Homework #1

MSN 500 – Concepts in Materials Science

1. The Apple M5 chip has a die area of approximately 158 mm². Suppose that a transistor could hypothetically be made from only 25 germanium atoms arranged in a monolayer. Estimate the maximum number of such transistors that could fit on the surface of the M5 chip. Make reasonable assumptions about the size and surface area occupied by a Ge atom, and clearly state your assumptions and calculation steps.

2.

a. What is the wavelength of an electron that has a kinetic energy of 1 eV, as might be used in an electron microscope?
b. Compare it with the wavelength of a photon with an energy of 1 eV, as might be used in an optical microscope.
c. How are these wavelengths related to the theoretical resolution limits of electron and optical microscopes? Which would be expected to provide better spatial resolution, and why?

3.

a. How A 2.00 keV electron has an energy uncertainty of 1.00%. Estimate the minimum uncertainty in its position.
b. Monochromatic light of wavelength 700 nm passes through a fast shutter that opens for 1 ns. Is the light that emerges still monochromatic? If so, why? If not, estimate the spread in wavelengths.
c. The ground-state energy of the hydrogen atom can be precisely known, but excited states have some uncertainty in their energies (an “energy width”). Is this consistent with the uncertainty principle in its energy form? Explain.

4. What is the de Broglie wavelength of each of the following objects?

a. A 50 kg block dropped from a 20 m-high building, just before it hits the ground.
b. An ant moving at a speed of 0.20 m/s (m_{ant}= 3 mg).
c. A 15 keV electron.
d. Based on your results, explain why the wave nature of matter is not apparent in our everyday experience.