The exam will be a close book exam. You will have whole 75 minutes. Exam composition: Part I: Fill in the blank with multiple choices (40 questions, 1 point each, 40/100); Part II: Sketch, Explain, Brief Essay, or Solving Problems (total 8 questions and choose 6 to answer, 10 points each, 60/100); one challenging question (for 10 points extra credit). No derivations, no complicated calculations (except for the challenging question). Majority of the questions are explanatory and based on notes online. Bring pencils, erasers, and a scientific calculator (calculator is needed only for the challenging question).

LECTURE 1: Overview of remote sensing
1. In-situ vs. remote sensing (slides #3 &6): Definition of each; difference between them; Examples
2. Active vs. passive remote sensing (slides #12-13): Definition of each; difference between them; Examples

There will be one part II question based on all of above.

LECTURE 2: No questions

LECTURE 3: Atmospheric radiation basics
3. Definitions of shortwave and longwave radiation; their frequency bands (slides #4-5).
4. Definition and characteristics of EM waves (slides #6-8).
5. Definitions of frequency, wavelength, and wavenumber (slides #9-10).
6. Understanding Planck-Einstein equation E=hf (slide #12).
7. Solid angle: definition (no derivation), the solid angle for a whole sphere is 4π (slides #15-16).
8. What is polarization (slide #25-27)

LECTURE 4: EM spectrum
9. Which bands are important to remote sensing? Visible, IR & microwave. Need to know the wavelength range & why they are important. (slides #15, 18, 23)

LECTURE 5: Emission
10. Definition of emission (page #1).
11. Definition of blackbody (page #1).
12. Know what the Planck Function tells us: B (T) is a function of wavelength and temperature (page #2).
14. Definition of emissivity (page #5).
15. Definition of graybody (page #6).
16. Definition of brightness temperature Tb. Characteristics of Tb at IR and microwave bands, respectively (page #7).

Part II question.

LECTURE 6: Absorption
17. Definition of absorption (page #1).
18. Physical explanation of emission and absorption using the Quantum theory. Know how to sketch the interaction between photon and electron during emission and absorption processes (page #1, part II question).
19. Kirchhoff’s law: what it says, and when it is valid (page #3).
20. Lambert’s law: understand what it tells us (the fractional energy absorbed from the radiation is proportional to the mass traversed by the radiation) (page #4-5).

LECTURE 7: Scattering
21. Definitions of scattering (page #1).
22. Physical explanation of scattering using the Quantum theory. Know how to sketch the interaction between photon and electron during the scattering process (page #1, part II question).
23. Size parameter. Define Rayleigh, Mie, and Optics scattering regimes using the size parameter (page #2, slide #2).
24. Difference of the angular distribution of scattering for Rayleigh and Mie regimes (page #3).
25. Definition of extinction (page #3).
**LECTURE 8: Radiative transfer equation**

26. Know which processes we need to consider in getting the radiative transfer equation, i.e., what are terms A, B, C, and D. Which are depletion terms, and which are source terms (page #1, part II question).

27. Non-scattering radiative transfer equation: valid in which regime (page #4).

28. Non-emission radiative transfer equation: valid in which regime (page #4).

**LECTURE 9: Reflection and refraction**

29. Definition of the complex index of refraction. What is the real part describing? What is the imaginary part describing? Which part is responsible for reflection and refraction? Which part is responsible for absorption? (slides #3-4)

30. Sketch the relationship between incident angle and reflection angle (these angles are equal). (slide #6-7 part II question)

31. Sketch the relationship between incident angle and refraction angle given the refractive indices of the two media such as air & water (know which angle is larger) (slide #8, part II question)

32. In atmospheric radiative transfer, under what condition do we need to consider the processes of reflection and refraction and use ray tracing (geometric optics) to solve radiative transfer problems? In contrast, under what condition do we need to consider scattering and use Mie/Rayleigh theory to solve radiative transfer problem? Know 1 or 2 examples for each condition. (slide #2 & #10; part II question)

33. Explain rainbow: what is responsible for the primary rainbow? Single internal reflection. (slide #14)

**LECTURE 10: Rayleigh and Mie scattering**

34. Understand the 3 key facts derived from Rayleigh solution (part II question):
   a. For a fixed wavelength, larger particle will scattering more strongly (6 power of the radius or diameter). This is the basis of weather radar (slide#15).
   b. Explain why the sky is blue (slide #16).
   c. The fact relevant to passive microwave remote sensing of cloud water: absorption is proportional to mass path, independent on particle size (slide #17).

35. Mie solution: understand Petty’s book Fig. 12.4 a. extinction efficiency Q->2 for large size parameter (slide #18-19).

**LECTURE 11: Radar hardware**

36. Antenna: directional in order to locate targets in space (slide #10).

37. What determines the shape of the radar antenna beam pattern? (slide #11)

38. What is the true antenna? (slide #14)

39. Functions of transmitter, receiver, duplexer, signal processor. (slide #5, 22, 23, 29)

**LECTURE 12: Curvature and refraction, radar equation for point targets**

40. Sketch how the radar wave propagates relative to the Earth curvature under standard refraction, sub-refraction, and super refraction conditions. (slide #15; 18-19, part II question)

41. Definition of ducting. (slide #18)

42. In Rayleigh, Mie, and Optics regimes, how does the radar back-scattering cross section relate to the target (particle)'s size/diameter/geometric area. (slide #26, 29, 30)

**LECTURE 13: Radar pulse Characteristics and Radar equation for distributed targets**

43. Definitions of pulse length, listening time, range resolution, Pulse Repetition Frequency (PRF). (page #1-2)

44. What determines the minimum range that radar could detect? (page #1)

45. What determines the maximum unambiguity range that radar could detect? (page #2)

46. Definition of radar reflectivity factor. (page #5)

47. Derive the radar sample volume (page #3), and understand Fig. 3.7 of the radar book (lec12 slide # 16). Part III extra credit question.