Natural Science I: Einstein's Universe MAP-UA-0204-010
Spring 2022 Meyer 121

Monday and Wednesday
2:00 – 3:15 p.m.
Dr. Burton Budick
Meyer 121 or remote
Office Phone: (212)-998-7683
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Office hours: Tuesday 2:15-3:15 pm in
Room 859 726 Broadway

A photograph of Einstein taken in 1912.

"The distinction between past, present, and future is only an illusion, even if a stubborn one." – Albert Einstein

"What I'm really interested in is whether God could have made the world in a different way; that is, whether the necessity of logical simplicity leaves any freedom at all." – Albert Einstein

"There is no better illustration of the unpredictable payback of fundamental science than the story of Albert Einstein and the Global Positioning System… the next time your plane approaches an airport in bad weather, and you just happen to be wondering "what good is basic science," think about Einstein and the GPS tracker in the cockpit, guiding you to a safe landing." – Clifford Will

The laws of physics are the same regardless of your motion. That's the theory of relativity. Though the statement of the relativity principle is simple, the implications of it will challenge your notions of space, time, energy, mass and gravity. This course is a historical presentation of relativity including its applications to astrophysics and cosmology. Some of the topics we will study are:

- Our place in the Universe
- Geocentric or heliocentric solar system
- The roots of special relativity in electromagnetism
- My now is not your now: the relativity of simultaneity
- Time and space intervals are relative
- What's not relative about relativity
- $E=mc^2$
- What is the universe made of?
- Radioactivity and nucleosynthesis
- General relativity
- Expansion of the Universe
- Cosmology: the Big Bang
- The size and shape of the Universe
- The future of the Universe
- Dark matter and Dark Energy

We will also discuss the life of Einstein, who, unlike most scientists, became a very public figure. Your lab manual contains a chronology of the life of Einstein and in lecture we will see a

documentary called *Einstein Revealed* that was made in 1996 and first shown on public television.

The course will consist of lectures, laboratory projects and homework problems. Homework is excellent preparation for all examinations. Homework assignments will be announced in class. The homework will be checked to see if everyone is keeping pace with the work, but they will not be graded.

Course texts

1. *Simply Einstein: Relativity Demystified* by Richard Wolfson, W.W. Norton and Co. This recently published volume gives a historical development of relativity before Einstein and sets the stage for Einstein's work and his special and general theories of relativity, along with the famous $E = mc^2$ formula.
2. *Big Bang* by Simon Singh, HarperCollins. Singh captures the excitement of both ancient and current cosmologies. The personalities of the scientists who have contributed to the Big Bang, as well as their efforts and insights, make for fascinating learning.
3. *Einstein* by Walter Isaacson, Simon & Schuster. This excellent biography intended for the general reader captures the many facets of the iconic Einstein: his politics, his religious beliefs, his personality, as well as his scientific achievements.
4. *Einstein's Universe Laboratory Manual.*

The video *Einstein Revealed* is also available on the second floor of Bobst Library in the Avery Fisher Center. The video will be presented in lecture (see lecture schedule.)

Mathematics

Galileo sought an understanding of nature on an empirical and mathematical description of physical reality. Natural science has followed his lead, so you will be required to use mathematics commonly treated in high school or middle school courses such as algebra, geometry, fractions, powers of numbers, the square root, and scientific notation.

Course Examinations

There will be two examinations during the semester in addition to a cumulative final exam. The examination will be based on (a) lecture topics and (b) homework problems. Lectures will be based on the readings. Questions will be handed out each week in lecture and will form the basis of what you are responsible for from our twice-weekly meetings. Many of the questions are answered in the course readings. The exams will be in the multiple-choice format. You will need to bring a calculator to all exams.

Examination Schedule and Course Grade

First examination:	15%	Monday February 28
Second examination:	15%	**Monday April 6**
Homework	10%	
Laboratory:	30%	
Final examination:	30%	**???**

The final exam period for the University runs from May 11-May 17. While there will be no make-up exams for those offered on February 28 and April 6, under exceptional circumstances a make-up final exam will be offered at the beginning of the Fall semester.

Laboratory Sessions

These weekly sessions are an important part of the course. You must be registered for one lab section. You will have to submit a lab report for each experiment performed. The lab report has to include answers to all questions and any data you may have collected. The lab report will be due in lab *one week* after the experiment has been performed. **The laboratory sessions will be held in Meyer 161 and will begin on Tuesday, January 28.**

The laboratory sessions will be devoted to

1. Doing experiments
2. Discussing the homework problems.
3. Discussing the lecture questions.

Laboratory Schedule					
Section	**Day**	**Time**	**Section**	**Day**	**Time**
2	Tuesday	3:30-4:45 p.m.	6	Tuesday	12:30-1:45 p.m.
3	Tuesday	4:55– 6:10 p.m.	7	Tuesday	2:00 – 3:15 p.m.
4	Wednesday	9:30 – 10:45 a.m.	8	Tuesday	9:30-10:45 p.m.
5	Wednesday	11:00 –12:15 p.m.	9	Tuesday	11:00-12:15 p.m.

The laboratory grade will be based on the following assignments:

Lab experiment and report	50%
Participation in homework/lecture question discussion sessions	50%
Total	100%

You must bring your written answers to the lecture questions to laboratory sessions devoted to discussing this work.

Attendance

If you arrive at least 10 minutes late for the lab session you will lose the participation credit for that lab session.

Absence Policy

Excused absences will only be given in the case of illness (with a doctor's note) or observation of a religious holiday. You must notify your lab instructor in advance in writing if you miss a lab due to religious reasons. All other absences will be considered unexcused and will result in a lab grade of zero. **You cannot make up a lab by attending a laboratory session that you are not registered for.**

Late Assignments

Late assignments will be penalized five points for each day late (excluding weekends). If you wish to submit a late lab report you must do so only at your laboratory instructor's office.

Lab Instructors

Each lab instructor will hold a weekly office hour where you can discuss lecture and laboratory material. Office locations and office hour time and day will be announced during the first laboratory session.

Contact Information

Zachary Forbes zforbes@nyu.edu	Navoday Borker
Joshua Dy Borja borja@nyu.edu	Burton Budick bb2@nyu.edu

Homework

Homework problems will be assigned each week in lecture. The source of the homework will be course handouts. Homework assignments are to help you understand the material and to prepare you for course examinations. The homework will count as 10% of your grade. You will submit each HW to the Gradebook.

Lecture Questions

The lectures are built on questions that scientists have pursued over the course of the history of physics. In order to help you organize the course material and to let you know what you are responsible for, question sheets will be handed out each week. Examinations will be built on these questions, and the homework, so you should write out the answers to these questions each week. *You must bring your written answers to the lecture questions to laboratory sessions devoted to discussing this work.* You will be asked to discuss your answers in laboratory.

Missed Exams

There are no make-up exams for students who miss one or both of the exams given during the semester. If you miss an exam because of illness, you must contact Dr. Budick by phone or email **before** the start of the exam and follow up with a doctor's note. If you miss an examination, for a valid reason (illness, injury or family emergency), your grade will be based on the following allocations:

Laboratory	30%
1 Midterm +	
Final examination (cumulative)	60%
HW	10%

Final Exam

A make-up for the final examination will be given under exceptional circumstances, which must be discussed with Dr. Budick before the examination. A doctor's note must be provided in the case of illness. In this case a grade of incomplete will be assigned and **the make-up will be scheduled for the beginning of the Fall 2022 semester**. Please avoid making travel plans before the date of the final exam. No alternative date for the final examination will be offered before the end of the Fall 2022 semester.

Religious Holidays

If you will be absent from lab for a religious holiday during the semester, you must inform your lab instructor *in advance*.

