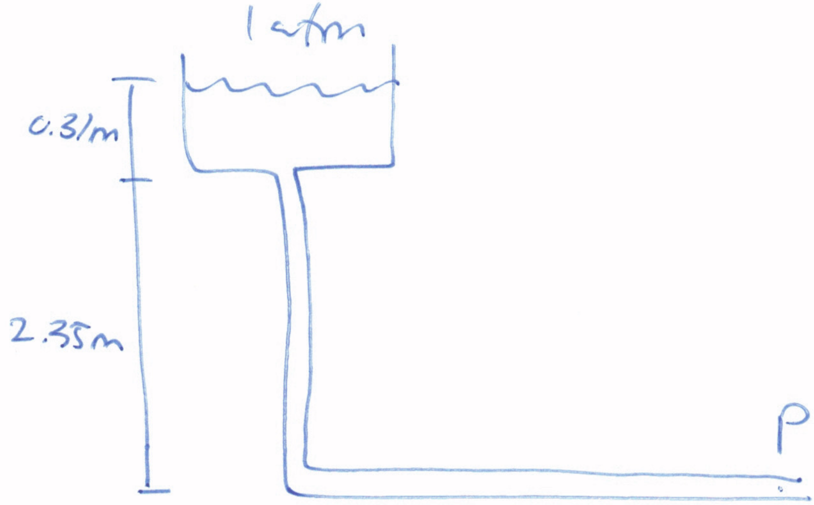
SOLUTION

$\boxed{\text{CM3110}}$ Exam 1

Spring 2021

1.



$$P_{bot} = P_{top} + \rho g h$$

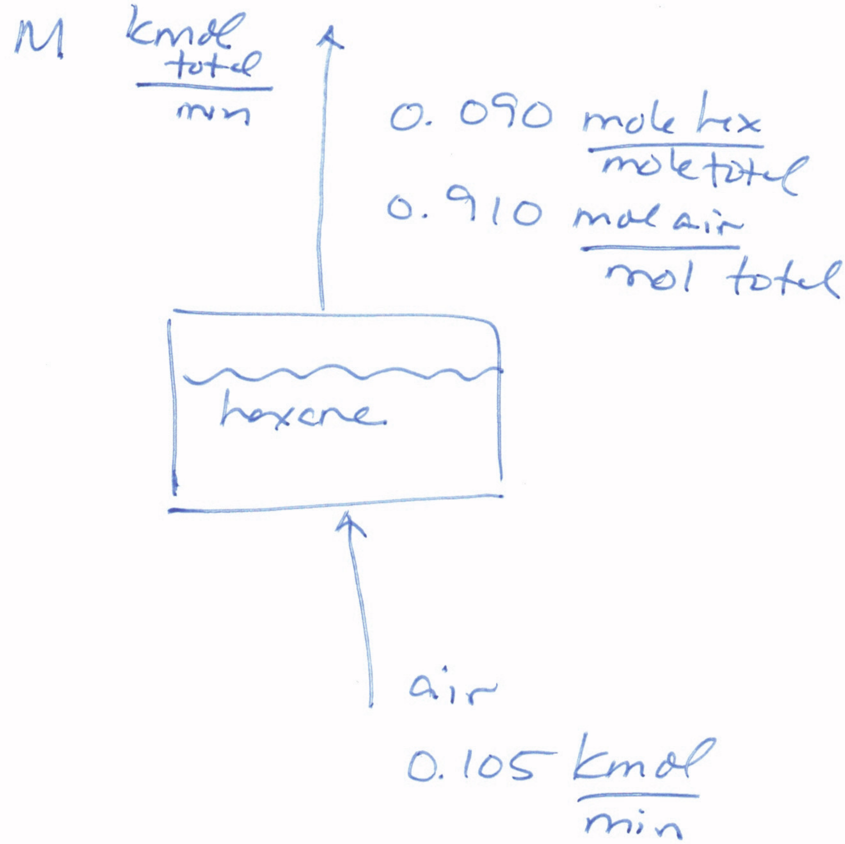
$$= 1\,atm + \left(997.08 \frac{\cancel{kg}}{\cancel{m^3}}\right)\left(9.8066 \frac{\cancel{m}}{\cancel{s^2}}\right)\left(2.66\,\cancel{m}\right) \times \frac{\cancel{N}\,\cancel{s^2}}{\cancel{kg}\,\cancel{m}} \frac{Pa\,\cancel{m^2}}{\cancel{N}}$$

$$= 1.01325 \times 10^5 + 2.600938 \times 10^4$$

$$= 1.2733 \times 10^5\ Pa$$

$$= \boxed{1.3 \times 10^5\ Pa}$$

2)



