

924.

Problem 56.31 (RHK)

We have to calculate the minimum temperature of the universe for the photons to produce $\pi^+ - \pi^-$ pairs; and find the age of the universe when it had this temperature.

Solution:

The rest mass energy of π^+ (π^-) is 140 MeV.

For photons to produce $\pi^+ - \pi^-$ pairs, the photon energy kT must be at least as large as the rest energy $m_{\pi^+}c^2$ of a pion that is 140 MeV. Therefore,

$$T = \frac{140 \text{ MeV}}{8.62 \times 10^{-5} \text{ eV/K}} = 1.62 \times 10^{12} \text{ K.}$$

The relation between the temperature and age of the universe is

$$T = \frac{1.5 \times 10^{10} \text{ s}^{\frac{1}{2}} \text{ K}}{t^{1/2}}.$$

Therefore, the age of the universe, when its temperature was $1.62 \times 10^{12} \text{ K}$, was

$$t = \frac{(1.5 \times 10^{10} \text{ K})^2}{(1.62 \times 10^{12} \text{ K})} = 8.57 \times 10^{-5} \text{ s.}$$

