University of Sheffield

Department of Electronic and Electrical Engineering

EEE207 Semiconductors for Electronics and Devices

Problem Sheet 6

1. Estimate the de Broglie wavelength of the following particles (note that as an *estimate* is required, you should make some reasonable guesses about numerical information you are not given):

i. an electron in a vacuum having average thermal energy (= $3kT/2$) at $T = 300$K

ii. a snail at maximum speed

iii. Concorde at maximum speed.

2. Electrons are required to produce X-rays of wavelength 0.2 nm. What potential difference must each electron be accelerated through to produce such X-rays from a metal target, assuming that the electron energies are each converted directly into the X-ray photon?
Calculate the de Broglie wavelength of each electron just before it hits the target.

3. Calculate the energy value where both the wavelength and energy for an electron and photon are equal.

4. The work function of a metal is 2.4 eV. Calculate the maximum wavelength of the photons required to cause photoelectric emission of electrons from its surface. What retarding potential between the plates is required to stop photoelectric current with photons of half the wavelength of that calculated above?

5. Electrons in a hydrogen atom are promoted from the lowest energy state to the first excited state in an electric discharge tube. Calculate the wavelength of light emitted from the tube.

6. An electron gun operating at 70V fires electrons onto the surface of a single crystal metal at an angle θ to the perpendicular. Adjacent atoms on the metal surface are 0.352nm apart (the lattice is simple cubic, i.e. atoms are spaced equally in orthogonal rows and columns, and the metal surface is parallel to the rows of atoms). A detector is arranged to receive only electrons scattered perpendicular to the metal surface. Sketch how the detector current varies with incident angle θ, calculating the values of θ giving maximum current. (Assume that only electrons diffracted from the surface layer contribute to the received current).

Numerical Answers

1. (*i*) 6.3×10^{-9}m; (*ii*) If mass = 10g, speed = 1m hr^{-1}, $\lambda = 2.4 \times 10^{-28}$m; (*iii*) Mass = 185tonne, speed = 2179km hr^{-1}, $\lambda = 5.9 \times 10^{-42}$m

2. 6·21 keV, 0·0156 nm 3. 0·00121 nm
4. 518 nm, 2·4V. 5. 122nm
6. 0°, 24·6°, 56·4°.