Homework problems 3

Group I

Problem No 7.2

Abundance of neutrino species

Let us make a wrong assumption that there is no Z^0 boson in Nature, while $W^\pm$ exist. Furthermore, let us neglect loop processes and neutrino oscillations (also wrong). What are the relic abundances of neutrinos of different types?

Problem No 8.1

Nucleosynthesis

Find nucleosynthesis temperature in a hypothetical case of fast production of He-4 directly from protons and neutrons.

Problem No 8.4

Neutron burning

Estimate the temperature and age of the Universe at the time when neutron burning terminates. What would be the residual neutron abundance if other reactions were negligible?

Problem No 9.4

Neutrino decoupling

Check that neutrino of mass $m_\nu = 6$ GeV indeed freezes out being non-relativistic. Find the values of the neutrino mass at which this property no longer holds. Show, nevertheless, that cosmologically excluded is the entire mass range of stable neutrino

$$20\text{eV} \lesssim \text{m}_\nu \lesssim 6\text{GeV},$$

where the lower value has been obtained in Chapter 7, formula (7.10).

Problem No 10.3

Effective Higgs potential

Calculate the terms of order $\phi^4 \log(\phi/T)$ in the high-temperature expansion of the effective potential, using the relation (10.20). Show that at $\lambda \sim h_i^2$ (the Higgs boson mass is comparable to those of other particles) and $h_i \ll 1$ (the couplings are small), these terms are small compared to those written in (10.29) in the entire interesting range of ϕ, namely, $0 < \phi \lesssim v$.