ASTRONOMY 100
Fall 2022

Dr. Edward Rhodes
MWF 2:00 p.m. – 3:20 p.m.

REGISTRATION AND QUESTIONNAIRE

PLEASE, COMPLETE AND TURN IN THE FOLLOWING:

NAME (PRINT) _____
LAST FIRST MIDDLE

SIGNATURE _____

EMAIL _____

STUDENT ID _____

SCHOOL ADDRESS _____

LOCAL PHONE NO. _____

What are your goals for this course?

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ASTRONOMY 100Lxg: The Universe

Fall Semester 2022: **August 22, 2022 – December 2, 2022**
Course Meetings: **MWF 2:00 p.m. – 3:20 p.m., SLH 102**

Instructor: **Dr. Edward J. Rhodes, Jr.**
Office: **SHS 374**
Office Hours: **M 3:25 – 4:15 p.m., WF 3:25 – 4:55 p.m. or by appointment**
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Laboratory Room: SGM 313
Laboratory Director: Joseph (Joe) Vandiver
Office: SGM 309
E-Mail: vandiver@usc.edu

Student Services Assistant: Giovanni Diaz
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Dept. Main Office: ACB 439
Dept. Telephone: (213) 740-1140

Textbooks, Course Readers, and Lab Manuals

Required Materials

- Theo Koupelis, ***In Quest of the Universe***, 7th Edition (packaged with student CD-ROM)
- Lecture slide set for Astronomy 100 (available on Blackboard, to be printed individually and brought to class or accessed via laptop during class)
- Laboratory manual (distributed during first lab session)

Optional Supplementary Textbook

- Roger Freedman, Robert Geller, & William J. Kaufmann, ***Universe***, 10th Edition

Assignments, Exams, and Grading

Exams

There will be three 80-minute midterm examinations and one two-hour final exam. The score of the lowest of the three mid-terms will be dropped and only the scores of the two highest exams will be counted in the final point total. In addition to the examinations, you must complete the six laboratory assignments. These assignments will be described later. The final point total will be computed as follows:

Assignment	Points	Percentages
Two midterm exams	2 * 60 = 120	2 * 25% = 50%
Final exam	72	30%
Laboratory assignments	48	20%
Total	240	100%

The final point total will be curved to determine the final grades in the course. Generally, there are about 22-24% As and A-s, 30% B+s, Bs, and B-s, 40% C+s, Cs and C-s, and 6% D+s, Ds and D-s. If you are taking this class on a Pass/No Pass basis, you must receive at least the equivalent of a C- to receive a pass. Attendance will be taken during each lecture and recorded. This attendance information will be used in deciding upon the divisions of the final curve.

Please note that the third mid-term exam will serve as a make-up exam for either of the first two exams. **There will not be any other make-up exams**. Any student missing two of the three mid-terms will only have recorded the points scored on the one exam taken unless he or she also completes the required minimum number of laboratory assignments. Please note that the Third Mid-Term Exam is scheduled for Monday, November 21, which is the week of the Thanksgiving Break, so if you miss either of the first two mid-terms, do not plan to leave the campus for the Thanksgiving Break prior to the evening of November 21.

The questions on the exams will cover the lectures, and the assigned readings. The questions on the exams will mainly be objective (multiple choice or matching); however, there may be a few short answer questions as well. The final exam will cover material from the whole course, although it will emphasize the material in the latter portion of the course. Each exam will be a closed book exam.

Examples of past examinations will be available on the course website on Blackboard.

Course Structure

During most weeks there will be three lectures. All three meetings will be held in the lecture hall. During some weeks, I will schedule an afternoon or evening review session before each of the exams.

Course Outline

The detailed course outline and reading assignment list are attached. Please note that the dates of the midterm exams listed on the course outline are subject to change during the course. Any changes in the mid-term schedule will be announced during the week preceding the scheduled time. All such announcements will be made during lecture only.

Course Goals

My goals for each of you this semester include the following:

1) That you will learn to understand how science is done, what questions science can answer, and what questions science cannot answer
2) That you will gain an appreciation for the historical development of astronomy, including the importance of past discoveries in the development of new knowledge
3) That you will gain a better appreciation for the wonders of the universe
4) That you will cultivate an interest in learning more about astronomy throughout your lives, such that you will want to read articles about astronomy in the future after this class has ended
5) That you will have an opportunity to observe the heavens using a telescope here on the USC campus

Laboratory Sections and Laboratory Grading

The laboratory meetings will be during the weeks beginning on the following Mondays or Tuesdays: Please see next page for lab schedule. Attendance during the first week is mandatory. Failure to attend the lab session for which you are registered may result in the cancellation of your lab registration. Each laboratory meeting will last approximately 110 minutes.

