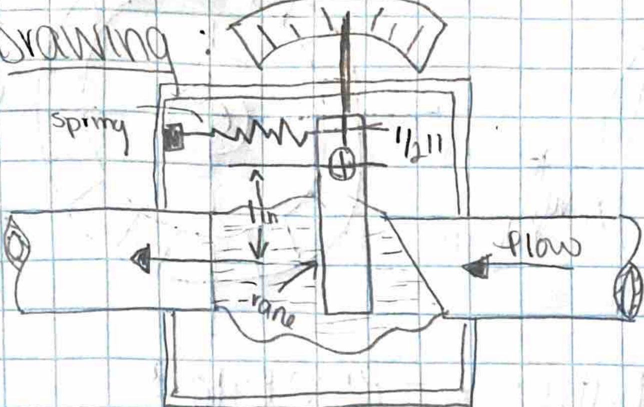
Amber Samm
MET 330
Homework #7

16-11 Purpose: calculate the spring force required to hold the vane in a vertical position.

Drawing:



Design considerations:
① incompressible fluid
② isothermal
③ steady state

Data: $Q = 100\,gal/min = 0.2228\,ft^3/s$
sche. 40: $D = 1.049\,in = 0.0874\,ft$
$A_p = 0.006\,ft^2$
$\rho_{water} = 1.94\,slugs/ft^3$

Procedure

Calculate velocity: $v = \frac{Q}{A} = \frac{0.2228\,ft^3/s}{0.006\,ft^2} = 37.133\,ft/s$

Calculate system mass flow rate: $\dot{m} = \rho Q$
$(1.94\,slugs/ft^3)(0.2228\,ft^3/s) = 0.432\,slugs/s$

$F_{fluid} = \dot{m} \cdot \Delta v_x = (0.432\,slug/s) \cdot (37.13\,ft/s) = 16.05\,lb$

$\Sigma M = 0$ (about pivot point)
$(F_{fluid} - r_{fluid}) - (F_s \cdot r_s) = 0$
$(16.05\,lb - 1\,in) - (F_s \cdot 0.5\,in) = 0$

$F_{spring} = \frac{16.05\,lb \cdot 1.0\,in}{0.5\,in} =$
$F_{spring} = \boxed{32.1\,lb}$

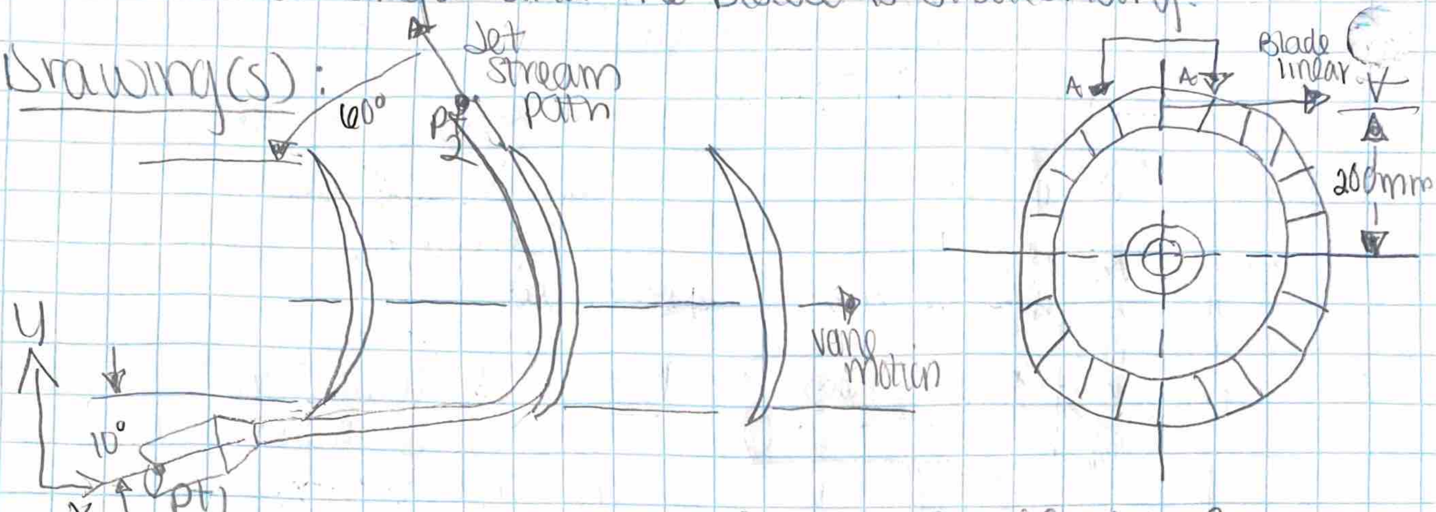
Summary: The spring force required to hold the vane in a vertical position is 32.1 lb.

