

Weekly assignment for week 11 (22/04/16) AST3220

Prepare for class (to be discussed in plenary)

Answer the questions on statistical physics and thermodynamics in the early universe listed below.

- a) What is the distribution function? Write it down and explain what the different terms are.
- b) The distribution function is different for bosons and fermions. What is the difference and can you explain why it is in terms of quantum mechanics? At what energies does this difference become important? What is the Boltzmann distribution, and how does it relate to the distribution functions for bosons and fermions?
- c) Explain how you can use the distribution functions to calculate thermodynamical quantities for large numbers of particles such as density and pressure.
- d) What is thermal equilibrium? What is needed in order to maintain a thermal equilibrium?
- e) Explain what happens when particles freeze out. How does the temperature of the frozen out particles behave?
- f) What happens to the remaining thermally coupled particles after the annihilation of a particle species?

Bonus problems from universeinproblems.com

Problems 2, 3, 5 and 6 from the section *Thermodynamics of Non-Relativistic Gas* and problems 1 through 9 from the section *Peculiarities of Thermodynamics in Early Universe*.