Spring, 2025

Orbital Mechanics 2 (with Python)
Wednesdays 10-11:30 ET

An Online Group Class
Offered by Eric Anthony Comstock, M.S. Aerospace Engineering '24
Georgia Tech PhD student,
and Davidson Young Scholar alumnus

About the instructor

I have a BS in aerospace engineering degree with engineering honors and minors in math and chemistry from Texas A&M University in College Station. I graduated, *magna cum laude,* in December, 2022. I will graduate with an M.S. in Aerospace Engineering in December of 2024 at Georgia Tech. I will continue at Georgia Tech as a PhD student in aerospace engineering in spring of 2025. I created this class for Davidson Young Scholars, and have been teaching this class for the past two years. I can be reached at: eric.comstock@gatech.edu

Course Overview

Are you interested in space travel? Have you ever wondered why movement in space is different from movement on Earth? If you are intellectually curious and interested in these questions, and if you have the background of Orbital Mechanics I which includes vector algebra, basic differential calculus, basic Python, the ability to catch on to mathematical concepts quickly, basic trigonometry, and the willingness to participate in class and complete homeworks, then this class is for you!

From these building block prerequisites, we will generally cover integral calculus, introductory differential equations, orbital elements, orbit determination, interplanetary and interstellar trajectories, and satellite navigation. The main product of the course will be a project involving a Python modeling of a custom satellite navigation system around a gravitationally rounded nonstellar object (the choice of which will be up to the student).

There is no age requirement for this class. Having grown up as an academically accelerated Davidson student, I realize that age has no bearing on intellectual merit.

I. Topics covered

I expect to cover one to three of these topics per one-and-a-half hour long lecture.

1. **Integral calculus (with proofs)**
    a. Review of differential calculus
        i. Definition of the derivative
        ii. Applications of the derivative
        iii. Derivatives of trigonometric functions
        iv. Review of limits
    b. Riemann sums and integrals
        i. Physical intuition of the integral
        ii. Definition of the Riemann sum
        iii. Evaluating Riemann sums
        iv. Solids of revolution
    c. Integrals of functions
        i. Integrals of polynomials
        ii. Integrals of trigonometric functions
        iii. x^{-1} and e^x
    d. Newton's method for solving nonlinear equations
        i. Application in Excel or LibreOffice Calc
        ii. General application
        iii. Use for multidimensional problems
        iv. Ways to enhance model stability
2. **Orbital mechanics math**
    a. Differential equations
        i. Separation of variables
        ii. Linear differential equations
        iii. How to guess solutions effectively
    b. Hyperbolic trigonometry
        i. Motivation
        ii. Hyperbolic trig functions
        iii. Derivatives and integrals
    c. Gravitation
        i. Review of gravitation
        ii. Solving the simplified two-body problem
    d. Reference frames
        i. Rotation matrices
        ii. Why we need reference frames
        iii. Ways to get around needing these in your code
    e. Orbits
        i. Orbital parameters and their derivations
        ii. Orbital periods
        iii. Orbit analytical propagation
3. **Orbit determination with the Python programming language**
    a. Orbital parameters and orbit position and velocity
        i. How to get parameters from position and velocity
        ii. How to get position and velocity from parameters
        iii. Edge cases, and how to get around them

    b. Analytical orbit propagation
    c. Hyperbolic orbits
        i. Velocity-at-infinity
        ii. Nonstandard eccentricity and semi-major axis meanings
4. **Advanced topics**
    a. Interplanetary and interstellar orbits
        i. Patched conics
        ii. General approximations
        iii. Interplanetary trajectories
        iv. Relativistic brachistochrone
        v. Interstellar travel
        vi. Advanced propulsion (fission, fusion, microquasar, antimatter, quantum vacuum thrusters, and warp drive, in order of effectiveness)
        vii. Intro to General Mission Analysis Tool (GMAT) and use cases (this will be explored more fully in a later dedicated course which I plan to offer in the Spring of 2025 – GMAT analysis I.)
    b. Satellite navigation
        i. Atomic clocks and position determination through light delay
        ii. Coverage radius
        iii. Orbit constellations
        iv. Effectiveness spotlight: Global Navigation Satellite System (GLONASS) – strengths and weaknesses (as an example to inform your project)

