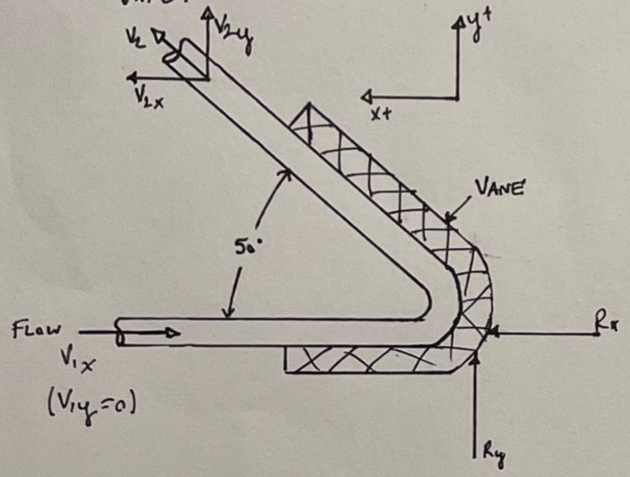
16.(6) THE FIGURE SHOWS A FREE STREAM OF WATER AT 180°F BEING DEFLECTED BY A STATIONARY VANE THROUGH A 130° ANGLE. THE ENTERING STREAM HAS A VELOCITY OF 22 $\frac{ft}{s}$. THE CROSS-SECTIONAL AREA OF THE STREAM IS CONSTANT AT 2.95 in^2 THROUGHOUT THE SYSTEM. COMPUTE THE FORCES IN THE HORIZONTAL AND VERTICAL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

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

$\theta = 130°, \quad 180° - 130° = 50°$

SOLUTION:

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

$Q = 0.450692 \frac{ft^3}{s}$

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

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

$\Sigma R_x = \rho_w \cdot Q \cdot (V_{2x} - V_{1x}) = 0$

$= (1.88 \frac{slugs}{ft^3})(0.450692 \frac{ft^3}{s})(14.1413 \frac{ft}{s} - 22 \frac{ft}{s}) = 0$

$= -6.659\ lb$

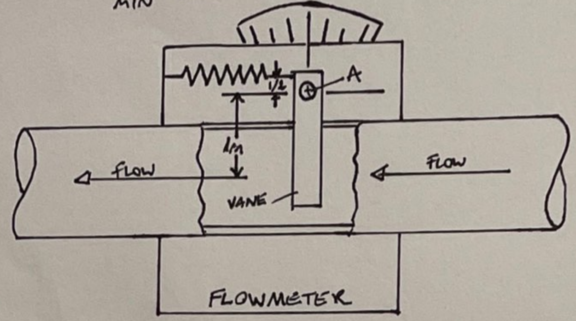
$R_x = 6.659\ lb \leftarrow +$

$\Sigma R_y = \rho_w \cdot Q \cdot (V_{2y} - V_{1y}) = 0$

$= (1.88 \frac{slugs}{ft^3})(0.450692 \frac{ft^3}{s})(16.853 \frac{ft}{s} - 0 \frac{ft}{s})$

$R_y = 14.2796\ lb \uparrow +$

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 in SCH. 40 $\rightarrow$ $A = 0.006\ FT^2$

