UNIVERSITÄT LEIPZIG

Experimental Physics IV IPSP

Problem Set 3

Deadline: Thursday, 28.04.2011, before the lecture

Problem 7: 5 points

The cosmic background radiation (CBR) is the thermal radiation which fills the entire universe. According to Planck's law the spectral energy density (in units of energy per unit volume per unit frequency step) is given by

$$u(\nu,T) = \frac{4\pi}{c}\, I(\nu,T) = \frac{8\pi h\nu^3}{c^3}\frac{1}{\exp\left[\frac{h\nu}{k_B T}\right]-1}\ .$$

Calculate the number of photons of the CBR in $1\ \mathrm{cm}^3$ of space assuming the temperature of the universe is uniformly distributed with $T_U = 2.726\ \mathrm{K}$! *Hint:*

$$\int_0^\infty \frac{x^2}{e^x - 1}\mathrm{d}x \approx 2{,}4$$

Problem 8: 7 points

Protons and electrons are accelerated in a linear accelerator with a voltage of 3 MV. The relativistic energy is given by $E^2 = m_0^2c^4 + p^2c^2$ with the relativistic momentum $p = m_0\, v\, (1 - v^2/c^2\,)^{-1/2}$.

Calculate the relativistic *and* non-relativistic velocity of both the protons and electrons in units of c. Compare the relativistic and non-relativistic velocities. How big is the difference of the relativistic effects? Are the non-relativistic calculations justified? *Hint*: E is the *total* energy of the particle.

Mass of the proton: $m_P = 938\,\frac{\mathrm{MeV}}{\mathrm{c}^2}$

Mass of the electron: $m_e = 0.511\,\frac{\mathrm{MeV}}{\mathrm{c}^2}$

Problem 9: 7 points

Derive Compton's scattering formula from conservation of energy, conservation of momentum and law of cosines!

a) Find an expression for the momentum of the electron after the scattering for both the conservation of energy and momentum! Use relativistic calculations for the energies.
b) Combine both expressions for the momentum to obtain Compton's scattering formula!