ME19b. HOMEWORK. Mar.2 Due Mar.8, 2007

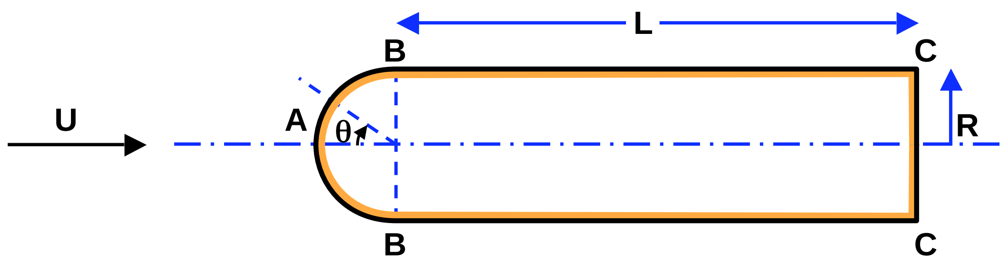
PROBLEM B21.

In 1844, to commemorate a visit by the Tsar of Russia, the Duke of Devonshire, the greatest landowner in Britain, wished to construct the tallest fountain ever built in the grounds of his great house at Chatsworth in Derbyshire. He employed the renowned engineer Joseph Paxton to build what was to become known as the Emporer Fountain. That fountain remains the tallest, gravity-fed fountain in the world, with a maximum height of $90.2m$ above the pond into which it falls. What Paxton did was to excavate a massive eight acre lake on a nearby hill such that the lake surface was $120m$ above the afore-mentioned pond. The pipe to the fountain was $800m$ long and had an internal diameter of $0.381m$. (Paxton knew that to maximize the height of the fountain he would have to make the pipe diameter large.) The result was that the maximum flow rate through the pipe (when the control valve was fully opened) was 15000 $liters/min$. Questions:

1. Using the above information find the friction factor for Paxton's pipe.
2. Find the Reynolds number for the flow in Paxton's pipe assuming a water temperature of $15°C$ so that the kinematic viscosity of the water $1.16 \times 10^{-6}\ m^2/s$.
3. What kind of flow is occuring in Paxton's pipe?
4. Using the answers to the first two questions estimate the typical height of the roughnesses in the interior surface of Paxton's pipe.
5. Assuming the same friction factor, what would the maximum height of the fountain have been if Paxton had used a pipe with a half of the above diameter?

PROBLEM B22.

The sketch below defines the geometry of an axisymmetric underwater body that is quite streamlined in the sense that L/R is large. This body travels through the incompressible water at a velocity, U, parallel to the axis.



It is to be assumed:

- that the velocity distribution over the spherical nose, BAB, is the same as in potential flow, that is to say the velocity outside the boundary layer is $\frac{3}{2}U\sin\theta$.
- that the flow separates at the sharp trailing edge, C, so that the pressure coefficient acting on the circular base, CC, is

$$C_p = -0.5$$

  Remember that the pressure coefficient is defined as, $C_p = (p - p_\infty)/\frac{1}{2}\rho U^2$ where p is the pressure, p_∞ is the pressure far upstream and ρ is the fluid density.
- that the skin friction forces on the spherical nose are negligible.

If the drag coefficient is defined as the drag divided by $\frac{1}{2}\rho U^2$ and the frontal projected area (πR^2) find:

1. The contribution of the form drag to the total drag coefficient (denote this by C_{DF}).
2. An estimate of the contribution of the skin friction on the cylindrical surface of the body (between B and C) to the total drag coefficient, assuming the boundary layer remains laminar. This should be in terms of the Reynolds number, $Re = 2UR/\nu$, where ν is the kinematic viscosity of the fluid.
3. For what aspect ratio, L/R, will the drag be comprised of equal parts of form and skin friction drag if $Re = 10000$?