In addition to the assignments to be done in the laboratory, there will also be one mandatory on-campus evening observing session will be scheduled to view the sky from the campus observatory. More details will be announced later. Sign-ups for each of the campus observing sessions will be handled by the TA's during the lab meetings. Additional evening observing sessions will be scheduled in case any of the planned sessions have to be canceled due to inclement weather. If bad weather interferes with all of the scheduled observing sessions, a required alternative assignment will be announced late in the term.

In order to get the maximum possible lab score, you will need to do all six assignments and attend the evening observing session. Each of the six assignments will count for a maximum of 20 points for a total of 120 possible points. The observing session will count for an additional 40 points, so that the maximum possible score you can have for the lab portion of the course will be 160 points. To convert this Raw Lab Score into the Scaled Lab Score which will count for a maximum of 48 points on the final grading curve at the end of the semester, your Raw Lab Score will be multiplied by the ratio of 48/160. If you skip any or all of the assignments, including the observing session, you will receive a zero score for those assignments. Please note that failure to participate in any of the laboratory assignments, including the on-campus observing session, will result in a score of 0 points for 20% of your final course grade. This will be a loss of 48 points, which will be enough to lower your final course grade substantially. So, please take the lab portion of this course seriously.

Course PowerPoint Slide Sets

All 37 of the PowerPoint slide sets are available on the class website on Blackboard. You may print out each set of slides prior to the lecture and bring the printouts with you, or you may bring a laptop to class and view the slides on the laptop during the lectures.

Attendance Policy

Attendance will be circulated during all 37 of the lectures. The total lecture attendance will be taken into consideration during the assignment of final grades at the end of this semester.

Labs will take place in SGM 313. All lab policies are outlined in the Laboratory Manual, including your attendance at one evening observation session.

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Support Systems:

Student Counseling Services (SCS) – (213) 740-7711 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. engemannshc.usc.edu/counseling

National Suicide Prevention Lifeline – 1 (800) 273-8255
Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. www.suicidepreventionlifeline.org

Relationship and Sexual Violence Prevention Services (RSVP) – (213) 740-4900 – 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender-based harm. engemannshc.usc.edu/rsvp

Sexual Assault Resource Center
For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: sarc.usc.edu

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086
Works with faculty, staff, visitors, applicants, and students around issues of protected class. equity.usc.edu

Bias Assessment Response and Support
Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. studentaffairs.usc.edu/bias-assessment-response-support

The Office of Student Accessibility Services
Provides certification for students with disabilities and helps arrange relevant accommodations. osas.usc.edu

Faculty Liaison
All courses in the Department of Physics & Astronomy have an assigned Faculty Liaison to serve students as a confidential, neutral, informal, and independent resource when they wish to discuss issues concerning their course without directly confronting their instructor. The Faculty Liaison for this course is Prof. Jack Feinberg, feinberg@usc.edu, 213-740-1134, SSC 327.

USC Support and Advocacy (USCSA) – (213) 821-4710
Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. studentaffairs.usc.edu/ssa

Diversity at USC
Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. diversity.usc.edu

USC Emergency Information
Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. emergency.usc.edu

USC Department of Public Safety – UPC: (213) 740-4321 – HSC: (323) 442-1000 – 24-hour emergency or to report a crime.
Provides overall safety to USC community. dps.usc.edu

Fall 2022 Lab Schedule

Week of Semester	Dr. Rhodes's Sections
Aug. 22nd	Experiment 1
Aug. 29th	No Labs
Sept. 5th	Experiment 2
Sept. 12th	No Labs
Sept. 19th	Experiment 3
Sept. 26th	No Labs
Oct. 3rd	Experiment 4
Oct. 10th	No Labs – Fall Break
Oct. 17th	No Labs
Oct. 24th	Experiment 5
Oct. 31st	No Labs
Nov. 7th	Veteran's Day Holiday No Labs
Nov. 14th	Digital Astrophotography
Nov. 21st	Thanksgiving Week No Labs
Nov. 28th	No Labs
Dec. 6th	Final Exams Begin

