MAE 180A: SPACECRAFT GUIDANCE I

Course Description: This is a course in Spacecraft Dynamics. The principles of Astrodynamics are studied, including the two-body orbital motion in conic orbits, as well as orbit determination techniques from radar observations. Basic spacecraft dynamics are addressed by studying orbital maneuvers, insertion into special spacecraft orbits, and interplanetary missions in the Solar System.

Prerequisite: *Upper-division standing in physics, mathematics, or engineering department.*

Instructor: Javier Urzay,

E-mail: jurzay@ucsd.edu

Office: 564 EBUII, Phone: 858 534 6123.

Office Hours: Thursdays 2:00-3:00 PM, and Mondays 3:00-4:00 PM, at 564 EBUII.

Reader: William Hayes,

E-mail: williamhayes14@gmail.com

Lectures: Tuesdays and Thursdays, 11:00-1:50 PM, WLH 2112. Total number of lectures: 10.

Textbook (Required): *"Fundamentals of Astrodynamics,"* Bate, R.R., Mueller, D.D. & White, J.E.; Dover Publications, 1971. Supplementary material will be provided in class.

Homeworks: There will be 4 homework assignments. Homework will be assigned each week and collected on Tuesdays on the 7th, 14th, 21st and 28th of July, at the beginning of the lecture. No late homeworks will be accepted. Homework solutions must be clean, clear and neatly written.

Exams: Midterm Exam: Thursday 16th, 11:00-12:30 PM, WLH 2112.

Final Exam: August 1st, 8:00-11:00 AM, location TBA.

Both exams will consist of two parts: i) Short Questions (closed books, closed notes, no calculator), and ii) Problems (open book and open notes, calculator required). No Blue Books required.

Grading Scheme: 20% Homeworks + 35% Midterm Exam + 45% Final Exam.

Academic Integrity: UCSD Policy on Integrity of Scholarship will be followed.

Accomodations for students with disabilities: Requests for appropriate accommodations must be presented to the instructor, and students must register with the Office for Students with Disabilities to verify their eligibility for appropriate accommodations.

TENTATIVE OUTLINE

I. MECHANICS OF PARTICLE MOTION.

1. Newton’s laws:

Newton’s laws of motion. Newton’s law of universal gravitation. Universal gravitational constant. Gravitational acceleration. Standard gravitational parameter. Weight.

2. Scalar and vector quantities:

Scalars. Vectors. Unit vector. Vector addition. Pseudovectors. Resolution of a vector. Scalar product. Cross product. Moment of a vector. Time-derivative of a vector.

3. Kinematics:

Velocity and acceleration. Curvilinear planar motion in polar coordinates. Radial and angular components. Tangential and normal components. Intrinsic coordinates. General case of space kinematics: absolute and relative motion. Motion relative to the rotating Earth.

4. Examples.

II. PLANETS AND SATELLITES ORBITS.

1. The N-body problem:

Total gravitational force. General equation of motion. Earth-satellite-planets system, Earth-satellite relative acceleration and perturbation effects from planets.

2. The two-body problem:

The equation of relative motion. Constants of the motion: angular momentum, areolar velocity and mechanical energy. Trajectory equation. Orbit eccentricity. Semi-latus rectum. Orbital Hamiltonian. Orbit classification: elliptic, circular, parabolic and hyperbolic orbits. Orbital period. Circular speed. Escape speed. Hyperbolic excess speed. Turning angle. Canonical units. Reference orbit.

3. Examples.

III. ORBIT DETERMINATION FROM OBSERVATIONS.

1. Coordinate systems:

The heliocentric-ecliptic coordinate system. Ecliptic and equatorial planes. Vernal equinox direction. Precession of the equinoxes. Nutation. The geocentric-equatorial coordinate system. The right ascension-declination system. Celestial sphere. The perifocal coordinate system. The topocentric-horizon coordinate system. Zenith and nadir directions.

2. Classical orbital elements:

Semi-major axis. Eccentricity. Inclination. Longitude of the ascending node. Argument of the periapsis. Longitude of the periapsis. True anomaly at epoch. Argument of latitude at epoch. True longitude at epoch. Euler angles. Direct and retrograde orbit motion.

3. Orbit determination from velocity and position vectors:

Fundamental vectors: angular momentum vector, node vector and eccentricity vector. Inverse problem.