Class Web Site

A web site for this class exists and is accessible through your *NYUHome* account or by going to

NYUClasses and logging on using your netID and the same password as that of your NYU email account. You must have an active NYU email account to access the site.
Aside from a copy of this syllabus you will find

- Email access to the lecturer, lab instructors and all students.
- Links to other web sites with information about topics discussed in the course.

Any questions on lecture topics, readings from the texts, homework problems or laboratory experiments can be submitted here at any time on any day (except when you are in class or lab of course).

Weekly Schedule of Topics, Readings and Laboratories

Note: Homework problems will be assigned in lecture each week.

Date	***Lecture Topic***	***Reading***	***Weekly Lab***
M Jan 24	Introduction of the Course/Syllabus Review Geocentric theories of the solar system	Singh: 1-36 Wolfson: Ch. 1, 2	2/1,2/2 Math Review
W Jan 26	Heliocentric theories, Kepler's Laws Newton's Laws Gravity	Singh Ch.37-84 Wolfson: Ch. 3	
M Jan 31	Wave motion and Interference Speed of light	Wolfson: Ch. 4 Singh: Ch. 2	2/8,2/9 Kinematics
W Feb 2	The wavelength of visible light The Electromagnetic spectrum	Wolfson: Ch. 4 Singh: 87-92,229-236	
M Feb 7	Electric and magnetic fields The Ether	Wolfson: Ch. 5 Singh: 85-98	2/15, 2/16 Newton's Second Law
W Feb 9	Michelson-Morley and Relativity	Wolfson: Ch. 6 Singh: 99-112	
M Feb 14	The Postulates of Special Relativity	Wolfson: Ch. 7	2/22, 2/23 Interference and Diffraction of Light
W Feb 16	Relativity of Simultaneity Time Dilation Length Contraction	Wolfson: Ch.8,9,10 Singh 113-116	
M Feb 21	Review		3/1, 3/2 Review
W Feb 23	*Video: "Einstein Revealed" part 1*	Isaacson Chapter 5	3/8, 3/9 Measuring the speed of sound
M Feb 28	☹ **Exam 1** ☹		
W March 2	Past, Present, Future and…Elsewhere	Wolfson: Ch. 11	
M March 7	Faster than Light? $E = mc^2$ Everything is not relative Space-Time Interval	Wolfson: Ch. 12	3/22, 3/23 Michelson Interferometer
W March 9	Radioactivity, mass to energy conversion, antimatter	Singh:158-159,216,265-353	
MMarch21	Nucleosynthesis, The curve of binding energy	Singh:473	3/29, 3/30 Special Relativity
WMarch23	A Problem of Gravity and the Principle of Equivalence, General Relativity	Wolfson: Ch. 14 Isaacson Ch. 18, 19	
MMarch28	Galaxies, The Great Debate	Singh: 167-249	4/5, 4/6 Photoelectric Effect
WMarch30	Cosmic distances, Cepheid Variable	Singh: 203-214	
M April 4	*Video: "Einstein Revealed" part 2*		4/12, 4/13Principle of Equivalence
W April 6	☹ **Exam 2** ☹		
M April 11	The Cosmological Principle Velocities of Galaxies, Hubble's Law	Singh: 214-261	

W April 13	**Early 20th century universe**	Singh: 144-161 Handouts	4/19, 4/20Hubble's Law and the expanding universe
M April 18	Big Bang Cosmology I	Wolfson Ch.15 Singh: 357-401	
W April 20	Cosmic Microwave Background	Wolfson: Ch. 15 Singh: 357-401	4/26, 4/27 Observing the Cosmological Redshift
M April 25	The Big Bang Cosmology II The size and shape of the universe	Singh: 401-465	
W April 27	Inflation, Abundance of the Elements	Singh: Epilogue, 479-482,Wolfson: Ch. 16	
M May 2	Big Bang Cosmology III	Singh: Epilogue Wolfson Chapter 16	
W May 4	Evidence for the Big Bang Dark matter and Dark Energy	Wolfson: Ch. 16 Singh: 479-482	5/3,5/4 Final Review
M May 9	Review		