Group 4 Homework 2.3

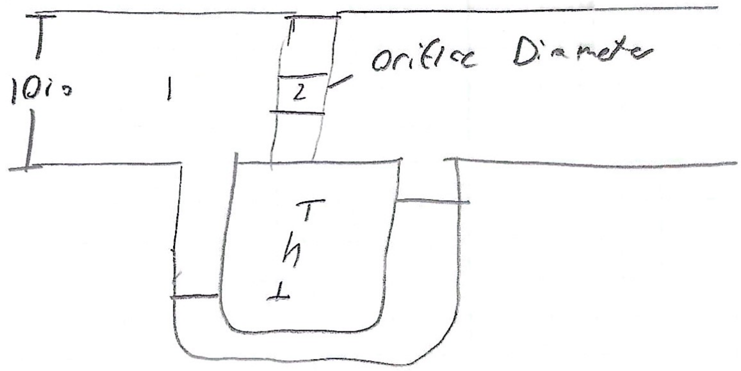
Chapter 15's problems were on different methods of measuring flow. They key information here is to mark what you know and then use the specific equation for the type of measurement device. Then it is important to do the work in excel or a similar program so that iterations can be completed. Doing these by hand would be a nightmare. Chapter 16's problems focused on reaction forces and forces caused by the movement of a fluid. The most important piece here was similarly to statics, free body diagrams. Once a correct free body diagram is drawn the problems become much easier to understand as well as solve.

15-4) $D_{pipe} = 10\,in$

$Q = 25\,gpm = 0.0557\,ft^3/s$

$S_g = 0.83$

$\nu = 2.5 \times 10^{-6}\ lb/ft^2$



$d_1 = 1.0\,in$

$d_2 = 7.0\,in$

$$Q = A_1 \cdot C \cdot \sqrt{\frac{2gh\left(\frac{\gamma_m}{\gamma_w} - 1\right)}{\left(\frac{A_1}{A_2}\right)^2 - 1}}$$

$$C = \frac{Q}{A_1 \sqrt{\frac{2gh\left(\frac{\gamma_m}{\gamma_w} - 1\right)}{\left(\frac{A_1}{A_2}\right)^2 - 1}}}$$

$$C = \frac{(0.0557\,ft^3/s)}{\pi\left(\frac{10/2}{12}\right)^2 \cdot \sqrt{\frac{2(32.2\,ft/s^2)\left(\frac{62.2\,lb/ft^3}{0.83(62.2\,lb/ft^3)} - 1\right)}{\left(\frac{\pi\left(\frac{10/2}{12}\right)^2}{\pi\left(\frac{1/2}{12}\right)^2}\right)^2 - 1}}}$$

$$C = \frac{0.0557\,ft^3/s}{0.545\,ft^2 \sqrt{\frac{13.19}{\left(\frac{0.545}{\pi\left(\frac{\frac{1}{2}}{12}\right)^2}\right)^2 - 1}}}$$

$C = 2.812$ for 1 in diameter

$C = 0.02$ for 7 in diameter

$$h = \frac{\left(\frac{Q}{A_1 \cdot C}\right)^2 \left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]}{2g\left(\frac{\gamma_m}{\gamma_w} - 1\right)}$$

h for 1 in = 0.0924 ft

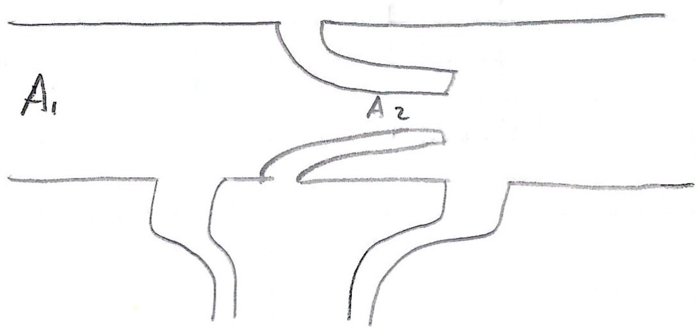
h for 7 in = 2.937 ft

15-9)

5in Type k copper tube

linseed oil @ 77°F

$Q = 1000 gpm = 2.676 ft^3/s$



h = 8in

$A_1 = 18.1107 \; in^2 = 0.1258 \; ft^2$

$$A_2 = \frac{A_1}{\sqrt{\dfrac{2gh\left(\frac{\gamma_m}{\gamma_w} - 1\right)}{\left(\frac{Q}{A_1 \cdot C}\right)^2} + 1}} =$$

