MEC516/BME516
Fluid Mechanics I

Chapter 5
Recommended Problem Set

I strongly recommended that you work through the details of these problems, with pen and paper. ***Be sure that you can solve these problems without looking at the solutions.***

1. A prototype automobile is designed for cold weather in Denver, Colorado (-10°C, p_{atm}=83 kPa). Its drag force is to be tested with a one-fifth (1/5th) scale model in a wind tunnel at V_m =160 mi/h located at sea level, p_{atm}=1 atm, 20ºC. If model and prototype satisfy dynamic similarity, what is the corresponding prototype velocity V_p?

2. When tested in a water tunnel at 20°C flowing at 2.0 m/s, an 8.0 cm diameter sphere has a measured drag force of 5.0 N. What will be the velocity and drag force on a 1.5 m diameter weather balloon moored in sea-level (1 atm) air at 20ºC under dynamically similar conditions?

3. The wall shear stress τ_w in a turbulent boundary layer is a function of stream velocity U, boundary layer thickness δ, local turbulence velocity fluctuation u', the fluid density ρ, and local pressure gradient dp/dx:

$$\tau_w = f(U, \delta\, u', \rho, \frac{dp}{dx})$$

Using ρ, U, δ as repeating variables, rewrite this relationship as a dimensionless function.

4. The thrust F of a propeller is a function of its diameter D and angular velocity Ω, the forward speed V, and the density ρ and viscosity μ of the fluid.

$$F = f(D, \Omega, V, \rho, \mu)$$

Rewrite this relationship as a dimensionless function. Use ρ, V, D as the repeating variables.

5. The wave drag (F_D) on the hull of a ship depends upon the velocity of the ship (V), the length of the ship's hull (ℓ), the density of the fluid (ρ) and the acceleration due to gravity (g). The effect of viscosity can be neglected. (This problem is from the Fall 2018 final exam.)

(a) Use the *Method of Repeating Variable*s to show that the dimensionless parameters for this problem can be expressed as:

$$\frac{F_D}{\rho\ V^2\ \ell^2} = f\left(\frac{V^2}{\ell\ g}\right)$$

If you need 1 repeating variable use V. If you need 2 repeating variables use V and ℓ. If you need 3 repeating variables use V, ℓ and ρ.

(b) The drag force on the model ship is measured to be $F_{D,m}$=14 N when it is towed in a water tank at a speed of 1.5 m/s. The model scale is 1:50 (the model fifty times smaller than the prototype). For ***dynamically similar flow conditions***, calculate the drag force on the full-scale prototype ship in kN. Both the model and prototype operate in fresh water at the same density.

6. A cylindrical support strut on a sign board has an external diameter of 5.5 cm. In a winter storm (-40^{o}C) the wind blows at 35 m/s. Estimate the force per unit length on the strut produced by this crossflow of air.

Want more solved problems? Some past exam problems ***with full solutions*** are posted on D2L.