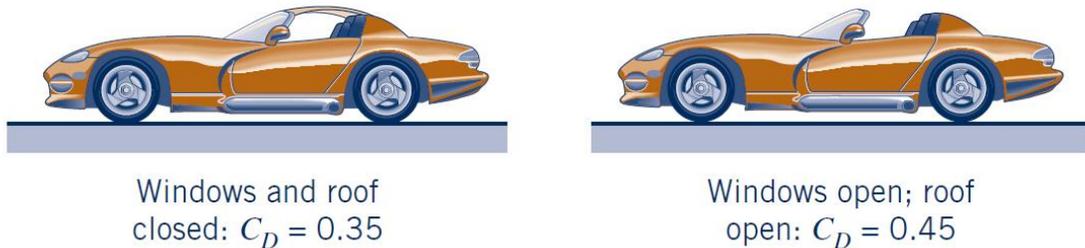
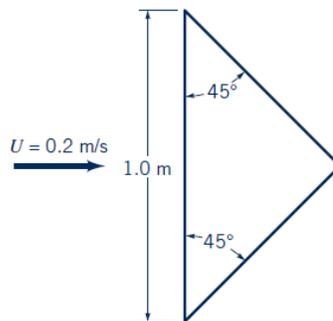


**REE 307 - Internal Fluid Flow**  
**Sheet 4**  
**Lift and Drag**

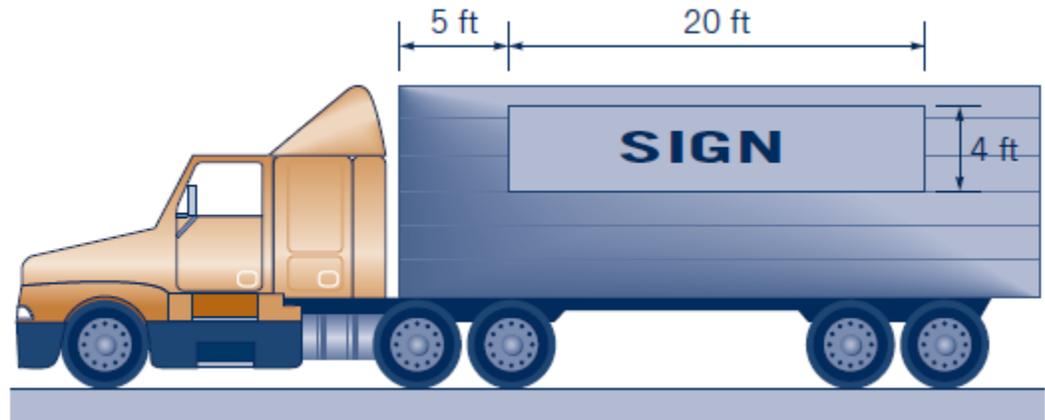
1. The aerodynamic drag on a car depends on the “shape” of the car. For example, the car shown in Fig. P9.39 has a drag coefficient of 0.35 with the windows and roof closed. With the windows and roof open, the drag coefficient increases to 0.45. With the windows and roof open, at what speed is the amount of power needed to overcome aerodynamic drag the same as it is at 65 mph with the windows and roof closed? Assume the frontal area remains the same. Recall that power is force times velocity.



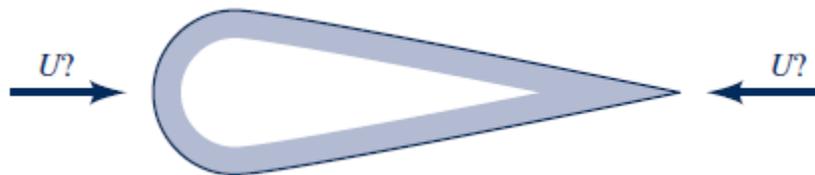
2. A baseball is thrown by a pitcher at 95 mph through standard air. The diameter of the baseball is 2.82 in. Estimate the drag force on the baseball.
3. If the drag on one side of a flat plate parallel to the upstream flow is  $D$  when the upstream velocity is  $U$ , what will the drag be when the upstream velocity is  $2U$ ; or  $U/2$ ? Assume laminar flow.
4. Water flows past a triangular flat plate oriented parallel to the free stream as shown in Fig. P9.47. Integrate the wall shear stress over the plate to determine the friction drag on one side of the plate. Assume laminar boundary layer flow.



5. A ceiling fan consists of five blades of 0.80-m length and 0.10-m width which rotate at 100 rpm. Estimate the torque needed to overcome the friction on the blades if they act as flat plates.
6. A thin smooth sign is attached to the side of a truck as is indicated in Fig. Estimate the friction drag on the sign when the truck is driven at 55 mph.

