Electromagnetic Fields
– exam questions –

2016 Fall

At the oral examination, one of the following questions is randomly given to each student. A preparation time of about 15 minutes is provided where a sketch of the answers is made in written form. After this preparation, the student answers to the questions in oral form, using the sketch previously made. The examiner might pose additional questions related to the topic.

The references are given to help the preparation for the examination. Note that certain specific points of the questions might not be covered in the references (but they were concerned at the lectures). At the same time, the references also cover topics that are not required at the examination. Consequently, the best way of preparation is to find the answers (in the lecture notes and in the references) for the specific questions given for each topic.

1 Maxwell’s equations

Write the Maxwell’s equations in integral and differential form. Illustrate the usage of the integral forms through the analysis of simple problems (electric field of a point charge, magnetic field of a straight conductor).

Reference: [Cheng] Sec. 7-3

2 Constitutive relations

How are the material parameters \(\epsilon\), \(\mu\) and \(\sigma\) used to formulate the constitutive relations between the electromagnetic field quantities? Present the boundary conditions for the electric field intensity \(E\) and electric flux density \(D\) at the interface of two different dielectric media.

Reference: [Cheng] Sec. 3-8, Sec. 6-7 (linear and isotropic cases), Eq. (5-37) with its explanation, Sec. 3-9

3 Energy and power

Express the electric and magnetic energy in terms of field quantities. Calculate the energy of a parallel plate capacitor. Define power density under steady-current conditions. Calculate the resistance of a straight wire based on the power dissipation.

Reference: [Cheng] Sec. 3-11.1, Sec. 6-12.1 (expression with \(H\) and \(B\)), Sec. 5-5

4 Electrostatics

Write the fundamental equations of electrostatics for \(E\) and \(D\). Define electric scalar potential. Write Poisson’s equation in vector notation and in Cartesian coordinates for a homogeneous, isotropic medium. Define Dirichlet and Neumann boundary conditions and illustrate them through an example for capacitance calculation.

Reference: [Cheng] Sec. 3-1, Sec. 3-2, Sec. 4-2, Sec. 4-5 (till Eq. (4-81))

5 Steady electric currents

Write the fundamental equations of steady electric currents for \(E\) and \(J\). Define electric scalar potential. Write Laplace’s equation in vector notation and in Cartesian coordinates for a homogeneous, isotropic medium. Define Dirichlet and Neumann boundary conditions and illustrate them through an example for resistance calculation.

Reference: [Cheng] Sec. 5-1, Sec. 5-2, Sec. 5-6, Sec. 5-7
6 Static magnetic fields

Write the fundamental equations of static magnetic fields for $B$ and $H$. Define magnetic vector potential $A$ and write vector Poisson’s equation. State Biot-Savart law and calculate the magnetic field in the middle of a circular loop carrying steady current. Outline the calculation of the inductance of a coil on a toroidal iron core.

Reference: [Cheng] Sec. 6-1 . . . 6-4, Sec. 6-11

7 Time-harmonic fields

What is a phasor and what are its advantages in electromagnetics? Write in terms of phasors the time-harmonic Maxwell’s equations for simple medium. Derive the vector Helmholtz’s equation for $E$ in a simple source-free medium. How do we define “good conductor” and “lossy dielectric” based on the propagation constant?

Reference: [Cheng] Sec. 7-7, Sec. 7-7.1 . . . 7-7.3

8 Eddy-currents

Define plane wave and discuss on how it propagates in a good conductor. Define skin depth. What does the electromagnetic field within a straight cylindrical conductor look like when the penetration depth is “small”? How do we calculate the “a-c resistance” of a wire? Why is the iron core of a transformer laminated?

Reference: [Cheng] Sec. 8-3, Sec. 8-3.2

9 Electromagnetic waves

Define plane wave and discuss on how it propagates in a simple ideal dielectric medium. Define phase constant, wavelength and phase velocity. What is the intrinsic impedance of the free space? Discuss on the reflection of a plane wave from a planar interface between two different dielectrics in the case of normal incidence.

Reference: [Cheng] Sec. 8-1, Sec. 8-2, Sec. 8-8

10 Method of images

Define the boundary value problem of electrostatics. State the uniqueness theorem of electrostatics. Outline the method of images and discuss on how it is related to the uniqueness theorem. Problem: A metal sphere with radius $a$ is located above an infinite conducting plate at a distance $d$ ($d \gg a$). Find the capacitance between the sphere and the plate (the medium is air).

Reference: [Cheng] Sec. 4-1 . . . 4-4 (intro), Sec. 4-4.1

11 Finite element method

Discuss on the basic concepts (discretization, mesh, basis function, local approximation) of the finite element method. Introduce the principle of weighted residuals for the solution of the scalar Poisson’s equation.


12 Integral equation method

Write an integral equation for electrostatics. Outline the solution by the method of moments. Show how the surface charge distribution on an electrode is calculated given the potential of the electrode.

Reference: [Gibson] Sec. 3.1 (intro) Sec. 3.1.1 or 3.1.2, Sec. 3.2 (intro), Sec. 3.2.1, Sec. 3.3.1

13 The transmission line model

Define transmission line. What is two-wire and coaxial transmission line? Discuss on the “per unit length” parameters of the transmission line. Write the general transmission-line equations for arbitrary time dependence. What is lossless transmission line?

Reference: [Cheng] Sec. 9-1, Sec. 9-3
14 Time-harmonic analysis of transmission lines

Write the time-harmonic transmission-line equations. Write the Helmholtz’s equation for the transmission line and discuss its general solution. Define propagation constant and wavelength. Write the instantaneous expression of the voltage at an arbitrary location on the line.

Reference: [Cheng] Sec. 9-3, Sec. 9-3.1

15 Transmission line as a network component

Define input impedance and ABCD parameters of a transmission line (lossy and lossless cases). Show their application for analyzing a simple transmission line network. Calculate and draw the input reactance of an open-circuited lossless transmission line in function of the length/wavelength ratio.

Reference: [Cheng] Sec. 9-4, Sec. 9-4.1, Sec. 9-4.4, for the ABCD parameters see Problem P.9-13/a

Literature:
