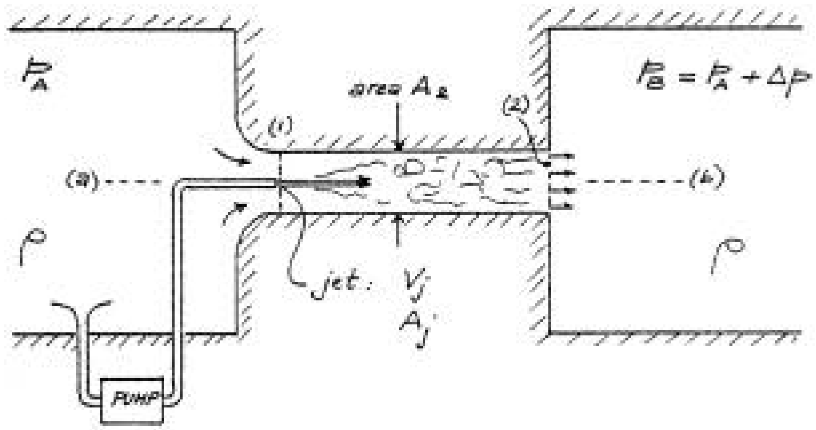
Problem 5.8

Jet pump



The device connected between compartments A and B is a simplified version of a jet pump. A jet (or ejector) pump is a device which uses a small, very high-speed jet with relatively low volume flow rate to move fluid at much larger volume flow rates against a pressure differential Δp, as shown in the figure.

The pump in the figure consists of a contoured inlet section leading to a pipe segment of constant area A_2. A small jet draws fluid from compartment A and ejects it at high velocity V_j and area A_j at the entrance plane (1) of the constant-area pipe segment. Between (1) and (2), the jet (the "primary" stream) and the secondary fluid flow which is drawn in from compartment A via the contoured inlet section mix in a viscous, turbulent fashion and eventually, at station (2), emerge as an essentially uniform-velocity stream. The pump operates in steady state.

To simplify the analysis, we make several physical assumptions that are not unreasonable. We assume

¾ that the flow is incompressible
¾ that the flow from compartment A to station (1) is inviscid,
¾ that, although viscous forces cause the turbulent mixing process between (1) and (2), the shear force exerted on the walls between those stations is small compared with $\Delta p A_2$,
¾ that gravitational effects are negligible, the flow being horizontal.

We also make two assumption about operating conditions that are also reasonable and considerably simplify the mathematics involved in the analysis:

$$A_j << A_2 \qquad \text{and} \qquad V_j A_j << V_2 A_2$$

(a) Derive an expression for Δp as a function of the total volume flow rate Q from compartment A to compartment B. The given quantities are A_1, A_2, ρ and V_j. Indicate the volume flow rate Q_o when $\Delta p = 0$ (the "short-circuit" volume flow rate) and the pressure Δp_o at which $Q = 0$. Write the pressure-volume flow rate relationship in universal dimensionless form as $\Delta p / \Delta p_o$ vs Q / Q_o and sketch it for positive values of pressure This is the “pump curve” in dimensionless form.

Show that for $A_j << A_2$,, $Q_o >> V_j A_j$.

HINT HINT 2 HINT3 ANSWERS

(c) Sketch the pressure distributions along the line a-b for the cases $\Delta p = 0$ and $\Delta p > 0$.

ANSWER

(d) Is your formulation in (a) valid when $Q=0$, i.e. when the total volume flow rate from A to B is zero? Explain. What is the minimum value Q_{min} of Q for which your formulation in (a) is valid?

ANSWER