PHY 240: Basic Electronics

Homework Problem H1

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1. How Fast Are Those lil' Buggers Moving?

   (a) The first step is to determine the number density of free electrons in a typical wire. I say "free" electrons because most of the electrons in a wire are bound to their atoms and may not move freely through the wire. We will assume that our wire is copper, and here are the only things that you may use while solving this problem:

   - The density of Copper at room temperature (approximately 8.95 g/cm^3).
   - The mass of a single Copper atom (63.55 amu)
   - The fact that each copper atom contriubutes *one* free electron.
   - Avagadro's Number.

   Use this information to determine the number density of free electrons (that is, the number of free electrons per volume) in Copper. Explain the reasoning behind each step of your calculation *clearly*.

   (b) Suppose that our wire is an AWG 14 gauge wire1 that has a current of 500 mA flowing through it. Determine the average velocity of the electrons "down the wire" that is necessary to produce this current.

   (c) The answer that you obtained for Part (b) above is called the "electron drift velocity", because it is the velocity at which electrons drift down the wire. Even if you turn the electric current off, however, the electrons are still moving in the wire (they simply lack a tendency to drift in any particular direction). Because of the Pauli exclusion principle, the electrons in copper are stacked up so high that the free electrons in the wire have a kinetic energy of roughly 7 eV.

   Convert this 7 eV to Joules. Look up the mass of an electron. Dust off your Physics I, and use the expression for kinetic energy to determine how fast these free electrons must be moving when the current is off. The velocity that you so determine is called the Fermi velocity, v_{ferm}.

(d) Let us now turn the 500 mA current back on. Compare the drift velocity, v_{drift}, to the Fermi velocity, v_{ferm}. What fraction of v_{ferm} is v_{drift}?

Ans:

(a)

(b)

(c)

(d)