**MAE 158**
**Recommended Homework 2**

From Shevell, *Fundamentals of Flight*
Problems 6.1, 6.2, 10.1, 10.3

**6.1.** Consider a sea-level, low-speed wind tunnel of circular cross section with a diameter upstream of the contraction of 22 ft and a working section diameter of 10 ft. The working section is vented to atmosphere. Temperature is 15°F above standard. If the working section velocity is 210 mph, what is:

**(a)** the upstream (22 ft section) velocity?

**(b)** the upstream pressure?

**(c)** the height of a mercury column being used to regulate the tunnel speed by measuring the pressure difference between the upstream and working section pressure? Mercury weighs 0.49 lb/in.$^3$.

**6.2.** An airfoil is moving through the air at 180 mph at 5000 ft pressure altitude. The temperature is 80°F. At a point on the airfoil upper surface the local velocity is 215 mph. What is the pressure at that point? If this is the average pressure on the surface, how much lift per square foot is being provided by the top surface? If the average speed on the lower surface is 160 mph, what is the pressure and average lift per square foot on the lower surface? What is the total lift per square foot of wing area?

**10.1.** Consider a high-speed subsonic wind tunnel. The conditions in the large-diameter section upstream of the test section are $V = 228$ mph and $T = 540°R$. At the test section, $T = 473°R$ and the pressure is two standard sea-level atmospheres.

Assume velocity ~ 960 ft/s at the test section.

**(c)** If a wind tunnel model, placed in the test section, has a wing chord of 12 in., what is the test Reynolds number based on that chord?

**(d)** What is the overall smooth flat-plate skin friction coefficient of the model wing if the boundary layer is turbulent? What is the $C_{D_p}$?

**(e)** Determine the boundary layer thickness at the trailing edge of the model wing.

**(f)** Calculate the skin friction drag in pounds. Model span is 3 ft.

**10.3.** A Piper Cherokee is flying at 4000 ft altitude at 120 mph on a standard day. The gross weight is 1850 lb. The wing has an area of 160 ft$^2$, 85% of which is exposed, is of rectangular planform, and has a span of 30 ft. Assume completely turbulent boundary layer flow. Pressure drag and surface roughness add 25% to wing parasite drag (above pure skin friction). Wing parasite drag is 38% of the total airplane parasite drag.

**(a)** Determine the smooth flat-plate skin friction drag of the wing in both coefficient and force terms.

**(b)** Determine the total parasite drag of the wing and the airplane in both coefficient and force terms.

**(d)** What is the boundary layer thickness of the wing trailing edge?

For problem 10.1: Note, for air, as T increases, μ increases. For air at standard sea-level temperature:

$\mu_{\text{standard sea-level temperature}} = 1.7894 \times 10^{-5}$ kg/m-s $= 3.7373 \times 10^{-7}$ lb-s/ft$^2$

The variation of viscosity in air with temperature is given in the following charts:

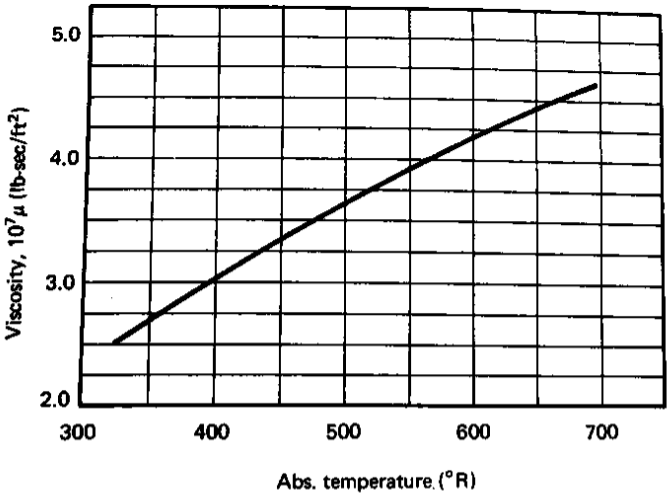


**Figure 10.14** Absolute viscosity of air.

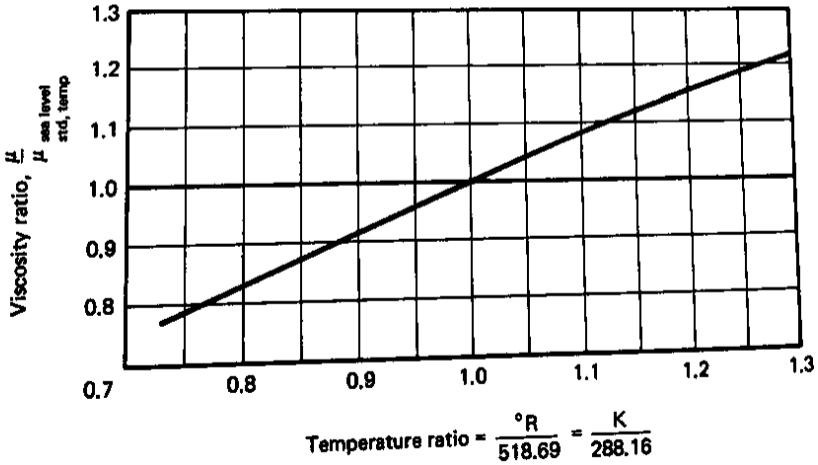


**Figure 10.15** Relative viscosity versus temperature ratio.