1a) For subsystem B,

$$P = 100\times10^3 + \frac{(2+3)\times9.81}{19.6\times10^{-4}}$$

$$= 125.0255102\,kPa$$

$$\approx 125\,kPa$$

$$T = T_{sat} @ 125kPa$$

$$= 105.97°C$$

$$pV_A = mRT$$

$$\left(100\times10^3 + \frac{2\times9.81}{19.6\times10^{-4}}\right)V_A = 0.01\times0.287\times10^3(105.97+273.15)$$

$$V_A = 9.890667953\times10^{-3}\,m^3$$

$$V_g = m\times v_g$$

$$= 0.002\times0.4(1.3750)$$

$$= 1.1\times10^{-3}\,m^3$$

1b) $v_{B_i} = v_f + x v_{fg}$

$= 0.001048 + 0.4(1.3750 - 0.001048)$

$= 0.5506288 \ m^3/kg$

$V_{B\,initial} = 0.002 \times 0.5506288$

$= 1.1012576 \times 10^{-3} \ m^3$

$V_{B\,final} = 1.1012576 \times 10^{-3} + 500 \times 10^{-3} \times 19.6 \times 10^{-4}$

$= 2.0812576 \times 10^{-3} \ m^3$

$v_{B\,final} = \dfrac{2.0812576 \times 10^{-3}}{0.002}$

$= 1.0406288 \ m^3/kg$

$\text{Volume ratio} = \dfrac{1.08049 - 1.0406288}{1.08049 - 0.95986}$

$= 0.33044184 7$

1b) $$\frac{200 - T_{final}}{200 - 150} = 0.33044847$$

$$T_{final} = 183.4779077°C$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Since P is constant,

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$V_2 = \frac{T_2}{T_1} V_1$$

$$= \frac{183.4779077 + 273.15}{105.97 + 273.15} \times (9.890667953 \times 10^{-3})$$

$$= 0.01191273215 \, m^3$$

$$\approx 0.0119 \, m^3$$

1c) $WD = 125\times10^3 \times 19.6\times10^{-4} \times 500\times10^{-3}$

$= 122.5\,J$

1d) For subsystem A,

$$Q - WD = m(u_f - u_i)$$

$$Q = mc_{v_{avg}}\Delta T + WD$$

$$T_{avg} = \frac{183.4779077+105.97}{2}$$

$= 144.7239538°C$

$= 417.8739538°C$

$$\frac{450-417.8739538}{450-400} = \frac{0.733 - c_{avg}}{0.733 - 0.726}$$

$c_{v_{avg}} = 0.728502353\,kJ/kg$

$$Q = 0.01(0.728502353)(183.4779077-105.97) + \left(100\times10^3 + \frac{2\times9.81}{19.6\times10^{-4}}\right)$$

$$(0.0119127321\,5 - 9.840667953\times10^{-3})\times10^{-3}$$

$= 0.787094626\,3\,kJ$

1d) For subsystem B,

$$Q - W = m(u_f - u_i)$$

$$Q = m(u_f - u_i) + W$$

$$\frac{2654.6 - u_f}{2654.6 - 2577.1} = 0.330441847$$

$$u_f = 2628.990757 \text{kJ/kg}$$

$$u_i = u_f + x u_{fg}$$

$$= 444.23 + 0.4(2068.8)$$

$$= 1271.77 \text{kJ/kg}$$

$$Q = 0.002(2628.990757 - 1271.77) + 122.5 \times 10^{-3}$$

$$= 2.836941514 \text{kJ}$$

$$Q_{Total} = 2.836941514 + 0.7870946263$$

$$= 3.62403614 \text{kJ}$$

$$\approx 3.62 \text{kJ}$$

2a) $h_i = 3457.2 \text{ kJ/kg}$

$$h_e = h_f + x h_{fg}$$
$$= 317.62 + 0.8(2318.4)$$
$$= 2172.34 \text{ kJ/kg}$$

$$\dot{W} = \dot{m}\left(h_i - h_e + \frac{V_1^2 - V_2^2}{2}\right)$$
$$= 20\left(3457.2 - 2172.34 + \frac{80^2 - 50^2}{2} \times 10^{-3}\right)$$
$$= 25.7362 \text{ MJ}$$

2b) $A_1 V_1 = A_2 V_2$

$$\frac{A_2}{A_1} = \frac{V_1}{V_2}$$

$$= \frac{80}{50}$$

$$= 1.6$$

2c) $\sum \dot{m}_i h_i = \sum \dot{m}_e h_e$

$20(2172.34) + 5(3457.2) = 25 h_e$

$h_e = 2429.312 \text{ kJ/kg}$

$T = T_{sat} @ 300 \text{ kPa}$

$= 133.52°C$

$$x = \frac{h_e - h_f}{h_{fg}}$$

$$= \frac{2429.312 - 561.43}{2163.5}$$

$= 0.8633612202$

$v = v_f + x v_{fg}$

$= 0.001073 + 0.8633612202(0.60582 - 0.001073)$

$= 0.5231881079 \text{ m}^3$

3ai) At point A,

$$P = \rho g h$$

$$= \frac{\rho g L}{4}$$

$$= 2.4525 \rho L$$

At point B,

$$P = \rho g h$$

$$= \rho g \left(\frac{L}{4} + \frac{L}{2}\right)$$

$$= \frac{3 \rho g L}{4}$$

$$= 7.3575 \rho L$$

ii) $\frac{\partial p}{\partial r} = \rho r w^2$

$$dp = \frac{\partial p}{\partial r} dr + \cancel{\frac{\partial p}{\partial \theta} d\theta}^{\,0} + \frac{\partial p}{\partial z} dz$$

