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

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

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

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

The mass of a proton or neutron is

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

The scale of electro-weak symmetry breaking is

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

The Planck mass is

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

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

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

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

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

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

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

years for time

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

and solar masses for mass

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