I am posting here the question Paper for the subject: General Theory of Relativity (GTR) and Cosmology (Theory I) for the III semester year 2017. The question paper is for the students of M.Sc Physics at the University of Delhi. Future students taking this course might find it helpful.

This question paper contains one sheet with both sides printed Your Roll No.....

M.Sc.(PHYSICS), III-Semester 2017 November-December, University of Delhi

Paper-PHYS-556: General Theory of Relativity & Cosmology-I

Time: 3 hours Maximum Marks: 70

(Write your Roll No. on the top of this question paper immediately on receipt)

Answer **all three** questions in Section-A and any one question from 4,5 in Section-B.
All notations have their usual meaning.

Section-A

1 (a) What is an irreducible tensor? Compute the number of components in an irreducible Ricci tensor $S_{\mu\nu}$ in GTR. Re-express the scalar $S^2_{\mu\nu}$ in terms of a reducible and an irreducible Ricci tensors.

(b) Decompose the Riemann tensor into its irreducible components in $(3+1)$-dimensions.

(c) Compute the number of components in the Weyl-Conformal tensor in (2+1)-dimensions. Is there a non-zero curvature in (2+1)-dimensional Einstein gravity? Give reasons for your answer.

(6+6+6)-marks

2 (a) List any four properties of the Riemann manifold. Define an S_3 manifold mathematically. Explain if there is an extrinsic or intrinsic curvature on S_3.

(b) State and explain the Equivalence Principle. Comparing geodesic equations, obtain the Christoffel connection in terms of the inertial x^μ and non-inertial ξ^μ coordinates.

(c) State the Newtonian limit of GTR. Obtain an expression for an acceleration in this limit.

(6+6+6)-marks

3(a) Under a δ-variation with respect to the metric, show that:

$$\delta R_{\mu\nu} = \nabla_\rho \left(\delta\Gamma^\rho_{\mu\nu}\right) - \nabla_\nu \left(\delta\Gamma^\rho_{\mu\rho}\right) .$$

(b) Compute: $K = \left(\epsilon_{\mu\nu\alpha\beta} R^{\alpha\beta}{}_{\lambda\rho} \mathcal{E}^{\lambda\rho\mu\nu}\right)$, where $\epsilon_{\mu\nu\alpha\beta}$ and $\mathcal{E}^{\lambda\rho\mu\nu}$ are the Levi-Civita tensor and Levi-Civita tensor density respectively. Evaluate K for a Schwarzschild and a Reissner-Nordstrom black hole.

(c) Start with the field equation in GTR and re-express it as: $\left(T_{\mu\nu} - \frac{1}{2} g_{\mu\nu} T\right) = \kappa^{-1} R_{\mu\nu}$. State the underlying symmetry if any between the Ricci and the energy-momentum tensors.

(6+6+6)-marks

Section-B

4 (a) Determine $\left(\Gamma^{\theta}_{\phi\phi}, \Gamma^{\phi}_{r\phi} \text{ and } R_{\theta\theta}\right)$ for the Schwarzschild metric.

(b) What is the shape of light cone at the event horizon of a black hole. Give reasons for your answer. Describe the nature of a geodesic at the horizon. What does the geodesic describe in this case?

(c) Re-express the Christoffel connection in a linear approximation.

(6+6+4)-marks

OR

5(a) Take $D_\mu=(\nabla_\mu - A_\mu)$, where ∇_μ is the covariant derivative in GTR and A_μ is a gauge field. Compute $[D_\mu, D_\nu]\Phi$, where Φ is a scalar field. Consider a $(3+1)$-dimensional theory defined with the derivative D_μ. Determine all the non-zero curvatures in the theory.

(b) Determine all the non-zero curvature tensors for a Schwarzschild black hole.

(c) Write down the general coordinate transformations of $g^{\mu\nu}$ and $\det g^{\mu\nu}$. Find their weights?

(d) $B_{\mu\nu\lambda}$ is a completely skew-symmetric tensor. Find the number of independent components of $B_{\mu\nu\lambda}$ in (3+1)-dimensions.

(6+4+4+2)-marks

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I'm a physicist specializing in theoretical, computational and experimental condensed matter physics. I like to develop Physics related apps and softwares from time to time. Can code in most of the popular languages. Like to share my knowledge in Physics and applications using this Blog and a YouTube channel.

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