THE UNIVERSITY OF BRITISH COLUMBIA

Physics 401 Assignment # 12:
RADIATION *2*

Wed. 29 Mar. 2006 — finish by Wed. 5 Apr.

1. (p. 450, Problem **11.3**) — **Radiation Resistance of a Cell Phone:**

Find the **radiation resistance** of the wire joining the two ends of the oscillating electric dipole described in Section 11.1.2. (This is the resistance that would give the same average power loss — to heat — as the oscillating dipole in *fact* puts out in the form of radiation.) Show that $R = 790(d/\lambda)^2\ \Omega$, where λ is the wavelength of the radiation. For the wires in an ordinary cell phone (say, $d = 5$ cm), should you worry about the radiation contribution to the total resistance? Does it matter whether your cell phone uses the 900 MHz band or the 1.9 GHz band?[1]

2. (p. 454, Problem **11.6**) — **Radiation Resistance of a Magnetic Dipole Antenna:**

Find the radiation resistance for the oscillating magnetic dipole shown in Fig. 11.8. Express your answer in terms of λ and b, and compare the radiation resistance of the *electric* dipole.[2]

3. (p. 464, Problem **11.13**) — **Nonrelativistic Bremsstrahlung Radiation:**

(*a*) Suppose an electron decelerates at a constant rate a from some initial velocity v_0 down to zero. What fraction of its initial kinetic energy is lost to EM radiation? (The rest is absorbed by whatever mechanism keeps the acceleration constant.) Assume $v_0 \ll c$ (nonrelativistic case) so that the Larmor formula can be used.[3]

(*b*) To get a sense of the numbers involved, suppose the initial velocity is thermal[4] (around 10^5 m/s) and the distance over which the electron decelerates to rest is 30 Å. What can you conclude about radiation losses for electrons in an ordinary conductor?

4. **Half-Wave Antenna:**

Consider a half-wave linear antenna of length ℓ, with current $I(z,t) = I_0 \cos kz \sin \omega t$, where $k = \pi/\ell$.

(*a*) Show that the linear charge density is $\lambda(z,t) = (I_0/c) \sin kz \cos \omega t$, (*i.e.* the charge density is maximum at the times when the current is zero.)

(*b*) If an FM radio station broadcasts at a frequency of 10 MHz with a power of 10 kW from a half-wave antenna, how long must the antenna be? What is the current?

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[1] You might also want to calculate the intensity of your cell phone's transmission signal at a distance of 10 cm (*i.e.* in your brain while you hold it to your ear). This is a topic upon which a great deal has been written. just Google it! But it's not part of this assignment.

[2] You should get $R = 3 \times 10^5 (b/\lambda)^4\ \Omega$.

[3] Relativistic electrons radiate furiously; this is known as *Bremsstrahlung* (German for "braking radiation", doh!) and is an important mechanism for energy loss of high energy electrons.

[4] This thermal velocity corresponds to about 330 K, not far above room temperature, and so appears realistic. In point of fact, the conduction electrons in a good metal have velocities on the order of $10^{-3}c$, thanks to the Pauli exclusion principle. However, their quantum mechanical wavefunctions are extended over distances large compared to 30 Å, and this classical picture of an accelerated point charge has to be reformulated with a quantum version. The present approximation is a reasonable compromise.