FACULTY
OF MATHEMATICS
AND PHYSICS
Charles University

Quantum information in curved spacetime: Exam questions

1 What to expect

You will be asked one computational and one conceptual question out of the following two sets. You will have 30 minutes to prepare your answers (no use of the study text is allowed during this period). After that, we will discuss your answers and some (un)related problems. The discussion should last about 30 minutes, including my feedback to you.

2 Computational questions

1) Derive the light-matter interaction Hamiltonian from first principles. How does it reduce to the UdW model?

2) Calculate the excitation probability of a UdW detector. What order in the perturbation theory is the communication via exchanging real photons?

3) Define a KMS state in QFT. Assuming a Gibbs state, derive the KMS condition.

4) Derive the detailed balance condition for KMS states. What is the 'thermality expectation' for a detector coupled to such a state? What are the conditions under which this happens?

5) What is superradiance? Derive the black hole superradiant condition using the first law of black hole thermodynamics. What would happen if instead of rotation we had a charge?

3 Conceptual questions

Most of these are just a story – no calculations are needed here!

1) Introduce Unruh de Witt (UdW) particle detector. How is it different from the J-C model used in quantum optics? What is a particle?

2) What is an Unruh effect? How would you convince me that it is real? (Just a story, no calculations needed here.)

3) What are analogue systems and what are the good for? (Just a story, no calculations needed here.)

4) Discuss how UdW detectors can tell us about structure of spacetime. Is it enough to always consider only one such detector? (Just a story, no calculations needed here.)

5) Write down the signal density matrix for quantum communication. Where does it come from? What are the corresponding peculiar features of quantum communication?

6) Discuss the Huygens principle. How general is it?

7) Discuss local passivity and strong local passivity of thermal states. What about thermalization?

8) Discuss the main idea of quantum energy teleportation and how it can break the strong local passivity theorem.