Welcome to 20'th Century Concepts of Space, Time, and Matter, V85.0020. This course is intended to provide you with a current picture of space, time and matter, as interpreted by physicists.

Our current ideas about space, time and matter were born in the three great revolutions of 20th-century physics: special relativity (1905), general relativity (1914) and quantum mechanics (1925-27). These theories served as the foundation for the subsequent development of elementary-particle physics and cosmology.

This course roughly divides into three parts. The first deals with classical physics. The second part is concerned with special and general relativity and the structure of space-time, and the third part is concerned with the quantum theory and the behavior of matter.

This course is intended as an introduction to *concepts* in physics – the emphasis will be on the concepts, not on equations *per se.* But just as one can't fully appreciate French poetry except in French, so the language of physics is mathematics, and the concepts of physics cannot be properly appreciated without using *some* mathematics. I will not assume any mathematics beyond high-school algebra and a very little bit of high-school geometry and trigonometry. **It is therefore essential that you be comfortable with the routine use of elementary algebra.** More details of what you need to know can be found in the Math Review handout; the first homework assignment reviews the needed mathematical concepts. If you have doubts about whether this course is right for you, please see me *promptly* so that we can discuss it.

Required books/documents:

Albert Einstein and Leopold Infeld: *The Evolution of Physics*
: This book was written by the Albert Einstein himself, and the discussion is almost entirely conceptual, with very little math. Available at the bookstore.

George Gamow and Russel Stannard: *The New World of Mr Tompkins*
: In this book Mr. Tompkins has dreams where the effects of relativity and quantum mechanics are much larger than in our world. Cambridge University Press, 1999 (should be in the bookstore later)

Richard Feynman: *Quantum Behavior*
: From the "Feynman Lectures" and available online at
`http://www.feynmanlectures.caltech.edu/I_37.html`

Tycho Sleator: *Lecture Notes for 20th Century Concepts in Space, Time, and Matter*
: This document is an essential resource for this course. It contains the notes (sometimes very detailed) for all the lectures and additional reading material, which you may find very helpful. Available on the course website.

Tycho Sleator and Paul Berman: *Supplementary Discussions for 20th Century Concepts in Space, Time, and Matter*
: This document is also essential for this course. It presents some of the topics discussed in the course in more detail that is given in the lecture notes. Available on the course website.

Recommended book:

John Gribbin: *In Search of Schrdinger's Cat: Quantum Physics and Reality* (Bantum Books, New York, 1984) (should be in the bookstore later)

A list of other related books are on the last page of this document.

This course is intended as an introduction to concepts in physics. The emphasis of this course will not be on equations, but rather on the concepts of physics. You will, however be required to manipulate some simple equations. **It is important that you are comfortable with elementary algebra and geometry. See the handout titled "Math Review" available on the course website.** Some knowledge of trigonometric functions would also be helpful, but will be taught in the course if needed. You will be given a handout outlining the type of math that you should know, and the first homework assignment will review these concepts. The major goal of this course is to leave you with a sense that a general knowledge of physics can be gained without any *advanced* mathematical background and to encourage you to continue to broaden your scientific knowledge. I welcome your suggestions for ways in which the course may be improved.

Your responsibility in this course is as follows:

- **Lectures:** It is important that you attend lectures. Since we will not be following any particular book very closely, there may be material presented in lecture that is not found in any of the assigned texts. Lectures are Tuesdays and Thursdays from 11:00 to 12:15.

- **Reading:** Also, it is important that you do the assigned reading **before coming to lecture**. You are encouraged to ask questions about the reading during lecture. Also, **read all of the handouts**.

- **Homework Problems:** Assignments will be made each week in Lecture. Your solutions are to be handed in at the beginning of lecture or in the box in Room 424 Meyer Building (4 Washington Place) on or before the date due. To find the box in room 424, turn left just past the counter as you enter the room. **Please do not email me your homework.** On your homework, you are strongly encouraged to type the answers to questions that just require English sentences. Any hand written answers must be written neatly, or they won't be graded. As clearly as possible, you should write on the top of the first page of your assignment "20 Century Concepts HW N", where "N" is the homework number (1, 2, *etc.*). Also, be sure to put your name at the top of the first page of your homework, and please staple the pages of your HW together.

  Late problems will not be accepted. Solutions to the homework will be posted on the course website. Some of the homework will require you to go to particular web sites (see below for more information about the course web site).

- **Exams:** There will be 2 in-class exams and a final exam. Absence from an exam will be excused only with advanced notice (if possible) and proof of **serious** illness. The date and time of the **final exam** is **May 12 at 10:00 – 11:50 am**. You should let me know **as soon as possible** if you have serious problems with your final exam schedule.

- **Class Participation:** Ask questions. If there is anything you don't understand, **ask!**. And please do not be embarrassed: in this class *no* question is stupid. If you are completely lost, let me know **as soon as possible** (either during lecture, or soon afterward). **it is very important not to get lost in this course**, as later lectures depend on the material covered in earlier lectures. I hope that the class atmosphere is relaxed enough to permit you to ask questions when you don't understand what has been said or if some foreign term was used.