MOLE BALANCE AIR

$$0.105 \frac{\text{kmol}}{\text{min}} = M\left(0.910 \frac{\text{kmol air}}{\text{kmol total}}\right)$$

$$\boxed{M = 0.115 3846 \frac{\text{kmol}}{\text{min}}}$$

QUANTITY OF HEXANE

$$0.090 \frac{\text{kmole hex}}{\cancel{\text{kmole}}}\left(0.1153846 \frac{\cancel{\text{kmol}}}{\text{min}}\right)$$

$$= 0.0103846 \frac{\text{kmol hex}}{\text{min}}$$

3

How long to vaporize 8.0 m3 hexane?

$$\rho_{HEXANE} = 0.659 \frac{g}{cm^3}$$

$$(8.0\ \cancel{m^3})\left(659 \frac{\cancel{kg}}{\cancel{m^3}}\right)\left(\frac{\cancel{kmol}\ hx}{86.17\ \cancel{kg}}\right) \times$$

$$\times \left(\frac{min}{0.0103846\ \cancel{kmol}\ hx}\right)$$

$$= 5892\ min$$

$$= \boxed{5900\ min}$$

3) a) $\frac{\partial}{\partial x}(3x^4 + 2x) = 12x^3 + 2$

b) $\frac{\partial}{\partial z}\left(\frac{4xz}{y}\right) = \frac{4x}{y}$

c) $\begin{pmatrix} 1 & 0 & 2x \end{pmatrix}\begin{pmatrix} 3x \\ 1 \\ 1 \end{pmatrix} = 3x + 0 + 2x$

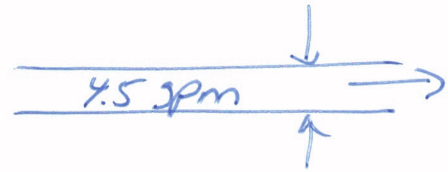
$= \boxed{5x}$

d $\begin{pmatrix} 1 & 0 & 2x \end{pmatrix}\begin{pmatrix} 1 & 0 & x \\ 1 & 7 & 3x \\ x & 0 & 1 \end{pmatrix}$

$= \begin{pmatrix} 1+2x^2 & 0 & 3x \end{pmatrix}$

//

4) a)



$\langle V \rangle = ?$

$ID = 1.153 \times 10^{-2}\ m$

$$\langle V \rangle = \frac{Q}{\pi R^2} = \frac{4Q}{\pi D^2}$$

$$\langle V \rangle = (4.5\ \cancel{gpm}) \frac{m^3/s}{15{,}850.32\ \cancel{gpm}} \left(\frac{4}{\pi}\right)\left(\frac{1}{1.153 \times 10^{-2}\ m}\right)^2$$

