# General Relativity or "GR" (PHYS 325) 

Spring 2024 v0.5

"*That one body may act upon another at a distance through a vacuum without the mediation of anything else, by and through which their action and force may be conveyed from one another, is to me so great an absurdity that, I believe, no man who has in philosophic matters a competent faculty of thinking could ever fall into it.*"
- Issac Newton in 1692 (letter to Bentley available from the Newton Project)

Welcome to GR! This course fixes Newton's "absurdity" by introducing Einstein's general relativity. We will spend the first bit of the course on curved space ("spacetime geometry") and the associated mathematics ("differential geometry"). After motivating the equations of motion, known as the "Einstein's equations" or "the field equations", we will concentrate on applications including the black holes, cosmology, and gravitational waves.

**Contact Info:**

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**Office Hours:** My official hours are after every class and Tuesdays 1:30 - 4 PM. We'll see how this goes but we may need to move from G064 to another available space like G047. If you cannot make these times, let's find a time when you and I are available.

**Course Info:**

The Phys 325 web site is here.

**Course Structure:**

The course will be in approximately traditional lecture-discussion format. We can take advantage of our smallish numbers to have plenty of spontaneous discussion, choose to have presentation if we wish, and determine which topics to focus on.

**Textbooks:**

There are many good GR texts. We will primarily use Schutz's *A first course in general relativity*, now out in the 3rd edition. On approximately the same level as our book there are Jim Hartle, *Gravity: An introduction to Einstein's General Relativity* and Ohanian and Ruffini, *Gravitation and Spacetime*. The Mother Book is *Gravitation* by Misner, Thorne, and Wheeler. This weighty book is fondly known as "MTW". There are two short (breath-takingly brief) introductions by Dirac and 't Hooft (Nobel prize winners). A much easier introduction to SR and some GR ideas is contained in the lovely book *Flat and Curved Spacetimes* by Ellis and Williams. Finally, I should add that Schutz has also written a fine introductory book on differential geometry.

**Work:**

We will have 11 problem sets (due on Thursdays) and we'll choose the form of the final: it could be a self-scheduled take-home final or the scheduled final (May 12 at 2 PM). I encourage you to work with others on the weekly problems. But you must cite when you do and with whom you worked. Also cite any other resources you use. Please write up your work with care. Each solution should be easy to read with the logic readily apparent. The weighting of the semester grade will be solutions 65%, final 25%, and participation 10%.

**Topics:**

- **Special Relativity**: (Schutz Chapters 1-3) the physics of SR, indices, 4-vectors, some tensors,
- **Curved Space**: (Schutz Chapters 5-7) tensor algebra, metric, covariant differentiation, Bianchi identities, curvature and physics, curvature and geometry
- **Einstein Equations**: (Schutz Chapter 8) The Theory, linear approximation
- **Black Holes**: (Schutz Chapter 11) Schwarzschild solution
- **Cosmology**: (Schutz Chapter 12 )
- **Gravitational Waves**: (Schutz Chapter 9 )