$$= \rho r w^2 dr - \rho (g + a_z) dz$$

$$= \rho r w^2 dr - \rho g dz$$

At point A,

$$P = \int_0^L \rho r w^2 dr - \int_{\frac{L}{4}}^{0} \rho g dz$$

$$= \frac{\rho L^2 w^2}{2} + \frac{\rho g L}{4}$$

$$= \frac{\rho L^2 w^2}{2} + 2.4525 \rho L$$

3aii) At point B,

$$P = \int_0^{\frac{L}{2}} \rho r w^2 \, dr - \int_{\frac{3L}{4}}^{0} \rho g \, dz$$

$$= \frac{\rho L^2 w^2}{8} + 7.3575 \rho L$$

iii) $P_A = P_B$

$$\frac{\rho L^2 w^2}{2} + \frac{\rho g L}{4} = \frac{\rho L^2 w^2}{8} + \frac{3}{4} \rho g L$$

$$\frac{3 \cancel{\rho} L^{\cancel{2}} w^2}{8} = \frac{1}{2} \cancel{\rho} g \cancel{L}$$

$$\frac{3 L w^2}{8} = \frac{1}{2} g$$

$$w^2 = \frac{4g}{3L}$$

$$w = \sqrt{\frac{327}{25L}}$$

$$P_{bp} = \frac{\rho L^2 w^2}{2} + \frac{\rho g L}{4}$$

$$= \rho L \left(\frac{1}{2} \cancel{L} \left(\frac{4g}{3\cancel{L}} \right) + \frac{g}{4} \right)$$

$$= \frac{3597}{400} \rho L$$

3 bi) $\frac{\rho_{wood}}{\rho_{water}} = \frac{V_{submerged}}{V_{object}}$

$$\rho_{wood} = \frac{0.2854}{0.7854} \rho$$

$$= \frac{1427}{3927}$$

$$= 0.3633817163 \ kg/m^3$$

bii) $\overline{GM} = \frac{I_0}{V} \overline{CG}$

$I_0 = \frac{1}{12} \times L \left(1 - \frac{1}{\sqrt{2}}\right)^3 r^3 = 2.09385547 \times 10^{-3} m^3$

$V = 0.2854 r^2 L$

$\overline{CG} = \left(\frac{r}{\sqrt{2}} - 0.6002r\right) + 0.1188r$

$= 0.2257r$

$\therefore \overline{GM} = 0.007336r - 0.2257r$

$= -0.21837r$

Since $r > 0$, $\therefore \overline{GM} < 0$

$\therefore$ It is unstable.

4ai) Bernoulli from A to 2

$$\cancel{\frac{p_A}{\rho g}} + \cancel{\frac{V_A^2}{2g}} + z_A = \cancel{\frac{p_2}{\rho g}} + \frac{V_2^2}{2g} + z_2$$

$$H = \frac{V_2^2}{2g} + 0$$

$$V_2 = \sqrt{2gH}$$

$$A_1 V_1 = A_2 V_2$$

$$\frac{\cancel{\pi} D_1^2}{\cancel{4}} V_1 = \frac{\cancel{\pi} D_2^2}{\cancel{4}} V_2$$

$$\left(\sqrt{2} D_2\right)^2 V_1 = D_2^2 V_2$$

$$2 V_1 = V_2$$

$$V_1 = \frac{1}{2} V_2$$

$$\therefore V_1 = \sqrt{\frac{gH}{2}}$$

4aii) Bernoulli from A to 1

$$\cancel{\frac{P_A}{\rho g}} + \cancel{\frac{V_A^2}{2g}} + z_A = \frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1$$

$$H = \frac{P_1}{\rho g} + \frac{\sqrt{\frac{gh}{2}}^2}{2g} + 0$$

$$H = \frac{P_1}{\rho g} + \frac{H}{4}$$

$$\rho g H - \frac{\rho g H}{4} = P_1$$

$$P_1 = \frac{3}{4}\rho g H$$

$$P_F = \frac{3}{4}\rho g H + \rho g \frac{H}{2}$$

$$= \frac{5}{4}\rho g H$$

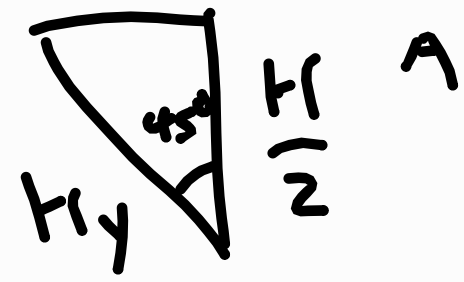
$$F_p = \frac{5}{4}\rho g H \times \frac{H}{2}$$

