ENGS-37 **Fall 2008**

INTRODUCTION TO ENVIRONMENTAL ENGINEERING

HOMEWORK #3

Assigned: Friday 10 October 2008
Due: 10:00 a.m., Friday 17 October 2008

1. (10 points) (Modified from Nazaroff & Alvarez-Cohen, Problem 4.6, pages 202-203) A smokestack of height H = 50 m emits a pollutant in a 3 m/s wind. The plume is carried downwind by advection (speed U = 3 m/s) and is simultaneously dispersing vertically with a turbulent diffusion coefficient D. The vertical diffusion causes the plume to widen vertically over time, with half-width (distance from centerline to edge) increasing as

$$\text{half width} = 2\sqrt{2Dt}\ .$$

The plume reaches the ground some distance L downwind of the base of the smokestack (see sketch in book on page 203).

(a) (5 points) If L = 2 km, estimate the value of the turbulent diffusion coefficient D.

(b) (3 points) Under the same wind speed and turbulence conditions, what would be the value of L if the smokestack were twice as high?

2. (10 points) A dusty airflow contains particles 8 μm in diameter and of density equal to 1800 kg/m^3. Design a conventional cyclone of standard proportions (Lapple type) that will remove 90% of these particles when the airflow is 2.5 m^3/s. In particular, what should be the values of the body diameter (D), inlet height (H), inlet width (W) and total height ($L_b + L_c$)?
A useful number in this context is: Air viscosity = μ = 1.80 x 10^{-5} kg/(m.s).

3. (10 points) Consider the removal of particles by a cyclone as illustrated in the example of the hand-out titled "Cyclones" on the course's web site. Everything else remaining unchanged, including the same total flow rate of air, what would be the new overall collection efficiency (η) if the width of the inlet were reduced by 25%? Compare this to the current value (70.6%) and explain in a few words why the efficiency increases or decreases?

4. (10 points) Determine the total plate area required for a 97% efficient electrostatic precipitator that is treating 150 m^3/s of dusty air. Air viscosity is 1.80 x 10^{-5} kg/m.s and the electrical field is 8 x 10^5 V/m. Assume that half the particles (on a mass basis) have a diameter of 0.50 μm and the other half 0.60 μm. All acquire a charge of 4 x 10^{-18} C.