SPACEFLIGHT MECHANICS – MANE 4100

Winter term, 2009 Class Hours: Tu, F 2:00-3:50 PM Room: Troy 2018

Kurt S. Anderson
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Office Hours: M 3:30-4:30 PM, W 9:00-10:00 AM, Th 3:00-4:00 PM (or by appointment).

TA: There is no TA for this course

Course Objective:
Analysis of basic aspects of spacecraft orbital and attitude dynamics. Analysis of spacecraft trajectories, target rendezvous, and interception; Rocket thrust problem, Holman transfer, escape trajectory, interplanetary missions, gravity assist, and the restricted three body problem. Rigid body dynamics as it relates to gyrodynamics, spin and gravity gradient stabilization.

Text:
Required "text" for this course is are:
Orbital Mechanics for Engineering Students, by Howard Curtiss, Elsevier Pub. 2005

Other texts which may be helpful:
ENGR-2090 text, by Beer and Johnston or equivalent
Introduction to Space Dynamic (ISD), by W. T. Thomson, Dover Pub. 1986
Fundamentals of Astrodynamics (FoA), by R.R. Bates, D.D. Mueller, J.E. White, Dover Pub., 1971.

Prerequisites:
ENGR 2090 (Engineering Dynamics), MANE 2060 and MATH 2400 (Intro. to Differential Equations) or equivalents
It is assumed that all students are have a good understanding of statics and basic planar (2-D) (Sophomore level) dynamics. Furthermore, students must be proficient in all of following basic mathematics:

a. *Basic vector algebra and calculus*: (e.g. dot product, cross product, chain rule for differentiation).
b. *Basic Linear Algebra*: Matrix multiplication, matrix inversion, etc.
c. *Trigonometric Identities and definitions*: (plus the law of Sines and the Law of Cosines)
d. *Basic Differential Equations*: Formulation and solution of simple homogeneous, non-homogeneous linear differential equations; exposure to simple eigenvalue problems and their solution.
e. *Numerical Analysis*: Numerical modeling will be performed extensively in this course.
f. *Multivariable calculus*: Double and triple integration, Differential equations in multiple variables.

Topics:
1. Introduction to Dynamics
2. Particle Kinetics
3. Orbital kinematics, transforms Kinematics
4. Satellite Orbits (Orbit Determination, Maneuvers, Intercept and rendezvous, transfers)
5. Rocket thrust, Rocket design
6. Rigid body Dynamics, Stability
7. Space vehicle motion

Homework:
Homework will account for 10% of the course grade. Problems will be assigned each week as indicated on the attached schedule and will be due on Friday of the following week (except for weeks with examinations). The problems are best done individually in a professional manner (neatness counts!). Problems will be generally be graded on a 10 point scale and will be returned in class approximately one week after they were due. Collaboration in the solution of the

homework problems is permitted and is strongly encouraged if it enhances the learning process, but mere copying of the solution is deleterious at best. In general, ***no*** late assignments will be accepted. However, extensions may be granted if a situation arises for which it is warranted. In these instances the student must request the extension in writing prior to the assignment due date, stating the reason for the request and the date the assignment is to be submitted. Solutions to all homework assignments will e-mailed to student on instructor's list.

Term Project:
This course will involve a project chosen by each student and approved by the instructor. The student may apply material learned in class (e.g. simulation of trajectory associated with n-body problem; trajectory design for mission of student's choosing; etc.), and write an associated report. The overall project will be worth 10% of the course grade.

Exams:
There will be three full period, in-class exams during the course. Each exam will be open book, open note (but is restricted to the course text, the student's personal notes, and materials provided by the instructor) . The approximate exam schedule is:

Exam 1: Topics 1, 2, 3	Feb. 20, '09
Exam 2: Topics 3, 4	Mar. 27 '09
Exam 3: Topic 5, 6	Apr. 24 '09
Final Exam	TBD.

Final Exam:
There will be a 3-hour in-class final exam given during the ***Finals Week*** interval set aside for exams. This final exam will be comprehensive. This exam is open-book, open-note (as described for exams, above).

Grade Appeal:
Students are encouraged to discuss there grades with the instructor as frequently as is necessary. Appeals of grades should be made within one week of the return of the homework/exam in question to the student.

Grading:
Homework 10%: Project 10% Exams 50%: Final Exam 30%

Statement of Academic Integrity:
Student-teacher relationships are built on trust. The students must trust that the instructor has made appropriate decisions about the structure, content, etc., of the courses they teach, and the instructors must trust that assignments which students turn in are their own. Acts which violate this trust undermine the education process.