Materials: water

Analysis: If the spring were to move further away from the pivot point, the lever arm would increase in efficiency and less force would be required to keep the vane vertical. The inverse is also true. The closer the spring is to the pivot point the less mechanical advantage it has and more force would be required.

16-29 Purpose: compute the force on one blade of the turbine if the stream is deflected through 160° angle and the blade is stationary.

Drawing(s):



Data: $\rho = 1000\ kg/m^3$

$D_{jet} = 7.5mm = 0.0075m$

$v = 25 m/s$

Inlet $\theta = 10°$

Outlet $\theta = 160°$

$A_{jet} = \pi/4 D^2 = \pi/4 (0.0075m)^2 = 4.418 \times 10^{-5} m^2$

Design considerations:
1. Steady state
2. Incompressible fluid
3. Isothermal

Procedure: calculate jet area; calculate mass flow rate $\dot{m} = \rho A v$

$(1000 kg/m^3) \cdot (4.418 \times 10^{-5}) \cdot 25 m/s = 1.1045 kg/s$

Inlet:

$V_{1x} = V \cdot \cos(10) = 25 \cdot \cos(10) = 24.62 m/s$

$V_{1y} = V \cdot \sin(10) = 25 \cdot \sin(10) = 4.341 m/s$

Outlet:

$V_{2x} = -V \cdot \cos(160) = -25 \cdot \cos(160) = -12.5 m/s$

$-V \cdot \sin(160) = 25 \cdot \sin(160) = 25.65 m/s$

The force exerted on blade is equal to rate of change of momentum

$F_x = \dot{m} \cdot (V_{1x} - V_{2x}) = 1.1045 \cdot (24.62 - (-12.5)) = \boxed{41.0N}$

$F_y = \dot{m} \cdot (V_{1y} - V_{2y}) = 1.1045 \cdot (4.34 - 21.65) = \boxed{-19.12N}$

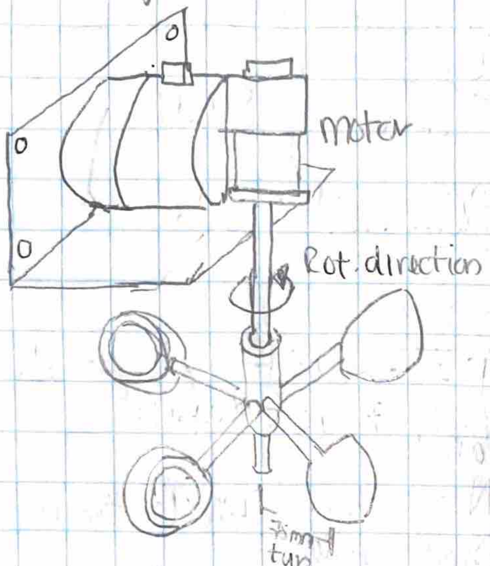
Summary: The force on one stationary blade would be 41.0N in the x and -19.12N in the y direction.

Materials: water.

17-11 Purpose: Calculate the torque that the motor must produce to maintain motion at 20 RPM when cups are: (a) air @ 30°C (b) gas at 20°C.

