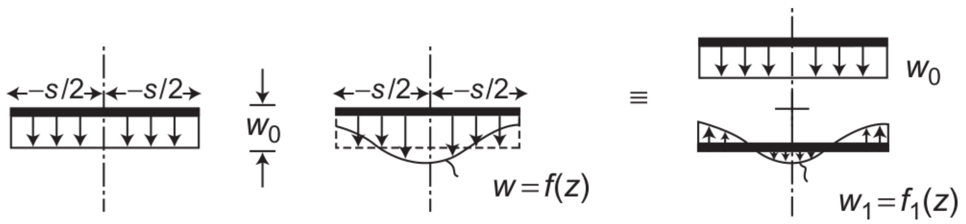
AE333: Aerodynamics
Tutorial 3

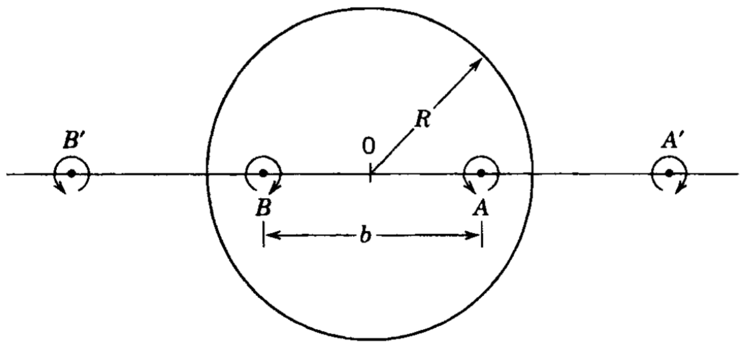
1. Using finite wing theory, show that the induced drag in steady, level flight is related primarily to the design parameter W/b termed span loading, where W is the weight of the aircraft.

2. Consider two wings A and B of equal span s with spanwise distributions in downwash velocity $w_A = w_0 =$ constant and $w_B = f(z)$. Without altering the latter downwash variation, it can be expressed as the sum of two distributions w_0 and $w_1 = f_1(z)$, as shown in the figure. If the lift (change in vertical momentum) due to both wings is the same under given conditions and the induced drag is given by the rate of change of kinetic energy, show that

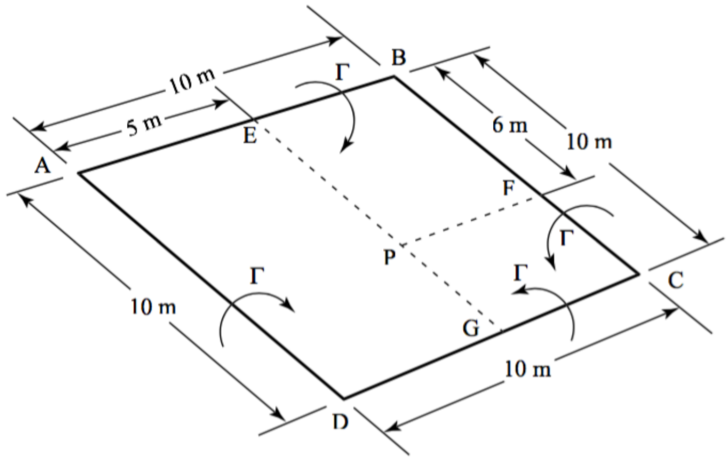
$$D_{iB} = D_{iA} + K \int_{-s/2}^{s/2} [f_1(z)]^2 dz.$$



3. Consider a wing of span b with circulation Γ in an airstream of radius R with impervious walls, as shown in the cross section in the figure. A and B are the trailing vortices of the wing; A' and B' are images of A and B calculated to establish the circle R as a streamline of the flow with $OA = OB = b/2$ and$OA' = OB' = R^2/(1/2)b$. Obtain the correction to the (a) angle of attack $\Delta\alpha$ and (b) drag coefficient ΔC_D in terms of the area of the wing S_W, cross section area of the tunnel S_T and the lift coefficient C_L.



4. A rectangular vortex filament of strength $\Gamma = 200m^2/s$ has the dimension as shown in the figure. The rectangle is in a plane defined by A-B-C-D. Find the magnitude of the velocity induced by the vortex in a direction normal to the plane at the point P if P lies in the same plane.



5. It is found that for rectangular or slightly tapered airfoils, the span-wise distribution of circulation does not depart drastically from elliptic distribution. Let

$$\Gamma(y) = \Gamma_0 \sqrt{1 - \left(\frac{2y}{b}\right)^2} \left(1 + 4\lambda \left(\frac{2y}{b}\right)^2\right)$$

be the circulation distribution for such cases. Notice that $\Gamma = 0$ at $y = \pm b/2$.
(a)Find the total lift generated by the wing and the lift coefficient.
(b)On the same graph, plot the circulation distribution for three wings with (i)$\lambda = 0$, (ii) $\lambda < 0$ and (iii) $\lambda > 0$, if they generate the same lift.
(c)How does the circulation about the center-span vary with λ for wings generating the same lift. Comment on the variation of circulation distribution from root to tip for $\lambda > 0$ and $\lambda < 0$ when compared with $\lambda = 0$.
(d)Find an expression for the downwash distribution on the wing in terms of λ.
(e) Find the total induced drag on the wing and the induced drag coefficient.
(f) Find the spanwise efficiency factor δ in terms of λ such that

$$C_{Di} = \frac{C_L^2}{\pi AR}(1 + \delta)$$