MET 330

HOMEWORK 1.7

CHAPTER 16

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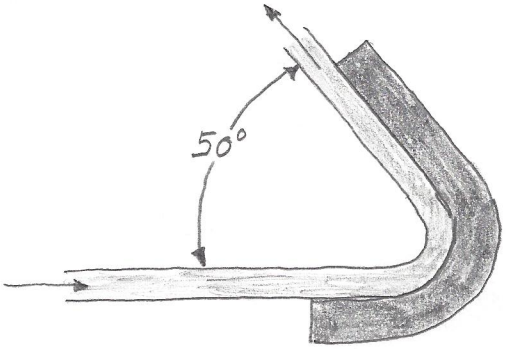
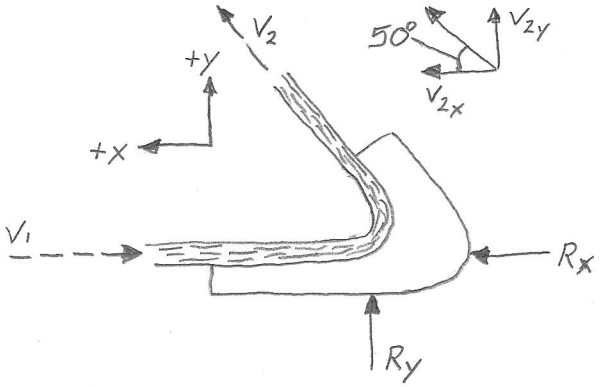
16-6) GIVEN: TEMPERATURE OF WATER = 180° F

DEFLECTION ANGLE BY STATIONARY VANE = 130°

VELOCITY OF STREAM = 22.0 ft/s

CROSS-SECTIONAL AREA OF STREAM = 2.95 in²





$$Q = Av = (2.95\ in^2)(22.0\ ft/s)\left(\frac{1\ ft^2}{144\ in^2}\right) = 0.451\ ft^3/s$$

$$R_x = \rho Q(v_{2x} - v_{1x}) = \rho Q[v_2 \cos 50° - (-v_1)]$$

$$R_x = \rho Q[v_2 \cos 50° + v_1]$$

$v_2 = v_1$

$$R_x = \rho Q v_1[\cos 50° + 1]$$

$$R_x = \left(\frac{1.88\ lb \cdot s^2}{ft^4}\right)\left(\frac{0.451\ ft^3}{s}\right)\left(\frac{22.0\ ft}{s}\right)(1.643) = 30.6\ lb$$

∴ FORCES IN THE HORIZONTAL DIRECTION = $R_x = 30.6\ lb$

$$R_y = \rho Q(v_{2y} - v_{1y})$$

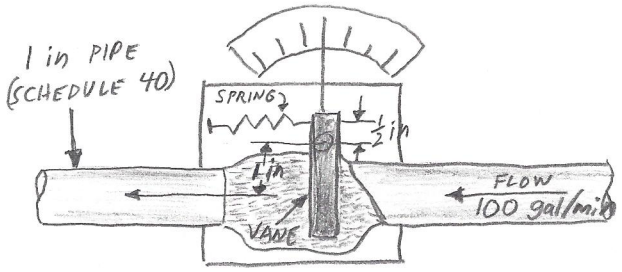
$$R_y = \rho Q[v_2 \sin 50° - 0]$$

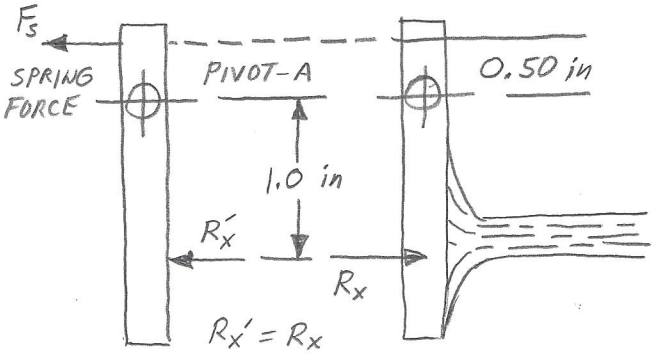
$$R_y = (1.88\ lb \cdot s^2)(0.451\ ft^3/s)(22\ ft/s \cdot \sin 50°) = 14.3\ lb$$

∴ FORCES IN THE VERTICAL DIRECTION = $R_y = 14.3\ lb$

16-11) GIVEN: FLOW RATE OF WATER = $Q = 100$ gal/min

PIPE = 1 in SCHEDULE 40





$$Q = (100 \text{ gal/min})\left(\frac{1 \text{ ft}^3/\text{s}}{449 \text{ gal/min}}\right) = 0.223 \text{ ft}^3/\text{s}$$

$$V_1 = \frac{Q}{A} = \frac{0.223 \text{ ft}^3/\text{s}}{0.0060 \text{ ft}^2} = 37.1 \text{ ft/s}$$