Grades: Course grades will be based on the two in-class exams, the final exam, assigned problems, and quizes. The relative weighting is:

Course Grade	
First Midterm Examination:	20%
Second Midterm Examination:	20%
Final Exam	35%
Homework	25%

I am available to answer questions about the lectures, homework, any aspect of the course, any aspect of physics, or anything else for that matter. You can reach me as follows:

Tycho Sleator (lecturer):	
Office:	Room 902 Meyer
Telephone:	998-7764
Email:	tycho.sleator@nyu.edu
Office Hours:	I will post office hours after classes begin. If you wish to see me before office hours are posted, you can see me immediately after class, email me for an appointment, or just come by and try to find me.

There is a teaching assistant for this course. He is also available to answer questions and help with homework:

Michael Wang (teaching assistant):	
Office:	Room 639 Meyer
Email:	mw3189@nyu.edu
Office Hours:	to be announced...

For the benefit of the students, I would like to schedule an optional recitation section for this course. Since the homework will be due midweek, you should think about times at the beginning of the week (Mon or Tue) that you could attend a recitation. The purpose of this would be to answer questions about any aspect of the course, including questions related to the homework assignments.

Of course, you are always welcome to send me email if you have any questions or comments.

Tycho Sleator

Course Outline (tentative)

Date	Lecture	Subject
Jan. 26	1	Introduction, purpose of the course, role of mathematics, "Powers of 10" video, and some history
28	2	Position, velocity, acceleration, vectors, circular motion
Feb. 2	3	Newton's Laws
4	4	Newtonian gravity, gravitational potential energy, escape velocity
9	5	Galilien relativity, non-inertial frames; energy, momentum, and conservation laws
11	6	Inertial and non-inertial frames, Mach's principle
16	7	Waves I: Wave velocity and amplitude, superposition of waves, periodic waves, wave intensity, Doppler shift
18	8	Electric charges, electric fields
23	9	Magnetic fields, Maxwell's equations, electromagnetic waves, electromagnetic spectrum
25	10	Postulates of relativity, consequences of the relativity postulates, time dilation
Mar. 1	Exam I	-
3	11	Length contraction, experimental test of relativity, space travel, relativity "paradoxes"
11	12	Space-time diagrams
13	13	Relativistic invariants: space-time interval, addition of velocities
25	14	Lorentz transformations, faster then light travel?
27	15	Momentum and Energy in relativity, 4-vectors
April 1	16	General relativity, principle of equivalence, consequences of the equivalence principle
3	17	Consequences of the equivalence principle, curvature of spacetime
8	18	Curvature of spacetime
10	19	Tests of the general theory of relativity, solutions to Einstein field equations
15	20	Cosmology - composition, history and fate of the universe
17	Exam II	-
22	21	Waves II: superposition and interference, Begin quantum mechanics
24	22	Photo-electric effect, black body radiation, photons, Bohr model and matter waves
29	23	Schrödinger equation, Meaning of the wave function
May 1	24	Two-slit "gedanken" experiment, "interaction-free" measurements
6	25	Measurement in quantum mechanics, Indefiniteness and uncertainty
8	26	Reality in quantum mechanics, Einstein, Rosen, Pedalsky paradox
May 12	Final Exam	10:00 – 11:50 am in the same room as the lectures. **Note that if the time of the final exam is a serious problem for you, you *must* inform me within the first few weeks of the semester**.

Other Selected Bibliography

Special relativity:

- Banesh Hoffman, *Relativity and its Roots* (Dover, New York, 1999)
- Banesh Hoffman, *Albert Einstein: Creator and Rebel* (Penguin, New York, 1972)
- N. David Mermin, *Space and Time in Special Relativity* (Waveland Press, Prospect Heights IL, 1989)
- Edwin F. Taylor and John A. Wheeler, *Spacetime Physics* (Freeman, San Francisco, 1963)

General relativity:

- P.C.W. Davies, *Space and Time in the Modern Universe* (Cambridge University Press, Cambridge-New York, 1977)
- Stephen W. Hawking, *A Brief History of Time* (Bantam, New York, 1988)
- Martin Rees, *Before the Beginning: Our Universe and Others* (Addison-Wesley, Reading MA, 1997)
- Lee Smolin, *, The Life of the Cosmos* (Oxford University Press, New York, 1997)
- Steven Weinberg, *The First Three Minutes: A Modern Veiw of the Origin of the Universe*, 2nd ed. (Basic Books, New York, 1993)

Quantum mechanics:

- Lee Smolin, *Three Roads to Quantum Gravity* (Basic Books, New York, 2001)
- John Gribbin, *In Search of Schrdinger's Cat: Quantum Physics and Reality* (Bantum Books, New York, 1984)

General:

- Brian Greene, *The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory* (Vintage, New York, 2000)
- Brian Green, *Fabric of the Cosmos* (Vintage Press, New York, 2005)
- Fritz Rohrlich, *From Paradox to Reality: Our Basic Concepts of the Physical World* (Cambridge University Press, 1987)
- George Gamow, *Mr Tompkins in Wonderland or Stories of c, G, and h* (Cambridge University Press, 1964, out of print)

Lecture Notes for 20th Century Concepts of Space, Time, and Matter: V85.0020 Spring 2016 Tycho Sleator New York University, Department of Physics February 16, 2016 Note that these notes may be revised throughout the semester, so if you want a printed version, consider printing only up through material covered in class. 20th Century Concepts of STM 1 Tycho Sleator V85.0020 Lecture Notes Spring 2016 1. What this Course is About a. What is Physics? i. Search for detailed description of nature. Precise language of mathematics is often used. ii. Establishment of fundamental laws: e.g. Conservation