$$= 2.719105\ m/s$$

$$= \boxed{2.7\ m/s}$$

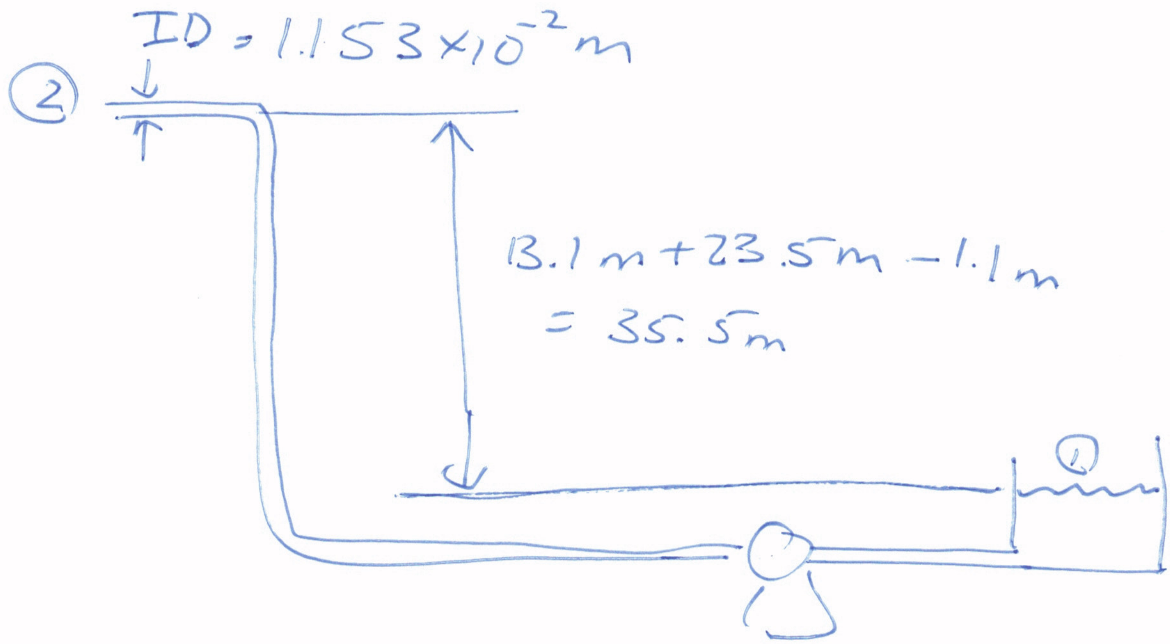
b) calc $W_{s,on}$

Mechanical Energy balance

Point 1: the surface of tank
Point 2: exit of pipe

$$\underbrace{\cancel{\frac{P_2 - P_1}{\rho}}}_{0} + \frac{V_2^2 - \cancel{V_1^2}}{\underbrace{2\alpha}_{=1\ (turbulent)}} + g(z_2 - z_1) + \underbrace{\cancel{F}}_{\approx 0} = \frac{W_{s,on}}{\dot{m}}$$

6



$P_1 = P_2 = 1\,atm$

$V_1 = 0$

V_2 = see part a)

$z_1 = 0$

$z_2 = 35.5\,m$

$F_{21} = 0$ (assumed)

$$\dot{m} = 4.5\,\cancel{gpm}\;\frac{\cancel{m^3}/s}{15{,}850.32\,\cancel{gpm}}\;\frac{997.08\,kg}{\cancel{m^3}}$$

$$\boxed{\dot{m} = 0.2830769\,\frac{kg}{s}}$$

$$\frac{V_2^2}{2} + g(35.5\,m) = \frac{W_{s,on}}{\dot{m}}$$

$$W_{s,on} = \left(0.2830769\,\frac{kg}{s}\right)\left[\overbrace{\left(\frac{2.719105\,m}{s}\right)^2\left(\frac{1}{2}\right)}^{3.696766} + \underbrace{\left(9.8066\,\frac{m}{s^2}\right)(35.5\,m)}_{348.134}\right]$$

$$= 99.595\,\frac{\cancel{kg}\,\cancel{m^2}}{\cancel{s^3}}\;\frac{\cancel{N}\,\cancel{s^2}}{\cancel{kg}\,\cancel{m}}\;\frac{\cancel{J}}{\cancel{Nm}}\;\frac{W\,\cancel{s}}{\cancel{J}}$$

$$= 99.595\,W$$

$$= \boxed{1.0 \times 10^2\,W} \quad \boxed{100\,W}$$

2 sig figs

5)

$$Q = \int_{-W}^{0}\int_{0}^{H} U_x(y)\, dy\, dz$$

$$U_x = \underbrace{\left(\frac{P_L - P_0}{2\mu L}\right)}_{\equiv \psi_0} (y^2 - Hy) + \frac{V}{H} y$$

$$= \psi_0 (y^2 - Hy) + \frac{V}{H} y$$

$$Q = \int_{-W}^{0}\int_{0}^{H} \left(\psi_0 (y^2 - Hy) + \frac{V}{H} y\right) dy\, dz$$

nothing is a function of z $\Rightarrow$ $\int_{-W}^{0} dz = z\Big|_{-W}^{0}$

$= 0 - (-W)$

$= W$

$$\frac{Q}{W} = \int_{0}^{H} \left(\psi_0 (y^2 - Hy) + \frac{V}{H} y\right) dy$$

$$\frac{Q}{W} = \left(\psi_o \frac{y^3}{3} - H\psi_o \frac{y^2}{2} + \frac{V}{H}\frac{y^2}{2} \right) \Big|_0^H$$

$$= \psi_o \frac{H^3}{3} - \psi_o \frac{H^3}{2} + \frac{V}{\cancel{H}}\frac{H^2}{2}$$

$$= \psi_o H^3 \left(\frac{1}{3} - \frac{1}{2} \right) + \frac{VH}{2}$$

$$\frac{Q}{W} = \psi_o H^3 \left(-\frac{1}{6} \right) + \frac{VH}{2}$$

$$Q = \frac{VHW}{2} - \frac{H^3 (P_L - P_0) W}{2\mu L\ (6)}$$

$$\boxed{Q = \frac{VHW}{2} - \frac{H^3 (P_L - P_0) W}{12 \mu L}}$$

check units m^3/s ?

2nd term: $m^3 \frac{\cancel{N}}{\cancel{m^2}} \frac{\cancel{m}\, \cancel{s}}{\cancel{kg}\, \cancel{m}} \frac{\cancel{kg}\, \cancel{m}}{\cancel{N}\, s^{\cancel{2}}} \cancel{m}$

$$= \frac{m^3}{s} \checkmark$$