MEEG 630, Intermediate Fluid Mechanics

Homework Set #6: Dynamic Similarity

1. Suppose that the power to drive a propeller of an airplane depends on d (diameter of the propeller), U (free-stream velocity), Ω (angular velocity of the propeller), c (velocity of sound), r (density of fluid), and m (viscosity). Find the dimensionless groups. In your opinion, which of these are the most important and should be duplicated in a model testing?

2. A 1/10 scale model of a submarine is being tested in a wind tunnel, in which $p = 200$ kPa and $T = 300\,\mathrm{K}$. If the prototype moves slowly at a speed of 1 km/hr, what should be the free-stream velocity in the wind tunnel? What is the drag ratio? Assume that the submarine would not operate near the surface of the ocean.

3. A model of a large 5-ft-diameter fan is to be studied in order that the operating characteristics of the prototype fan can be predicted. The model is one-fifth size. In operation, it moves air at the rate of 200 cfs while rotating at 2500 rpm. (a) Predict the flow rate and rotational speed of the prototype fan; (b) also determine the ratio of power required to run the prototype compared to that required to run the model.

4. A model of a harbor is made on the length ratio of 280:1. Storm waves of 1.5 m amplitude and 9 m/s velocity occur on the breakwater of the prototype harbor. (a) Neglecting friction, what should be the size and speed of the waves in the model? (b) If the time between tides in the prototype is 12 hr, what should be the tidal period in the model?

5. A centrifugal pump is being designed for the cooling system of a nuclear reactor. The coolant is to be liquid sodium at 400 ^{o}C, at which temperature it has a density of 850 kg/m^3 and dynamic viscosity of 0.269×10^{-3} Pa.s. The pump is to circulate 0.03 m^3/s at a total pumping head of 2 m. It will be driven by a motor turning at 1760 rpm.

   A model of this pump is to be constructed at four times life size and tested with water at 20 ^{o}C. In modeling, the Reynolds number is to be considered the significant parameter. In computing this parameter, the diameter and peripheral velocity of the impeller may be taken as the characteristic length and velocity, respectively. Find (a) the appropriate impeller rotational speed, (b) the discharge, (c) the head of the model pump (note that the head is proportional to the kinetic energy generated in the pump).