$\gamma_m = 844.9 \; lb/ft^3$

$\gamma_w = 58.0 \; lb/ft^3$

From excel iterating & chart

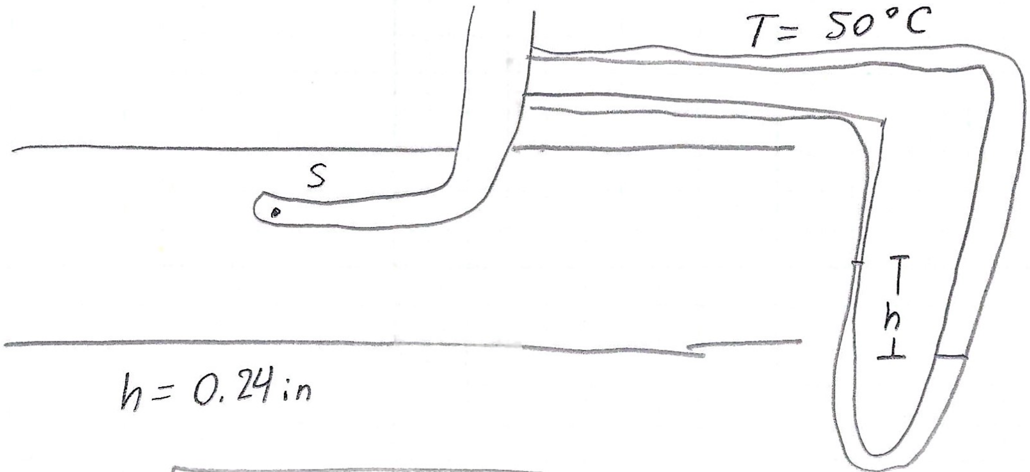
$C: 0.95$ & $A_2 = 0.0785 \; ft^2$

$$h = \frac{\left(\frac{Q}{A_1 C}\right)^2 \left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]}{2g\left(\frac{\gamma_m}{\gamma_w} - 1\right)} = 0.61756 = 7.4 \text{in}$$ less than 8in

A1	Q	gamma mercury	gamma linseed	g	D
0.1258	2.227	844.9	58	32.2	0.40021686

C	A2	d	Beta	V2	Re	C calculated	h calculated
0.580	0.100	0.357	0.892	22.246	20682.995	0.955	0.618
0.590	0.099	0.356	0.889	22.388	20748.642	0.955	0.618
0.600	0.099	0.355	0.886	22.531	20814.777	0.955	0.618
0.610	0.098	0.354	0.884	22.675	20881.384	0.955	0.618
0.620	0.098	0.352	0.881	22.821	20948.444	0.955	0.618
0.630	0.097	0.351	0.878	22.968	21015.942	0.955	0.618
0.640	0.096	0.350	0.875	23.117	21083.860	0.955	0.618
0.650	0.096	0.349	0.872	23.267	21152.182	0.956	0.618
0.955	0.078	0.316	0.790	28.381	23361.454	0.960	0.618

15-15)



$h = 0.24\,in$

$$V_1 = \sqrt{2gh\,(\gamma_g - \gamma)/\gamma}$$

$\gamma_g = 9.69\ kN/m^3$ @ $50°C$ $= 9690\ N/m^3$

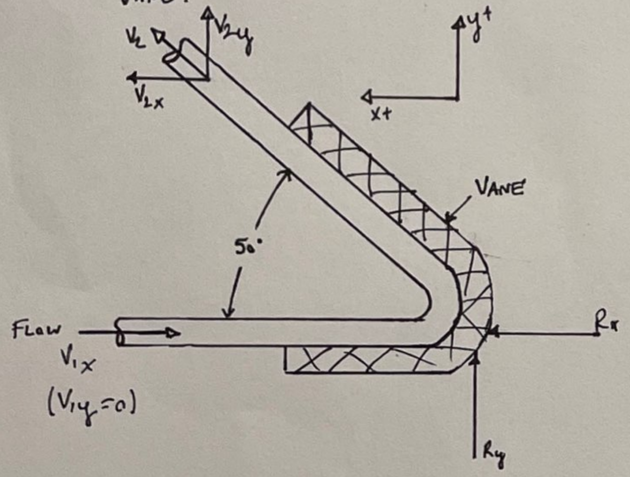
$\gamma_{Air} = 10.71\ N/m^3$ @ $50°C$

$h = 0.24\,in = 0.006096\,m$

$$V_1 = \sqrt{2 \cdot 9.81\,m/s^2 \cdot 0.0060906\,m\,(9690\,N/m^3 - 10.71\,N/m^3)/10.71}$$

