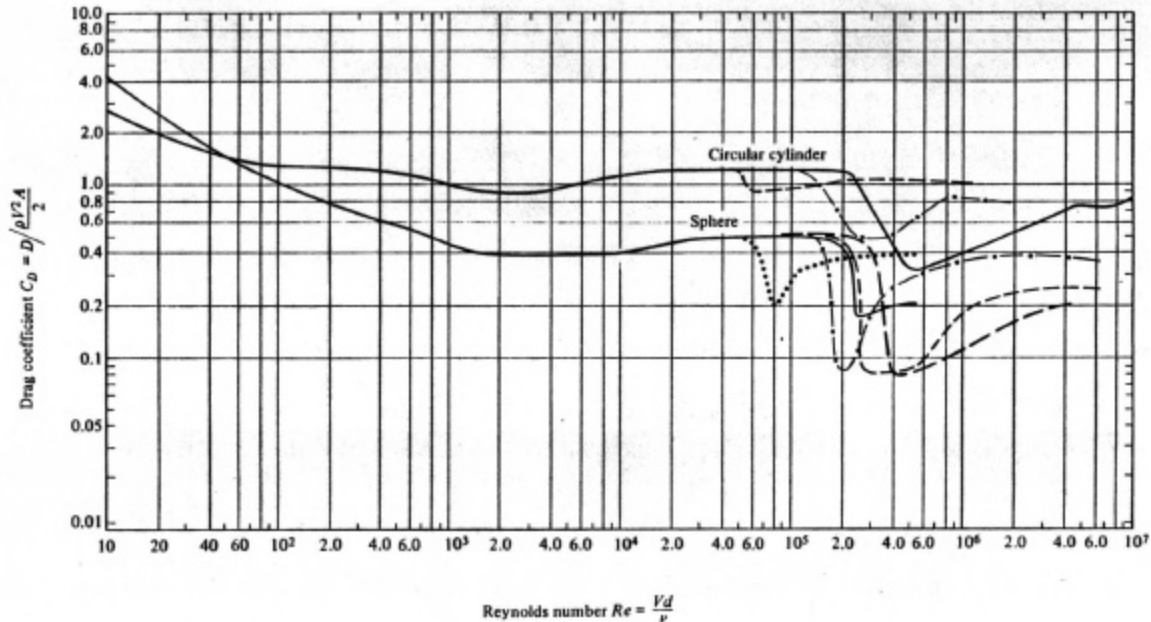


## MEEG 630, Intermediate Fluid Mechanics

### Homework Set #10: Flows over circular bodies and turbulence

Note: For problems 1, 2, and 3 below, you may use the drag coefficient curves shown in the following figure:



Drag coefficients for a sphere and a cylinder as a function of Reynolds number. The Reynolds number is based on the diameter, and  $A$  is the projected area normal to the flow. The data are taken from References [9], [10], and [11]. The solid lines are for smooth surfaces. For the cylinder, the dashed line corresponds to a roughness ratio  $k/d = 9 \times 10^{-3}$ ; the dash-dot line to  $k/d = 1 \times 10^{-3}$ . For the sphere, the dotted line corresponds to  $k/d = 17.5 \times 10^{-3}$ ; the dash-dot line to  $k/d = 1.5 \times 10^{-3}$ ; and the long dash line to  $k/d = 0.25 \times 10^{-3}$ . The short dash lines are a second set of experimental results for a smooth sphere, indicating the range of variation of available data.

1. Electrical transmission towers are stationed at 400-m intervals and a smooth conducting cable 1.3 cm in diameter is strung between them. If a 30 m/s wind is blowing transversely across the wires, compute the total drag force on one such wire in between two towers. The drag coefficient  $C_D$  for a cylinder is defined by the equation

$$C_D = \frac{\text{drag per unit length of cylinder}}{\frac{1}{2} \rho U^2 d},$$

where  $d$  is the diameter of cylinder. For air assume that the kinematic viscosity  $\nu = 1.5 \times 10^{-5} \text{ m}^2/\text{s}$  and that the air density  $\rho = 1.2 \text{ kg}/\text{m}^3$ .

2. A toy balloon is filled with hydrogen and inflated to a diameter of 0.3 m. The balloon is then allowed to escape and after a few seconds has reached a steady condition. The height at which this occurs is such that normal atmospheric conditions may be assumed. The weight of the balloon (including the skin as well as the gas inside) is equal to one-tenth of the displaced atmospheric air. Find the steady rise rate of the balloon.

3. Think of at least three examples of turbulent flow, and describe, for each case in your own words, how the flow is generated and maintained.
4. A mass of 10 kg of water is stirred by a mixer. After one hour of stirring, the temperature of the water rises by  $1^{\circ}\text{C}$ . What is the power output of the mixer in watts? What is the size  $h$  of the dissipating eddies?
5. Calculate the zero-lag cross-correlation  $\overline{u(t)v(t)}$  between two periodic series  $u(t) = \cos \omega t$  and  $v(t) = \cos(\omega t + \mathbf{f})$ . For values of  $\mathbf{f} = 0$ ,  $\mathbf{p}/4$ , and  $\mathbf{p}/2$ , find the correlation coefficient between  $u(t)$  and  $v(t)$ . Also plot the scatter diagrams of  $u$  versus  $v$  at different times.