ASTRONOMY 100
REQUIRED READING ASSIGNMENTS
COURSE OUTLINE AND EXAM SCHEDULE
(All required reading assignments are in parenthesis after the topics)

Wk.	Lec.	Date	Topics
WEEK 1	1	August 22	Introduction; Early Astronomy (pp.1-5; Sections 1-9 and 1-10).
	2	August 24	Celestial sphere; geographic coordinates; celestial coordinates; Earth's motions and orientation in space (Section 1-2)
	3	August 26	The equinoxes and solstices; the seasons; the zodiac (Section 1-3); Early Greek Astronomy (The Geocentric view); Aristotle; Proofs for Rotation and Revolution of the Earth (beginning of Chapter 2 to end of fourth paragraph on p.43). Beginning of Section 2-4 to end of discussion of Aristarchus in the middle of p.48)
WEEK 2	4	August 29	Motions of the Planets; the Ptolemaic Model (last three paragraphs on p.43 to end of Section 2-3 on p. 46); Criteria for choosing among models; Pre-Renaissance Astronomy (Section 2-5); Copernicus and the Heliocentric Model (Section 2-6).
	5	August 31	Comparison of Ptolemaic and Copernican Models (Section 2-7); Tycho Brahe (Section 2-8); Johannes Kepler; Kepler's Laws of Planetary Motion; (Section 2-9 through end of Section 2-10 on p.63)
	6	September 2	Galileo Galilei Section 3-1); Newton and his laws of physics (Section 3-2); circular motion and conservation of angular momentum (Section 3-3).
WEEK 3		September 5	**NO CLASS – Labor Day Holiday**
	7	September 7	Newton's Law of Universal Gravitation; (Sections 3-4 and 3-5); Center of Mass (Section 3-6); The Tides (beginning of Section 6-2 to middle of p. 156); Non-spherical shape of the Earth and Precession (middle of p. 156 to end of Section 6-2).
	8	September 9	The Effects of Precession on the Severity of the Seasons; Perturbation Theory and the Discovery of Neptune (Historical Notes on page 269 and on page 273) ; Spacecraft Orbits (p. 83); Beyond Newton (Section 3-7); Electricity and Magnetism; Electromagnetic Radiation or Light
WEEK 4	9	September 12	The Wave Nature of Light (Section 4-2); The Speed of Light (discussion on p.101); Refraction; Dispersion; Interference; The Dual Nature of Light; The Electromagnetic Spectrum (Section 4-3) Thermodynamic and Motions; Heat; Temperature (Section 4-1); Heat Transfer; Black body Radiators.
	10	September 14	Characteristics of Black Body Radiation and the Radiation Laws; (Section 4-4) the Ultraviolet Catastrophe; Planck's Quantum Idea; The Photoelectric Effect The Beginnings of Astrophysics; Kirchhoff's Rules of Spectral Analysis (Section 4-5); Early 20th Century Models of the Atom; The Bohr Model of the Hydrogen Atom (p.106).
	11	September 16	Orbits and Energy Levels in Atoms; Excitation, de-excitation, ionization, and recombination of electrons; Absorption and emission of light by atoms (top of p. 107 to bottom of p.109 and page 112 to end of Section 4-6); the Particle Nature of Light (The Wave-Particle Duality of Light discussion on pages 110 and 111); Quantum Modifications of the Bohr Model of the Atom; The Heisenberg Uncertainty Principle; The Doppler Effect and Radial Velocities (Section 4-7).
WEEK 5	12	September 19	The Size and Distance of the Moon; Angular diameter (Section 6-1); Lunar Phases and Blue Moons and the synodic orbital period of the Moon (Section 1-4); Lunar Eclipses (Section 1-5); Solar Eclipses (Section 1-6); The Earth's Interior and Seismology (Section 6-3 to middle of p. 159).
	E1	**September 21**	**First Mid-Term Exam (Wed.)**

