ASTRONOMY 400
The Solar System
Fall 2023

Instructor:	**Prof. Edward J. Rhodes, Jr.**
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Grader:	**Julie Xue**
Grader Office Hours:	**TBA**
Grader Office:	**TBA**
Grader Mailbox for	
Homework Dropoff:	**SHS 364**
Course Location:	**MWF in KAP 138**
Course meetings:	**MWF 2:00 - 3:20 pm**

No Class: Monday, Sept. 6, Friday, Oct. 13, Friday, Nov. 10, Wed., Nov. 22, and Friday, Nov.24

Last day of class:	**Friday, Dec. 1, 2023**
Final Exam:	**Friday, Dec. 8, 2023, 2 pm - 4 pm**

- **Required and Supplemental Textbooks, Lecture Slides, and Lecture Notes:**

1. **Textbook on Spherical Astronomy,** Smart, required.

2. **Classical Dynamics of Particles and Systems, Fifth Edition**, Thornton and Marion, required.

3. **Interplanetary Astrodynamics,** Spencer, supplemental ebook available for reading and downloading at
https://usoc.primo.exlibrisgroup.com/permalink/01USC_INST/mbk0s6/alma9910441301330
03731

4. **Lecture Slides and Lecture Notes to accompany Astronomy 400 are available via Blackboard. Each set should be printed out prior to lecture and brought to class. Also available are nine different video demonstrations to accompany six different lectures.**

- **Work Required:**

Homework Problem sets and Observing Visits	45%
2 mid-term exams 2 hours each	30%
Final exam 2 hours	25%
	100%

Grading Scale: Modified curve (45% As and A-s, 45% B+s, Bs, and B-s, 5.8% C+s, 3.6% Cs, .6% C-s)

Prerequisite: Math 226 (at least)

We will have one evening observing session using USC's 14-inch Meade LX-600 telescope and one Saturday morning trip to the Mount Wilson Observatory to see a partial solar eclipse.

Please note that **there will not be any make-up exams**. Any student missing one of the two mid-terms will only have recorded the points scored on the one exam taken.

The questions on the exams will cover the lectures, assigned readings, and the homework assignments. Each of the two mid-term exams and the final exam will consist of three parts. The first part will be a closed-book, machine scored portion of multiple-choice and matching questions. The second part will be closed-book, short-answer section to be written in an exam booklet. The third part will be an open book, open-notes section to be done in an exam booklet and graph paper. We will supply the Scantron sheets for Part I and the exam booklets for Parts II and III. Each of the two midterms will take considerably longer than the normal class time, so if there is a conflict with another class following the end of our regular class period, the third portion of the exam will have to be completed as a Take-Home 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 room. During two of the weeks, I will schedule an afternoon or evening review session before the exams. I will also schedule a review session during one of the two stop days prior to the beginning of the Final Exam Period at the end of the term.

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.

Homework Assignment Submission and Feedback

The homework assignments are all located under the "Assignments" tab on the Blackboard site for the class. All of these assignments (with the exception of Assignment #14) have been set up so that you will be able to submit your solutions online so that the Grader will be able to access them online as well. The scores will be posted in the Grade Center on the class websites on Blackboard. The dates that the

assignments will be assigned are given in the Course Outline and they are repeated at the top of each assignment. The due date for each assignment is listed at the end of that assignment. The number of points that each assignment will be worth is given at the end of each assignment.

Homework 14 is a research-style assignment that will have several dues dates at which times you will submit your work for partial grading. I will personally grade each partial submission of this assignment. I will suggest revisions, if necessary, after each partial submission in order to provide guidance while you are completing this assignment. It will count for the largest number of points of any assignment during the course, so it will be in your interest to complete this assignment.

Late Homework Policy

All of the assignments are due on their respective due dates. A late penalty of 2% of the total possible points will be deducted for each day that an assignment is turned in after the due date.

Exam Feedback

For the two mid-term exams, the grader will return your graded question booklets to me, and I will pass them back at the end of lectures once they have each been graded. The scores for the various portions and the total scores for each of the mid-term exams will also be posted in the Grade Center on Blackboard.

Recordings of Lectures

Synchronous Recordings will be made of the lectures. Trimmed versions of these recordings will be uploaded to the class website on Blackboard by the end of the day when each lecture is given.

