UNIVERSITÄT LEIPZIG

Experimental Physics IV IPSP

Problem Set 3

Deadline: Wednesday, 02.05.2012, before the seminar

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: 1+1+2+2+1 points

The reflection coefficient R of light is related to the change of diffractive index at the boundary of two surfaces with the refractive indices n_1 and n_2.

For optics: $R = \frac{I_{in}}{I_{out}} = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2$

For microwaves: $R = \frac{I_{in}}{I_{out}} = \frac{Z_{end} - Z_0}{Z_{end} + Z_0}$

Here I_{in} and I_{out} denote the incoming or outcoming intensities and Z_{end} is the impedance of the source while Z_0 describes the impedance of the load.

a) How do optical coatings reduce the reflection, e. g. at a camera lens surface?
b) What is the microwave equivalent of optical coating?
c) Microwaves are preferably reflected by metals or conducting materials. Why and how?
d) Explain how X-ray mirrors could be realized. What are the problems to solve?
e) Do γ-ray mirrors exist? Explain your answer.

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!

Problem 10: 4 points

Calculate the differential cross section $\frac{d\sigma}{d\Omega}$ of two rigid spheres of diameter *d* depending on the displacement of the two spheres.

Extra Problem: 2 extra points

Design an electron mirror based on magnetic fields