	13	September 23	The Structure of the Earth; the Geomagnetic Field, the Earth's Magnetosphere, the Solar Wind, and the Aurorae (bottom of p. 161 to end of Section 6-3); Plate Tectonics (bottom of p. 159 to end of second paragraph on p. 161); The Ice Ages; Origin and Structure of the Earth's Atmosphere; Ozone Layer Depletion (sub-section entitled "Earth's Atmosphere" on p. 161).
WEEK 6	14	September 26	Global Warming Controversy; The Surface, Interior, and History of the Moon; the Origin of the Moon (Sections 6-4, 6-5, and 6-6; p. 173); Measuring Sizes, Distances and Masses in the Solar system (beginning of Chapter 7 to end of Section 7-3); Classifying the Planets: The Terrestrial and Giant Planets (Section 7-4).
	15	September 28	Planetary Atmospheres and Escape Velocities (Section 7-5); Formation of the Solar System (Section 7-6); Discovery of Planets orbiting other stars (Section 7-7); Julia Childs and the Building Blocks of Life and the Search for Extra-Terrestrial Life (Chapter 19).
	16	September 30	Mercury and its Motions (beginning of Chapter 8 to end of Section 8-1); Venus (Section 8-2).
WEEK 7	17	October 3	Mars: Its Motions and Topography; Volcanoes on Mars; Search for Life on Mars; Martian Polar Caps; Martian Atmosphere; Possible Past Martian Water: The Martian Moons; (Sections 8-3 and 8-4); Recent Mars Mission Discoveries: Curiosity, MAVEN, InSight, and Perseverance (Section 8-4 to end of Chapter 8);
	18	October 5	Jupiter: Its Size, Mass, and Density; Jupiter's Rapid Rotation and Oblate Shape; Spacecraft visits to Jupiter; Jupiter's Atmosphere and Clouds; Jupiter's Interior and Magnetic Field; Jupiter's Magnetosphere; Jupiter's Moons; Jupiter's Ring System; NASA's current Juno mission and USC's role in supporting it (beginning of Chapter 9 to end of Section 9-1).
	19	October 7	Saturn and Its Ring System; Saturn's Motions; Saturn's Rotation and oblateness; Saturn's Atmosphere; Saturn's Moons; The Roche Limit for Planets; Formation of Saturn's Rings (Section 9-2); Uranus and its Ring System; Unique Orientation of Uranus; Its Moons; Its Magnetic Field (Section 9-3).
WEEK 8	20	October 10	Neptune; Neptune's Ring System; Neptune's Moons; (Section 9-4) Accidental Discovery of Pluto; Discovery of Pluto's Moon, Charon; Pluto's Mass; Pluto's Atmosphere; What is Pluto? (Beginning of Chapter 10 to end of Section 10-1); Solar System Debris (Section 10-2); The Asteroids; Discovery of Ceres; Asteroid Orbits and Kirkwood's Gaps; The Trojan Asteroids; Origin of the Asteroids; the OSIRIS-Rex Mission to the asteroid Bennu (Section 10-3).
	21	October 12	Halley's Comet; Comets: their Parts and their Orbits (Section 10-4); The Oort Cloud and the Kuiper Belt (Section 10-5); Meteoroids; Meteors; Meteor Showers and Comets; Meteorites; Asteroid Impacts on Earth; did an Asteroid Impact Kill the Dinosaurs? (Section 10-6 to end of Chapter 10 on p. 303); Will We Be Luckier than the Dinosaurs in the Future?
		October 14	**NO CLASS – Fall Recess**
WEEK 9	22	October 17	Basic Solar Data (the beginning of Chapter 11 to the end of Section 11-1); the "Solar Constant" and Why It Is Not Constant (the beginning of Section 11-2 to middle of p. 311); The Solar Photosphere and Its Motions and the other parts of the Solar Atmosphere (Section 11-5); Sunspots and the Solar Activity Cycle; George Ellery Hale and the Discovery of Solar Magnetic Fields; The Zeeman Effect; The Maunder Minimum (beginning of Section 11-6 to bottom of p.329); Solar Cycles 23,24, and 25.
	23	October 19	A Model for the Solar Cycle (From the last paragraph on p. 329 through middle of p. 332); Solar Flares; Solar Filaments and Prominences (from last paragraph of p. 332 through end of Chapter 11 on p. 335); The Energy Source of the Sun (Last four paragraphs on p. 311 to first paragraph on p.312); The Equivalence of Mass and Energy; Sub-atomic particles; quarks, hadrons, and leptons; Anti-Particles; Thermonuclear

