MIT HSSP 2013 - S7291
Gravity: from Principles to Black-holes

Instructor: Charlie G Payne **email:** cpayne@seas.harvard.edu

Lectures: Sunday, 1:35pm - 2:55pm **Room:** 1-135

Course Description:

General Relativity is Einstein's theory of gravity, something one rarely has an introduction to in high school, and instead might see in their senior year of undergraduate physics. Its results are fascinating, and its mathematics are advanced. However, the principles from which it can be derived are elegant and inspiring. In this course, I will attempt to make General Relativity attainable for your young mind, without the use of senior-level university mathematics. Our goal is to build your qualitative intuition and get you excited about theoretical physics.

We will start with a review of classical gravity theory, explain its faults, then discover Einstein's insights, and detail the extraordinary predictions of General Relativity. Are you prepared to face: gravitational lensing, spacetime curvature, time dilation, black-holes, and cosmology? With time permitting, we will touch on some the modern problems with General Relativity, such as its incompatibility with Quantum Mechanics and the black-hole information paradox.

Prerequisites:

- Required: algebra, geometry, trigonometry, physics
- Desired *(but not required)*: precalculus, calculus, higher-level physics

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Course Schedule:

1) History Repeating

We first review old gravity theory, that of Newton and his falling apple, and explain its downfalls. Then we'll follow Einstein's footprints, and walk through his historical background.

2) Einstein's Happiest Thought

Now we move on to the famous "equivalence principle". After describing its weak and strong forms, we'll see how it naturally predicts the gravitational lensing of light.

3) Spacetime

What really is spacetime? Is it a mathematical framework, or something more? In this class, we'll discover how gravity is a geometrical property of spacetime. That will require a peak into curvature, geodesics, and the Einstein Field Equations.

4) Gravitational Time Dilation

If gravity is the curvature of spacetime, then what does this tell us about the passage of time itself? It turns out there is no absolute clock of the universe, time is relative, spacetime is dynamic, and time ticks slower when you're deeper in a gravitational well.

5) Black-holes

Some things are so gravitationally warped that not even light can escape their grasp. That's right, the moment you've been waiting for, let's discover black-holes.

6) Cosmology

How did the universe begin, and where is it going? This week we'll explore General Relativity's insights on the big bang, dark matter, and the accelerated expansion of the universe.

7) Additional Topics

Why don't Quantum Theory and General Relativity want to hold hands? Can we permanently destroy information in a black-hole? In this class we'll need some help from our friends, Stephen Hawking and Leonard Susskind. (no, no, they aren't coming to the lecture)

Expectations:

From me, you can expect that I will do my best to get you excited about the material and help you understand its depths. From you, I expect that you attend every lecture possible (on time), you respect your fellow classmates, you treat MIT's staff & campus with the utmost of gratitude, and you conduct yourself in a mature manner. I will treat this course as though it is a university-level lecture series, and thus I expect that you will communicate to me when I'm moving too fast, I have to re-explain things, or you have an insightful question and/or remark.

There will be no homework, tests, or graded components to this course, so sit back and enjoy. However, I would highly recommend taking notes, as this is a critical skill to your success when you get to university. If you need any advice on your future in academics, don't hesitate to ask; I was recently in your shoes, after all.