Physics Comprehensive Exam
Atmospheric Electricity Section

Do 3 of the following problems

1. Field Reversal Distance

Assume a thunderstorm exists with a dipole charge structure. It has a -40C charge at 5 km above ground and a $+40$C charge at 8 km above ground. This storm is 20 km due west of you. It is moving due east at 20 m/s. Assume that the charge structure does not change with time.

(a) Derive the expression for the field at your location.

(Numerical values)
(b) What is field at your location at $t = 0$?

(c) At what time does the field go to 0?

(d) At what time does the maximum *fair weather* field occur, and what is its value?

(e) At what time does the maximum *foul weather* field occur, and what is its value?

2. Electric Field Enhancement

A spherical balloon, with radius r and a highly conductive surface, is placed in a uniform electric field.

(a) What is the relative electric field strength and surface charge density at various points around the balloon?

(b) What is **E** at the center of the balloon?

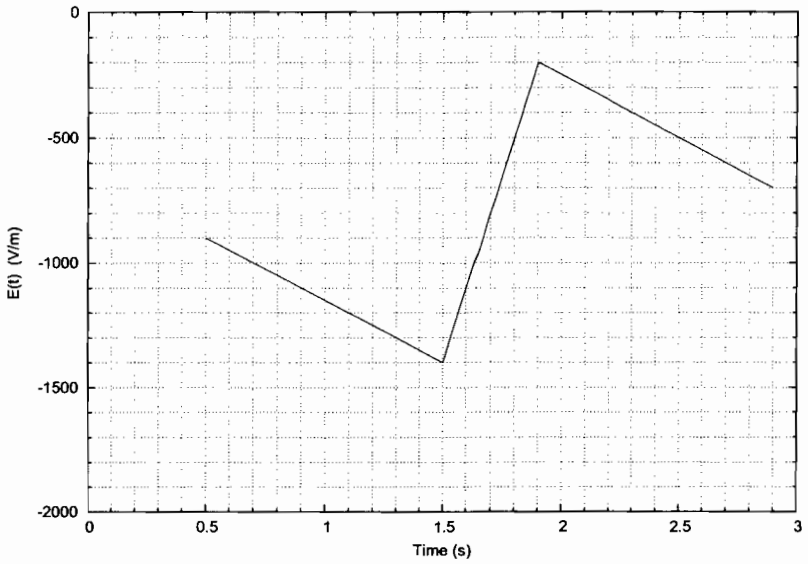
(c) If the balloon rose to a higher altitude in the Earth's atmosphere but **E** was still uniform, how would this affect the balloon and the electric field at the surface of the balloon?

(d) What modifications would you make to the balloon to enable **E** measurements? Discuss some of the problems and ramifications.

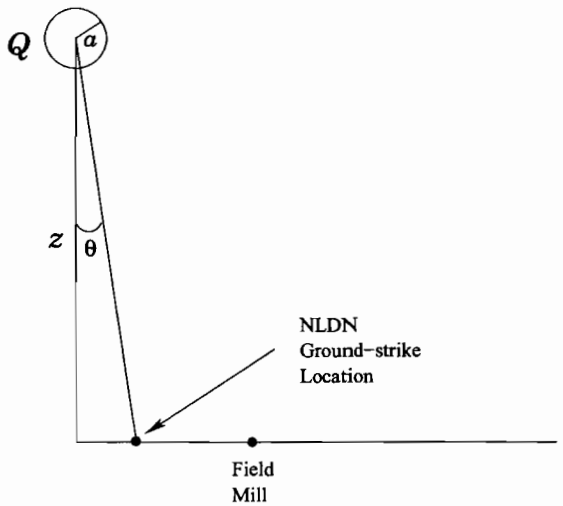
3. Charge Retrieval

A ground flash occurs near a ground-based field mill.

(a) From the given field mill record, compute the lightning-caused field change, ΔE (begins at 1.5 s on the graph).



This flash effectively deposits a charge (Q) in the cloud at an altitude of 7 km. The ground-strike location is reported at a point 2 km from the field mill. A Lightning Mapping Array also sensed the flash, which was essentially straight, but inclined at an angle of 8.13° from vertical.



(b) How much charge was deposited by this flash?

(c) Assuming that the breakdown strength of air at 7 km is 300 kV/m, what are the dimensions of the charge volume?

(d) Assume that the charge is distributed uniformly throughout the volume. What is the charge density of this volume?

4. THUNDERSTORM FIELDS

For the given data:

(a) Plot the electric field profile (**E** horizontal, z vertical),

(b) Calculate the thickness and density of the space charge layers,

(c) Label each layer and (thunderstorm) feature.

(d) Use Paschen's Law (approximated by $V = 0.003p + 1350$) to estimate the breakdown strength of air across a 1 mm gap. p is pressure in mbar.

(e) At any point in this storm, do we get close to breakdown, according to Paschen's law? If not, how much geometrical enhancement would be required by hydrometeors to get to breakdown? Is a sphere "enough"?

E (kV/m)	Alt (km)	Pressure (mbar)	Feature
0.5	0.5	1000	Release
0.5	2.0	950	Cloud Base
0.5	2.5	920	
60	3.6	810	
−130	3.8	800	
50	5.5	700	
−2	7.0	600	
−2	10.0	500	Terminate data