Physics 323, Spring Quarter 2016
Electrodynamics: Homework Assignment 1
(a) Turn in all problems and clearly note all constants and assumptions you use.
(1-point penalty each otherwise)
(b) Use 8½ x 11 paper & staple
(1-point penalty each otherwise)
(c) Due April 7 either 9:00 am in class or 8:45 am in the instructor's mailbox;
late homework gets 0.

1. Consider a long solid bar of resistivity ρ, length L, radius r (r greater than the skin depth) carrying high-frequency longitudinal currents at angular frequency ω. In this problem, you should properly use the ∇^2 operator in cylindrical coordinates, but it's simpler to approximate the tube geometry by neglecting the curvature of the surface of the tube and, unrolled, regarding it as a flat strip. You may want to remind yourself why you can you probably ignore displacement currents. For definiteness you can take currents as flowing in the y-direction, the normal to the strip in the x-direction. You can assume currents are uniform across the y-direction.
a. What equation do current densities obey? (Hint: It's closely related to Griffith's equation 9.122).
b. Suppose the amplitude of the current is J_0 at the outer surface of the tube, what's the current density throughout the strip?
c. With the amplitude of (b), what's the total current travelling down the strip?
d. What's the time-average power dissipated in the strip? (Hint: I^2R is the familiar total instantaneous power, from that argue ρJ^2 is the power per unit volume.)
e. What's the high-frequency resistance of the wire?

2. Consider plane waves of angular frequency ω normally incident on a non-magnetic good conductor of conductivity σ.
b. What's the skin depth?
c. What's the reflection coefficient?
d. What's the phase change on reflection? (Hint: Grifffiths section 9.4.2).
e. Now suppose the waves are visible light and the metal is copper with conductivity 10^7 /(Ωm). What's the numerical value of the skin depth? What's the numerical value of the reflection coefficient?
f. With part (e) in mind, comment on the observation that copper is strongly colored.

3. Recall from last quarter's homework that we defined the wave impedance of free space as the ratio of E/H and this is around 377 Ω. Again consider plane waves of angular frequency ω normally incident on a non-magnetic good conductor of conductivity σ.
a. What's the complex wave impedance of the metal?
b. What is the reflection coefficient in terms of the wave impedance of free space and the wave impedance of the metal?

4. The ADMX experiment here at the University of Washington uses copper microwave structures cooled by liquid helium. The measured skin depth is around 3×10^{-5} cm at 1 GHz.
a. What's the implied conductivity of the copper for these conditions?
b. The conductivity from (a) is much worse than the DC (zero frequency) conductivity at this temperature. Can you guess a reason for this?