

Recitation Questions for

Chapter 9 – Time-Varying Fields and Maxwell's Equations

in W. H. Hayt, Jr. and J. A. Buck, *Engineering Electromagnetics*, 9th ed., McGraw-Hill, 2019, pp. 279-302.

The purpose of these recitation questions is to assist the reader in assessing their mastery of the key concepts introduced in this chapter. The answers can be found in the textbook. ELEC 311 students should be prepared to provide answers to these questions in class or on an exam.

Introduction

1. What is the focus of this chapter?
2. How did Maxwell and Faraday know each other?

9.1 Faraday's Law

1. What inspired Faraday to believe that a magnetic field could induce a current?

9.1.1 Faraday's Law in Point and Integral Form

1. How is Faraday's law customarily stated?
2. What three situations may result in a non-zero value of $d\Phi/dt$?
3. What is the significance of the minus sign in Faraday's law?
4. What is Lenz's law?
5. How is Faraday's law modified to account for an N -turn filamentary conductor, i.e., an N -turn thin wire coil?
6. What is emf and how is it defined?
7. How can Φ be defined in terms of B ?
8. What theorem relates the integral form of Faraday's law in (4) to the point form in (6)?
9. Explain the right-hand relationship between the integrals in (5).
10. How do (4) and (6) compare when fields are: a) time-varying and b) static?

9.1.2 *EMF Arising from a Time-Varying Magnetic Field*

1. Briefly describe the scenario described in this section
2. What caution do the authors offer concerning the given field \mathbf{B} ?

9.1.3 *Motional EMF*

1. Briefly describe the scenario described in this section.
2. How is motional emf defined?
3. To what scenario does (14) correspond? Explain the significance of each term.

$$emf = \oint \mathbf{E} \cdot d\mathbf{L} = - \int_S \frac{\partial \mathbf{B}}{\partial t} \cdot d\mathbf{S} + \oint (\mathbf{v} \times \mathbf{B}) \cdot d\mathbf{L} \quad (14)$$

4. What types of contrived examples may present difficulties when one attempts to apply Faraday's law?
5. How is the separation of emf into two parts in (14), one due to the time rate of change of \mathbf{B} and the other to the motion of the current, somewhat arbitrary?

9.2 *Displacement Current*

9.2.3 *Modifying Ampère's Law for Time-Varying Fields*

1. What is Ampère's law for steady magnetic fields?
2. What is the equation of continuity, also known as the continuity condition?
3. What paradox occurs if one takes the divergence of Ampère's law for steady magnetic fields?
4. How can this paradox be resolved?
5. What is Ampère's law for time-varying magnetic fields in point form?
6. What are three types of current density?
7. What is the result of applying Stokes' theorem to Ampère's law for time-varying magnetic fields in point form?

9.2.3 *An Illustration of Displacement Current*

1. Briefly describe the scenario described in this section.
2. What is an expression for the displacement current within the capacitor?
3. When does displacement current exist?
4. Why was displacement current likely never discovered experimentally?

9.3 *Maxwell's Equation in Point Form*

1. Recite the four Maxwell's equations for time-varying fields in point form. State the physical significance of each.
2. What is the most important implication of (20) that distinguishes time-varying from static scenarios?
3. State the four auxiliary equations or constitutive relations. State the physical significance of each.
4. What are the corresponding relationships involving the polarization and magnetization fields?
5. What is the Lorentz force equation?

9.4 *Maxwell's Equations in Integral Form*

1. Recite the four Maxwell's equations for time-varying fields in integral form. State the physical significance of each.
2. How can Maxwell's equations for time-varying fields in integral form be obtained from the corresponding equations in point form?
3. How do Maxwell's equations for time-varying fields in integral form allow us to find the conditions for \mathbf{B} , \mathbf{D} , \mathbf{H} , and \mathbf{E} at media boundaries, *i.e.*, boundary conditions?
4. What are the conditions for \mathbf{B} , \mathbf{D} , \mathbf{H} , and \mathbf{E} at media boundaries with and without charges or currents on the boundaries?
5. Why is it necessary to account for the conditions for field strength and flux density at media boundaries?

9.5 *The Retarded Potentials*

1. Give expressions for the scalar electric potential in both integral and point form under static conditions?
2. Give expressions for the vector magnetic potential in both integral and point form under dc conditions?
3. How does one obtain \mathbf{E} and \mathbf{B} from V and \mathbf{A} under static or dc conditions?
4. How must the expression for \mathbf{E} in (49) be modified when fields are time-varying?
5. How must the expression for \mathbf{B} in (50) be modified when fields are time-varying?
6. What form does the expression for V in (45) take when fields are time-varying?
7. What form does the expression for \mathbf{A} in (46) when fields are time-varying?
8. Why are the expressions for V and \mathbf{A} in (45) and (46) referred to as retarded potentials?