**MRes in Physics at the Nanoscale**
**Course CPPNS1 (X-Rays)**

**Problem Sheet B**

In ALL the questions below, you should provide appropriate comments on your answers.

1. A new synchrotron is planned, with an electron beam energy of 10 GeV and a bending magnet field of 1.5 T. Determine the characteristic wavelength.

   For certain experiments, comparisons must be made between measurements carried out using bending magnet and undulator radiation at the same wavelength. Technological considerations limit the undulator period to be at least 9 mm. For this period, determine the on-axis field of the undulator that would provide on-axis fundamental radiation at the same wavelength as the bending magnet characteristic wavelength, $\lambda_c$.

   Calculate also the wavelength of the fundamental radiation 0.5 mrad and 1 mrad off axis.

2. Derive an expression for the change in energy when a photon undergoes Compton scattering from an electron, stating your assumptions.

3. Discuss the possibility of using the synchrotron of question 1, at $\lambda_c$, to study Compton scattering from a copper target. Assuming that it is required to detect Compton scattering through a range of angles from 5° to 15° determine the energy resolution of the detector that will be needed. Discuss briefly and qualitatively whether the same apparatus could be used to detect similar scattering from the nucleus, rather than from an electron, for x-rays of similar energy.

4. Look up the optical constants $\delta$ and $\beta$ at $\lambda_c$ for copper (Cu) and carbon (C). Then answer the following questions, all of which refer to $\lambda_c$.

   (a) Determine the critical, $\theta_c$, and Brewster, $\theta_B$, and angles for Cu and C.

   (b) Calculate the ratio of the s- and p-polarised reflectivities for both Cu and C at $\theta_c$ and $\theta_B$.

   (c) *Estimate*, stating your assumptions, the *maximum* number of layer pairs of a Cu/C periodic multilayer that would contribute to the overall reflectivity at normal incidence.

   (d) A Cu zone plate is made with a diameter of 150 μm and an outer zone width of 30 nm. Determine the first-order focal length, the first-order focal spot size (assuming a source size of 5 μm at a distance of 50 m), the thickness of Cu required to give optimum efficiency, and the corresponding efficiency.

Answers (one copy), showing full working, must be handed in to Julia Kilpatrick by 17:00 on Friday 11 December 2009. You should **not** assume that a late submission will automatically be marked **unless** there is a medical or other extenuating reason for lateness, supported by an appropriate medical certificate or documentation.
Remember that you are being trained in research techniques; these include the ability to discuss problems with your colleagues. You are therefore encouraged to do this, before asking members of staff for assistance/hints. Remember, however, that the work submitted MUST be your own.

Professor AG Michette 09/11/2009