$V_1 = 10.39\ m/s = 34.09\ ft/s$

16.(6) THE FIGURE SHOWS A FREE STREAM OF WATER AT 180°F BEING DEFLECTED BY A STATIONARY VANE THROUGH A 130° ANGLE. THE ENTERING STREAM HAS A VELOCITY OF 22 $\frac{ft}{s}$. THE CROSS-SECTIONAL AREA OF THE STREAM IS CONSTANT AT 2.95 in^2 THROUGHOUT THE SYSTEM. COMPUTE THE FORCES IN THE HORIZONTAL AND VERTICAL DIRECTIONS EXERTED ON THE WATER BY THE VANE.



GIVEN: $V_{1x} = 22 \frac{ft}{s}$

$A_s = 2.95 in^2 \cdot \frac{1 ft^2}{144 in^2} = 0.020486\ ft^2$

* STATIONARY VANE *

$\rho_w = 1.88 \frac{slugs}{ft^3}$

$\theta = 130°$, $180° - 130° = 50°$

SOLUTION:

$$Q = A_s \cdot V_1 = (0.020486\ ft^2)(22 \tfrac{ft}{s})$$
$$Q = 0.450692 \tfrac{ft^3}{s}$$

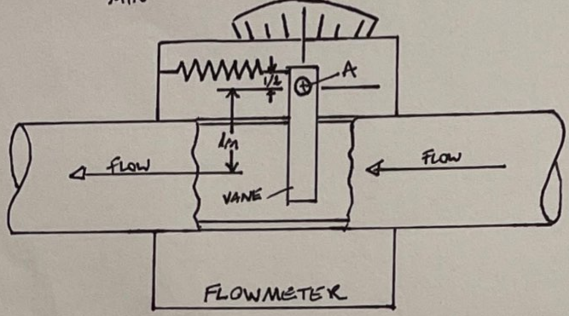
$$V_{2x} = V_1 \cos(50°) = (22 \tfrac{ft}{s})\cos(50°) = 14.1413 \tfrac{ft}{s}$$

$$V_{2y} = V_1 \sin(50°) = (22 \tfrac{ft}{s})\sin(50°) = 16.853 \tfrac{ft}{s}$$

$$\Sigma R_x = \rho_w \cdot Q \cdot (V_{2x} - V_{1x}) = 0$$
$$= (1.88 \tfrac{slugs}{ft^3})(0.450692 \tfrac{ft^3}{s})(14.1413 \tfrac{ft}{s} - 22 \tfrac{ft}{s}) = 0$$
$$= -6.659\ lb$$
$$\underline{\underline{R_x = 6.659\ lb \leftarrow +}}$$

$$\Sigma R_y = \rho_w \cdot Q \cdot (V_{2y} - V_{1y}) = 0$$
$$= (1.88 \tfrac{slugs}{ft^3})(0.450692 \tfrac{ft^3}{s})(16.853 \tfrac{ft}{s} - 0 \tfrac{ft}{s})$$
$$\underline{\underline{R_y = 14.2796\ lb \uparrow_+}}$$

16.11) THE FIGURE REPRESENTS A TYPE OF FLOWMETER IN WHICH THE FLAT VANE IS ROTATED ON A PIVOT AS IT DEFLECTS THE FLUID STREAM. THE FLUID FORCE IS COUNTERBALANCED BY A SPRING CALCULATE SPRING FORCE REQUIRED TO HOLD THE VANE IN A VERTICAL POSITION WHEN WATER AT 100 $\frac{GAL}{MIN}$ FLOWS FROM THE 1 in SCH. 40 PIPE TO WHICH THE METER IS ATTACHED.