4. Transformation of coordinates:

Rotational transformation matrix. Transformation from geocentric-equatorial to topocentric-horizon coordinates. Transformation from perifocal to geocentric-equatorial coordinates.

5. Orbit determination from a single radar observation:

Position and velocity relative to the radar site. Position and velocity from the geocentric-equatorial coordinate system.

6. Orbit determination from three position observations:

The Gibbsian method. Determination of the satellite velocity.

7. Influences of Earth's oblateness:

The reference ellipsoid. Equatorial and polar radius. Eccentricity of the Earth. Astronomical, geodetic and geocentric latitudes. Station coordinates. Position of the Topocentric-horizon system on an ellipsoidal Earth.

8. The measurement of time:

Apparent solar time. Mean solar time. Sidereal time. Time zones and the Universal time. The Greenwich-meridian longitude.

9. Ground track of a satellite:

Ground trace on a rotating and non-rotating Earth. Maximum latitude above equator. Spacecraft elevation angle. Spacecraft horizon. Subsatellite point. Swath width. Launch azimuth. *(Lecture 5)*

10. Examples.

IV. ORBITAL MANEUVERS.

1. In-plane orbit maneuvers:

Orbital velocity. Simple coplanar orbit change. General coplanar maneuver. The Hohmann transfer. Time of Flight. General coplanar transfer. Time of flight as a function of the eccentric anomaly. *(Lecture 6)*

2. Out-of-plane orbit maneuvers:

Simple plane changes.

3. Time of flight as a function of the eccentric anomaly:

Time of flight on the elliptical orbit. Kepler's equation. Mean motion. Mean anomaly. Time of flight on parabolic and hyperbolic orbits.

4. Propulsion for maneuvers:

Thrust. Mass of propellant. Specific impulse.

5. Examples.

V. SPECIAL ORBITS.

1. Low-altitude Earth orbits:

LEO orbits. Van-Allen belt radiation and drag effects. Regression of the line of nodes. Rotation of the line of apsides.

2. High-altitude Earth orbits:

The Geosynchronous orbit (GEO). The Geosynchronous transfer orbit (GTO). The GEO mission. Supersynchronous orbits. The Graveyard orbit. Sun-Synchronous orbits. The Molniya orbit.

VI. INTERPLANETARY MISSIONS.

1. The Solar system:

Geometry of the Solar system. The ecliptic plane. The astronomical unit. The Astronomical Almanac.

2. Patched conic approximation:

Sphere of influence. Heliocentric transfer orbits. Mission stages. Transfer stage. Orbital velocity at departure. Time of flight transfer. Departure stage. Phase angle at departure. Launch opportunity. Synodic period. Escape from the Earth’s sphere of influence. Hyperbolic excess velocity. Velocity and point of injection. Departure body of revolution. Launch window. Arrival at the target planet. Offset miss distance. Effective collision section. Establishment of planetary orbit at arrival.

3. Gravity-assisted maneuvers:

Spacecraft velocity decrease and increase maneuvers. Maximum turning angle. Maximum spacecraft velocity increase.

4. Examples.

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SUMMER SESSION I

MECHANICAL AND AEROSPACE ENGINEERING

UNIVERSITY OF CALIFORNIA SAN DIEGO

SPECIAL LECTURE

Thursday July 30th, 11:00 AM-12:00 PM, 479 EBUII

"MAKING THE SPACE SHUTTLE A FLYING MACHINE",

BY

Dr. LEE R. SCHERER.

Dr. Scherer was involved in the Space Program from its beginning in the early 1960's. He served a total of 22 years in NASA. Assignments included Director of Unmanned Lunar Programs (NASA Headquarters), Director of the Apollo Lunar Exploration Office (NASA Headquarters), Center Director of Dryden Flight Research Center, and Center Director of Kennedy Space Center. In industry he worked for General Dynamics as Marketing Director for Atlas Launch Services to satellite users. Since retirement he has acted as a consultant on Space matters to industry and to the federal government. Dr. Scherer holds a B.Sc. degree (Marine Engineering) from the U.S. Naval Academy and a B.Sc. degree (Aeronautical Engineering) from the Navy Post Graduate School. He also has a Professional Degree (Aeronautical Engineering) from the California Institute of Technology (Caltech), and an Honorary Doctorate in Engineering from the University of Central Florida.

His lecture will briefly review the history of manned space flight and focus on the Space Shuttle.

The MAE community is cordially invited.