FROM APPENDIX F
TABLE F.1
FLOW AREA FOR 1 in SCHEDULE 40 PIPE
$= 0.0060 \text{ ft}^2$

R_x = FORCE EXERTED BY VANE ON WATER

$$R_x = \rho Q (V_{2x} - V_{1x})$$

$$R_x = \rho Q [0 - (-V_1)] = \rho Q V_1$$

$$R_x = \left(\frac{1.94 \text{ lb}\cdot\text{s}^2}{\text{ft}^4}\right)\left(\frac{0.223 \text{ ft}^3}{\text{s}}\right)\left(\frac{37.1 \text{ ft}}{\text{s}}\right) = 16.0 \text{ lb}$$

R_x' = FORCE EXERTED BY WATER ON VANE

$$\Sigma M_A = 0 = F_s (0.5 \text{ in}) - R_x' (1.0 \text{ in})$$

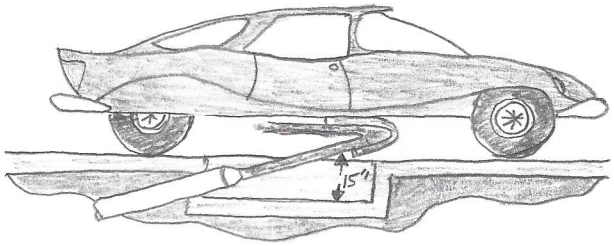
$$F_s = R_x'\left(\frac{1.0 \text{ in}}{0.5 \text{ in}}\right) = 2 R_x' = 2 (16.0 \text{ lb}) = 32.0 \text{ lb}$$

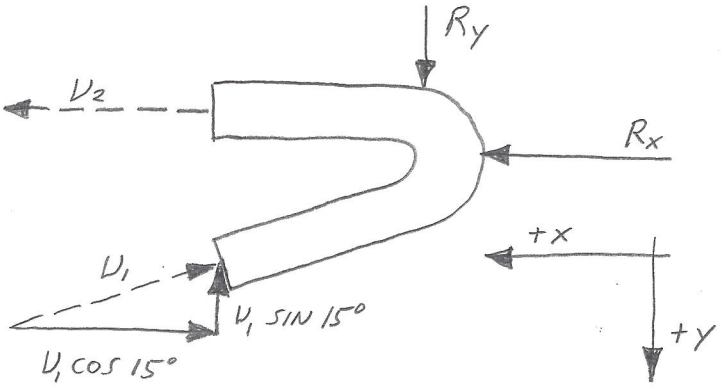
SPRING FORCE REQUIRED TO HOLD THE VANE IN A VERTICAL POSITION:

$F_s = 32.0$ lb

16-20) GIVEN: VELOCITY OF JET = $V = 30$ m/s

DIAMETER OF NOZZLE = 200 mm





$Q = AV = (3.142 \times 10^{-2}\ m^2)(30\ m/s) = 0.943\ m^3/s$

a) FORCE ON THE VEHICLE IF IT IS STATIONARY:

X-DIRECTION

$$R_x = \rho Q(V_{2x} - V_{1x}) = \rho Q(V_2 - (-V_1 \cos 15°))$$

$$R_x = \rho Q V(1 + \cos 15°) = 1.966\,\rho Q V$$

$$R_x = (1.966)\left(\frac{1000\ kg}{m^3}\right)\left(\frac{0.943\ m^3}{s}\right)\left(\frac{30\ m}{s}\right)$$

$R_x = 55.6 \times 10^3\ kg \cdot m/s^2 = 55.6\ kN$ = FORCE OF CAR ON WATER ←

FORCE ON CAR (X-DIRECTION) = $R_x = 55.6\ kN \rightarrow$

Y-DIRECTION

$$R_y = \rho Q(V_{2y} - V_{1y}) = \rho Q(0 - (-V_1 \sin 15°)) = \rho Q V \sin 15°$$

$$R_y = \left(\frac{1000\ kg}{m^3}\right)\left(\frac{0.943\ m^3}{s}\right)\left(\frac{30\ m}{s}\right)(0.259)$$

$R_y = 7.32 \times 10^3\ kg \cdot m/s^2 = 7.32\ kN$ = FORCE ON WATER ↓

FORCE ON CAR (Y-DIRECTION) = $R_y = 7.32\ kN \uparrow$

CONTINUED

16-20) CONTINUED:

b) FORCE ON THE VEHICLE IF IT IS MOVING AT 12 m/s:

INLET JET ACTS AT AN ANGLE TO THE X-Y DIRECTIONS

$V_{1x} = V_1 \cos(15°) = (30\ m/s)(0.966) = 28.98\ m/s$

$V_{1y} = V_1 \sin(15°) = (30\ m/s)(0.259) = 7.76\ m/s$

ONLY V_{1x} IS AFFECTED BY THE MOVING VANE.

