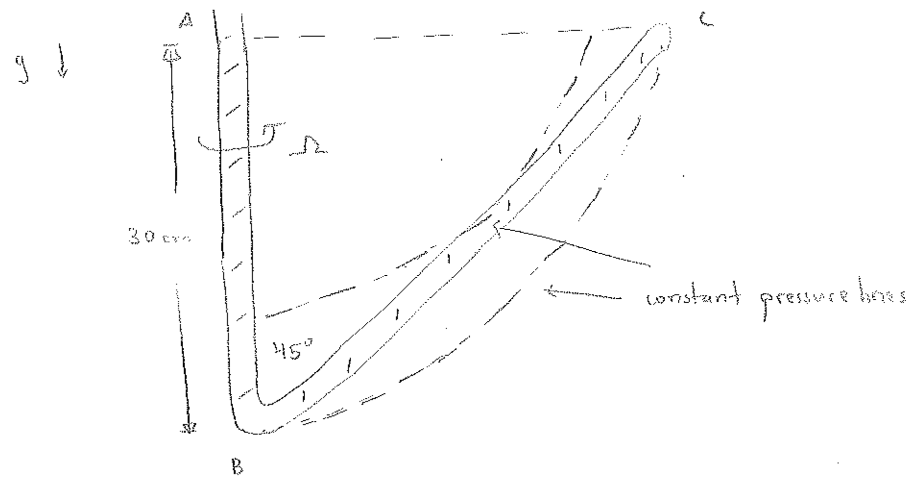
1.



a) If pressures are equal at B and C, they must lie on a const. pressure paraboloid surface as sketched in the figure. If $z_B = 0$, then from Eq. 2.32:

$$z_C = 0.3\text{ m} = \frac{\Omega^2 r_C^2}{2g} = \frac{\Omega^2 (0.3\text{ m})^2}{2(9.81\ \frac{m}{s^2})}$$

Rearrange for Ω:

$$\boxed{\Omega = 8.09\ \frac{rad}{s} = 77\ \frac{rev}{min}}$$

b) The minimum pressure occurs where the highest paraboloid pressure contour is tangent to BC, as shown in the figure. Again using Eq. 2.32 with Ω (in $\frac{rad}{s}$) from part (a):

$$z = \frac{\Omega^2 r^2}{2g} + \text{const.} = r\tan(45°)$$

Plug in for Ω, g, and tan(45°).

$$\text{const.} + 3.333r^2 - r = 0 = f(r) \quad \text{for any constant pressure line}$$

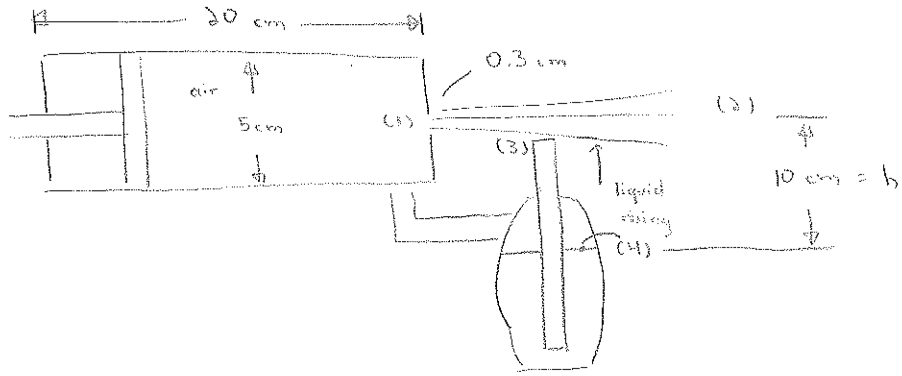
The minimum is found when $\frac{df}{dr} = 0$, so we get:

$$\boxed{r = 0.15\text{ m}}$$

Since $z = r\tan(45°)$:

$$\boxed{z = 0.15\text{ m}}$$

2.



Assumptions:

1) Flows are steady, incompressible, and inviscid.

2) Air is an ideal gas.

3) The reservoir is open to the atmosphere.

4) Device is horizontal.

5) Water velocity through the tube is low.

Analysis:

Point 1 is at the pump exit, 2 is far from the exit on a horizontal line, point (3) is at the exit of the liquid tube but close enough to point 1 that they can be assumed coincident, and point 4 is at the free surface of the reservoir liquid. Thus, $P_2 = P_4 = P_{atm}$ and $P_1 = P_3$. Also, $z_1 = z_2 = z_3 = 0$ and $z_4 = -h$, and $v_2 = v_3 = v_4 = 0$.

Apply B. eqn. to water (3 - 4):

$$\frac{P_3}{\rho g} + \frac{v_3^2}{2g} + z_3 = \frac{P_4}{\rho g} + \frac{v_4^2}{2g} + z_4 \rightarrow \frac{P_1}{\rho g} = \frac{P_{atm}}{\rho g} - h \rightarrow P_1 - P_{atm} = -\rho_{water} g h \quad (1)$$

Apply B. eqn. to air (1-2).

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 \rightarrow \frac{P_1}{\rho g} + \frac{v_1^2}{2g} = \frac{P_{atm}}{\rho g} \rightarrow v_1 = \sqrt{\frac{2(P_{atm} - P_1)}{\rho_{air}}} \quad (2)$$

where $\rho_{air} = \dfrac{P}{RT} = \dfrac{95 \text{ kPa}}{\left(0.287 \frac{\text{kPa}\cdot\text{m}^3}{\text{kg}\cdot\text{K}}\right)(293 \text{ K})} \rightarrow \rho_{air} = 1.13 \frac{\text{kg}}{\text{m}^3}$

Combining (1) and (2):

$$v_1 = \sqrt{\frac{2\rho_{water} g h}{\rho_{air}}} = \sqrt{\frac{2(1000)(9.81 \frac{m}{s^2})(0.1 m)}{1.13}} \rightarrow v_1 = 41.7 \frac{m}{s}$$

2. Since the flow is steady and incompressible:

$$v_1 A_1 = v_{piston} A_{piston}$$

$$v_{piston} = \left(\frac{A_1}{A_{piston}}\right) v_1 = \frac{\cancel{\frac{\pi}{4}} d_1^2}{\cancel{\frac{\pi}{4}} d_{piston}^2} v_1 = \frac{(0.3\ cm)^2}{(5\ cm)^2}\left(41.7\ \frac{m}{s}\right) \rightarrow \boxed{v_{piston} = 0.15\ \frac{m}{s}}$$