Course Description

This course will include elements of spherical trigonometry, the motions and orientation of the Earth; descriptions of various astronomical coordinate systems; transformations between coordinate systems; types of time; calendars; effects of refraction upon astronomical observations; historical development of the overall structure of the solar system; elementary celestial mechanics; theories of formation of the Solar System; tides; precession; gravitation force and potential; astronomical constants; perturbations of orbits; Earth's motions; lunar and solar eclipses; interior of the Earth; the geomagnetic field; the magnetosphere; the Sun; the discovery of exoplanets; the other planets and their satellites; comets; asteroids and their past impacts on the Earth; meteorites; interplanetary matter.

Course Goals

My goals for each of you this semester include the following:
1) That you will learn a wide range of mathematical and graphical skills that you will likely use after your graduations in your future careers.
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 solar system
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 USC's refurbished Campus Observatory.

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. ([Living our Unifying Values: The USC Student Handbook](#), page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. ([Living our Unifying Values: The USC Student Handbook](#), page 13).

Since creating, analytical, and critical thinking skills are part of the learning outcomes of this course, all assignments should be prepared by the student working individually or in groups. Students may not have another person or entity complete any substantive portion of the assignment. Developing strong competencies in these areas will prepare you for a competitive workplace. Therefore, using AI-generated tools is prohibited in this course, will be identified as plagiarism, and will be reported to the Office of Academic Integrity.

Statement on Academic Conduct and Support Systems

Academic Integrity:

The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, compromises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

Counseling and Mental Health - *(213) 740-9355 – 24/7 on call*

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline - *988 for both calls and text messages – 24/7 on call*

The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

[Relationship and Sexual Violence Prevention Services (RSVP)](#) - *(213) 740-9355(WELL) – 24/7 on call*

Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

[Office for Equity, Equal Opportunity, and Title IX (EEO-TIX)](#) - *(213) 740-5086*

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

[Reporting Incidents of Bias or Harassment](#) - *(213) 740-5086 or (213) 821-8298*

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

[The Office of Student Accessibility Services (OSAS)](#) - *(213) 740-0776*

OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

[USC Campus Support and Intervention](#) - *(213) 740-0411*

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

[Diversity, Equity and Inclusion](#) - *(213) 740-2101*

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

[USC Emergency](#) - *UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call*

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call

Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)

A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice - (323) 442-2850 or otfp@med.usc.edu

Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.

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.

Astronomy 400
Fall 2023
DETAILED COURSE OUTLINE

Week 1

Lecture 1   Mon., Aug. 21   Administrative Details; Celestial Sphere; Celestial Poles; Angles on Celestial Sphere; Geographic Coordinates; Definition of Spherical Triangles. **(Assignment #1)**

Lecture 2   Wed., Aug. 23   Derivation of 1st Spherical Law of Cosines; Statement of 2nd and 3rd Spherical Cosine Laws; Statement of Spherical Law of Sines; Statement of 4-Parts Formula; Statement of Plane Laws on Sines and Cosines; Simple Memory Aids for Plane Trig functions; Sample Numerical Problems. **(Assignment #2)**

Lecture 3   Fri., Aug. 25   Completion of Numerical Examples; Polar Triangles; General Spherical Coordinates; Polar-cartesian transformations; Coordinate System Rotations; Setup of Spherical Triangle for General Coordinate Transformations; Terrestrial Coordinate System; Beginning of the Horizon Coordinate System; Definition of Zenith and Horizon Plane.

Week 2

Lecture 4   Mon., Aug. 28   Completion of Horizon Coordinate System; Definition of Cardinal Points; Definition of Celestial Meridian, altitude, azimuth, vertical circle, zenith distance, nadir; Complications in Defining latitude due to Oblate shape of Earth, astronomical latitude, geographical latitude, geocentric latitude; Equator 1 Coordinate System, hour angle and declination; Earth's Motions and Apparent Motions of Celestial objects in the sky; the Ecliptic Plane; Annual Motion of Sun; The obliquity of the ecliptic.

