ECEG 390 Theory and Applications of Electromagnetics Spring 2025

##### Representative Topics for Individual Investigation Assignment



For this assignment, you must select a topic or task within the scope of the course but not included in the material that will be covered in the lectures. You may choose a topic in a portion of the textbook not covered by the course or one that is not included in the textbook. To help you get started, I am providing the following list of representative topics. You may choose a topic from this list, but you do not have to. If you choose another topic, be sure to get my approval before you begin work.

Remember that the primary purpose of this exercise is to demonstrate that you have developed a deep understanding of a topic relevant to the course beyond the regular classroom coverage. You should acquire enough knowledge about the topic to achieve one of the following:

1. Carry a derivation to a more technically sophisticated level,
2. Apply theory to a challenging real-world problem, or
3. Provide some other evidence of your thorough understanding of the technical details of a very focused topic in the area of electromagnetics.

Note that several topics listed below involve derivations. If you choose one of those topics, the derivation that you present must include details that go well beyond what the textbook provides, and you must demonstrate a deep understanding of the derivation. Derivations that are well developed in the textbook should be avoided unless you plan to provide one or more insights that the textbook omits.

Examples of Acceptable Topics **(Updated 8:10 pm on Apr. 17, 2025)**

The label “TAKEN” next to a topic means that someone else has chosen it for their presentation. It is therefore no longer available.

1. **[TAKEN]** Derive the formula for the transmission line parameter *L*′, the inductance per unit length, for a coaxial line.
2. Derive the formula for *L*′ for a two-wire line. (If necessary, you may assume (*D*/*d*)2 >> 1.)
3. **[TAKEN]** Derive the formula for the transmission line parameter *C*′, the capacitance per unit length, for a coaxial line.
4. **[TAKEN]** Derive the formula for *C*′ for a two-wire line. (If necessary, you may assume (*D*/*d*)2 >> 1.)
5. **[TAKEN]** Derive the formula for the transmission line parameter *R*′, the resistance per unit length, for a coaxial line.
6. Derive the formula for *R*′ for a two-wire line. (If necessary, you may assume (*D*/*d*)2 >> 1.)
7. Derive the formula for the transmission line parameter *G*′, the conductance per unit length, for a coaxial line.
8. Derive the formula for *G*′ for a two-wire line. (If necessary, you may assume (*D*/*d*)2 >> 1.)
9. Explain the derivation of the formula for *r*-circles (called *rL*-circles in the textbook) on the Smith chart. (This topic is not available to students who have taken or are taking ECEG 497.)
10. Explain the derivation of the formula for *x*-circles (called *xL*-circles in the textbook) on the Smith chart. (This topic is not available to students who have taken or are taking ECEG 497.)
11. **[TAKEN]** Explain how to use the Smith chart to design a single-stub matching system with a series element. The chart must be used to determine the distance from the load at which the stub must be placed, and it must be used to determine the stub length. (This topic is not available to students who have taken or are taking ECEG 497.)
12. **[TAKEN]** Explain how to use the Smith chart to design a single-stub matching system with a shunt stub. The chart must be used to determine the distance from the load at which the stub must be placed, and it must be used to determine the stub length. Immittance charts, which include g/b circles as well as r/x circles, are available upon request. (This topic is not available to students who have taken or are taking ECEG 497.)
13. Explain how to use the Smith chart to design an LC (inductor-capacitor) impedance matching system. I have some supplemental reading material that I can send to anyone who chooses this topic. (This topic is not available to students who have taken or are taking ECEG 497.)
14. Produce a bounce diagram to describe transient signal propagation along a transmission line with arbitrary source and load impedances. (Limiting to real load impedances is okay.)
15. Derive the transformation equations to express each of the unit vector components in one coordinate system in terms of the unit vectors in another coordinate system and vice versa. Coordinate systems must be limited to Cartesian, spherical, or cylindrical. (e.g., express , , and  as functions of , , and  and vice versa.)
16. Derive the formula for the input impedance of a **lossy** loaded transmission line:

, where  and *Z*0 is complex,

and discuss one or more important general or specific implications of it.

1. Derive the general formula for the array pattern of a phased array antenna with uniform excitation current magnitudes, uniform element-to-element phase shift between excitation currents, and uniform element spacing. (This topic is not available to students who have taken or are taking ECEG 497.)
2. Explain how magnetic sails propel spacecraft. Include some type of derivation of the velocity obtained after a given amount of exposure to the solar wind.
3. **[TAKEN]** Explain how electric sails propel spacecraft. Include some type of derivation of the velocity obtained after a given amount of exposure to the solar wind.
4. Derive the mutual inductance between two flat solenoids. This topic is applicable to the theory underlying how some wireless readers and wireless chargers work.
5. Derive the mutual inductance between two cylindrical solenoids. This topic is applicable to the theory behind how transformers work as well as the emerging field of wireless power.
6. **[TAKEN]** Derive the far electric field radiated by a uniformly illuminated rectangular aperture (applies to horn antennas).
7. Derive the far electric field radiated by a microstrip antenna. (Applying significant simplifying assumptions is okay. This topic is not available to students who have taken or are taking ECEG 497.)
8. **[TAKEN]** Derive an expression for the input impedance of a microstrip antenna. (Applying significant simplifying assumptions is okay. This topic is not available to students who have taken or are taking ECEG 497.)
9. **[TAKEN]** Derive the monostatic radar equation. Be prepared to explain how variables such as path loss, antenna polarization, and incidence angle relative to the target affect the computation of the returned radar signal.
10. Show that a linearly polarized plane wave can be expressed as the superposition of a left-hand circularly polarized wave and a right-hand circularly polarized wave. Explain which aspects of the circularly polarized waves control the orientation of the E-field vector of the linearly polarized wave.
11. Derive the field expressions, cut-off frequency formula, and propagation constant formula for the TM (transverse magnetic) modes of a rectangular waveguide.
12. Derive the field expressions, cut-off frequency formula, and propagation constant formula for the TE (transverse electric) modes of a rectangular waveguide.
13. Apply the method of moments (MoM) to find the capacitance of an arbitrarily shaped or parallel-plate capacitor. (Very challenging; recommended only for students who are very comfortable with linear algebra and the relationship between electric fields and electric potential and who have relatively good programming skills. Coding the MoM solution could take significant time.)
14. Apply the one-dimensional form of the finite difference time domain (FDTD) method to simulate wave reflection from a planar interface. (Very challenging; recommended only for students who are very comfortable with the vector curl operation and who have relatively good programming skills. Coding the FDTD solution could take significant time.)
15. Develop and program a finite difference solution to the Telegrapher’s equations, and use it to simulate voltage and current wave propagation along a transmission line for various types of sources and loads. (Challenging; recommended only for students who are very comfortable with partial differential equations and who have relatively good programming skills. Coding the finite difference solution could take significant time.)
16. Predict the effect on over-the-air television reception due to multipath fading from an overflying aircraft. Derive an expression that predicts the rate at which the picture degrades as a function of aircraft height, aircraft speed, height difference between the transmitting and receiving antenna, and distance between the TV transmitter and receiver.
17. Explain the design equations of a double resonant solid state Tesla coil.
18. Measure the hand capacitance vs. distance to the “antenna” of a theremin, and fit a curve to the measured data.
19. Explain the theory underlying beamforming in array antennas with application to jamming and nulling.
20. Explain the theoretical basis for the operation of directional couplers, which are an important part of vector network analyzers.

Topics that will be covered in class later in the semester but that will not be covered before your presentation are also acceptable. Topics in this category that have been claimed so far:

[none]