Materials: air + gasoline

Drawing:



Design considerations:
① incompressible
② isothermal
③ steady state

Data:
$R = 75mm = 0.075m$
$N = 20rpm$
$\omega = \frac{2\pi(20)}{60} \approx 2.094 rad/s$
$V = \omega \cdot R = 2.094 \times 0.075 = 0.1571 m/s$
$d_{cup} = 25mm = 0.025m$
$A = \frac{\pi d^2}{4} = \frac{\pi(0.025)^2}{4} = 4.909 \times 10^{-4} m^2$
$\rho_{air@30} = 1.164 kg/m^3$
$\rho_{gas@20} = 680 kg/m^3$

Procedure:
$C_D = 1.35$ (Table 17.1)
4 cups acting same distance from R:
$T = 4(F_D \times R) = 4(\frac{1}{2} C_D \cdot \rho \cdot V^2 \cdot A) R$
$= 2(C_D \cdot \rho \cdot V^2 \cdot A \cdot R) = 2 \times C_D \times \rho \cdot (0.1571)^2 \times (4.909 \times 10^{-4}) \times 0.075$
$T = C_D \cdot \rho \cdot (1.815 \times 10^{-6})$

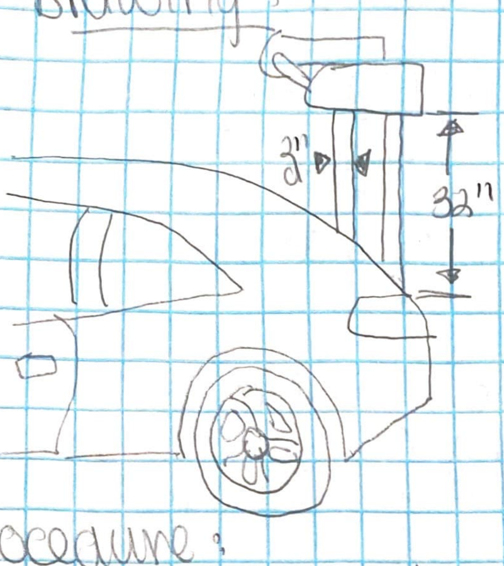
(a) in Air @ 30°C
$T = 1.35 \times 1.164 \times 1.815 \times 10^{-6} = \boxed{2.85 \times 10^{-6} N \cdot m}$

(b) gasoline @ 20°C
$T = 1.35 \times 680 \times 1.815 \times 10^{-6} = \boxed{1.667 \times 10^{-3} N \cdot m}$

Summary: The torque that the motor must produce to maintain 20rpm is $2.85 \times 10^{-6} N \cdot m$ in air at 30°C and $1.667 \times 10^{-3} N \cdot m$ in gasoline at 20°C.

17-14 Procedure: compute the drag force exerted on the car due to rods when car is travelling through still air.

Drawing:



Design considerations:

1. incompressible
2. isothermal
3. steady state

Materials: air

Data:

$T = -20°F$ $\rho_{air} = 2.80 \times 10^{-3}$ slugs/ft³

$\nu_{air} = 1.17 \times 10^{-4}$ ft²/s

$N = 2$ (rods) $L_{rod} = 32 in = 2.67 ft$

$D_{rod} = 0.1667 ft$

$V = 150 mph = 220 ft/s$

$A = 0.1667 ft \cdot 2.667 ft =$
$= 0.4445 ft^2$

Procedure:

calculate Reynolds number:

$Re = \frac{V \cdot D}{\nu} = \frac{220 ft/s \times 0.1667 ft}{1.17 \times 10^{-4} ft^2/s}$

$= 313,453 = 3.13 \times 10^5$

Determine C_D: 1.2 (Figure 17.16)

Compute Drag Force (F_D): $F_D = n \cdot (C_D \cdot \frac{1}{2} \rho V^2 \cdot A)$

$F_D = 2 \cdot (1.2 (\frac{1}{2}(2.80 \times 10^{-3} slugs/ft^3)(220 ft/s)^2 (0.4445 ft^2)$
$= 2 \cdot (36.143 lb) = \boxed{72.3 lb}$

Summary: The drag force exerted on the car due to rods when the car is travelling through still air is 72.3 lb.