GIVEN: $Q = 100 \frac{GAL}{MIN} \cdot \frac{1\ FT^3/s}{449 \frac{GAL}{MIN}} = 0.222717 \frac{FT^3}{s}$

$1\text{ in SCH. }40 \longrightarrow A = 0.006\ FT^2$

$D = 0.0874\ FT$

$\rho_w = 1.94 \frac{SLUGS}{FT^3} \cdot \frac{32.174\ lb}{1\ SLUG} = 62.4 \frac{lb}{FT^3}$

SOLUTION: $V = \frac{Q}{A} = \frac{0.222717 \frac{FT^3}{s}}{0.006\ FT^2} = 37.1195 \frac{FT}{s}$

$F_w = \rho_w \cdot Q \cdot V = \left(\overset{62.4 \frac{lb}{FT^3}}{\cancel{1.94 \frac{SLUGS}{FT^3}}}\right)\left(0.222717 \frac{FT^3}{s}\right)\left(37.1195 \frac{FT}{s}\right)$

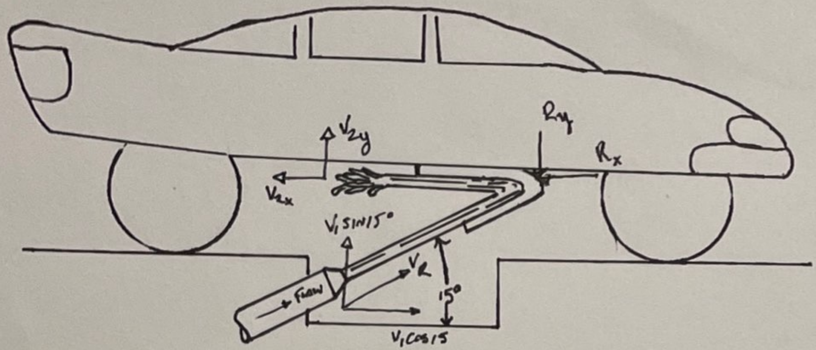
$F_w = 515.87\ lb$

$\Sigma M_A = F_w(1\text{ in}) - F_s(0.5\text{ in}) = 0$

$F_s = \frac{F_w(1\text{ in})}{0.5\text{ in}} = \frac{515.87\ lb(1\ \cancel{in})}{0.5\ \cancel{in}}$

$F_s = 1031.74\ lb$

16.20) A VEHICLE IS TO BE PROPELLED BY A JET OF WATER IMPINGING ON A VANE AS SHOWN. THE JET HAS A VELOCITY OF 30 $\frac{m}{s}$ AND ISSUES FROM A NOZZLE WITH A DIAMETER OF 200 mm. CALCULATE THE FORCE OF THE VEHICLE (a) IF IT IS STATIONARY AND (b) IF MOVING AT 12 $\frac{m}{s}$.



GIVEN: $\rho_w = 1.88 \frac{slug}{ft^3} = 1000 \frac{kg}{m^3}$

$V_{J_1} = 30 \frac{m}{s}$

$D = 200mm = 0.2m$

$V_c = 12 \frac{m}{s}$

SOLUTION: $A = \frac{\pi}{4} D^2 = \frac{\pi}{4}(0.2m)^2 = 0.031416 \, m^2$

$Q = A \cdot V_1 = (0.031416 \, m^2)(30 \frac{m}{s}) = 0.94248 \frac{m^3}{s}$

$V_2 = V_1$

(a) (F_x) $\sum R_x = \rho_w \cdot Q (V_2 + V_1 \cos 15°)$ $\quad -(-) \rightarrow +$

$= (1000 \frac{kg}{m^3})(0.94248 \frac{m^3}{s})(30 \frac{m}{s} + 30 \frac{m}{s} \cos 15°)$ $\quad \frac{kg \, m}{s^2} = N$ *

$= 55585.4 \, N$

(F_y) $\sum R_y = \rho_w \cdot Q (V_2 + V_1 \sin 15°)$

$= (1000 \frac{kg}{m^3})(0.94248 \frac{m^3}{s})(0 \frac{m}{s} + 30 \frac{m}{s} \sin 15°)$

$= 7317.95 \, N$

(b) SOLVE FOR NEW VELOCITIES, $V_{x_1} = V_1 \cos 15° - V_c = 30 \frac{m}{s} \cos 15° - 12 \frac{m}{s}$

