

Seminars on Science

SPACE, TIME AND MOTION

Syllabus

Course Title

Space, Time and Motion: Physical Science

Course Description

Throughout history, humans have grappled with questions about the origin, workings, and behavior of the universe. This seminar begins with a quick tour of discovery and exploration in physics, from the ancient Greek philosophers on to Galileo Galilei, Isaac Newton and Albert Einstein. Einstein's work then serves as the departure point for a detailed look at the properties of motion, time, space, matter, and energy.

The course considers Einstein's Special Theory of Relativity, his photon hypothesis, wave-particle duality, his General Theory of Relativity and its implications for astrophysics and cosmology, as well as his three-decade quest for a unified field theory. It also looks at Einstein as a social and political figure, and his contributions as a social and political force.

Scientist-authored essays, online interaction, videos, and web resources enable learners to trace this historic path of discovery and explore implications of technology for society, energy production in stars, black holes, the Big Bang and the role of the scientist in modern society.

Class Schedule

This is a six-week online graduate course with an additional week for assignment completion. The course is asynchronous and does not have specific meeting times. Assignments and discussions change on a weekly basis. Students are expected to complete work within the specific week it is assigned.

For the current schedule of offerings, please visit www.amnh.org/learn/calendar.php.

Instructors

This graduate course is co-taught by an experienced educator along with a research scientist. **For example**, a recent course featured:

Mr. Jason Petula

Tunkhannock Area High School
Tunkhannock, PA

Dr. Charles Liu

Department of Earth and Planetary Sciences
American Museum of Natural History

For current instructor information, please contact seminfo@amnh.org.

Format

1. **Space, Time and Motion** is a six-week online graduate course with an additional week for assignment completion. Enrollment is restricted to current or future educators.
2. **Weekly activities** introduce the basic tools used to measure the speed of light, mass, and weight, and how they relate to special relativity, thermodynamics, grand unified theory, superstring theory and society at large. Computer interactives, image galleries, and videos will help learners visualize and master the content.
3. **Online discussions** encourage reflection on course content, support and model the inquiry process, and sustain interaction between the offering scientists, seminar instructors, and course members.
4. **Final course projects** support either the development of a proposal planning how you might research a question related to a seminar topic you find particularly interesting or the creation of inquiry-based lesson plans focused on a key course concept that you might incorporate into your teaching practice.

Required Textbook

This course requires the following textbook. An online version is available at no charge, but a hardcopy can be purchased.

One Universe: At Home in the Cosmos

by Neil De Grasse Tyson, Robert Irion, Charles Tsun-Chu Liu

Hardcover: 218 pages; Dimensions (in inches): 1.02 x 12.33 x 9.82

Publisher: Joseph Henry Press; (March 2000)

ISBN: 0309064880

This book can also be viewed free of charge at <http://www.nap.edu/html/oneuniverse/index.html>

Recommended Textbooks

The following textbooks are recommended as general references but are not required.

The Universe in a Nutshell

A fascinating, if often challenging, book that takes readers to the edge of current understanding about cosmology and particle physics.

by Stephen Hawking

Hardcover: 224 pages; Dimensions (in inches): 0.91 x 10.21 x 7.82

Publisher: Doubleday; 1st edition (November 6, 2001)

ISBN: 055380202X

The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory

A best-selling exposition of string theory and cosmology, quite challenging in sections, and with some very creative analogies.

by Brian Greene

Paperback: 464 pages; Dimensions (in inches): 1.01 x 8.01 x 5.23

Publisher: Vintage Books; (February 29, 2000)

ISBN: 0375708111

Cosmic Horizons: Astronomy at the Cutting Edge

A collection of essays by scientists working in modern astrophysics and cosmology.

by Neil De Grasse Tyson, Steven Soter, American Museum of Natural History

Paperback: 256 pages; Dimensions (in inches): 0.69 x 9.24 x 7.54

Publisher: New Press; (May 2001)

ISBN: 1565846028

Support Services

Technical support is available for technical issues on a 24/7 basis. Please call (303) 873-0005 or email helpdesk@amnh.college.com.

Grading

Assessments are based on a detailed grading rubric developed for this course:

Course Assignments	25%
Course Participation & Communication	45%
Final Project	30%

1. **Course assignments** will include reflection questions and written assignments.
2. **Class participation** will be evaluated based on the quality and consistency of contribution to the discussion forum. The grades for participation will be posted two weeks after each question opens.
3. **Final Project:** There are two options for the course project:

Option I: Teaching Practice

This option is for learners who would like an opportunity to develop an application based on the course content that could be taught to students or other educators. The final form may be a unit or workshop plan (if it will be used as part of a professional development experience).

Option II: Research Question

This option is for learners who would like an opportunity to further explore and grapple with the science and skills presented in this course. The task is to develop a research question of interest based on some element of the content presented in the course.

4. **Policy:** Everything submitted as an assignment, project, or discussion post must be an original work. References to resource materials are expected and proper citation is required.

Weekly Overview and Expectations

Week 1: What is Motion?

In 1904, the world was full of confident physicists and excited engineers. Physicists could predict the motion of the planets, understood that light was an electromagnetic wave, and could send a radio signal across the Atlantic Ocean (the first telecommunication). Then along came Einstein, whose theories radically changed our views of motion, time, space, energy and matter. In this first week, Drs. Charles Liu and Orsola De Marco introduce the essentials of the scientific process, provide a brief summary of scientific frontiers at the turn of the 20th century, and explore the concept of motion.