$V_{el_x} = V_{1x} - 12\ m/s = 16.98\ m/s$

$V_{el_y} = V_{1y} = 7.76\ m/s$

$|V_{el_y}| = \sqrt{(16.98\ m/s)^2 + (7.76\ m/s)^2} = 18.67\ m/s$

TOTAL EFFECTIVE MASS FLOW RATE INTO THE VANE = M_e

$M_e = \rho Q = \rho A V_{el} = \left(\frac{1000\ kg}{m^3}\right)(3.142 \times 10^{-2}\ m^2)(18.67\ m/s) = 586.6\ kg/s$

VELOCITY V_{e_1} ACTS AT AN ANGLE α, WITH RESPECT TO THE HORIZONTAL

$\alpha = \tan^{-1}\left(\frac{7.76\ m/s}{16.98\ m/s}\right) = 24.58°$

β = THE DIFFERENCE BETWEEN α AND THE ANGLE OF THE VANE INLET

$\beta = 24.58° - 15° = 9.58°$

$V_{e_1(PAR)} = (V_{e_1}) \cos 9.58° = (18.67\ m/s)(0.986) = 18.41\ m/s$

$V_{e_2} = 18.41\ m/s$ TO THE LEFT

X-DIRECTION

$R_X = M_c(\Delta V_{ex}) = M_c(V_{e2x} - V_{e1x}) = (586.6\ kg/s)[18.41 - (-16.98)]\ m/s$

FORCE ON CAR MOVING AT 12 m/s (x-DIRECTION) = $R_x = 20.86\ kN$

Y-DIRECTION

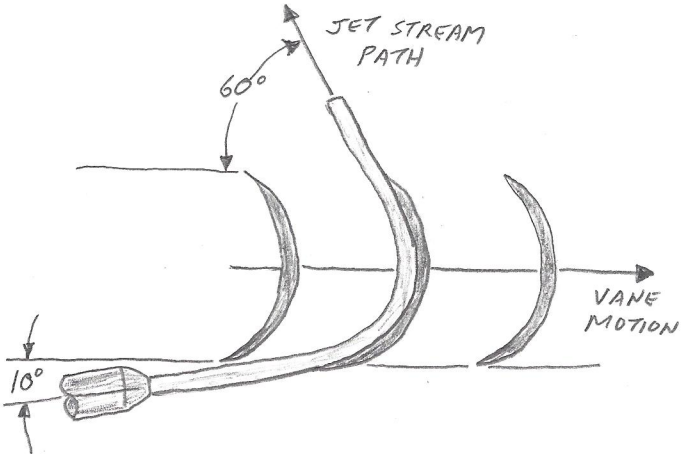
$R_y = M_c(\Delta V_{ey}) = M_c(V_{e2y} - V_{e1y}) = (586.6\ kg/s)[0 - (-7.76)]\ m/s$

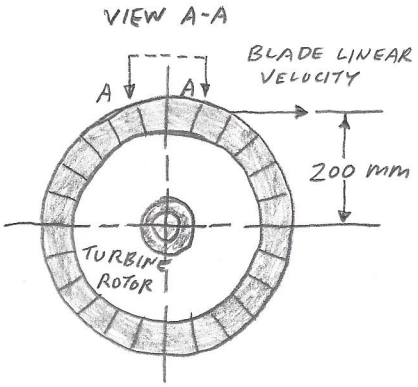
FORCE OF CAR MOVING AT 12 m/s (Y-DIRECTION) = $R_y = 4.55\ kN$

16-29) GIVEN: TEMPERATURE OF WATER = 15° C

DIAMETER OF WATER STREAM = 7.50 mm

VELOCITY OF WATER STREAM = 25 m/s





$$R_x = M(\Delta v_2) = M(v_{2x} - v_{1x}) \longrightarrow M = \rho A v$$

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

$$M = \rho A v = (1000\ kg/m^3)(4.418 \times 10^{-5}\ m^2)(25\ m/s) = 1.105\ kg/s$$

$$v_{1x} = v_1 \cos 10^\circ = (25\ m/s)(0.985) = 24.62\ m/s$$

$$v_{1y} = v_1 \sin 10^\circ = (25\ m/s)(0.174) = 4.34\ m/s$$

$$v_2 = v = 25\ m/s$$

$$v_{2x} = v_2 \cos 60^\circ = (25\ m/s)(0.5) = 12.5\ m/s$$

$$v_{2y} = v_2 \sin 60^\circ = (25\ m/s)(0.0866) = 21.65\ m/s$$

FORCE IN THE X-DIRECTION:

$$R_x = M(\Delta v_x) = M(v_{2x} - v_{1x}) = (1.105\ kg/s)[12.5 - (-24.62)]\ m/s$$

$$R_x = 41.0\ N$$

FORCE IN THE Y-DIRECTION:

$$R_y = M(\Delta v_y) = M(v_{2y} - v_{1y}) = (1.105\ kg/s)[21.65 - 4.34]\ m/s$$

$$R_y = 19.1\ N$$