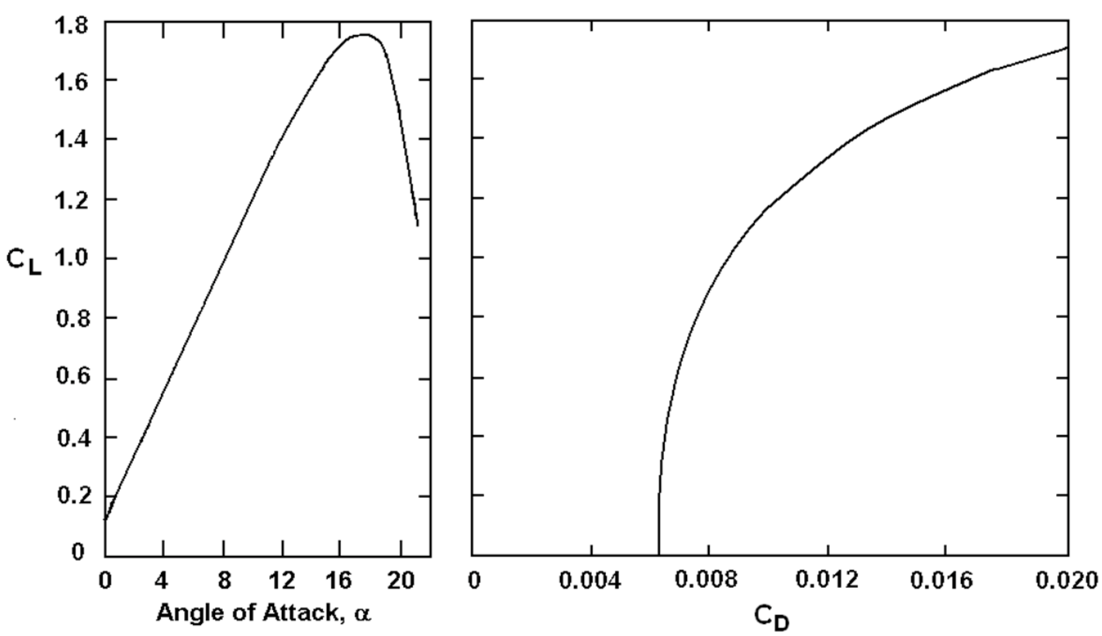
PROBLEM B23.

Many versions of the Boeing 747 (weight 3×10^6 $kg\ m/s^2$) are powered by four Pratt and Whitney JT9D-7A turbofan engines, each of which can produce a thrust at sea-level of approximately $200,000$ $kg\ m/s^2$ (neglect the fact that this may change with forward speed). During take-off with flaps partially down the lift coefficient based on a wing planform area of 550 m^2 is 1.6 and the lift/drag ratio is 22. Assume an air density of 1.2 kg/m^3 . Calculate:

1. The take-off speed.
2. The runway length from a standing start to take-off and the acceleration during this time assuming the drag can be neglected.
3. The actual acceleration at take-off when the drag is included in the calculation.

PROBLEM B24.

A glider weighs 2000 $kg\ m/s^2$, has a wing planform area of 10 m^2 and flies through air with density 1.0 kg/m^3. The lift and drag characteristics of the wings are as follows:

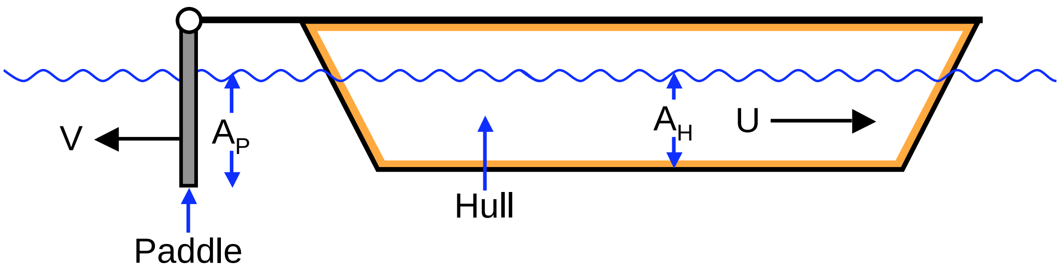


1. If the wing lift characteristic is as shown on the left above, calculate the **stall** speed for horizontal flight assuming zero drag.

2. In fact, the drag on the glider causes the glider to continously lose altitude when flying through still air. The inclination of this trajectory to the horizontal is called the *glide angle*. Find the *minimum* glide angle if the drag is as given in the right graph above. Neglect any drag on the other parts of the glider such as the fuselage. What is the horizontal component of the velocity of the glider under these conditions?

PROBLEM B25.

Consider a simplified view of the propulsion of a paddle steamer:



Suppose that there is always an effective area, A_P, of paddle submerged in the water off the stern of the boat and that this is moving backwards with a velocity, V, *relative to the hull*. Denote the drag coefficient of this effective area of paddle by C_{DP} and assume that the flow around the paddle is unaffected by the presence of the hull. This paddle propels the boat through the water at a forward velocity, U; denote the drag coefficient for the hull by C_{DH} based on the frontal projected area of the hull, A_H.

1. What is the relation between the propulsion velocity, U, and the relative paddle velocity, V ?

2. What is the efficiency of this method of propulsion in terms of A_P, A_H, C_{DP} and C_{DH}? Efficiency, remember, is the ratio of useful work done to total work done. Comment on the result and the geometry which would be neccessary to obtain reasonable efficiencies given that the drag coefficients will be of order unity.