Information before oral exam FYTN08, General Relativity, version vt19

1 Course content

- Chapter 1
- Chapter 2
- Chapter 3
- Chapter 4: definition of the energy momentum tensor and a few examples of it, perfect fluid
- Chapter 5, not section 5.5 on the noncoordinate basis
- Chapter 6
- Chapter 7
- Chapter 8
- Chapter 9: sections 9.1 and 9.3 but in both cases not the last part about exact solutions. Section 9.2: principle of laser interferometers and orders of magnitude in detection involved included. Section 9.4 not included and section 9.5 only cursory.
- Chapter 10: 1.-5, in 10.6 only constant density solution, not Buchdal's exact solution, 10.7 only cursory (including knowing what Chandrasekhar mass limit is but not derive it in detail)
- Chapter 11 Sections 11.1-3 and 5; 11.4 only cursory.
- Chapter 12 and cosmology: Robertson-Walker metric, Friedman-Lemaître universes, solutions of the Friedman-Lemaître equation (this is (12.54) p355 in the book). Cosmic microwave background, expanding universe, cosmological redshift,cosmological parameters, fluctuations in the cosmological microwave background. I.e. sections 12.1-3 and 12.4 only cursory.
- The lectures on modern developments are meant to make you aware of them. These are not part of the examination.

2 Typical oral exam questions

The exam is meant to test understanding not memory. That means that exact memorization of formulas is not required but principles of derivation are.

Chapter 1

- Sketch the arguments used to prove that Δs^2 is independent of reference frame.
- Sketch the derivation of Lorentz transformations, what is assumed as input.
- How do you add velocities?

Chapter 2 and 3

- What are vectors, one-forms, tensors?
- Define a basis for those quantities.
- Why do we want to use this type of structures?

Chapter 4

- What is the energy-momentum tensor?
- What is a perfect fluid?

Chapter 5

- Explain the gravitational redshift experiment and its main consequences
- What is the equivalence principle?
- Why do we need curved space-time?
- What are Christoffel symbols?
- Explain the relation between Christoffel symbols and metric.
- What is the definition of a covariant derivative and explain the meaning of the terms in it.

Chapter 6

- What is a locally flat frame and how is it related to a local inertial frame?
- How do you prove that such a frame always exists (principles, not full derivation)?
- Argue for the definition of covariant derivative used in a general curved space.
- What is parallel transport, why is it useful?

- What is a geodesic and why is it important in general relativity?
- What is the physical/geometric meaning of the Riemann tensor? Why do we choose just this particular combination as the most important aspect of curvature? Which physical effect does it quantify?
- Properties of the Riemann tensor
- What are the Ricci and Einstein tensor and why do we introduce the latter?
- Why do we want $g_{\alpha\beta;\gamma} = 0$?
- What is geodesic deviation and how do you calculate it?

Chapter 7 and 8

- When do you (obviously) have conserved quantities and which are they? Can you prove it?
- Why should the matter side of Einstein's equations be a two-tensor?
- Why should the gravitational side of Einstein's equations be the Einstein tensor?
- When given a particular metric $g_{\alpha\beta}$, are there circumstances where there are obviously conserved quantities? Can you show this?
- How do you derive the weak field limit and equations?
- Sketch the arguments involved in the derivation of Newton's gravity from general relativity.
- Can you define a global mass of an isolated system? If yes, how?
- Are there other global properties that can be similarly defined?

Chapter 9

- How do you see that the field equations have wave solutions?
- How do you measure a gravitational wave?
- What is the effect of a passing gravitational wave?
- What polarizations does a gravitational wave have? How can you see this from the solutions?

Chapter 10

- What is the form of a static, spherically symmetric metric and which arguments do you use to bring it in that form?
- Sketch the derivation of the Schwarzschild metric.
- When, i.e. under which physical circumstances, is the Schwarzschild metric the correct metric to use?
- What equations do you need to solve for a star? Where do those equations come from?
- How would you solve the equations for a constant density star? What is the Chandrasekhar mass limit?

Chapter 11

- What types of orbits are possible in the Schwarzschild metric?
- Describe the derivation of the orbits.
- Describe the derivation of the perihelion shift?
- Describe the bending of light and gravitational lensing and sketch its derivation.
- What is the Schwarzschild horizon for a Schwarzschild black hole?
- Is there a real singularity there? Explain.
- What is an ergoregion?
- What is the Penrose process? Why is such a process possible?
- What is Hawking radiation?
- Surface theorem of black holes and Bekenstein entropy: what is it and arguments for it.

Chapter 12 and cosmology

- Which arguments go into the specific form of the Robertson-Walker metric?
- What is the Hubble parameter?
- The universe as a whole, what types of geometry can it have?
- Cosmic Microwave Background: what is it?