# COURSE ROADMAP

1. Basic mathematical concepts/numbers that we will use
   1.1. The approximate values of $\pi$, $e$, $\sqrt{2}$, $\sqrt{3}$, $\sin 30°$, $\sin 60°$, $\sin 90°$, and related values for the cosines in both degrees and radians
   1.2. Taylor expansions, especially for $(1+x)^{\alpha}$.
   1.3. Geometric series
   1.4. Complex numbers and their manipulation (polar and Cartesian representations)
2. The five wave parameters:
   2.1. What are they?
   2.2. Which are independent and which are dependent? Dependent on what?
   2.3. How are angular frequency and frequency related? How are wavenumber and wavelength related? How are all these quantities related to the phase velocity?
   2.4. Given a rate of attenuation and an initial magnitude, what is final magnitude? Of amplitude? Of power? In standard units and in dB.
   2.5. Given a birefringence, at what length does the phase change by $2\pi$?
   2.6. Phasor domain representations and the demonstration of equivalence between the time and phasor domain representations, given the frequency.
   2.7. Demonstration of the relationship between the phasor and time domain representations of power.
3. Basic transmission lines
   3.1. What are the four transmission line parameters?
   3.2. Derivation of the four transmission line parameters in the three geometries where they can be obtained analytically (parallel plate, coaxial cable, twisted wire pair).
   3.3. Derive the telegrapher's equation: In the time domain. In the phasor domain.
   3.4. Given an input transient (with simple generator and load numbers), find the load and generator currents and voltages.
   3.5. What is the standing wave ratio? How far are the first maxima and minima of the current and voltage from the load?
   3.6. What is the generator voltage and impedance. (Not possible unless some very simple numbers can be found.)
   3.7. What is the power flow in the transmission line? How much power is dissipated in the load and how much in the generator? (Simple case required.)
4. Special transmission lines
   4.1. Short-circuited line; open circuited line; use as equivalent capacitors and inductors
   4.2. Impedance matching (quarter-wave transformer)
   4.3. Half-wave transformer (impedance matching across a barrier)
5. Vector algebra

5.1. How are the three types of multiplication defined? Give the definition of the triple scalar product and show that it equals the volume of the parallelepiped described by the three vectors. Give the definition of the triple product and simplify it.
5.2. Define the three basic coordinate systems. How do you transfer from one coordinate system to another? How do you transform the unit vectors?
5.3. How do you integrate over one of the coordinate systems? (This could appear in an energy or current integration problem.)
5.4. Give the basic definitions of the gradient, divergence, and curl. Find the general expression for them in any orthogonal coordinate system. Apply this general result to one or more of the three basic coordinate systems.

6. Maxwell's equations
   6.1. What are Maxwell's equations in differential form? Integral form? Phasor domain form?

7. Electrostatics
   7.1. What are the electric field and the voltage from a single charge? Two charges of the same or opposite sign? Where are the fields zero? Or zero in a particular direction? Where are the voltages minimum or maximum? Can you draw the fields and contours of constant voltage?
   7.2. What is the field/voltage of an electric dipole? In the near field? In the far field? Why is the dipole important?
   7.3. Define line, surface, and volume charges. Using Gauss's law to obtain Coulomb's law. Use Gauss's law to find the field from a line charge, a surface charge, or a parallel plate. Use Coulomb's law to do the same thing.
   7.4. Ohm's law. What is the resistance of a wire?
   7.5. Boundary conditions for the electric field and flux. Why don't they change when the system is dynamic?
   7.6. Definition of capacitance. What is the capacitance and conductance in our three analytical geometries? How are they related?
   7.7. Electrostatic energy. What is it in the three analytical geometries?

8. Magnetostatics
   8.1. Lorenz forces: What are the forces acting on a charge in a combined electric and magnetic field? What are the equations of motion? What is their solution?
   8.2. What are the forces that a magnetic field exerts on a current?
   8.3. Biot-Savart law: What is the magnetic field from a current? What force does on current exert on another?
   8.4. What is the magnetic field from a dipole? Calculate the near- and far-field vector potential and field from a square loop. Calculate the far field from a circular loop.
   8.5. Magnetic boundary conditions. Why don't they change when dynamics is taken into account?
   8.6. Definition of inductance What are the field and capacitance of a solenoid?

8.7. What is the inductance of the three analytical geometries and how is that related to the conductance and capacitance?
8.8. Magnetic energy. What is it in the three analytical geometries?

9. Faraday's Law and displacement current
   9.1. Find the forces acting on a moving current loop in a static magnetic field. Find the forces acting on a static current loop in a changing magnetic field. If the two are related by changing to a moving frame, show that they are equivalent. Why are they equivalent?
   9.2. Describe the forces and torques acting on a simple motor. A simple generator. What are these forces acting on a square or a circular current loop?
   9.3. If you have a capacitor in our three analytical geometries, show that the displacement current equals the conduction current.
   9.4. Derive Kirchhoff's laws. When do they fail to hold?
   9.5. Show that the time-delayed potential implies the existence of radiating fields.

10. Plane wave propagation
   10.1. What are the magnetic and electric fields for a lossless plane wave. Show that there are two independent solutions.
   10.2. Polarization states: Given an input, show that the polarization state is linearly, circularly polarized (right or left) or elliptical (right or left).
   10.3. What is the impedance of the vacuum? How do plane waves propagate in a slightly lossy medium? In a very lossy medium? Show that the phase difference between the electric and magnetic fields in a lossy medium is $45°$ ($\pi/4$).
   10.4. Solve for the electric and magnetic fields when the numbers are simple. What are wavenumbers and attenuation coefficients?
   10.5. Definition of Poynting flux. What is the power flow in the time domain and the phasor domain? Determine the power flow in a lossy medium.
   10.6. Find the resistance per unit length in our three analytical geometries.

11. Transition from one medium to another
   11.1. Derive the reflection and transmission coefficients for normal incidence.
   11.2. Find the standing wave ratio.
   11.3. Demonstrate energy conservation
   11.4. Derive Snell's laws
   11.5. Derive the condition for total internal reflection. Use it to find the acceptance angle in a planar geometry or an optical fiber.
   11.6. Define Brewster's angle. What is the polarization of light that is reflected from the road into your eyes at an acute angle?