PHYSICS 535, Spring 2016 – HOMEWORK #5 Due 3/11/2016

Readings –

1) P. Krehbiel, J. Riousset, V. Pasko, R. Thomas, W. Rison, M. Stanley, H. Edens, "Upward Electrical Discharges from Thunderstorms', *Nature Geoscience,* Published online: 23 March 2008; doi:10.1038/ngeo162.

2) P. Krehbiel, et al., Supplement to "Upward Electrical Discharges from Thunderstorms', *Nature Geoscience,* Published online: 23 March 2008; doi:10.1038/ngeo162.

Do Article Summary and Questions for Article #1 only. Article #2 is provided for reference for problems 5

Article summaries should include what YOU think were the most important points in the chapter. If one section contained most of what you found valuable, you can focus on that section.

Article Questions –

In addition to your summary, pose two questions raised by each of the readings suitable for homework or class discussion. You should know how to answer one of these questions.

PROBLEM SET #5

For your reference in problems 4-2, 4-3, 4-4, I have posted Storm20160224_HW5.html. It contains all the functions I wrote, as well as descriptions of what they are supposed to do. I included code for some of the trivial ones (like print_simple, and LogData) to save you some time. You have to write the code for the rest ... and you are free to structure your program any way you like.

5-1) Beginning with the continuity equation for charge density and Gauss's law in differential form, arrive at an expression for charge density as a function of time in a medium with uniform conductivity. If the conductivity if the air at the top of a thunderstorm is $\sigma = 2 \times 10^{-12} (\Omega\, m)^{-1}$, how long would it take screening charge to decay to 1/e if there were no charging current? If the conductivity in a cloud is $\sigma = 1 \times 10^{-15} (\Omega\, m)^{-1}$ how long would it take a thunderstorm to dissipate without charging currents (and without any advection or convection!!)

5-2) Extend your model from problem 4.2 (I recommend making that whole thing a function you can call in a loop). Use the same initial conditions as last week (you can also find them in the function StormInit posted as part of theStorm20160224_HW5.html. Include charging currents (in Amperes) suggested in the Krehbiel article.

```
I_MNLP=0.1;
I_MNUP=1.5;
I_UPSC=0.31;
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Create and submit 3 figures with 10 second time steps showing how the storm charges.
(I gave you the absolute value of the currents ... Make sure the sign is right so that the charging is realistic ... refer to the article for confirmation)

5-3) Include a calculation of breakdown field vs. altitude using the formula suggested in the article. Include the breakdown field on your plot. You only need to plot the initial state of the storm.

5-4) Add a logging function and run your simulation for 10 steps. Generate a log file which shows how your charges are changing with time. (Feel free to use my logging function). You don't yet have flashes in your simulation.

5-5) Add a function that decides when there should be a lightning flash based on the criteria of the article. Also, let the lightning flash change the values of charges as suggested in the article. Run your storm for at least 20 time steps (5 seconds might be a good step time) and submit the log which should now include flash type (or 'NF' for no flash). Also submit two sets of figures, one immediately before and after an IC, and one before and after a CG.
[To debug this function, I first wrote a script that "told" the storm what kind of flashes it was going to have, and then made sure it rearranged the charges properly. I then added the ability for the storm to decide what kind of flashes to have. So you might want to do this part in two steps.]

5-6) Replace the constant screening current (I_UPSC) with a screening current you calculate yourself that varies as the field above the thunderstorm varies.
At each time step, the current has two components. The screening charge decreases proportional to itself. (You can use 60 seconds for the time constant). Also, the total field at the very top of the screening charge causes a charging current density (J=sigma E) which varies as the total electric field above the storm changes. (Usually the charging current will make the negative screening charge more negative, but sometimes it will briefly change sign as the storm charges readjust below it.)
Run for at least 20 time steps and submit the log again. The log should include a column for screening current.

5-7) Let your storm run. See what you get. Have fun. We'll keep exploring this model now that you have made it work.