

Homework

#1

- a. List all Nobel Physics Prizes related to Particle Physics and Cosmology in the previous five periods (1945-2005) of Modern Particle Physics;
- b. In the current period (2005-2020), write down all possible works in Particle Physics and Cosmology, which would win Nobel Physics Prizes;
- c. Predict at least 10 possible Nobel Physics Prizes in the Super-Heroic period.

#2

- a. In QCD, the instanton quantum effect breaks the chiral global symmetry $U(1)_A$ to a discrete symmetry, find out this discrete symmetry if there are N_f flavors;
- b. Calculate the rate of $\pi^0 \rightarrow \gamma\gamma$ in terms of the anomalous triangle loop diagrams;
- c. Write down the names of particles, whose masses are determined by the theory.

#3

- a. In your own words, explain why the neutrino mass has to be zero in the standard model of particle physics;
- b. For the Type-I Seesaw mechanism, find out the eigenvalues and eigenstates of the neutrino mass matrix with one generation;
- c. Find the correspondence between the Type-II Seesaw mechanism and dimension-5 Weinberg operator.

- #4**
- a. For the CMB temperature fluctuation spectrum, which peak is the most important one for the existence of Dark Matter;
 - b. For the indirect dark matter searches, if the antiproton flux is the same as the background, what can you conclude about the nature of dark matter?
 - c. For the direct dark matter searches, the experimental limits are approaching to the so called “Neutrino Floor”. Discuss what this floor means and why there is such a floor.

- #5**
- a. Explain why the equation of state for the cosmological constant is 1, i.e. $w=1$;
 - b. It is known that the phantom dark energy models correspond to negative kinetic energy. Why this type of models is problematic?
 - c. In the quintom model, the equation of state can cross the phantom divide line of $w=1$. Explain why it is the case.

Modern Particle Physics: 7 Periods

1. *< 1945 -- Pre-Modern Particle Physics Period*
2. *Startup Period (1945 -- 1960) : Early contributions to the basic concepts of modern particle physics.*
3. *Heroic Period (1960 -- 1975): Formulation of the standard model of strong and electroweak interactions.*
4. *Period of Consolidation and Speculation (1975 -- 1990): Precision tests of the standard model and theories beyond the standard model.*
5. *“Frustration” and “Waiting” Period (1990 -- 2005)*
6. *Preparation Period (2005--2020)*
7. *Super-Heroic Period (2020--2035)*