**Relativity (PHY 408)**

Jacobus Verbaarschot

[Announcements](http://chi.physics.sunysb.edu/lectures/spring-2024/announce.shtml)

[Homework Assignements](http://chi.physics.sunysb.edu/lectures/spring-2024/homework/homework.shtml)

[Lecture Notes](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)

[Mathematica Notebooks](http://chi.physics.sunysb.edu/lectures/spring-2024/notebooks/notebooks.shtml)

This course covers special and general relativity. After a review of special relativity and relativistic covariance, we cover the basics of geometry and tensor analysis to arrive at the Einstein equations. We will discus the non-relativistic limit of these equations, the black hole solutions and the gravitational wave solutions. The textbook is Sean Carrol, Spacetime and Geometry: An Introduction to General Relativity. Also useful are [lecture notes by Gerard 't Hooft](http://chi.physics.sunysb.edu/lectures/spring-2024/thooft.pdf) and the textbook, A first Course In General Relatibvity, by Bernard Schutz.

A tentative course plan is [available](http://chi.physics.sunysb.edu/lectures/spring-2024/plan.pdf).

Class attendance is essential, and your feedback is very important. Everyone should be able to follow the lecture at all times. Questions during class on the material and my explanations are strongly encouraged. I may give quizzes to find out if I have been sufficiently clear.

This class meets Mon-Wed 4.00-5.20 in Melville Library N4000 The first class meeting is Monday January 22, at 4.00 pm, and I will send you the Zoom link.

**Prerequisites**

A Griffiths level course in electrodynamics is essential as well as a strong background in Mathematics. Basic knowledge of Mathematica is required -- some of the homework problems rely on this framework.

**TextBook and Lecture Notes**

As I said above, the required text book is Sean Carrol, Spacetime and Geometry: An Introduction to General Relativity.

**Grade Calculation**

The course grade will be based on homework, a midterm exam, a final exam and class participation, according to the formula 15 percent homework, 5 percent for class participation (including possible quizzes), 30 percent for the midterm and 50 percent for the final. Students who get less than 25 percent correct of the final can expect an F grade for this course.

**Final Exam:** Monday May 13, 2024, 5.30 -- 8.00 pm. Frivolous excuses such as I have booked a flight back home or I have two exams on the same day will not be accepted.

**Class Times and Venue:**Mon-Wed 4.00 -- 5.20, in Physics P117.

**Office Hours**

Wednesday 12.00 -- 2.00, may change if there are conflicts.

**Homework**

Homework will be assigned weekly, and must be submitted on paper. It will be assigned on Tuesday and is due next Sunday at midnight. No extensions of the homework deadline will be given. If the handwriting or scan is not sufficiently clear, it is my prerogative not to grade the homework. Copying homework solutions from the internet is not allowed, but collaboration with fellow students is encouraged. I will check if homework solutions have been copied from the web or other sources.

**Course Website:** [PHY 408 Website](http://chi.physics.sunysb.edu/lectures/spring-2023/index.shtml)

**University Policies**

We will comply with University Policies with regards to religious holidays, accessibility, disabilities, academic integrety, etc.. See, [the Provost Webpage](https://www.stonybrook.edu/commcms/provost/faculty/handbook/academic_policies/policies_and_procedures_for_instructors.shtml) and [University Syllabus statement](https://www.stonybrook.edu/commcms/provost/faculty/handbook/academic_policies/syllabus_statement.shtml) for details.

Send corrections and comments about this WEB page to jacobus.verbaarschot@stonybrook.edu. Last updated 01/19/2024.

**Lecture Notes for Relativity (PHY408)**

**Spring 2024, Jacobus Verbaarschot**

[Lecture 1, 1-22-2024 (by Zoom)](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/p1-33)  
Relativity, Invariant Distance, Proper Time, Lorentz Transformatioons (Caroll 1.2, 1.3) [Lecture 2, 1-24-2024 (by Zoom)](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/p1-33)  
Rapidity, Lorentz Contraction, Addition of Velocities, 4 Vectors

(Carroll 1.3, 1.4) [Lecture 3, 1-29-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/p1-33)  
Lie algebra of the Lorentz Group, Tensors (Carroll 1.3, 1.6, 1.7)

[Lecture 4, 1-30-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/p1-33)  
Invariant Tensors, Action of a Relativistic Particle (Carroll 1,9, 1.10)

[Lecture 5, 2-5-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/p1-33)  
Lagrangian, Lagrange Equations of Motion (Carroll 1.10)

[Lecture 6, 2-7-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/p1-33)  
Lagrangian of EM field, Lorentz Force. Lorentz Transformations of E and B (Caroll 1.8, 1.10)

[Lecture 7, 2-12-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/p1-33)  
Lorentz Transformations (Carroll 1.8, 1.10) , Energy Momentum Tensor (Carroll 1.9)

[Lecture 8, 2-14-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Ideal Fluid and Euler Equation (Carroll 1.9), Manifolds, Tangent Vectors, Form s (Carroll 2.2, 2.3)

[Lecture 9, 2-19-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Metric, Signature, Canonical Form (Carroll 2.5)

[Lecture 10, 2-21-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Domain of Dependence, Horizon (Carroll 2.7) Tensor Densities (Carroll (2.9), Derivatives (Carroll 3.2)

[Lecture 11, 2-26-2026](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Tensorial Property (Carroll 2,2), Covariant derivative of GR (Carroll, 3.3)

[Lecture 12, 2-28-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Parallel Transport, Geodesic Equation (Carroll 3.3)

[Lecture 13, 3-4-2024, bY Prof. Syritsyn](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Curvature Tensor, Ricci Tensor (Carroll 3.6) Properties of the Riemann Tensor (Carroll 3.7)

[Lecture 14, 3-6-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
The Expanding Universe (Carroll 3.5)

[Lecture 15, 3-18-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Eistein Equationt (Carroll 4.2)

[Lecture 16, 3-20-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Midterm Exam

[Lecture 17, 3-25-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Eistein Equation, Newtonian Limit (Carroll 4.2, 7.1)

[Lecture 18, 3-27-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Gravitational Radiation (Carroll 7.4, 7.5)

[Lecture 19, 4-1-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
The Schwartzschild Solution (Carroll 5.1)

[Lecture 20, 4-3-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Bending of Light (Carroll 7.3)

[Lecture 21, 4-8-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Perihelium Shift (Carroll 7.3)

[Lecture 22, 4-10-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Singularities of the Schwartzschild Metric (Carroll 5.6, 5.7)

[Lecture 23, 4-15-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Penrose Diagram, Kruskal Coordinates (Carroll 5.7)

[Lecture 24, 4-17-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Hilbert Einstein Action, Killing Vectors (Carroll 4.3, 3.8)

[Lecture 25, 4-22-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Killing Vectors, Application to Schwartzschild Metric (Carroll 3.8, 5.4)

[Lecture 26, 4-24-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Equivalence Priciple, Rindler Coordinates (Carroll 3.8, 5.4)

[Lecture 27, 4-29-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Thermodynamics of Black Holes and Hawking Radiation (Carroll 9.6)

[Lecture 28, 5-1-2024](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)  
Cosmology and Robertson-Walker Metric (Carroll 8.1, 8.2)

[Final Exam, Monday. 5-13-2024, 5.30-8.00 pm in regular class room](http://chi.physics.sunysb.edu/lectures/spring-2024/notes/notes.shtml)