AerE310: Incompressible Aerodynamics

Homework Problem Set #07:

<u>Due</u>: 5:00pm on Friday, 05/03/2024

<u>Problem#1:</u>

A rectangular plate, whose streamwise dimension (or chord c) is 0.2 m and whose width (or span b) is 1.8 m, is mounted in a wind tunnel. The freestream velocity is 40 m/s. The density of the air is 1.2250 kg/m^3, and the absolute viscosity is 1.7894*10^{-5} kg/m·s.

- Graph the velocity profiles at x = 0.0 m, x = 0.05 m, *x* = 0.10 m, and *x* = 0.20 m.
- Calculate the chordwise distribution of the skin-friction coefficient and the displacement thickness.
- What is the drag coefficient for the plate?

TABLE 4.3 Solution for the Laminar Boundary Layer on a Flat Plate ($\beta = 0$)

η	f	f'	f''
0.0	0.0000	0.0000	0.4696
0.1	0.0023	0.0470	0.4696
0.2	0.0094	0.0939	0.4693
0.3	0.0211	0.1408	0.4686
0.4	0.0375	0.1876	0.4673
0.5	0.0586	0.2342	0.4650
0.6	0.0844	0.2806	0.4617
0.7	0.1147	0.3265	0.4572
0.8	0.1497	0.3720	0.4512
0.9	0.1891	0.4167	0.4436
1.0	0.2330	0.4606	0.4344
1.2	0.3336	0.5452	0.4106
1.4	0.4507	0.6244	0.3797
1.6	0.5829	0.6967	0.3425
1.8	0.7288	0.7610	0.3005
2.0	0.8868	0.8167	0.2557
2.2	1.0549	0.8633	0.2106
2.4	1.2315	0.9010	0.1676
2.6	1.4148	0.9306	0.1286
2.8	1.6032	0.9529	0.0951
3.0	1.7955	0.9691	0.0677
3.2	1.9905	0.9804	0.0464
3.4	2.1874	0.9880	0.0305
3.5	2.2863	0.9907	0.0244
4.0	2.7838	0.9978	0.0069
4.5	3.2832	0.9994	0.0015

Problem#2:

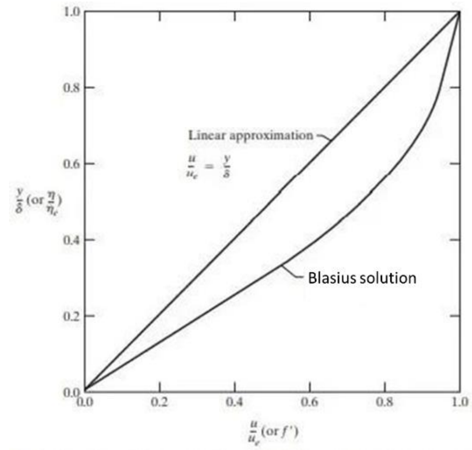


Figure 4.7 Comparison of velocity profiles for a laminar boundary layer on a flat plate.

The streamwise velocity component for a laminar boundary layer is sometimes assumed to be roughly approximated by the linear relation $u = \frac{y}{\delta} u_e$ where $\delta = 1.25 * 10^{-2}\sqrt{x}$. Assume that we are trying to approximate the flow of air at standard sea-level conditions past a flat plate where u_e = 2.337 m/s.

- Calculate the streamwise distribution of the displacement thickness (δ^*), the velocity at the edge of the boundary layer\left (v_e), and the skin-friction coefficient C_f.
- Compare the values obtained assuming a linear velocity profile with the Blasius solutions.

Problem#3:

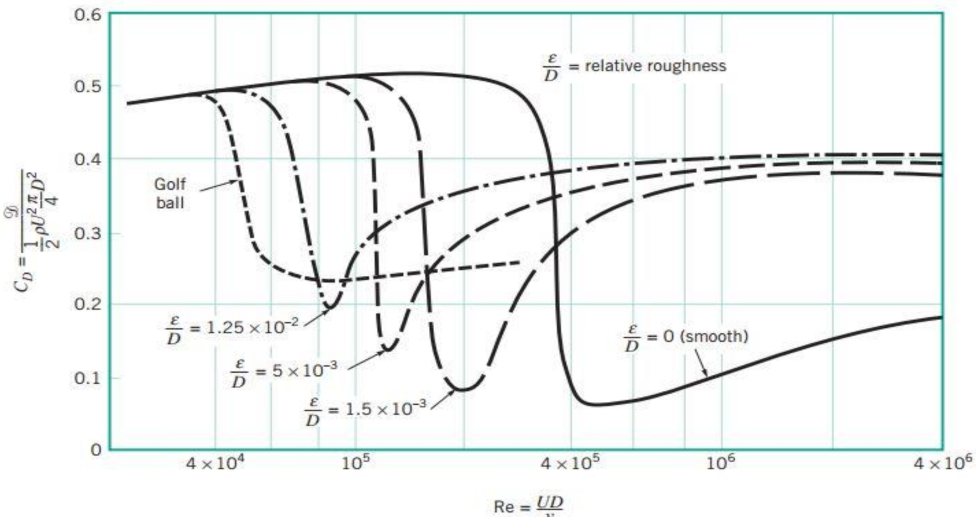
A small airplane flies at speed of 90 m/s at 1000 m altitude. The airplane wing has rectangular shape with chord length of 1m and span of 11m. Assume boundary layer over the wing surface is fully laminar and model the wing airfoil as a flat plate.

- a) Estimate the boundary layer thickness at the trailing edge.
- b) Estimate the displacement thickness at the trailing edge.
- c) estimate the friction drag of the wing.

Problem#4:

A well-hit golf ball (diameter D=1.69 in., weight w=0.0992 lb) can travel at U=200 ft/s as it leaves the tee. A well-hit table tennis ball (diameter D=1.50 in., weight w= 0.00551 lb) can travel at U=60 ft/s as it leaves the paddle.

- Determine the drag on a standard golf ball, a smooth golf ball, and a table tennis ball for the conditions given.
- Also determine the deceleration of each ball for these conditions.



■ **FIGURE 9.18** **The effect of surface roughness on the drag coefficient of a sphere in the Reynolds number range for which the laminar boundary layer becomes turbulent (Ref. 4).**