$V_{x_1} = 16.978 \frac{m}{s}$

$V_{y_1} = V_1 \sin 15 - 0 = 30 \sin 15° = 7.765 \frac{m}{s}$

$V_{y_1} = 7.765 \frac{m}{s}$

$M = \rho \cdot A \cdot V_R$

$= (1000 \frac{kg}{m^3})(0.031416 \, m^2)(18.669 \frac{m}{s})$

$= 586.505 \frac{kg}{s}$

$V_R = \sqrt{(V_{x_1})^2 + (V_{y_1})^2}$

$= \sqrt{(16.978 \frac{m}{s})^2 + (7.765 \frac{m}{s})^2} = 18.669 \frac{m}{s}$

$\theta = \tan^{-1}\left(\frac{7.765}{16.978}\right) = 24.577°$

$\beta = \theta - 15° = 24.577° - 15°$

$= 9.577°$

$\sum F_x = 0$, $R_x = M(V_{EFF_x} + V_{x_1})$

$= (586.505 \frac{kg}{s})(18.409 \frac{m}{s} + 16.978 \frac{m}{s})$

$= 20754.7 \, N$

$V_{EFF_x} = V_R \cos \beta$

$= 18.669 \frac{m}{s} \cos 9.577°$

$= 18.409 \frac{m}{s}$

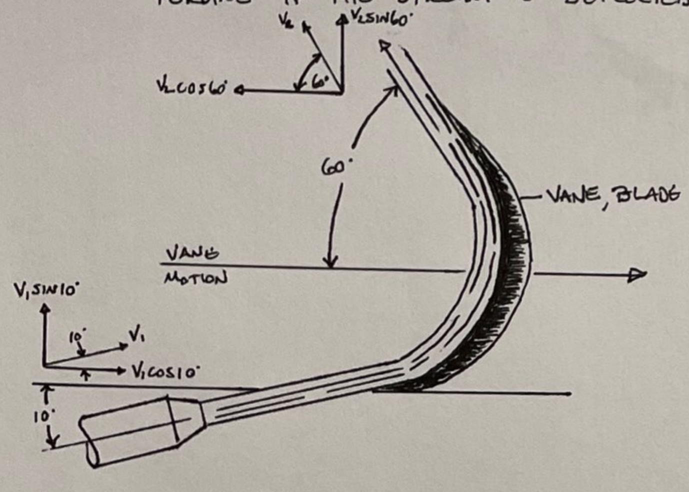
$\sum F_y = 0$, $R_y = M(V_{EFF_y} + V_{y_1})$

$= (586.505 \frac{kg}{s})(0 + 7.765 \frac{m}{s})$

$= 4554.21 \, N$

$V_{EFF_y} = 0$

16.29) TURBINE IN WHICH THE INCOMING STREAM OF WATER AT 15°C HAS A DIAMETER OF 7.5mm AND IS MOVING WITH A VELOCITY OF 25 $\frac{m}{s}$. COMPUTE THE FORCE ON ONE BLADE OF THE TURBINE IF THE STREAM IS DEFLECTED THROUGH THE ANGLE SHOWN AND THE BLADE IS STATIONARY.

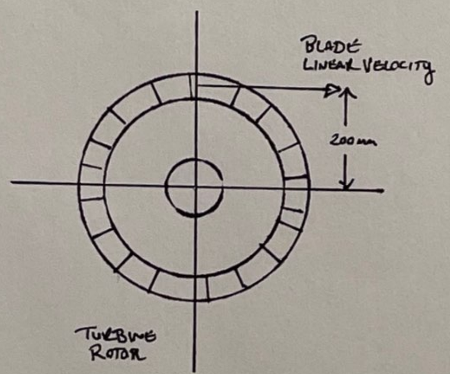


GIVEN: $D = 7.5mm = 0.0075m$

$V_1 = 25\frac{m}{s} = V_2$

BLADE IS STATIONARY

$\rho_w = 1000\frac{kg}{m^3}$



SOLUTION: $A = \frac{\pi}{4}D^2 = \frac{\pi}{4}(0.0075m)^2 = 0.00004418$
$= 4.418\times10^{-5}m^2$

$Q = A\cdot V = (4.418\times10^{-5}m^2)(25\frac{m}{s}) = 0.0011045$
$= 1.1045\times10^{-3}\frac{m^3}{s}$

$\Sigma F_x = 0,\ R_x = \rho_w\cdot Q\cdot(V_1\cos 10° - (-V_2\cos 60°))$
$= (1000\frac{kg}{m^3})(1.1045\times10^{-3}\frac{m^3}{s})(25\frac{m}{s}\cos 10° + 25\frac{m}{s}\cos 60°)$
$= 40.9993 = 41\ N$

$\underline{R_x = 41N}$

$\Sigma F_y = 0,\ R_y = \rho_w\cdot Q\cdot(V_1\sin 10° - V_2\sin 60°)$
$= (1000\frac{kg}{m^3})(1.645\times10^{-3}\frac{m^3}{s})(25\frac{m}{s}\sin 10° - 25\frac{m}{s}\sin 60°)$

$\underline{R_y = -19.1183\ N}$