MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Physics Department

Physics 8.286: The Early Universe May 8, 2002
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ERRATA

Lecture Notes 10:

At the bottom of Table 3 on p. 7, John Schwarz's last name was misspelled as "Schwartz". It should be Schwarz.

Review Problems for Quiz 3:

Problem 2(a): The solution should read "1 sec. *[This is the time at which the weak interactions begin to "freeze out", so that free neutron decay becomes the only mechanism that can interchange protons and neutrons.] . . . ". I have added the words "begin to," because the process actually happens gradually.*

Problem 2(c): The numbers needed to be updated. The solution should read: "10^{-37} sec. [We learned in Lecture Notes 7 that kT was about 1 MeV at $t = 1$ sec. Since 1 GeV = 1000 MeV, the value of kT that we want is 10^{19} times higher. In the radiation-dominated era $T \propto R^{-1} \propto t^{-1/2}$, so we get 10^{-38} sec.]

Quiz 2 Solutions:

In the solution to Problem 1(c), the first blocked set of reactions was mistyped in the copies that were handed out in class. If you downloaded these solutions from the web, then the copy you have is already corrected. The equations should be written as:

$$
\begin{array}{ccll}
n & \longrightarrow & p^+ + e^- + \bar{\nu}_e & \text{(beta decay)} \\
n + e^+ & \longleftrightarrow & p^+ + \bar{\nu}_e & (e^+ \text{ capture}) \\
n + \nu_e & \longleftrightarrow & p^+ + e^- & (e^- \text{ capture}) \\
e^+ + e^- & \longleftrightarrow & 2\gamma & \text{(ann./pair-prod.)} \\
e^+ + e^- & \longleftrightarrow & \nu_e + \bar{\nu}_e & \text{(weak reactions)}
\end{array}
$$

Lecture Notes 13:

On p. 1, Andrei Linde's first name was misspelled. It should be "Andrei".

On p. 8, in the second full paragraph, the word "Astronomer's" should have been typed as "Astronomers". This typo was corrected prior to posting the notes on the web page.

On p. 10, in the middle of the first full paragraph on the page, a sentence had been muddled. It should read: "Since that time, continued supernova measurements of the Hubble diagram and much-improved measurements of the cosmic background radiation anisotropies have continued to provide evidence that the universe fits the predictions of inflation." This typo was corrected prior to posting the notes on the web page.

Problem Set 6 Solutions:

Despite some confusion in class when these notes were handed back, the solution to Problem 1(b) was not the solution to some other problem. One student pointed out that the question concerned the weak interactions, and the answer did not mention the weak interactions. That was true, but after describing a change in the strength of the weak interactions, the question went on to describe the initial effect of this change: "Suppose the weak interactions were stronger than they actually are, so that the thermal equilibrium distribution between neutrons and protons were maintained until $kT \approx 0.25$ *MeV." The solution did not mention the weak interactions, but it did refer to the consequences of maintaining thermal equilibrium for longer than the usual length of time. Nonetheless, the was one IMPORTANT MISTAKE in the solution. It should have read:*

> *The predicted helium abundance would be smaller. Neutrons are heavier than protons, so in thermal equilibrium their abundance is suppressed relative to protons by the Boltzmann factor* $\exp\{-\Delta mc^2/kT\}$. *This factor gets SMALLER as* T *gets smaller, so the extension of thermal equilibrium to low temperatures implies that the density of neutrons is further reduced, so fewer are available for nucleosynthesis.*

In the version that was printed and in the version on the web, it says "BIGGER" where it should say "SMALLER".