Chapter 10: Fluid Mechanics

1. Calculate the drag force acting on a 105 kg (including the bicycle) cyclist moving at 10 m/s, at 20 m/s and at 30 m/s. Use a drag coefficient of 0.8, a frontal surface area of 1.0 m^2, and a density of 1.0 kg/m^3.

$$F_D = 0.5 C_D \rho A v^2$$

@10m/s $F_D = 0.5(0.8)(1)(1)(10^2)$ = 40 N

@20m/s $F_D = 0.5(0.8)(1)(1)(20^2)$ = 160 N

@30m/s $F_D = 0.5(0.8)(1)(1)(30^2)$ = 360 N

2. If the cyclist of #1 was coasting down a 5 degree hill, estimate the terminal velocity that the cyclist would attain.

$$v = \sqrt{\frac{-2mg\sin\theta}{C_D \rho A}} = \sqrt{\frac{-2(105)(-9.8)\sin(5°)}{0.8(1)(1)}} = 15.0 \text{ m/s}$$

3. Imagine that you are entered in a 10 km running race on an out and back flat course. Estimate your time for running 10 km and your average running speed. Determine what the drag force which would be acting against your motion. Drag coefficient of 0.8, frontal area of 1.0 m^2, and density of 1 kg/m^3.

Now consider what would happen with a constant wind of 1 m/s blowing as a headwind in the first half and a tailwind in the last half of the race. What would the drag forces be in the two halves of the race? How much work against the drag force would be done under the wind condition versus if there were no wind blowing?

If 40 minute 10 km: $Speed = \dfrac{10000m}{2400s}$ = 4.17 m/s

No Wind: $F_D = 0.5 C_D \rho A v^2 = 0.5(0.8)(1)(1)(4.17^2)$ = 6.98 N

$U = Fd = 6.98(10000)$ = 69.8 kJ

Total work without wind = 69.8 kJ

With 1 m/s headwind for 5000 m then 1 m/s tailwind for 5000m

Headwind: $F_D = 0.5 C_D \rho A v^2 = 0.5(0.8)(1)(1)(5.17^2)$ = 10.7 N

$U = Fd = 10.7(5000)$ = 53.5 kJ

Tailwind: $F_D = 0.5 C_D \rho A v^2 = 0.5(0.8)(1)(1)(3.17^2)$ = 4.02 N

$U = Fd = 4.02(5000)$ = 20.1 kJ

Total work with 1 m/s wind = 73.6 kJ