Fluid Mechanics and Rate Processes: Tutorial 7

P1. Consider fully-developed, incompressible flow (density ρ, viscosity μ, average velocity V) through a long, horizontal pipe, of circular cross-section (diameter D), as shown in Fig P1. Because of frictional forces between the fluid and the pipe wall, there exists a shear stress τ_w on the inside pipe wall as sketched. We assume some constant average roughness height ε along the inside wall of the pipe. Develop a non-dimensional relationship between shear stress τ_w and the other relevant parameters in the problem.

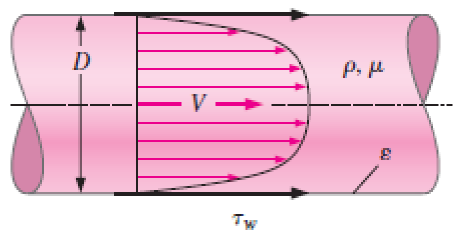

Fig. P1

P2. The power P generated by a certain windmill design depends upon its diameter D, the air density ρ, the wind speed V, the rotation rate Ω, and the number of blades n. (a) Write this relationship in dimensionless form. A model windmill, of diameter 50 cm, develops 2.7 kW at sea level when V = 40 m/s and when rotating at 4800 rev/min. (b) What power will be developed by a *similar* prototype, of diameter 5 m, in winds of 12 m/s at 2000 m standard altitude? (c) What is the appropriate rotation rate of the prototype?

P3. A one-twelfth-scale model of an airplane is to be tested at 20°C in a pressurized wind tunnel. The prototype is to fly at 240 m/s at 10-km standard altitude. Assuming air to be an ideal gas, find the tunnel pressure (in atm) to scale both the Mach number and the Reynolds number accurately?