ME 637 **FINAL EXAM**

1. (30 points) Suppose that the turbulent diffusivity near the wall is given as

$$\nu_T^+ = 0.02y^+$$

Assume that the concentration is C_o at $y^+ = 30$ and vanishes at the stopping distance of particle at $y^+ = \tau^+$.

i) Evaluate the expression for the deposition velocity and the corresponding concentration profile. Use your formula and evaluate the deposition velocity for 10 μm particles.

ii) Compare your solution for the deposition velocity with that given by the empirical equation of Wood for 10 μm particles. (Assume a kinematic viscosity of $1.5\times10^{-5}\ m^2/s$, S=2000, a shear velocity of 0.3 m/s and a temperature of 300 K.) (λ=0.07μm)

3. (30 points) Consider a cloud of 9 μm quartz particles with a concentration of 10^5 particles per cm^3.

i) Find the average absolute number of charge for the equilibrium Botzmann distribution.

ii) Determine the number of particles that will carry 5 positive charges. How many will carry no charges in this case?

iii) Find the number of charges on the particle for the saturation condition in a field of 1000 volt/cm.

iv) Find the electrostatic precipitation velocity for a field of 1000 volt/cm for the mixtures with the average absolute charge distribution, and for the quartz particles that carry the saturation field charge. (The density of air is 1.2 kg/m^3, the density ratio of quartz particle to air is 2000, and for quartz $\varepsilon_p = 4.3$.)

4. (40 points) The instantaneous velocity and vorticity in turbulent flows satisfy the following equations:

$$\frac{\partial u_i'}{\partial t} + U_j\frac{\partial u_i'}{\partial x_j} + u_j'\frac{\partial U_i}{\partial x_j} + u_j'\frac{\partial u_i'}{\partial x_j} = -\frac{1}{\rho}\frac{\partial p'}{\partial x_j} + \nu\frac{\partial^2 u_i'}{\partial x_j \partial x_j} + \frac{\partial \overline{u_i'u_j'}}{\partial x_j}$$

$$\frac{\partial \omega_i'}{\partial t} + U_j\frac{\partial \omega_i'}{\partial x_j} = -u_j'\frac{\partial \Omega_i}{\partial x_j} - u_j'\frac{\partial \omega_i'}{\partial x_j} + \Omega_j d_{ij}' + \omega_j' D_{ij} + \omega_j' d_{ij}' + \nu\frac{\partial^2 \omega_i'}{\partial x_j \partial x_j} + \frac{\partial \overline{\omega_i' u_j'}}{\partial x_j} - \overline{\omega_j' d_{ij}'}$$

i) Develop a transport equation for velocity-vorticity correlations ($\overline{u_i'\omega_j'}$).

ii) Identify various terms.

iii) Evaluate the order of terms in terms of u, λ, Λ.

iv) Propose a closure model.