PERIMETER SCHOLARS INTERNATIONAL

Relativity
Core Course 2023
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List of Interview Questions

1 What to expect

You will be asked one theoretical and one computational question out of the following two sets. You will have 30 minutes to prepare your answers. After that, we will discuss your answers and related problems. The second part will not last more than 30 minutes.

2 Computational questions

1) What is a gravitational redshift? You should be able to derive it for a satellite orbiting the Earth, and static Rindler/Schwarzschild observers

2) Discuss in detail the Newtonian limit of geodesic equation. What happens when the sub-leading in velocity term gets included? What do we get from the Einstein equation in the two cases (no derivation)?

3) Discuss the symmetries and basic characteristics of the Riemann curvature tensor. How many components does it have in various dimensions – please present the counting argument. What is its physical significance?

4) How do we describe matter in curved spacetime? Derive the corresponding field equations and define the associated energy momentum tensor. Discuss when and why it is conserved.

5) Discuss the Maxwell theory in curved spacetime. Is charge still conserved?

6) What are the Killing vectors and why do we care? Talk briefly about conserved charges in general relativity. Simple derivations maybe asked.

7) Derive (similar to what was done in the lecture) the Einstein equations from an action principle (using action and formalism of your preference). Can we write another geometrical gravity theory in 4 dimensions?

8) Study geodesics in Schwarzschild. In particular, discuss to some detail the perihelion shift of Mercury and/or the light bending around the Sun.

3 Theoretical questions

1) What is the principle of equivalence? Discuss the idea of Einstein's elevator, as well as the corresponding mathematical formulation using the differential geometry language.

2) What is the Rindler spacetime and what can we learn from it? Discuss the analogy with black holes: horizons, gravitational redshift, maximal extension,....

3) Compare the Newton, Maxwell, and Einstein classical field theories.

4) Introduce the following concepts: manifold, scalar field, curve, vector field, tensors, connection, covariant derivative, metric.

5) What do we mean by the 'double agent role' of Einstein's equations? Thence discuss the conservation of energy momentum in general relativity. Do we get any conserved charges?

6) Discuss gravitational waves: how to produce them, how many polarizations, any other characteristics? Why are we so excited?

7) What is a gravitational energy momentum pseudotensor? How to calculate the energy loss of an isolated system due to gravitational radiation?

8) Introduce the Schwarzschild metric and discuss its basic properties. What physical situations does it apply to?

9) Convince me that Einstein's theory is a reasonable theory of gravity: discuss as many as you can experimental verifications.