Problems for the oral examination
Particles & Gravity I
2011/12, summer semester

1. Derive the covariant Maxwell equations from the non-covariant ones.
2. Derive the formula for "the Lorentz force"from the covariant equations of motion for a charge particle moving in an electromagnetic field.
3. Show that the energy momentum tensor for set of particles is conserved when the contribution from the electromagnetic field is taken into account.
4. Discuss local gauge symmetry using scalar electrodynamics as an example.
5. Construct Lagrangian for non-Abelian gauge theory interacting with scalar fields.
6. "Derive"the Dirac equation.
7. Construct Lagrangian for non-Abelian gauge theory interacting with femionic fields.
8. Derive the conserved Noether current for internal symmetries (no space-time coordinate transformations).
9. Show time independence of the 4-momentum vector for a system described by a given Lagrangian. Discuss uniqueness of the energy-momentum tensor definition.
10. Derive a formula for gauge invariant energy-momentum tensor for electrodynamics.
11. Derive the Yukawa potential for interactions mediated by a scalar field from the energy-momentum tensor for massive scalar-field theory.
12. Derive the Yukawa potential for interactions mediated by a vector field from the energy-momentum tensor for massive electrodynamics.
13. Derive the Lagrangian for massless symmetric tensor field.
14. Derive the field equations for massless symmetric tensor field.
15. Discuss the gauge invariance of field equations for massless symmetric tensor field.
16. Derive the propagator for massless symmetric tensor field in the harmonic gauge.
17. Construct the Lagrangian for massive symmetric tensor field.
18. Construct the propagator for massive symmetric tensor field.
19. Discuss deflection of light by massive sources for massive and massless gravitons.
20. Present and discuss the Principle of Equivalence.
21. Derive equations of motion for a particle moving upon the influence of gravitational field.
22. Derive relations between the metric and coefficients of the affine connection.
23. Show that particle falling freely in the gravitational field follows a path that extremize the proper time measured along the its trajectory.

24. Discuss Newtonian limit of equation of motion for a particle moving upon the influence of gravitational field.

25. Formulate and illustrate the Principle of General Covariance.

26. Discuss properties of tensor and tensor densities for general coordinate transformations.

27. Show how does the affine connection transform.

28. Derive equations of motion for a particle moving upon the influence of gravitational field adopting the Principle of General Covariance.

29. Introduce the covariant derivative of a tensor and discuss its properties.

30. Formulate equations of motion for electrodynamics in the presence of gravity.

31. Define the curvature tensor and discuss its properties.

32. Define differentiation along a curve and its properties.

33. Discuss round trips of a vector by parallel transport.

34. Prove the necessary and sufficient conditions for a metric to be equivalent to the Minkowski metric.

35. Discuss commutation of covariant derivatives of a tensor. Show gauge field analogy.

36. Derive Bianchi identities.

37. "Derive"the Einstein field equations.

38. Discuss harmonic gauge conditions for gravity.

39. Derive the weak field approximation for the Einstein field equations.

40. Construct the plane wave solutions for the weak field approximation for the Einstein field equations. Show electrodynamic analogy.

41. Discuss energy and momentum of gravitational field.

42. Postulate the action for charged particles moving in electromagnetic field in a given gravitational background and show that it implies the correct equations of motion.

43. Introduce the gravitational definition of the energy-momentum tensor and calculate it for electrodynamics.

44. Discuss the general covariance and the energy-momentum conservation.

45. Postulate the action for gravitational field and show that its variation leads the the Einstein equations.

46. Discuss gravitational fluctuations around gravitational background.

47. Discuss the Weyl transformation.