Problem 1

$L' = 6\ N/m$, $U_\infty = 3\ m/s$ $R = 0.136\ m$

where are the stagnation points?

$$\theta = \sin^{-1}\left(-\frac{\Gamma}{4\pi U_\infty R}\right) \qquad \Gamma = \frac{L'}{\rho_\infty U_\infty} \quad \text{(Kutta-Joukowski)}$$

$$\therefore \frac{-\Gamma}{4\pi U_\infty R} = \frac{-L'}{4\pi \rho_\infty U_\infty^2 R} = \frac{-(6\ N/m)}{4\pi (1.23\ kg/m^3)(3\ m/s)^2 (0.136\ m)}$$

$$= -0.3173$$

$$\theta = \sin^{-1}(-0.3173)$$

$$\theta = -18.5^\circ \text{ or } -0.3229\ rad$$

The other point is symmetric about vertical:

$$= -18.5 - (2 \cdot (90 - 18.5)) = -161.5^\circ$$

$$\text{or } -2.82\ rad$$

$$\boxed{\theta = -18.5^\circ \text{ and } -161.5^\circ}$$

Problem 2

Design criteria: $L = W = 2450$ lbs

@ cruise speed of 122 knots

$\Gamma = 2\pi w R^2$

Use $L' = \rho_\infty U_\infty 2\pi w R^2$ Determine: span of cylinder
radius of cylinder
rotation of cylinder

122 knots = 206 ft/s

Density of air @ 8000 ft: $\rho = 0.00188$ slug/ft^3

Now choose: span = 30 ft, Diameter = 3 ft

$$2450 \text{ lb} = (0.00188 \text{ slug/ft}^3)(206 \text{ ft/s})\, 2\pi w (1.5 \text{ ft})^2$$

$w = 447.7$ rad/s $\therefore$ $RPM = \dfrac{(447.7 \text{ rad/s})\, 60}{2\pi}$

$= 4277.5$ RPM

Designed wing:

span = 30 ft
diam = 3 ft
RPM = 4277.5

Answers vary based on choice of parameters.

Problem 3

Flettner rotor ship: each rotor: 50 ft high, 9 ft diam., 750 RPM

$U_\infty = 25$ ft/s

$\rho_\infty = 0.002377$ slug/ft^3

$\omega = 78.5$ rad/s

$$L = L' b = \rho_\infty U_\infty 2\pi \omega R^2 b$$

$$L = \left(0.002377 \frac{\text{slug}}{\text{ft}^3}\right)(25 \text{ ft/s})\, 2\pi\, (78.5 \text{ rad/s})\, (4.5 \text{ ft})^2 (50 \text{ ft})$$

$L = 29{,}661$ lbs for each rotor

Total force = 59,323 lbs