Lecture 5   Wed., Aug. 30   Motions of Sun, Moon, and Planets; the ecliptic; the equinoxes; the solstices; reasons for the seasons; Equator 2 Coordinate System; right ascension and declination; topocentric coordinates versus geocentric coordinates; Ecliptic System; celestial latitude and celestial longitude. **(Assignment #3)**

Lecture 6   Fri., Sept. 1   Transformation from Equator 2 to ecliptic coordinates. Transformation from Horizon to Equator 1; Reverse transformation from Equator 1 to Horizon; PZX Triangle; Drawings of celestial sphere from different vantage points and relevant PZX triangles.

Week 3

            Mon. Sept. 4.   **No Class (Labor Day Holiday)**

Lecture 7   Wed., Sept. 6   Completion of Drawings of PZX triangle; sunrise and sunset conditions; definition of circumpolar stars; definitions of civil, nautical, and astronomical twilight; Effects of Refraction in terrestrial atmosphere on celestial coordinates; Introduction to Heliographic coordinates. **(Assignment #4 in evening at USC's campus observatory on the south roof of AHF)**

| Lecture 8 | Fri., Sept. 8 | Completion of Heliographic Coordinates; Handouts describing other solar system Coordinate systems; **Last day to drop this class without a mark of "W" and receive and receive a tuition refund. Also, last day to change enrollment option to Pass/No Pass. Also, last day to add this class. (Assignment #5)** |

Week 4

| Lecture 9 | Mon., Sept. 11 | Time and Calendars; Retrograde motions of the Planets; Ibn al-Shatir; Nicholas Copernicus and the Heliocentric Hypothesis; Planetary configurations; synodic and sidereal orbital periods. |

| Lecture 10 | Wed., Sept. 13 | Continuation of Copernican System; His Explanation of Retrograde Motion; Tycho Brahe; Johannes Kepler; Kepler's 3 Laws of Planetary Motion and properties of ellipses. **(Assignment #6)** |

| Lecture 11 | Fri., Sept. 15 | Galileo Galilei; Sir Isaac Newton; Newton's 3 Laws of Physics; Newton's Law of Universal Gravitation; Center of Mass; Earth-Moon Barycenter; Definition of the Elements of an Orbit. **(Assignment #7)** |

Week 5

| Lecture 12 | Mon., Sept., 18 | Orbital Elements for Halley's Comet; Computation of the trajectories of celestial objects given knowledge of their orbital elements; Completion of the "Forward Problem" of Orbit Determination; Tables of Orbital Elements from the Astronomical Almanac . |

| Lecture 13 | Wed., Sept., 20 | Elementary Celestial Mechanics; Beginning of Review of Vectors; Differentiation of Vectors. (**Assignment #8**) |

| Lecture 14 | Wed., Sept., 22 | Change of unit vector; derivation of velocity vector in Plane Polar coordinates; Statement of velocity vector in spherical coordinates. |

Week 6

| Lecture 15 | Mon., Sept. 25 | Gradient of a scalar point function; Central-Force Motion; Vector Form of Newton's 3 Laws; Angular Momentum; Torque; Work and Energy; Conservative Fields. |

| **Exam #1** | **Wed., Sept. 27** | *1st Mid-Term Exam; exam time will be 2:00 until 5:00 PM. Please let me know as soon as possible if this date will cause any religious conflict. In that case, I will re-schedule the exam for the following week.)* |

| Lecture 16 | Fri., Sept. 29 | Conservation Theorems for a System of Particles; questions Newton had to answer in deriving his law of Universal Gravitation |

Week 7

| Lecture 17 | Mon., Oct.2 | Two-Body Problem; reduced mass; derivation of acceleration vector for particles traveling on conic sections (i.e., on orbits). **(Assignment #9)** |

Lecture 18	Wed., Oct. 4	Derivation of Law of Universal Gravitation; Gravitational Potential and Potential Energy; effective potential energy; Gaussian constant of Gravitation.
Lecture 19	Fri., Oct. 6	Derivation of Kepler's Laws from Newtonian Equations; Effective Potential Energy; Vis-viva Equation; Astronomical Constants **(Assignment #11) Last day to drop without a mark of "W" on transcript. Last day to change from Pass/No Pass to letter grade option.**

Week 8

Lecture 20	Mon., Oct. 9	Kepler's Equation and Least-energy Interplanetary Trajectories. **(Assignment #10)**
Lecture 21	Wed., Oct. 11	Perturbation Theory and Its use in the Discovery of Neptune by Galle after predictions by Adams and Leverrier; changes to orbital Elements; Perihelion Advance of Mercury. **(Assignment #11)**
	Fri., Oct. 13	**No Class, Fall Recess**
	Sat., Oct. 14	**Field Trip to Mount Wilson Observatory 7:45 to 11:00 AM to See the Partial Solar Eclipse Using the 150-Foot Solar Tower. (Assignment #12)**