			Fusion Reactions; The Proton-Proton Chain (Sub-section of Section 11-2 Entitled "Solar Nuclear Reactions" on pp..312-314).
	24	October 21	The Solar Interior (Section 11-3); The Solar Oscillations, the Field of Helioseismology, and the Solar Neutrino Problem; (Section 11-4); Observed Properties of Stars: Apparent magnitudes; absolute magnitudes; Stellar Parallaxes and Distances; Stellar luminosities; Stellar Motions: Proper Motions; Radial Velocities, Tangential Velocities, and Total Space Velocities(Beginning of Chapter 12 through end of Section 12-3).
WEEK 10	25	October 24	Spectral Classifications; Reasons for Different Appearance of Stellar Spectra; Revision of Spectral Sequence (beginning of Section 12-4 to end of first paragraph on p.348); The Hertzsprung-Russell Diagram; The Main Sequence Stars; The Red Giant Stars; The Supergiant Stars; White Dwarfs (beginning of second paragraph on p. 348 through end of first paragraph on p. 349); Spectroscopic Parallax (second paragraph on p.349 through end of second paragraph on p.350); Luminosity Classes (sub-section on p. 350); Inferring stellar sizes from their locations in the H-R Diagram(top of p. 351 to end of Section 12-4 on p. 353); Multiple Star Systems: Types of Binaries (Section 12-5).
	E2	October 26	**Second Mid-Term Exam (Wed.)**
	26	October 28	Stellar Mass Estimates (Section12-6); Stellar Mass-Luminosity Relationship (Section 12-7); Cepheid Variable Stars and the Period-Luminosity Relationship; Use of Cepheids as distance indicators (Section 12-8 to end of Chapter 12 on p. 362). The Interstellar Medium: Gas and Dust Between the Stars; Emission Nebulae; Dark Nebulae; Reflection Nebulae (pp. 366-373); Radio astronomy and the study of the neutral interstellar hydrogen gas clouds.
WEEK 11	27	October 31	Star Formation: Giant Molecular Clouds; Evaporating Gaseous Globules; Shockwave triggering; Protostars; cocoon nebulae; Pre-Main Sequence Evolutionary Tracks in the H-R Diagram; upper and lower mass limits for the stars (Sections 13-2 and 13-3). Star Clusters: Open and Globular Clusters (Section 13-4 to end of Chapter13; Brown Dwarfs;
	28	November 2	Life on the Main Sequence; (Beginning of Chapter 14 on p. 38i8 to end of Section 14-3); The Flyweight Stars (Section 14-4); The Lightweight Stars; Post-Main Sequence Evolution of Lightweight Stars: Red Giants and the Helium Flash; Super lightweight stars (Section 14-6 to middle of p. 399; There Goes the Earth (middle of p. 399 to end of p. 400); The formation of Planetary Nebulae (bottom of p. 400 to end of p.401). Structure of Planetary Nebulae (p. 402- end of p. 404; White Dwarfs (middle of p. 391 – bottom of p.404); Theory of White Dwarfs (p.405- top of p. 407); Close Binary Stars, White Dwarfs, and Novae (top of p. 407 to middle of p. 408).
	29	November 4	The Chandrasekhar Mass Limit for White Dwarfs (p. 405); Type Ia, Type .Ia, Type Ib, and Type Ic Supernovae (Section 14-8); Deaths of Middleweight and Heavyweight Stars and Type II Supernovae; Nucleogenesis (p. 415-p. 420). SN 1987a (Section 15-3); Ground-based Observations of Neutrinos from Supernovae; a new type of Extremely Luminous Supernova.
WEEK 12	30	November 7	Neutron Stars and The Discovery of Pulsars (Section 15-4): Indirect Evidence for the Existence of Neutron Stars (Section 15-5); Deaths of Middleweight Stars: Formation of Neutron Stars (Section 15-6); Einstein's Theory of Special Relativity (p. 431); Einstein's Theory of General Relativity (Section 3-8 and p.431 to bottom of p. 432).
	31	November 9	Experimental Tests of General Relativity (Section 3-9 to end pf Chapter 3 on p. 91); Binary Pulsars as Tests of General Relativity (Bottom of p. 432 to end of Section 15-7); Deaths of the Heavyweight Stars and the Formation of Black Holes; Do Black Holes Exist? Is the Universe a Black Hole? Do Black Holes Evaporate? (Beginning of Section 15-8 on p. 433 to end of Chapter 15 on p. 443); Wormholes. The Laser Interferometric

