Electromagnetism. Lecture 5

Topics:
-Electric and magnetic fields.
-Faraday's and Ampère's law.
-The inconsistency of Ampère's law.
-Maxwell's equations.
-Solving Maxwell's equations.
-Free space propagation of plane waves.
-Transmission line analogy.

Reading:
GMF pages 51-72 and 82
It is recommended that you take a look at the transmission line theory again, as we will use the formulas from here.

Only the exercises with the Chef hat are mandatory.

Exercise 15.1
Olsen has decided to use a living room antenna for his TV to receive K5 (175.25 MHz), as it does not rust as much as an outdoor one.
He has seen in the drawings, that his house is built of bricks with a relative permittivity of 4 and that the walls are 55 cm thick. When calling Frejlev, he is told that the field strength in his backyard is approx. 60 mV/m.
Set up transmission line analogy and answer the following:
a. What is the intrinsic impedance of Olsen's house?
b. How thick are the walls in radians?
c. What is the input impedance for perpendicularly incident signal?
d. What is the electric field strength on the outside of the wall?
e. What is the magnetic field strength at the same location?

Exercise 15.2
Calculate the magnitude of the displacement current for:
a. A radio wave of 100 MHz with the field strength 1 V/m
b. The field between 2 high voltage lines carrying 270 kV/50 Hz. The wires are hanging 5 m apart.
c. The laser beam in Olsen's CD player. The wavelength is 780 nm, and the power 0.2 mW. The beam is concentrated on a spot with a diameter of 1.7 m.

Exercise 15.3
In this task, rectangular coordinates are calculated, and we consider an area where the conductivity is 0. In the area there is a magnetic field, given by:

$$\overline{H} = [H \sin(\beta x) \cos(\omega t)]\hat{z} \quad (A/m)$$

a. Determine $\bar{E}$ in the area.

b. Find the voltage induced in a square loop of side length a located in the xy-plane.

c. Show that in order to fulfil both equations $\nabla \times \bar{E} = -\frac{\partial}{\partial t}\bar{B}$ and $\nabla \times \bar{H} = \frac{\partial}{\partial t}\bar{D} + \bar{J}$, β should be $\beta = \omega\sqrt{\mu\varepsilon}$.

Solutions:

Exercise 15.1	$60\pi\ \Omega$	4,037 rad	$165{,}1 < -36°\ \Omega$38,15 mV/m	231 uA/m
Exercise 15.2	5,56 nA/m^2	150 uA/m^2	3,894 GA/m^2	
Exercise 15.3	$-H\beta/(\omega\varepsilon)\cos(\beta x)\sin(\omega t)\hat{y}$	$H\beta a/(\omega\varepsilon)\sin(\omega t)(1-\cos(\beta a))$		