(1)\[ p \propto \frac{1}{a^2} \]

Hence (1) grows, with the radiation energy per unit mass decreasing as the scale factor increases.

For the first radiation form of matter, the mass density \( \rho \) decreases as the scale factor increases. The energy density becomes the gas energy per unit volume. In this problem we consider a homogeneous, isotropic universe described by a radiation-dominated universe because the pressure of the radiation is significant. In this problem we explore the effects of pressure for several radiation forms of matter.

**EQUATION (10 points)**

**PROBLEM 2: THE EFFECT OF PRESSURE ON COSMOLOGICAL EVOLUTION**

\( A(p) \) grows and \( v \) decreases as \( t \) increases. Using these facts, show that

\( \frac{d}{dt} \left( \frac{p}{\rho} \right) = -\frac{3}{a^2} \left( \rho + 3p + 3p \right) \)

This equation describes the evolution of the cosmological expansion. Note that there are contributions from the mass density \( \rho \), but also from the pressure. The scale factor evolves according to the relation given in Section 7.

\( 1 = \frac{3}{a^2} \left( \frac{\rho}{\rho} + 3p + 3p \right) \)

Where the dot denotes differentiation with respect to \( t \).

\( (a) \quad \frac{\rho}{v} \frac{d}{dt} = \frac{d}{dt} \left( \frac{\rho}{v} \right) \)

and then that

\( \left( \frac{\rho}{v} \right) \frac{d}{dt} = \left( \frac{\rho}{v} d \right) \frac{d}{dt} \)

Using these relations, show that

\( \frac{\rho}{v} = \Omega \)

The energy of the gas in this region is then given by

\( \rho \frac{\rho}{v} \)
is the contribution to $g$ from each of these particles?

From each of these particles?

What is the value of $\ell$ for\[ \frac{\theta_h}{\theta} = \frac{\theta_0}{\theta}\]and $\theta_0$?\[ \text{[Hint: the answer is proportional to the mass density.]}\]

What is the value of $g$ in terms of a normalization constant $\beta$?\[ \frac{e^Q}{e^A} \beta = n\]

Is the formula for the energy density of black-body radiation,\[ \text{[Formula]}\]

What is the possible contribution to standard assumptions, and what would it be if there were one other species of massless neutrino?

Is there a known particle with a mass between that of an electron and that of a muon. There is also an antimuon ($\mu^-$) with the same spin as the electron.

According to the standard assumptions (which were used in the lecture notes), there are three species of effectively massless neutrinos. In the temperature range $kT < 100\text{ MeV}$, the mass density of the universe is believed to have been dominated by the black-body radiation of photons, electron-positron pairs, and these neutrinos, all of which were in thermal equilibrium.

The formula for the entropy density of black-body radiation is given in Lecture Notes 7.

The derivation of this formula has been left to the statistical mechanics course that you either have taken or are taking. The entropy density of black-body radiation follows from the thermal equilibrium mix of black-body radiation and charged particles, such as electron-positron pairs. The entropy density falls as the universe expands.

The entropy density is given in Lecture Notes 7. The derivation of this formula is given in Lecture Notes 7. The formula for the entropy density of black-body radiation is given in Lecture Notes 7.

When the electron-positron pairs disappear from the thermal equilibrium mix, the entropy density falls off as $1/t^3$ due to the expansion of space. Since total entropy is conserved, the entropy density increases by a factor of $(4/3)^{11/5}$ after the electron-positron pairs disappear. The entropy density falls off as $1/t$ after the electron-positron pairs disappear. The entropy density falls off as $1/t^3$ due to the expansion of space.

As the universe expands, the mass density of this form of matter decreases as $1/t^3$.

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The derivation of this formula is given in Lecture Notes 7. The formula for the entropy density of black-body radiation is given in Lecture Notes 7.
When the mean energy of the particles in the Black-Body radiation is below 10 MeV, the muons disappear from the equilibrium. At these temperatures all of the other particles in the Black-Body radiation are interacting fast enough to maintain equilibrium, so the heat given off from the muons is shared among all the other particles. Letting $a$ denote the Robertson-Walker scale factor, by what factor does the quantity $aT$ increase when the muons disappear?