Week 9

Lecture 22	Mon., Oct. 16	Restricted 3-Body problem and the Trojan Asteroids; orbital Resonances and Kirkwood's Gaps.
Lecture 23	Wed., Oct. 18	The Size and Shape of the Earth; Centrifugal Force and Oblateness; Tides **(Assignment #13)**
Lecture 24	Fri., Oct. 20	Precession; The Chandler Wobble; The Foucault Pendulum; The Coriolis Effect

Week 10

Lecture 25	Mon., Oct. 23	Distance to the Moon; Changing Lunar Angular Diameter; Lunar Phases; Lunar Eclipses; Solar Eclipses .
Lecture 26	Wed., Oct. 25	The Sun: Basic Solar Data; the Solar Atmosphere; Coronal Holes and the Speed of the Solar wind; Sunspots; the Zeeman Effect. **(Assignment #14)**
Lecture 27	Fri. Oct. 27	The Sun (cont.): The Solar Activity Cycle; Possible Sun-Climate Influences; Source of Solar Energy; the Proton-Proton Chain; The Solar Interior.

Week 11

Lecture 28	Mon., Oct. 30	The Solar Neutrino Problem; Solar Models; Solar Oscillations; Helioseismology from the Earth and from Space. **(Assignment #15)**
Lecture 29	Wed., Nov. 1	The Earth: Its Interior; Seismic Waves; the Geomagnetic Field; the Magnetosphere; the Interplanetary Magnetic Field; the Van Allen Belts; Plate Tectonics; Pangaea; Ice Ages; Earth's Atmosphere.

| Lecture 30 | Fri., Nov. 3 | Earth's Atmosphere (cont.); Ozone Layer Depletion; Global warming Controversy; the Moon: Basic Data; Lunar History; Theories of Lunar Formation; Distances in the Solar System; Masses of Solar System objects; Planetary Motions. |

Week 12

| Lecture 31 | Mon., Nov. 6 | Classifying the Planets: the Terrestrial and the Giant Planets; Planetary Sizes; Planetary Masses; Planetary Densities; Planetary Rotational Periods; Theories of Formation of the Solar System. Last day to drop with a mark of "W" **(Assignment #16)** |

| **Exam #2** | **Wed., Nov. 8** | **Second Mid-Term Exam (note exam time of 2:00 to 5:00 PM)** |

| | **Fri., Nov. 10** | **No Class: Veterans Day Holiday** |

Week 13

| Lecture 32 | Mon., Nov. 13 | Detection of Extra-Solar Planets and the Search for Extraterrestrial Life; History of Interplanetary Missions; Mercury; Venus; Rotation of Venus. **(Assignment #17)** |

| Lecture 33 | Wed., Nov. 15 | Completion of Venus; Beginning of Mars. |

| Lecture 34 | Fri., Nov. 17 | Completion of Mars; Beginning of Jupiter. **(Assignment #18)** |

Week 14

| Lesson 35 | Mon. Nov. 20 | Completion of Jupiter; Jupiter's Moons; Jupiter' Rings; Beginning of Saturn |

| | **Wed., Nov. 22** | **No Class: Thanksgiving Holiday** |
| | **Fri., Nov. 24** | **No Class: Thanksgiving Holiday** |

Week 15

| Lecture 36 | Mon. Nov. 27 | Completion of Saturn; Titan; Uranus; Neptune. |

| Lecture 37 | Wed., Nov. 29 | Discovery of Pluto; recent discoveries about Pluto and its moon Charon from NASA's New Horizons Mission; Pluto's other moons; Asteroids; Comets. |

| Lecture 38 | Fri., Dec., 1 | Completion of Comets; the Oort Cloud and the Kuiper Belt; Meteors and Meteor Showers; Asteroids, the OSIRIS-Rex and DART Missions; Past Asteroid Impacts on Earth and Current Efforts to Prevent Future Impacts. |

FINAL EXAM: FRIDAY, DEC. 8, 2023 – Exam time 2 P.M. - 4 P.M.