GRAVITATION : 24 Lectures - Semester 7

1. Preliminaries (2 lectures)

1.1 Cartesian Tensors
1.1.1 Simple example : Conductivity
1.1.2 Definitions
1.1.3 Properties of tensors
1.1.4 Tensor detection theorem : Quotient rule
1.1.5 Isotropic tensors

1.2 Variational Calculus
1.2.1 Euler-Lagrange equations
1.2.2 First integrals
1.2.3 Simple examples
1.2.4 Generalizations

1.3 Newtonian mechanics and gravity
1.3.1 Newton's laws
1.3.2 Inertial frames
1.3.3 Galilean Relativity
1.3.4 Newtonian gravity
1.3.5 Weak equivalence principle
1.3.6 Particle orbits

1.4 Review of Special Relativity
1.4.1 Principles of Special Relativity
1.4.2 Minkowski spacetime
1.4.3 Doppler-shift formula
1.4.4 Velocity additions formula
1.4.5 4-momentum
1.4.6 Maxwell's laws of electromagnetism

1.5 Einstein's lift experiment
1.5.1 Strong equivalence principle
1.5.2 Simple thought experiment
1.5.3 Gravitational redshift
1.5.4 Fermat's principle and the SEP

1.6 Einstein's vision of General Relativity

2. Manifolds, metrics and tensors (4 lectures)

2.1 Manifolds
2.2 Curves and surfaces
2.3 Coordinate transformations
2.4 The metric and line element
2.5 Tangent vectors
2.6 Vectors, co-vectors and tensors
2.7 Conformal metrics

3. Connection and tensor calculus (4 lectures)

3.1 Covariant differentiation and Torsion
3.2 Affine Geodesics
3.3 Metric Geodesics and the Metric Connection
3.4 Locally Interial Coordinates
3.5 Isometries and Killing's Equation
3.6 Computing Christoffel symbols and Geodesics

4. Curvature (2 lectures)

4.1 Riemann Tensor, Ricci Tensor and Ricci Scalar
4.2 Symmetries of the Riemman tensor and the Bianchi idenities
4.3 Round trips by parallel transport
4.4 Geodesic deviation

5. Einstein equations (3 lectures)

5.1 Energy-momentum tensor
5.2 Einstein tensor and the Einstein Equations
5.3 Newtonian limit
5.4 Gravitational radiation

6. Schwarzschild Solution (5 lectures)

6.1 Spherically symmetric vacuum solution of Einstein equations
6.2 Birkhoff's theorem
6.3 Dynamics in the Schwarzschild solution : particle and photon orbits
6.4 Gravitational Redshift
6.5 Light deflection
6.6 Perhelion precession
6.7 Black holes and event horizons

7. FRW universe (4 lectures)

7.1 Expansion, isotropy and homogeneity
7.2 FRW metric
7.3 Friedmann and Raychaudri equations
7.4 Solutions in matter and radiation eras
7.5 Cosmological constant
7.6 Cosmological redshift
7.7 Cosmological distance measures
7.8 Flatness Puzzle