Seminar in Celestial Mechanics

MATH 392-02, MTuTh 1:00 - 1:50, O'Neil 123, Spring 2008

Dr. Gareth Roberts

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Office hours: Mon. 2 - 3, Wed. 1 - 2, Tues. & Thurs. 11 - 12 or by appointment.

Required Texts: *Celestial Mechanics* by Harry Pollard, Carus Mathematical Monographs, No. 18 published by the MAA (xeroxed copy available in bookstore) and *Celestial Mechanics: The Waltz of the Planets* by Alessandra Celletti and Ettore Perozzi, published by Springer-Praxis Books.

Course Prerequisites: MATH 304 (Ordinary Differential Equations)

Web page: `http://mathcs.holycross.edu/~groberts/Courses/MA392/homepage.html` Homework assignments, project information, schedule changes, useful links and other important information will be posted at this site. Please bookmark it!

Course objectives:

- Learn and apply some of the mathematics underlying celestial mechanics.
- Become proficient at making clear and coherent mathematical arguments.
- Work and communicate with your peers.
- Have fun learning celestial mechanics!

Syllabus: This is an applied mathematics course focusing on the classical Newtonian n-body problem. It will be run as a "capstone" seminar, requiring the synthesis and application of various mathematical topics including calculus (in particular, multivariable calculus), linear algebra, ordinary differential equations, dynamical systems and perhaps, even a little algebraic geometry.

Celestial mechanics concerns the motion of celestial bodies (stars, planets, moons, rings, comets, spacecraft, etc.) acting solely under the influence of gravity. The equations of motion describing the dynamics are a complicated set of nonlinear differential equations. Still, there is a great deal of mathematics that can be used to understand even the most complicated of problems. The fact that we, humankind, have been able to send spacecraft to all the planets in the solar system as well as place astronauts on the Earth's moon, is a testament to the success of this mathematics.

A rough outline of topics for the semester is given below. Some topics will be approached at a graduate level, providing a glimpse of current research in the field. We will cover much of the material in Pollard's book.

- Central force problems, the Kepler problem (3 weeks)
- The general n-body problem: Hamiltonian systems theory, integrals of motion, special coordinate changes (3 weeks)
- Central configurations, relative equilibria, linear stability (2 weeks)
- The restricted 3-body problem, libration points, stability (2 weeks)

- Variational calculus, the figure-eight orbit (1 week)
- Spacecraft transport, gravity assists, cheap energy orbits (1 week)
- Final project presentations (1 week)

Homework: There will be a problem set due every Thursday at the START of class. Assignments will be posted on the course web page. There will be a list of problems for you to hand in, a nonempty subset of which will be graded. While you are allowed and encouraged to work on homework problems with your classmates, the solutions you turn in to be graded should be your own. Take care to write up solutions **in your own words**. Plagiarism will not be tolerated and will be treated as a violation of both the departmental policy on academic integrity and the college's policy on academic honesty.

NOTE: LATE homework will NOT be accepted. The only excused homework which is late will be accompanied by a letter from your Class Dean. However, you will be allowed ONE "mulligan" over the course of the semester where you can turn in the assignment up to one week after the original due date.

In-class Presentations: During the semester you will be expected to give two in-class presentations covering material on the problem set due that day. These presentations will be fairly brief and are designed to enhance your oral communication skills as well as prepare you for your final project presentations. A schedule of presentations will be given out shortly. You are encouraged to consult with me before your presentations.

Final Project: You are required to complete a substantial final project focusing on some particular aspect or application related to the course material. Details and suggestions of topics will be distributed later in the semester. Your project will include both a written report and an in-class presentation during the final week of class. You will be allowed to work in pairs for the project although it is expected that all members of a given group will contribute equally.

Academic Integrity: The Department of Mathematics and Computer Science has drafted a policy on academic integrity to precisely state our expectations of both students and faculty with regards to cheating, plagiarism, academic honesty, etc. You are required to read this policy and sign a pledge agreeing to uphold it. Anyone who violates the Departmental Policy on Academic Integrity will receive a 0 for that assignment as well as possible further disciplinary action involving your Class Dean.

Grade: Your course grade will be based on the scores you receive for each of the following items:

- classroom participation/interest 5%
- problem sets 60%
- in-class presentations 10%
- final project/presentation 25%

How to do well in this course:

- Attend class, participate and ask questions.
- Work with your classmates. Organize study groups.
- Be an active, aggressive learner.
- Read the texts.