1 Overview

1.1 Units

Throughout these lectures I will use natural units [1]

$$c = 8\pi G = \hbar = 1 \tag{1}$$

Occasionally, I will reintroduce some units for clarity, for emphasis, or to follow standard conventions. I define the Planck mass as

$$M_{\mathrm{Pl}} \equiv \left(\frac{\hbar c}{8\pi G}\right)^{1/2} = 4\,\mu\mathrm{g} \tag{2}$$

The Planck length and time are defined similarly and are extremely small.

The standard units of high energy physics are to set $c = \hbar = 1$ and use the giga electron volt or GeV as the remaining dimensionful parameter. In these units, the mass of an electron is

$$m_{\mathrm{e}} = 5 \times 10^{-4}\,\mathrm{GeV} \tag{3}$$

The mass of a proton or neutron is

$$m_{\mathrm{p}} \simeq m_{\mathrm{n}} = 0.9\,\mathrm{GeV} \tag{4}$$

The scale of electro-weak symmetry breaking is

$$m_{\mathrm{EW}} \sim 10^2\,\mathrm{GeV} \tag{5}$$

The Planck mass is

$$M_{\mathrm{Pl}} = 2.436 \times 10^{18}\,\mathrm{GeV} = 9 \times 10^4\,\mathrm{kcal} \tag{6}$$

[1] Note that many authors instead choose to set $G = 1$.

The standard units of the late universe are megaparsecs or Mpc for length

$$\mathrm{pc} = 3.3\,c\,\mathrm{yr} \tag{7}$$

$$\mathrm{Mpc} = 1.6 \times 10^{38}\,\mathrm{GeV}^{-1} = 3.8 \times 10^{56} \tag{8}$$

$\mathrm{km\,s^{-1}}$ for velocity

$$\mathrm{km\,s^{-1}} = 3.3 \times 10^{-6} \tag{9}$$

years for time

$$\mathrm{yr} = 4.8 \times 10^{31}\,\mathrm{GeV}^{-1} = 1.2 \times 10^{50} \tag{10}$$

and solar masses for mass

$$M_\odot = 1.1 \times 10^{57}\,\mathrm{GeV} = 4.6 \times 10^{38} \tag{11}$$