$D = 0.0874\ FT$

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

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

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

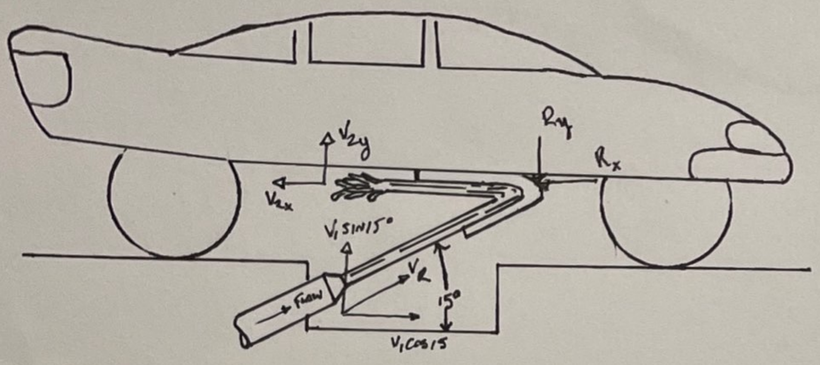
$F_w = 515.87\ lb$

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

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

$F_s = 1031.74\ lb$

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

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

$D = 200\,mm = 0.2\,m$

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

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

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

$= 55585.4\ N$

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

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

$= 7317.95\ N$

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

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

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

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

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

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

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

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

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

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

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

$= 9.577°$

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

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

$= 20754.7\ N$

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

$= 18.669 \frac{m}{s} \cos 9.577°$

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

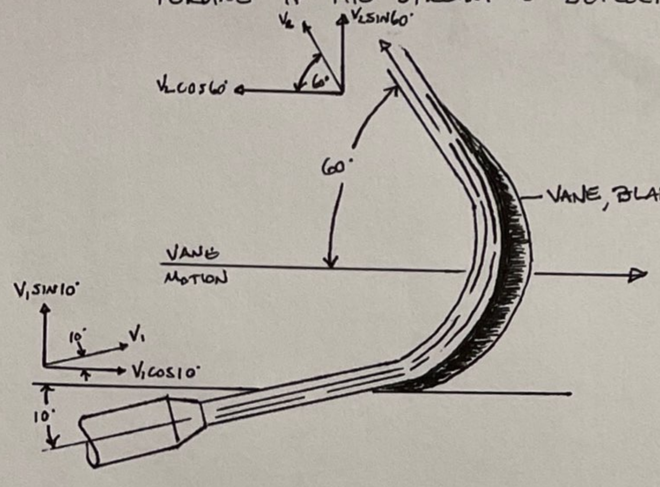
$\Sigma F_y = 0,\ R_y = M(V_{EFF_y} + V_{y_1})$

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

$= 4554.21\ N$

$V_{EFF_y} = 0$

16.29) TURBINE IN WHICH THE INCOMING STREAM OF WATER AT 15 °C HAS A DIAMETER OF 7.5 mm AND IS MOVING WITH A VELOCITY OF 25 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: $D = 7.5\,mm = 0.0075\,m$

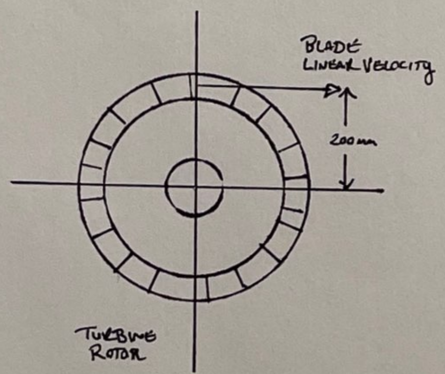
$V_1 = 25\,\frac{m}{s} = V_2$

BLADE IS STATIONARY

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

SOLUTION: $A = \frac{\pi}{4} D^2 = \frac{\pi}{4}(0.0075\,m)^2 = 0.00004418$
$= 4.418 \times 10^{-5}\,m^2$

$Q = A \cdot V = (4.418 \times 10^{-5}\,m^2)(25\,\frac{m}{s}) = 0.0011045$
$= 1.1045 \times 10^{-3}\,\frac{m^3}{s}$



$\Sigma F_x = 0,\ R_x = \rho_w \cdot Q \cdot (V_1 \cos 10° - (-V_2 \cos 60°))$

$= (1000\,\frac{kg}{m^3})(1.1045 \times 10^{-3}\,\frac{m^3}{s})(25\,\frac{m}{s} \cos 10° + 25\,\frac{m}{s} \cos 60°)$

$= 40.9993 = 41\,N$

$\underline{R_x = 41\,N}$

$\Sigma F_y = 0,\ R_y = \rho_w \cdot Q \cdot (V_1 \sin 10° - V_2 \sin 60°)$

$= (1000\,\frac{kg}{m^3})(1.645 \times 10^{-3}\,\frac{m^3}{s})(25\,\frac{m}{s} \sin 10° - 25\,\frac{m}{s} \sin 60°)$

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