ATMO 489/689
Radar Meteorology
Fall 2005
STUDY GUIDE – Exam #1

Date: Friday, 9/30/05
Time: Class period: 50 minutes, 12:40 – 1:30 PM. Please arrive a few minutes early to allow time to hand out exam.
Location: O&M, Room 1210
Type: Closed book and notes. *You must work independently!*

Form of Exam: Approximately three major questions with sub-parts. Midterm exams can be a mixture of objective (e.g., multiple choice, true/false) and/or subjective (e.g., short answer/definition, problem solving, derivation) questions. A typical midterm might include 1) multiple choice/true-false questions (10 minutes, 20%), 2) short answer questions (20 minutes, 40%), and 3) a problem solving/derivation question with sub-parts (20 minutes, 40%).

Material Covered: - Lecture notes, lab notes, and web-page lecture materials (Chapters 1-3) from 8/29/05 to 9/27/05, inclusive.
- Lab assignments # 1 and 2.
- Assigned reading from the class text book, Rinehart (2004) – Chapters 1, 2, and 3 and Appendix A.

Instructional/Learning Objectives

1) Outline an abbreviated history of the beginnings of radar meteorology.
2) List some common radar meteorological applications.
3) Define and describe the application of Doppler and polarimetric properties of electromagnetic waves to radar meteorology.
4) Identify and describe bistatic versus monostatic radar configurations.
5) Define, compare, and contrast continuous wave versus pulsed radars.
6) Define the pulse repetition time (PRT) and pulse repetition frequency (PRF) and list a simple mathematical relationship between the two parameters.
7) Define the pulse duration and pulse length and list a simple mathematical relation between the two parameters.
8) Identify and describe PPI (Plan Position Indicator) and RHI (Range Height Indicator) radar operations. Interpret PPI and RHI displays.
9) Identify the advantages and disadvantages of PPI and RHI scan operations.
10) Define and differentiate a PPI (or RHI) full volume scan mode from a PPI (or RHI) sector volume scan mode.
11) List a range of typical angular rotation rates for a PPI or RHI scan.
12) Calculate the time required for a single PPI or RHI sector scan given the angular rotation rate and sector size.

13) Estimate the time required for a multi-tilt PPI or RHI sector scan volume, if given the angular rotation rate, sector size, and the antenna time delay (i.e., time to decelerate, change elevation (or azimuth) angle, and accelerate again).
14) Derive an expression for the maximum unambiguous range (R_{max}) for a pulsed meteorological radar as a function of the PRF and speed of light (c). Use the equation to calculate R_{max}.
15) Explain and demonstrate using a quantitative example why it is safe to assume that a rotating radar is quasi-stationary during the measurement of weather echo from a single radar pulse.
16) Identify and describe the primary function(s) of the key components of a radar system (e.g., transmitter, waveguide, duplexer, receiver, modulator, computer/signal processor, waveguide, antenna, reflector, feed horn, and display).
17) In layman's terms, explain how these radar components function together to transmit, receive and process electromagnetic radiation in order to produce useful meteorological information.
18) Compare and contrast two different types of common radar transmitters (e.g., magnetron and klystron).
19) Define and describe the purpose of a rotary joint.
20) Identify the direction of the electric and magnetic field in a waveguide or feed horn.
21) Define power in terms of the relative logarithmic scale, decibels (dB). For example, define power in terms of dBm.
22) Define the dynamic range, minimum detectable signal (MDS) and saturation power of a radar receiver. List a simple mathematical relationship between the three parameters and calculate one, if given the other two. List a typical range of values for each parameter.
23) List and describe three different types of commonly used antenna systems for meteorological radars.
24) List the three basic characteristics of an antenna system.
25) Differentiate between a reflector dish and an antenna. Identify the most common form of antenna for meteorological radars.
26) Define a directional versus an isotropic antenna.
27) Define and describe antenna gain.
28) Define and describe the half power (or 3-dB) beamwidth of an antenna system.
29) List the mathematical relationship of gain to beamwidth, reflector diameter, and wavelength. Calculate antenna gain from beamwidth or from wavelength and reflector size (or vice versa) for a circular parabolic reflector. Or, given various scientific and hardware constraints, design an "ideal" antenna system.
30) Given a Gaussian expression for gain, calculate antenna gain as a function of the angular displacement from the bore-sight (or center axis of the reflector).
31) Define an antenna radiation pattern. Define the main and side lobes of an antenna.
32) Describe typical idealized (i.e., without side lobes), modeled, and measured radiation patterns of a typical weather radar antenna.
33) Identify and describe the source of problems associated with antenna side lobes in both receive and transmit mode.
34) List the relationship between the speed, wavelength, and frequency of an electromagnetic wave. Calculate one parameter if given two of the others.

35) List the electromagnetic spectrum and band designations associated with meteorological radars, identify different operational and research radars in each band and describe their broad meteorological applications.
36) Define the electric and magnetic fields. Draw the electric and magnetic flux lines, if given a dipole or conducting current, respectively.
37) Describe (i.e., with words and a sketch) the co-evolving relationship between the oscillating charge density, voltage difference, and current in a half-wavelength antenna. Describe (in layman's terms) how these oscillations create an induction and radiation field.
38) Show that if energy per unit area is conserved, then energy of a spherical electromagnetic wave is proportional to $1/(\text{range})^2$ (i.e., inverse square law).
39) Define the Poynting Vector both mathematically and descriptively.
40) Define the refractive index and refractivity. List typical values for both.
41) Using Snell's law, demonstrate that radar waves typically bend downward in most meteorological conditions.
42) Define curvature of a circle both descriptively and with an equation.
43) List an equation for the curvature of a radar ray relative to the earth's surface.
44) Describe the apparent effect of earth curvature on the radar beam relative to the earth's surface. Given the equation for H, calculate the height (H) of the radar beam assuming curvature effects only (no atmosphere – no refraction).
45) Define an effective (or fictitious) earth radius (R′) that accounts for radar ray curvature associated with both actual earth curvature and vertical changes in the refractive index.
46) Given a profile of refractivity (N) with respect to height (H) in a layer, calculate the effective (or fictitious) Earth's Radius (R′).
47) Describe the propagation environment for radar waves in the atmosphere. Calculate the refractivity (N), vertical refractivity gradient (dN/dH), and actual radar beam height (H) from provided meteorological data in the vertical (e.g., pressure, temperature, and vapor pressure), if given equations for N and H.
48) Explain how temperature (T), pressure (P), and vapor pressure (e) affect the propagation of radar waves. Determine the refractivity conditions with and without moisture and discuss implications for radar wave propagation.
49) Define standard refraction. Describe the 4/3R model for standard atmospheric conditions. Given an equation for H, calculate the radar beam height (H) assuming standard refraction.
50) Identify and describe two models of standard refraction. For the linear model, list the value of dN/dH for standard refraction. Note: It is *not* necessary to memorize the equation for the exponential model.
51) Define and describe sub-refraction and super-refraction.
52) Using calculations of the refractivity gradient, determine whether a radar wave would experience standard or non-standard refraction in a given layer. Identify the type of non-standard refraction and explain how a radar beam would behave relative to the same wave in a standard atmosphere.
53) Identify meteorological conditions associated with non-standard refraction.