Quantum Physics – Homework 4

Due Thursday 9th February at 4. Attempt answers to all questions.

Hand in your script by the deadline into the post box near the secretaries' offices on level 1. **Assignments handed in past the deadline will not be marked.** Course title, week number and student name should appear on every sheet of the worked exercises, which should be securely bound together. Please *also* write your tutor's initials and time of tutorial on the cover sheet.

Problem 1 [9 marks]

An electron at the LHC has energy $E = 1$ GeV.

(i) Find its kinetic energy. **[3]**

(ii) Determine its momentum (in units of eV/c). **[3]**

(iii) Finally, find the value of $\gamma := (1 - v^2/c^2)^{-1/2}$. **[3]**

Problem 2 [27 marks]

A beam of X-ray photons of wavelength equal to 1Å Compton-scatters off an electron which is initially at rest (note: 1 Å $= 10^{-10}$m. It is the typical size of atoms).

(i) Determine the shift in the wavelength of the observed radiation when the outgoing photons are observed at an angle $\theta = 30°$. **[5]**

(ii) For the same angle as in part (i), find the kinetic energy of the recoiling electron. **[8]**

(iii) The scattered electron has a non-zero momentum component p'_y along the direction orthogonal to that of the incident photon. Find for which value of the angle θ its absolute value $|p'_y|$ reaches its maximum (θ is the angle between the directions of incoming and outgoing photons). **[14]**

Hint: in order to answer question (iii) correctly you have to realise that once you fix the energy E of the initial photon (which is assigned) and the angle θ, everything is determined, including p'_y. Therefore you have to re-express this quantity as a function of E and θ – only then you can maximise with respect to θ.

Quick part A type questions `[14 marks]`

(i) Explain briefly what a blackbody is. **[3]**

(ii) State the Stefan-Boltzmann law for the emissive power of blackbody radiation. **[3]**

(iii) A monochromatic wave of red light (with $\lambda = 700$ nm) hits a zinc plate. Given that the work function for zinc is $W = 4.31$eV, will electrons be emitted thanks to photoelectric effect? Support your conclusion with a calculation. **[4]**

(iv) Describe *briefly* one experiment that can be used to determine Planck's constant h. **[4]**

Useful constants: Planck constant $h = 6.62 \times 10^{-34}$ J s. Boltzmann constant $k = 1.38 \times 10^{-23}$J/K. Speed of light $c = 3 \times 10^{8}$m/s. Electron mass: $m_e \simeq 0.5$ Mev/c^2.