ATS 620 Example Final Exams

Final Exam (Fall 2007)

1. (20 points)
This question relates to raindrop growth.

a. Develop an expression that describes the rate (dr1/dt) that a raindrop of radius r_1 grows continuously by collecting small cloud drops present in a concentration of n with size r_2. Define all symbols that you introduce. State assumptions as well, if any.

b. Why is this particular expression only an approximation for actual raindrop growth? By what process is raindrop growth more accurately calculated?

c. Describe the basic shape of raindrops with radii greater than 1 mm.

d. Why is it observed that raindrops typically have a maximum size of 8 mm or so?

e. Why is the fallspeed of very large raindrops essentially independent of size?

2. (25 points)
This question addresses the non-inductive (precipitation) mechanism for the electrification of clouds. Begin by discussing how charge separation operates on the scale of individual hydrometeors. Integrate the concepts of an electrical double layer and a quasi-liquid layer in your discussion. Discuss the relationships between the sign of charge on riming ice particles when their surface states are in deposition, sublimation and wet growth regimes, respectively. Finally, discuss how this non-inductive mechanism could lead to the formation of dipole and tripole charge structures in thunderstorms.

3. (20 points)

a. Derive an expression for the relative humidity over a spherical droplet of radius r containing m grams of salt, with molecular weight M. Let Mo represent the molecular weight of water. Let ρ' represent the densit of the solution. Define any other symbols you introduce.

b. for a dilute solution, derive a simpler form of the expression derived in (a). Identify the solute term and curvature term. You will need to make use of te following series expansions:

$$e^x \cong 1 + x + \frac{x^2}{2!} + \ldots$$

$$(1+x)^{-1} \cong 1 - x$$

c. Using the expression derived in (b), derive expressions for the droplet radius r* and critical supersaturations s* located at the peak of the particular Köhler curve.

d. Define concepts of a haze droplet and an activated droplet. Indicate the locations of these states on a generic Köhler curve plot.

4. (20 points)
An ice crystal is growing by vapor deposition in a water-saturated environment at a temperature of -12 C.

a. What is the expected shape of the ice crystal under these conditions?

b. .List and describe the physical mechanisms that must be invoked to calculate dm/dt, where m is the mass of the ice crystal and t is time. Note: You do not have to necessarily derive equations to successfully answer this question.
c. Consider the following hypothetical situation. Assume all variables are constant, event he degree of water saturation, but suddenly the crystal starts growing at -20 C. Does it grow faster or slower at -20 compared to -12 C? Why?

5. (15 points)
a. Assume giant CCN (GCCN) are introduced into a cloud that forms in a very "clean" environment, with a background CCN concentration of 50 cm^{-3}. What impacts might the GCCN have on the development of drizzle sized drop? Assume the summit temperature of the cloud is 0 C.

b. Now let the same situation occur in an environment with background CCN concentrations of 1000 cm^{-3}. What impact might the GCCN have in this case?

Example questions from various prior exams:

1. Ship track clouds are found to be brighter or more reflective than surrounding clouds. They are also found to exhibit higher liquid water contents and in some cases are deeper than surrounding stratocumulus clouds.

a. Explain how ship track clouds can be more reflective than surrounding stratocumulus clouds.

b. Describe and discuss how ship track clouds can exhibit higher liquid water contents.

c. Describe and discuss how ship track clouds can be sometimes deeper than surrounding stratocumulus clouds.

2. Describe, discuss and critique each of the following concepts for suppressing hail damage:

a. The glaciation concept.

b. The embryo competition concept.

c. Early rainout and/or trajectory lowering concept.

3. Thunderstorm / Cloud Electrification

a. Provide a simple plot of a cloud showing the "typical" tripole charge structure of a thunderstorm. Include a temperature scale.

b. Explain the key differences between convection charging theory and particle charging theory.

c. Provide a physical explanation / description for both induction and non-induction charging theories.

d. Suppose a hailstone is undergoing dry growth at -5 C in an environment rich in ice crystals. Based on the charge-reversal mechanism, would one expect the hailstone to become positively or negatively charged?

4. Consider a graupel particle growing by both riming and deposition. The accreted supercooled droplets freeze, releasing the latent heat of fusion that raises the temperature of the graupel particles. Thus reduced the growth rate by deposition and, with a sufficiently large accretion rate (i.e., liquid water content), may effectively stop growth by deposition. Considering the equations for riming and deposition growth, along with the conduction of heat to the environment, formulate an expression for the critical liquid water content that just stops growth by deposition. (Hint: Consider the deposition equation to be of the form,

$$\left(\frac{dm}{dt}\right)_d = 4\pi C D_v(\rho_{v,s} - \rho_{v,o})$$

where C is the capacitance, D_v the diffusivity and the term in parentheses is the water vapor density difference between the ambient air and the surface of the crystal.