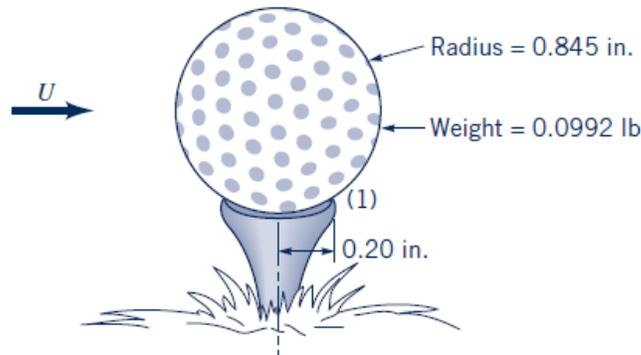


7. A hot-air balloon roughly spherical in shape has a volume of 70,000 ft<sup>3</sup> and a weight of 500 lb (including passengers, basket, balloon fabric, etc.). If the outside air temperature is 80 °F and the temperature within the balloon is 165 °F, estimate the rate at which it will rise under steady-state conditions if the atmospheric pressure is 14.7 psi.
8. It is often assumed that “sharp objects can cut through the air better than blunt ones.” Based on this assumption, the drag on the object shown in Fig. P9.56 should be less when the wind blows from right to left than when it blows from left to right. Experiments show that the opposite is true. Explain.

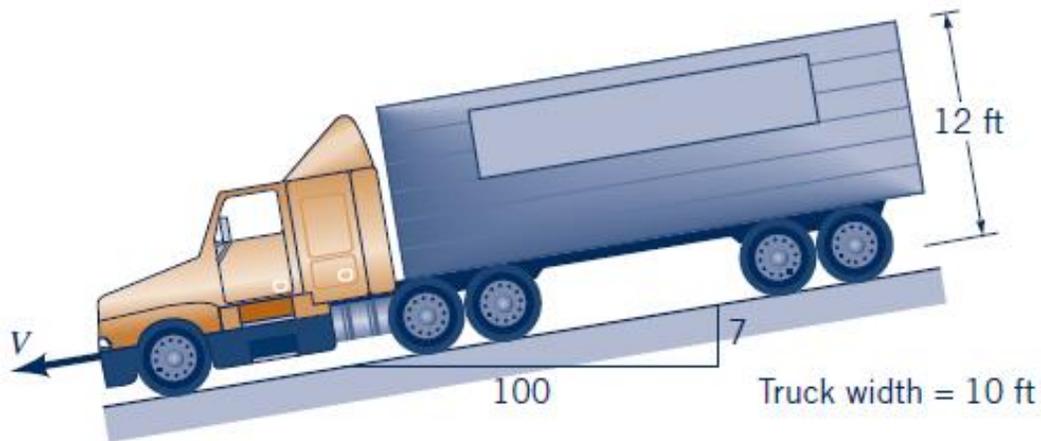


9. A 12-mm-diameter cable is strung between a series of poles that are 50 m apart. Determine the horizontal force this cable puts on each pole if the wind velocity is 30 m/s.
10. How fast do small water droplets of 0.06 μ-mm ( $6 \times 10^{-8}$  m) diameter fall through the air under standard sea-level conditions? Assume the drops do not evaporate. Repeat the problem for standard conditions at 5000-m altitude.

11. A strong wind can blow a golf ball off the tee by pivoting it about point 1 as shown in Fig. P9.62. Determine the wind speed necessary to do this.



12. How much more power is required to pedal a bicycle at 15 mph into a 20-mph head-wind than at 15 mph through still air? Assume a frontal area of 3.9 ft<sup>2</sup> and a drag coefficient of  $C_D = 0.88$ .
13. A 25-ton (50,000-lb) truck coasts down a steep 7% mountain grade without brakes, as shown in Fig. The truck's ultimate steady-state speed,  $V$ , is determined by a balance between weight, rolling resistance, and aerodynamic drag. Determine  $V$  if the rolling resistance for a truck on concrete is 1.2% of the weight and the drag coefficient based on frontal area is 0.76.



14. As shown in Fig., the aerodynamic drag on a truck can be reduced by the use of appropriate air deflectors. A reduction in drag coefficient from  $C_D = 0.96$  to  $C_D = 0.70$  corresponds to a reduction of how many horsepower needed at a highway speed of 65 mph?



(a)  $C_D = 0.70$



(b)  $C_D = 0.96$