

~~8.02x Electricity and Magnetism~~

~~Problem Set 11~~

~~Issued: Sun, April 24~~

~~Due: Fri, April 29, 4PM < note Date & Time!~~

~~Note that Exp AMP check-off and write-up are also due 4/29~~

~~Reading suggestions (from Young & Freedman)~~

~~Mon, 4/25: RLC circuits, Resonance: 30.6, 31.3, 31.5~~

~~Wed, 4/27: Displacement current, Maxwell's Equations: 29.7~~

~~Fri, 4/29: Electromagnetic Waves: 32.1 to 32.3~~

\ **Problem 1 (10 points)**

How do you know that sound is not an electromagnetic wave? What kind of wave is it?

~~Problem 2 (10 points) Young & Freedman 29.38~~

~~Problem 3 (10 points) Young & Freedman 32.6~~

8.02x – Problem Set 11 Solutions

Problem 1 (10 points)

How to tell whether sound is an EM wave? Let us just list some of the obvious differences. Sound waves do not propagate in vacuum, they need some medium (gas, solid, or liquid) to support them. The speeds of propagation have very different magnitudes for sound and EM waves.

However, to be sure to tell the two types of waves apart, we should measure their effects. Simply said, you can see light and hear sound, but not the reverse. An antenna (a metal rod) can “catch” EM waves, they would make the free charges move in it. This effect can be measured. However, you will not get any effect by trying to induce charge motion (or EM fields) by sound. On the other hand, you can hear a sound wave (your ears measure pressure changes), but not an EM wave.

Sound is a *longitudinal* mechanical wave, molecules of air bumping and pushing each other, making the signal spread towards the receiver. Longitudinal means the displacements of air molecules are in the direction of the signal. On the other hand, EM waves are *transverse*, meaning that the displacements (electric and magnetic fields) change in the direction perpendicular to the signal direction.

Y&F 29.38 (10 points)

~~a) Let us use the microscopical Ohm's law. The electric field is proportional to resistivity and current density.~~

$$~~E = \rho j = \frac{\rho I}{A} = \frac{(2.0 \times 10^{-8} \Omega \text{m})(16 \text{A})}{2.1 \times 10^{-6} \text{m}^2} = 0.15 \frac{\text{V}}{\text{m}}.~~ \quad (1)$$

~~b) The field is changing at rate~~

$$~~\frac{dE}{dt} = \frac{d}{dt} \left(\frac{\rho I}{A} \right) = \frac{\rho}{A} \frac{dI}{dt} = \frac{2.0 \times 10^{-8} \Omega \text{m}}{2.1 \times 10^{-6} \text{m}^2} (4000 \text{A/s}) = 38 \frac{\text{V}}{\text{ms}}.~~ \quad (2)$$

~~c) The displacement current density in the wire is (taking $\epsilon \approx \epsilon_0$ for copper)~~

$$~~j_D = \epsilon_0 \frac{dE}{dt} = 3.4 \times 10^{-10} \frac{\text{A}}{\text{m}^2}.~~ \quad (3)$$

~~d) The magnitude of the displacement current is~~

$$~~I_D = A j_D = (2.1 \times 10^{-6} \text{m}^2)(3.4 \times 10^{-10} \text{A/m}^2) = 7.14 \times 10^{-16} \text{A}.~~ \quad (4)$$