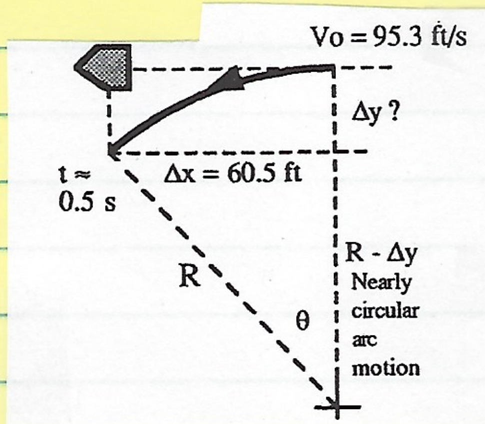
P7.110 A baseball pitcher throws a curveball with an initial velocity of 65 mi/h and a spin of 6500 r/min about a vertical axis. A baseball weighs 0.32 lbf and has a diameter of 2.9 in. Using the data of Fig. P7.108 for turbulent flow, estimate how far such a curveball will have deviated from its straightline path when it reaches home plate 60.5 ft away.



Assume circular motion and neglect g:

$$a_{xo} = \frac{-D}{m} = \text{constant} = \frac{dV}{dt} \qquad C_D = \frac{D}{\frac{1}{2}\rho V^2 A_p}$$

$$V = a_{xo} t + c_1 \qquad V(0) = V_o$$

$$\frac{dx}{dt} = a_{xo} t + V_o \qquad \text{Since } x(0) = 0$$

$$x = \frac{a_{xo}}{2} t^2 + V_o t + \cancel{c_2}$$

$$a_{yo} = -\frac{L}{m} = \text{constant} \qquad C_L = \frac{L}{\frac{1}{2}\rho V^2 A_p}$$

$$|a_{yo}| = \frac{V_{ave}^2}{R} \qquad \text{centripetal acceleration}$$

Sea level air: $\rho = .00238 \text{ slug/ft}^3$

$\mu = 3.72E-7 \text{ lb} \cdot \text{s/ft}^2$

$V_0 = 65 \frac{mi}{h} = 95 \text{ ft/s} \qquad \omega = 6500\left(\frac{2\pi}{60}\right) = 681 \frac{rad}{s}$

$\frac{\omega r}{V_0} = \frac{681 \times (2.9/2 \times 12)}{95} = .86$ Fig P7.108

$C_D = .44 \quad C_L = .17$

$-\frac{D}{m} = a_{x_0} = -\frac{.44 \times \frac{1}{2} \rho V^2 A_p}{W/g = .32/32.2} = -22 \text{ ft/s}^2$

$-\frac{L}{m} = a_{y_0} = -\frac{.17 \times \frac{1}{2} \rho V^2 A_p}{W/g} = -8.5 \text{ ft/s}^2$

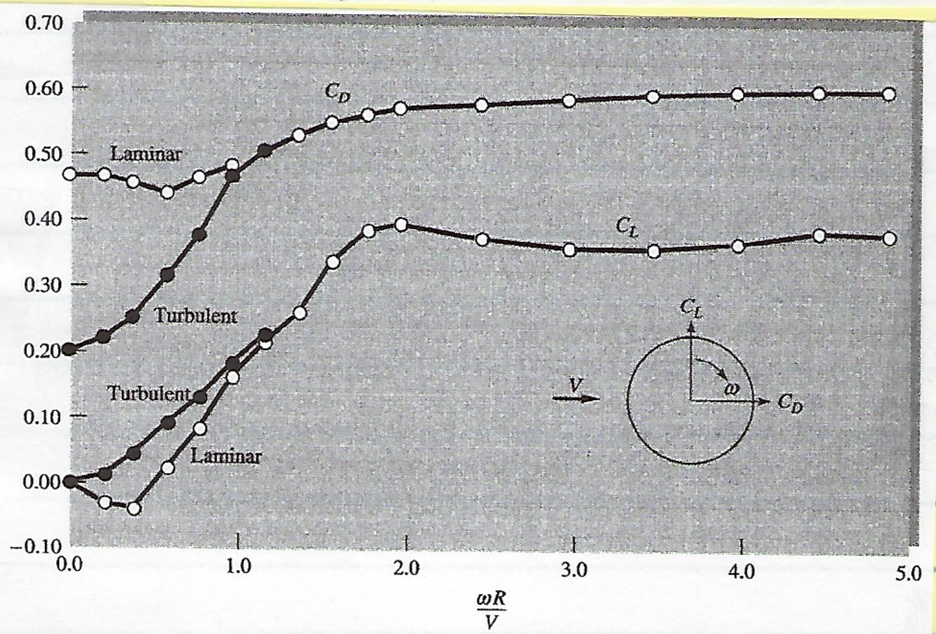


Fig. P7.108

$X = 60.5 = \frac{1}{2}(-22)t^2 + 95t \Rightarrow t = .69$ sec

$V = a_{x_0}t + V_0 = 79.8$ ft/s

$R = V_{ave}^2 / |a_y| = 898.9$ ft $V_{ave} = \frac{95 + 79.8}{2}$

$\theta = \sin^{-1}\left(\frac{\Delta x}{R}\right) = 3.86°$ $\Delta x = 60.5$, $R = 898.9$

$\Delta y = R(1 - \cos\theta) = 2.03$ ft