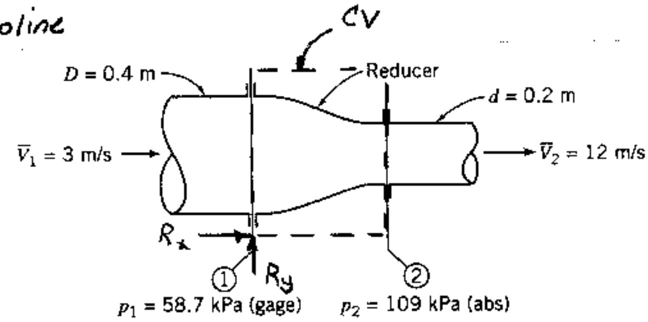
Problem 4.71

Given: Flow through reducer in gasoline piping system, as shown.

$M = 25\ kg \quad \forall = 0.2\ m^3$



Find: Force needed to hold reducer in place.

Solution: Apply the x and y components of the momentum equation, using the CV and coordinates shown. Use gage pressures to cancel patm.

Basic equations:

$$F_{Sx} + \underbrace{F_{Bx}}_{=0(1)} = \underbrace{\frac{\partial}{\partial t}\int_{CV} u\rho\, d\forall}_{=0(2)} + \int_{CS} u\rho\vec{V}\cdot d\vec{A}$$

$$F_{Sy} + F_{By} = \underbrace{\frac{\partial}{\partial t}\int_{CV} v\rho\, d\forall}_{=0(2)} + \int_{CS} v\rho\vec{V}\cdot d\vec{A}$$

Assumptions: (1) $F_{Bx} = 0$
(2) Steady flow
(3) Uniform flow at each section
(4) Incompressible flow, $SG = 0.72$ {Table A.2, Appendix A}

From the x component of momentum,

$$R_x + p_{1g}A_1 - p_{2g}A_2 = u_1\{-|\rho V_1 A_1|\} + u_2\{+|\rho V_2 A_2|\} = (V_2 - V_1)\rho V_1 A_1$$

$$u_1 = V_1 \qquad u_2 = V_2$$

$$R_x = p_{2g}A_2 - p_{1g}A_1 + (\bar{V}_2 - \bar{V}_1)\rho\bar{V}_1 A_1 \qquad \text{Note } \rho = SG\,\rho_{H_2O}$$

$$= (109-101)10^3\frac{N}{m^2}\times\frac{\pi}{4}(0.2)^2 m^2 - 58.7\times10^3\frac{N}{m^2}\times\frac{\pi}{4}(0.4)^2 m^2$$

$$+ (12-3)\frac{m}{s}\times(0.72)1000\frac{kg}{m^3}\times 3\frac{m}{s}\times\frac{\pi}{4}(0.4)^2 m^2\times\frac{N\cdot s^2}{kg\cdot m}$$

$R_x = -4.68\ kN$ (force must be applied to left) $\qquad R_x$

From the y component of momentum,

$$R_y - Mg - \rho g\forall = \underbrace{v_1}_{=0}\{-|\rho V_1 A_1|\} + \underbrace{v_2}_{=0}\{+|\rho V_2 A_2|\}$$

$$R_y = Mg + \rho g\forall$$

$$= 25\ kg\times 9.81\frac{m}{s^2}\times\frac{N\cdot s^2}{kg\cdot m} + (0.72)1000\frac{kg}{m^3}\times 9.81\frac{m}{s^2}\times 0.2\ m^3\times\frac{N\cdot s^2}{kg\cdot m}$$

$R_y = 1.66\ kN$ (force must be applied up) $\qquad R_y$