Quantum Field Theory I

Instructor: Shehu AbdusSalam

Shahid Beheshti University

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Problem Set 1

Please answer the following questions and provide us by the end of the TA class on Esfand 22.

1. Find the mass dimension of the coupling constant below Lagrangian which is called ϕ^3 scalar field theory.

$$\mathcal{L} = \frac{1}{2}\partial_\mu\phi\partial^\mu\phi - \frac{1}{2}m^2\phi^2 + \lambda\phi^3. \tag{1}$$

2. Show vector Klein-Gordon Lagrangian has global $SO(3)$ symmetry and then find Noether current of this symmetry.

$$\mathcal{L} = \frac{1}{2}\partial^\mu\vec{\chi}\partial_\mu\vec{\chi} - \frac{m^2}{2}\vec{\chi}\cdot\vec{\chi}, \tag{2}$$

   where $\vec{\chi} = \begin{pmatrix}\chi_1 & \chi_2 & \chi_3\end{pmatrix}^T$.

3. Please asnwer to problem 3.1 of [Sch14]
4. Please asnwer to problem 3.5 of [Sch14]
5. Please asnwer to problem 3.6 of [Sch14]
6. Find canonical energy-momentum tensor for electromagnetic field.
7. What is the difference between canonical and symmetric energy-momentum tensors?
8. (Bonus) Find Noether current of Lorantz $SO(1,3)$ symmetry in general Lagrangian.

$$\mathcal{L} = \frac{1}{2}\partial_\mu\phi\partial^\mu\phi - \frac{1}{2}m^2\phi^2 + \lambda\phi^4. \tag{3}$$

9. (Bonus) Find symmetric energy-momentum tensor for electromagnetic field using variation by metric.

References

[Sch14] Matthew Dean Schwartz. *Quantum field theory and the standard model*. Cambridge University Press, New York, 2014.