$$= \frac{5}{8}\rho g H^2$$

4b i) $F_h = \rho g h_c A$

$$= \rho g \left(\frac{3}{4}H\right)\left(\frac{H}{\sqrt{2}}\right)$$

$$= \frac{3}{4\sqrt{2}}\rho g H^2$$



$$\cos 45° = \frac{A}{H_y}$$

$$H_y = \frac{H}{2\cos 45°}$$

$$= \frac{H}{\sqrt{2}}$$

$$y = \frac{I_{xc}}{y_c A} + y_c$$

$$= \frac{\frac{1}{12}\times 1 \times \left(\frac{H}{\sqrt{2}}\right)^3}{\frac{3}{4}(\cancel{\sqrt{2}}H)\left(\frac{H}{\cancel{\sqrt{2}}}\right)} + \frac{3}{4}\sqrt{2}H$$

$$= \frac{\frac{H^3}{24}\times\frac{1}{\sqrt{2}}}{\frac{3\cancel{H^2}}{4}} + \frac{3}{4}\sqrt{2}H$$

$$= \frac{H}{18\sqrt{2}} + \frac{3}{4}\sqrt{2}H$$

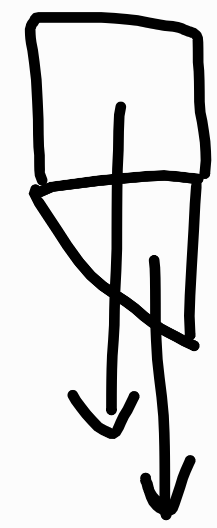
$$= \frac{7}{9}\sqrt{2}H$$

4bii) $F_v = \rho g V$

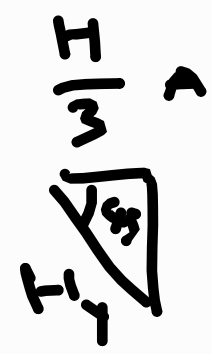
$$= \rho g \left(\frac{H}{2} \times 1 \times \frac{H}{2} + \frac{1}{2} \times \frac{H}{2} \times \frac{H}{2} \right)$$

$$= \frac{3}{8} \rho g H^2$$

4biii) $\frac{\cancel{\rho g H^2}}{4}\left(\frac{H}{2\sqrt{2}}\right) + \frac{\cancel{\rho g H^2}}{8}\left(\frac{2H}{3\sqrt{2}}\right) = \frac{3}{8}\cancel{\rho g H^2} L$



$$\frac{H}{8\sqrt{2}} + \frac{H}{12\sqrt{2}} = \frac{3}{8} L$$



$\cos 45 = \frac{A}{H_y}$

$H_y = \frac{A}{\cos 45°}$

$$\frac{12\sqrt{2}H + 8\sqrt{2}H}{192} = \frac{3}{8} L$$

$$\frac{5\sqrt{2}H}{48} = \frac{3}{8} L$$

$$L = \frac{5\sqrt{2}}{18} H$$

4biii) $F_v \cos 45^\circ \left(\frac{5\sqrt{2}}{18} H\right) + F_h \cos 45^\circ \left(\frac{\sqrt{2}}{4} H\right)$

$$= F_p L_{oD}$$

$$\frac{3}{8} \cancel{\rho g H^2} \left(\frac{1}{\cancel{\sqrt{2}}}\right)\left(\frac{5\cancel{\sqrt{2}}}{18} H\right) + \frac{3}{4\sqrt{2}} \cancel{\rho g H^2} \left(\frac{1}{\cancel{\sqrt{2}}}\right)\left(\frac{\cancel{\sqrt{2}}}{4} H\right)$$

$$= \frac{5}{8} \cancel{\rho g H^2} L_{oD}$$

$$\frac{5}{48} H + \frac{3\sqrt{2}}{8} \left(\frac{1}{4} H\right) = \frac{5}{8} L_{oD}$$

$$\frac{5}{48} H + \frac{3\sqrt{2}}{32} H = \frac{5}{8} L_{oD}$$

$$L_{oD} = 0.378798701 H$$

4c) $V_{in} = V_{out}$

$$A_2V_2 = \frac{\dot{m}_e}{\rho} + \frac{2\dot{m}_a}{\rho_{air}}$$

$$\frac{H}{100} \times \int (V_2) - \frac{\dot{m}_e}{\rho} = \frac{2\dot{m}_a}{\rho_{air}}$$

$$2\dot{m}_a = \rho_{air}\left(\frac{HV_2}{100} - \frac{\dot{m}_e}{\rho}\right)$$

$$\dot{m}_a = \frac{\rho_{air}}{2}\left(\sqrt{\frac{2gH^3}{100^2}} - \frac{\dot{m}_e}{\rho}\right)$$