This is a tentative schedule of what we will cover in the course. It is subject to change, often without notice. These will occur in response to the speed with which we cover material, individual class interests, and possible changes in the topics covered. Use this plan to read ahead from the textbooks,


so you are better equipped to ask questions in class.

- **PRELIMINARIES**

  Suggested literature: Lecture notes
  Secs. 1.1-1.3, 2.1-2.3 in [2]
  Secs. 4.1-4.8 in [3] (kinematics of rigid body motion)

  Suggested literature: Lecture notes
  Secs. 1.1-1.7 in [1]
  Secs. 7.1-7.5 in [3] (classical mechanics of special theory of relativity)

  **Basic facts from CM and EM (self study)**: Maxwell’s equations. Energy and momentum. Classical field theory.
  Suggested literature: Sec.1.8-1.10 in [1]
  Secs. 13.1-13.7 in [3] (Lagrangian formulations for continuous systems and fields)

  Suggested literature: Lecture notes
  Secs. 2.4-2.6 in [2]
• **ELEMENTS OF THE DIFFERENTIAL GEOMETRY**

**Manifolds:** Topological space. Definition of the manifold. Examples: $S^n$, $O(N)$, $SO(N)$, $\mathbb{R}P^n$, $T^n$, ….

Suggested literature: Lecture notes

- Secs. 2.1, 2.2 in [1]
- Secs. 3.1 in [2]


Suggested literature: Lecture notes

- Secs. 2.3, 2.4, 2.8 in [1]
- Secs. 3.2, 3.3, 4.1, 4.2 in [2]


Suggested literature: Lecture notes

- Sec. 3.3-3.7 in [2]


Suggested literature: Sec. 2.9, 2.10, Appendix E [1]

- Secs. 5.1-5.3, 5.5 in [2]

• **SPACE - TIME IN GENERAL RELATIVITY**

**(pseudo-)Riemannian manifolds:** Metric. Physical coordinates. Geodesics in a (pseudo-)Riemannian manifold. Locally geodesic coordinates.

Suggested literature: Lecture notes

- Sec. 2.5, 3.1-3.4 in [1]
- Secs. 7.1, 7.2 in [2]

**Levi-Civita connection:** Particle in the gravitational field (Free motion. Newtonian limit). Absence of torsion in General Relativity. Connection vs metric.

Suggested literature: Lecture notes

- Sec. 3.1-3.3, in [1]

**Curvature tensor in (pseudo) Riemannian space:** Curvature vs metric. Flatness condition. Free fall and Fermi normal coordinates (self study). Properties of the Riemann tensor: Symmetries, number of independent components, Bianchi identity. Geodesic deviation equation.

Suggested literature: Lecture notes

- Secs. 3.6, 3.7, 3.10 in [1]
- Secs. 7.3 in [2]

For Fermi normal coordinates, see F.K. Manasse and C.W. Misner, “Fermi normal coordinates and some basic concepts in differential geometry”, Journal of Mathematical Physics 4, no. 6, p. 735 (1963)
• GRAVITATIONAL FIELD EQUATIONS

**Einstein equations:** Energy-Momentum tensor. Einstein’s equation. Coordinate conditions. Harmonic coordinates.

Suggested literature: Lecture notes

Secs. 4.1, 4.2 in [1]


Suggested literature: Lecture notes

Secs. 10.1-10.5 in [3] (Hamilton-Jacobi theory)
Secs. 7.1-7.3 in [1]

**Variational principle:** Lagrangian formulation. Derivation of Einstein’s equation from variational principle.

Suggested literature: Lecture notes

Secs. 4.3-4.5 in [1]
Secs. 8.1-8.5 in [2]

• EXACT SOLUTIONS OF EINSTEIN’S EQUATION

**Schwarzschild solution:** Static and stationary solutions. Rotationally invariant metrics. Schwarzschild metric.

Suggested literature: Lecture notes

Secs. 5.1, 5.3 in [1]

**Rotational symmetry and relativistic stellar structure:** Gravitating spherical body. Tolman-Oppenheimer-Volkoff equation. Incompressible matter. Gravitational stability condition for a static star.

Suggested literature: Lecture notes

Sec. 5.8 in [1]

**Geodesics of Schwarzschild:** Kepler problem. Fall to the center.

Suggested literature: Lecture notes

Secs. 5.4-5.6 in [1]
Secs. 3.7, 3.8 in [3] (Kepler in Classical Mechanics problem)

**The maximally extended Schwarzschild solution:** Rindler space-time. Kruskal coordinates.

Suggested literature: Lecture notes

Secs. 5.7 in [1]

**Isometries:** Killing vectors. Lie bracket. Birkhoff’s theorem.

Suggested literature: Lecture notes

Secs. 3.8, 5.2, Appendix B in [1]
Sec. 4.4 in [2]

**Stars and black holes:** Comoving coordinates. Gravitational collapse. Collapse of dust-like matter.
Suggested literature: Lecture notes
Secs. 5.8 in [1]
• **GRAVITATIONAL RADIATION**

  **Gravitational waves:**
  Suggested literature: Lecture notes
  Secs. 7.4 in [1]

  Suggested literature: Lecture notes
  Secs. 7.5-7.7 in [1]

• **ROTATION**

  **Rotating star:** Kerr metric. Weak field approximation. Precession of orbits.
  Suggested literature: Lecture notes
  Secs. 6.1, 6.6 in [1]
  Secs. 3.7-3.9 in [3] (Kepler in Classical Mechanics problem, Laplace-Runge-Lenz vector)

• **GENERAL RELATIVITY AND COSMOLOGY**

  **Geometry of a isotropic space:** Isotropic and homogenous manifolds. Spatially isotropic Space-Time
  Suggested literature: Lecture notes
  Secs. 8.1 in [1]

  **Cosmological models:** Robertson-Walker metric. Friedman equation.
  Suggested literature: Lecture notes
  Secs. 8.2-8.4 in [1]

  **Isotropic models and observations:** Cosmological red-shift,...
  Suggested literature: Lecture notes
  Secs. 8.5, 8.7 in [1]