The *Rensselaer Handbook* defines various forms of Academic Dishonesty and procedures for dealing with them. All forms are violations of the trust between the students and instructors. All students should familiarize themselves with this portion of *the Rensselaer Handbook* and should note that the penalties for the various forms of dishonesty can be quite harsh.

Proposed Schedule
(Wish List)

Spaceflight Mechanics – MANE 4100

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#	Date	Topic [Sections in Text], {HW Problems}
1.	Tu 1/13	Introduction, review, definitions, position, velocity, acceleration [Chapt 1]{1.3, 1.6, 1.7}
2.	F 1/16	No Class (On Travel)
3.	Tu 1/20	Two-Body Problem: Equations of motion, Angular momentum, Energy[2.1-2.4]{2.4,2.6.2.7}
4.	F 1/23	Energy, Angular Momentum, Circular Orbits, Elliptic Orbits [2.4-2.7]{2.14, 2.16, 2.18,}
5.	Tu 1/27	Parabollic orbits, Hyperbolic Orbits [2.8, 2.9]{2.23, 2.24}
6.	F 1/30	Perifocal Frame; [2.10]
7.	Tu 2/3	Perifocal Frame; Lagrange coefficients [2.10-11]{2.28}
8.	F 2/6	No Class! At NSF
9.	Tu 2/10	Lagrange Coefficients [2.11] {2.33}
10.	F 2/13	*Restricted Three-Body Problem [2.12]{2.38}*
11.	**Tu 2/17**	NO CLASS, This is a “Monday”
12.	F 2/20	**Quiz #1**
13.	Tu 2/24	Kepler’s Equations, Orbital Position as function of time, Circular and elliptic orbits [3.1-3.4]{3.5, 3.6}
14.	F 2/27	3-D orbits; Classical Orbit Parameters [4.1-4]{4.2, 4.5}
15.	Tu 3/3	Coordinate (Basis) transformations [4.5-6]{4.7, 4.8};*Earth’s Oblateness [4.7]{}*
16.	F 3/6	Gibb’s Method for Orbit Determination [5.1-2], {5.1, 5.3}
17.	Tu 3/10	Lambert’s Problem [5.3]{5.5-6}
18.	F 3/13	Spring Break, NO CLASSES!!!
19.	Tu 3/17	Spring Break, NO CLASSES!!!
20.	F 3/20	Hohmann transfers [6.1-3]{6.3, 6.5}
21.	Tu 3/24	Bi-Elliptic Transfers, Phasing Maneuvers [6.14, 6.15]{}
22.	F 3/27	**Quiz #2**
23.	Tu 3/31	*Non-Hohmann Transfers [6.6-6.8]{6.18}*
24.	F 4/3	Inclination Changes [6.9]{6.28, 6.29}
25.	Tu 4/7	Wiltshire Clohessey Equations [7.1-7.4]{7.14, 7.15}
26.	F 4/10	Basic Rocket Design[11.1-4], Handout
27.	Tu 4/14	Optimal staging [11.5-6]{11.1, 11.2}
28.	F 4/17	Rigid Body Dynamics [9.1-9.10]{9.21, 9.24}
29.	Tu 4/21	Torque Free motion [10.1-2]{10.2, 10.6}
30.	F 4/24	**Quiz #3**
31.	Tu 4/28	Stability of Torque-Free motion[10.3]{10.7}.

Recommendations for format of problem solutions:
The following should be included in the solution of all homework problems.

1. Problem description: Brief description/statement of problem to be solved.
2. Diagram of problem clearly showing all relevant quantities and coordinate frames.
3. Free-Body-Diagram and Mass-Acceleration Diagram if formulation warrants them.
4. Basic Laws/Formulas: clearly give relevant formulas necessary to solve problem.
5. Assumptions: Clearly state and briefly justify all assumptions used in analysis
6. Analysis: Carry through analysis symbolically to the point where numerical substitution is appropriate.
7. Number and underline important intermediate equations.
8. Numbers: When numbers are substituted into expressions, use consistent units and limit the number of significant figures to that appropriate with the given data.
9. Label (BOX) your final answer.
10. Odds and Ends:
    a) Always start a problem on a new page
    b) Use lined (ideally Engineering) paper
    c) Organized flow to work
    d) Always use a straight edge
    e) Only write on the front side of each sheet of paper
    f) Don't annoy the TA or the Instructor with sloppy, hard to follow work!!!!

Comments on Project:
Each student is to produce a term project which is related to the material covered in this course. The topic is of the students choosing and should take the material to the next level (beyond what was covered in lecture/text). Because this is a design/analysis course, the project should not be strictly historical, but must have act least some analysis/coding component.

The write-ups do not need to be long (I prefer that the actual written text be fewer that 10 pages, but supporting material, references, appendices, etc, may make it longer). All references must be properly cited!