QFTII: theory questions for the exam

1. Discuss the construction of the massive irreducible unitary representations of the Poincarè group.
2. Discuss the construction of the massless irreducible unitary representations of the Poincarè group.
3. Gauge invariance in quantum field theory.
4. The quantization of the EM field: the problems encountered and the different approaches to tackle them (Coulomb gauge, Gupta-Bleuler, etc...)
5. Gupta-Bleuler quantization.
6. Physical states and physical operators in Gupta-Bleuler quantization. As a concrete example, show that the helicity operator $h = i\epsilon_{ijk} \int d\Omega_p a_i^\dagger(p) a_j(p) p_k$ is physical.
7. The massive vector field and its quantization.
8. The quantized massive vector field and the Lorentz transformation properties of the associated 1-particle states
9. Discuss the notion of causality in classical and quantum field theory.
10. Discrete symmetries in quantum field theory.
11. The role of discrete symmetries in quantum field theory. Illustrate with some examples (QED, Z decay, π decay, ...)
12. Parity and time reversal in quantum field theory. You can help yourself with examples.
13. Parity and Charge conjugation in quantum field theory. Can you discuss P and C for a state involving a charged scalar and its antiparticle? (work in the rest frame of the system).
14. Asymptotic states and the S matrix.
15. The Lippmann-Schwinger equation.
16. The S matrix in perturbation theory.
17. Symmetries of the S matrix
18. From amplitude to decay rate and lifetime. Emphasize that the behavior of the result under Lorentz transformations is the expected one.

19. From the S-matrix to the cross section (possibly emphasize the result behaves as expected under rotations and boosts).

20. State Wick theorem and possibly illustrate the strategy of its proof; as an application evaluate $\langle 0|T\left(\phi^3(x)\phi^3(y)\right)|0\rangle$ in terms of Feynman propagators and represent the result graphically.

21. Basic ideas of the perturbative expansion of the S matrix using Feynman diagrams.

22. Give the definition for the propagator $D(x-y)$ of a real massive scalar field. Recall (proving it, if you can) the differential equation satisfied by $D(x-y)$ and find its solution in Fourier space.

23. Symmetries of quantum electrodynamics.

24. Gauge invariance for the free and and for the interacting electromagnetic field.

25. Physical states and gauge invariance of the observables in the theory of the quantized electromagnetic field.

26. Discuss gauge invariance of physical observables, and of the S matrix in particular, in quantum electrodynamics.

27. Gauge invariance and the interactions of vector fields

28. Non-abelian Gauge Symmetry and the Standard Model.

29. Describe the Higgs Mechanism and mass generation in the Standard Model (no need to go beyond the level with which it was discussed in class). In particular emphasize the analogy with the simple theory of a free massive vector field.