Expectations

- Review the course orientation.
- Reflect on the concept of motion and how our understanding has changed over time.
- Examine the geocentric and heliocentric models of Earth's motion.
- Determine the significance of Galileo's discoveries regarding planetary motion and the moons of Jupiter.
- Become familiar with the concept of momentum.
- Explore the complex nature of gravity and how it has been perceived.
- Participate in the Icebreaker Discussion.
- Respond to the Discussion Question: Is this Rocket Science?

Week 2: What is Time?

In our daily lives, we use time as a way to mark past, present, and future events. We rely on the motion of the Sun, Moon, planets, and stars to synchronize our timepieces, and our schedules. No matter how precise our measurements, time can "stand still," or fly. According to Einstein's Special Theory of Relativity, time runs differently depending on how fast you move. And the challenge of understanding the concept of relative time — the relationship between time, motion, and frame of reference — transcends our experience. This week, Drs. Liu and De Marco introduce Einstein's Special Theory of Relativity and explore what happens when scientific paradigms shift.

Expectations

- Review the concept of time as a "frame of reference."
- Explore the relationship between time and motion.
- Trace the history of scientists' perception of time.
- Investigate the tools used to measure time.
- Gain an understanding of the speed of light.
- Reflect on the concept of Galilean relativity.
- Learn how Einstein's Theory of Special Relativity redefined our thinking.
- Respond to the Discussion Question: Understanding Time
- Complete the Discussion Question: Frames of Reference
- Complete the Assignment: What a Long, Short Trip

Week 3: What is Space?

Philosophers and scientists have tried to define space, portraying it as an absolute void or describing it as a vessel within which everything moves. This week, learners explore the concept. Einstein defined space as a four-dimensional continuum, with time as the fourth dimension. His questions about the nature of gravity and the relationship between space and mass led to a completely new view of space as an agent of physics: mass bends space, and space determines how mass moves. Drs. Liu and De Marco introduce Einstein's General Theory of Relativity and how its verification catapulted Einstein into the international limelight.

Expectations

- Examine the concept of space and how the ancient Greek philosophers, Galileo Galilei, and Isaac Newton perceived it.
- Analyze the concept of space-time.
- Explore the relationship among mass, weight, and gravity
- Review the theory and meaning of general relativity.
- Learn about the relationship between gravity and mass.
- Explore the research of Albert Einstein and Sir Arthur Eddington on the gravitational bending of light.
- Examine the phenomenon of a black hole.
- Respond to the Discussion Question: Looking for a Heartbeat
- Complete the Assignment: Length Contraction
- Present preliminary thoughts on the final project

Week 4: What is Matter?

For most of recorded history, the study of matter and how it interacts with itself has been the domain of chemists. But as we look more and more closely at matter's finer structure, chemistry gives way to physics. Einstein and his contemporaries confronted the idea that the laws of motion lose their focus at microscopic scales. This week learners consider the nature of matter, and read about Einstein's work on Brownian motion and the photoelectric effect — work that advanced the quantum revolution.

Expectations

- Examine the concept of matter.
- Study how scientists' conceptions of the composition of matter have changed over time.
- Trace the atomic revolution, and determine its relevance to scientists' understanding of our physical world.
- Review the concept of Brownian motion.
- Examine Max Planck's research on the nature of light.
- Discover how Einstein's study of the dual nature of light helped launch the field of quantum mechanics.
- Learn how the study of quantum mechanics led to the development of the laser.
- Respond to the Discussion Question: Is light matter?
- Complete the Assignment: Relativistic Mass

Week 5: What is Energy?

This week, learners explore the nature of energy and how it operates in the physical world. Once conceived of simply as the ability to do work, energy comes in many forms. Einstein's Special Theory of Relativity added greatly to our understanding of not just how matter manifests itself, but what it *is*. Learners encounter the world's most famous equation, $E=mc^2$, and consider the impact of its applications — atomic energy in particular — on society.

Expectations

- Examine the concept of energy.
- Consider the distinction between potential and kinetic energy.
- Review the concept of thermodynamics.
- Learn about Einstein's famous equation, $E=mc^2$.
- Determine the relationship between the kinetic energy, mass, and velocity of an object.
- Study the equivalence of mass and energy.
- Learn about the formation, composition, and destruction of stars.
- Investigate the relationship between light and gravity.
- Trace how the scientific works of various 20th-century scientists, along with Einstein's discoveries in thermodynamics, led to the construction of the first atomic bomb.
- Complete the Discussion Question: Picture this . . .
- Complete an outline of the Final Project

Week 6: Where Are We Now?

This week explores the quest for a "theory of everything:" one that would explain how the entire universe works. Einstein spent the latter part of his life trying — unsuccessfully - to develop such a unifying theory . Theoretical physicists are still trying to resolve contradictions between the two main pillars of modern physics (general relativity and quantum mechanics), as well as trying to explain dark energy, a force that appears to be pushing the universe into an ever-faster expansion. Drs. Liu and De Marco wrap up the course with a discussion of why, almost a century after the publication of Einstein's Special Theory of Relativity, we may be on the threshold of a new revolution in our view of the universe.

Expectations

- Review the concept of cosmology.
- Examine the concept of an expanding universe.
- Study the "GUT," or grand unified theory.
- Evaluate superstring theory.
- Respond to the Discussion Question: On the Scientific Frontier
- Complete the Final Project