			Gravitational Wave Observatory (LIGO) and the Recent Proof that Gravitational Waves Exist; Stellar Populations.
		November 11	**NO CLASS – Veteran's Day Holiday**
WEEK 13	**32**	November 14	Early Views of Our Galaxy; Modern Views of our Galaxy: The Milky Way Galaxy (p.447 to end of Section 16-1 on p.453); Components of the Milky Way Galaxy; The Galactic Nucleus Sections 16-2 through 16-5); The Evolution of our Galaxy (Section 16-6); The Controversy over the Nebulae; The Resolution of the Controversy by Edwin Hubble: Proof that Other Galaxies Do Exist.
	33	November 16	The Hubble Classification of Galaxy Types: Ellipticals, Spirals, Barred-Spirals, and Irregulars; Do Galaxies Evolve from one Shape to Another? Stellar contents of Different Galaxies; Distance Methods for other Galaxies; Evidence for the Expansion of the Universe: The Hubble-Lemaitre Law; Mass Estimates of Galaxies; Clusters of Galaxies: The Local Group (pp. 473 – top of p.488) Superclusters of Galaxies: The Local Supercluster; The so-called Missing Mass; Abnormal Galaxies; Peculiar Galaxies.
	34	November 18	Radio Galaxies; Seyfert Galaxies; Active Galaxies: N Galaxies, Blazars, and Quasars (beginning of Section 17-5 to middle of p. 500) ; Gravitational Lenses (Middle of p. 500 to end of Chapter 17 on p. 508); Cosmology: The Nature of the Universe (Beginning of Chapter 18 to middle of p. 514); Key 20th Century Cosmological Ideas (Section 18-3); Expanding, Relativistic Models of the Universe; Spacetime can be closed, flat, or open (middle of p. 514 to end of Section 18-1);Empty model; Steady State Model; Positive Cosmological Constant Model; the Non-expanding, Changing-Gravity Model; The Inflationary Model.
WEEK 14	**E3**	**November 21**	**Third Mid-Term Exam (Monday)**
		November 23	**NO CLASS – Thanksgiving Break**
		November 25	**NO CLASS – Thanksgiving Break**
WEEK 15	35	November 28	Einstein's Static Model of the Universe; The Cosmological Constant: Was It Einstein's Greatest Blunder or Not? The Steady-State Theory (p. 523 to top of p.524); What is Expanding? (Section 18-2); The Big Bang; The Planck Epoch; The Grand Unification Epoch Spontaneous Pair Production; Grand Unification Theories; the discovery of the Higgs Boson at CERN; The Inflationary Model and the Inflationary Epoch (Section 18-6); Alan Guth, who proposed the Inflationary Model.
	36	November 30	The Post-Inflationary Quark Soup; the Big Freeze Out (p. 525 to top of p.526); The Opaque Era; The Recombination Era (beginning of Section 18-7 to bottom of p. 533); The Evidence that a Big Bang Actually Occurred: The Cosmic Microwave Background Radiation or CMBR. (Beginning of Section 18-4 to middle of p.526; pages 534 and 535); the COBE Mission and evidence for structure formation in the very early universe; The Grand Structure of the Universe; Structure Formation in the Early Universe; Hidden Dimensions of Spacetime; The Hubble Time and the Age of the Universe (p. 526 to end of Section 18-4); What Model Universe De We Live In? What Will the Future of the Universe Be Like: Will We Expand Forever or Will We Fall into the Big Scrunch? (Beginning of Section 18-5 to middle of p. 529); The Oscillating Model of the Universe.

	37	December 2	The Hubble Diagram and previous attempts to determine the proper model of the universe; Recent evidence that the expansion of the universe is accelerating; Perhaps Einstein Was Right After All and there is a Positive Cosmological Constant (middle of p. 529 to end of Section 18-5); Need for Dark Matter and Dark Energy in our best current model of the universe (blue box on p. 537 and Figure 18-29); Oscillations in the Very Early Universe (middle of p. 536 to middle of p. 538) ; Limits in how far back in time we can observe; The Hubble Tension; Observations of the polarization of the CMBR (middle of p. 538 to middle of p. 540). A cautionary tale of announcing cosmological results via press conferences. Where we go from here in cosmology (Conclusion of Chapter 18).
Final Exam			**Friday, December 9, 2022, 2:00-4:00 p.m. PDT (The Location May Be Different Than SLH 102. The Actual Location Will Be Announced During Lectures in Case We Have to Move The Final Exam)**