

MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
Department of Electrical Engineering and Computer Science

Problem Set No. 1  
Fall Term 2006

6.630 Electromagnetic Theory

Issued: Week 1  
Due: Week 2

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**Reading assignment:** Section 1.1-1.2 ; J. A. Kong, “*Electromagnetic Wave Theory*,” EMW, 2005.

**Problem P1.1**

An electromagnetic wave has spatial frequency  $k_o = 100 \text{ K}_o$ . Determine the wavelength in meters and the temporal frequency in GHz.

Determine the spatial frequency in units of  $\text{K}_o$  for a laser light at wavelength  $\lambda = 0.350 \mu\text{m}$ .

Determine the spatial frequency in units of  $\text{K}_o$  for a microwave oven at frequency 2.45 GHz.

**Problem P1.2**

Electromagnetic waves satisfy all of the Maxwell equations. Consider, in free space, the following electric field vectors:

$$\begin{aligned}\bar{E}_1 &= \hat{z} \cos(\omega t - kz) \\ \bar{E}_2 &= (\hat{x} + \hat{z}) \cos\left(\omega t + k|x - z|/\sqrt{2}\right) \\ \bar{E}_3 &= (\hat{x} + \hat{z}) \cos(\omega t + ky)\end{aligned}$$

(a) Do these electric field vectors satisfy the wave equation

$$\left(\nabla^2 - \mu_o \epsilon_o \frac{\partial^2}{\partial t^2}\right) \bar{E} = 0$$

What is the relationship between  $\omega$  and  $k$ ?

- (b) Find the corresponding magnetic field vectors for each of the three electric field vectors.  
(c) Which of the three fields qualify as electromagnetic waves? For those not qualified as electromagnetic waves, you should state which of the Maxwell equations are violated. Show that for those qualified as electromagnetic waves, the electric and magnetic field vectors are perpendicular to the direction of propagation.

### Problem P1.3

The known spectrum of electromagnetic waves covers a wide range of frequencies. Electromagnetic phenomena are all described by Maxwell's equations and, by convention, are generally classified according to wavelengths or frequencies. Radio waves, television signals, radar beams, visible light, X rays, and gamma rays are examples of electromagnetic waves.

- (a) Give in meters the wavelengths corresponding to the following frequencies:
- (i) 60 Hz
  - (ii) AM radio (535–1605 kHz)
  - (iii) FM radio (88–108 MHz)
  - (iv) *C*-band (4–6 GHz)
  - (v) Visible light ( $\sim 10^{14}$  Hz)
  - (vi) X-rays ( $\sim 10^{18}$  Hz)
- (b) Give in Hertz the temporal frequencies corresponding to the following wavelengths:
- (i) 1 km, (ii) 1 m, (iii) 1 mm, (iv)  $1 \mu\text{m}$ , (v)  $1 \text{ \AA}$ .
- (c) Give in unit  $K_o$  the spatial frequencies corresponding to the wavelengths in (b).