II. Homework and Grading

Homework will be present in approximately half to two thirds of the weeks, and will be assigned one class and generally due at 11:59 PM the day before the next class. Homeworks will consist of 3-4 questions per homework. Every week that the homework is late will deduct from the student's grade, as follows:

0 to 1 days late	-3% reduction
1 day to 1 week late	-15% reduction
1 week to 2 weeks late	-30% reduction
2 weeks to 3 weeks late	-45% reduction
Greater than 3 weeks late	-60% reduction

Homeworks that are incomplete may be submitted, and questions that are answered later will have their grades deducted individually based on the above rubric. My fundamental goal is helping these students learn and not punishing them for turning in homework late. While some standards are necessary for any learning environment, I want my learning environment to be sensitive to the needs of young learners in order to encourage and foster a love of math and science.

I generally expect to give short but thought-provoking homeworks, designed to test understanding of as much of the material as possible as quickly as possible. Students are thus highly encouraged to come to office hours to ask questions about the homework – I will be happy to help them through the solution to a similar problem. Extra credit will be available on some homeworks, but its inclusion is up to my discretion. If included, it will usually involve some kind of proof or generalization.

No exams are given, but the materials learned in the course will contribute towards a project, the improvement of which is likely to be the majority of the homeworks later in the semester. The main product of the course will be a project involving a Python modeling of a custom satellite navigation system around a gravitationally rounded nonstellar object (the choice of which will be up to the student). The details of the project, such as which object (e.g. planet or moon), what the spacecraft capabilities will be, and which constellation model is used, can be up to the student, but of course, must fall within realistic ranges. This project is a major product of this class and can serve to be added to the student's personal portfolio.

The student's total grade will be determined as follows:

Homework weighted average	90%
Attendance	10%

III. Prerequisites

Students are recommended to enter the course with knowledge of Orbital Mechanics I which includes vector algebra, basic differential calculus, and basic Python. Basic trignonometry is also recommended. Enthusiasm for learning, as well as the ability to pick up math concepts quickly, will also enhance the experience significantly, since much of the course is designed to be driven by individual curiosity.

Deeper experience in trigonometry, algebra II, advanced Python, or physics will be useful, but is not required.

IV. Schedule

Classes will be held on Wednesday mornings 10:00 to 11:30 ET, beginning Wednesday, Janurary 22 according to the schedule below. My office hours will be Wednesdays between 8 AM and 9 AM ET and Fridays between 5:30 and 7:30 pm ET for questions related to the homework, a resource which students are strongly encouraged to use. The number of students for each section of this class is capped at 8.

How fast the class goes depends upon how well the class goes. If most students are having trouble then I will likely slow down so that they are better able to understand the material. And, if the class is doing well, then I will likely speed up to present them a challenge. For these reasons, I do not have a specific end date, but I expect the class to last on the order of a school semester.

Preliminary Schedule (First three blocks)	
Date	***Class number***
First Block: $150	
Jan 22	1
Jan 29	2
Second Block: $375	
Feb 5	3
Feb 12	4
Feb 19	5
Feb 26	6
Mar 5	7
Third Block: $375	
Mar 12	8
Mar 26*	9
Apr 2	10
Apr 9	11
Apr 16	12

***Note that Mar 19 is revserved for spring break, and will be skipped.

Blocks are how tuition is billed. Please see the tuition section below for more information. Note that a fourth block is almost certain, but its length will depend on class progress during the third block, likely between 3 and 6 sessions.

V. Tuition

Tuition will be $75 per 1.5 hour class ($50/hour). Two weeks tuition will be due up front to secure your spot in the class with no ongoing obligation. Upon payment receipt, a link will be sent to join the online class.

Tuition may be paid via Zelle to
Eric Comstock, eric.comstock@gatech.edu.

After the first two weeks, if you decide to continue in the class, five weeks tuition will be due by 11:59 pm the day before the third class. An updated link for the third through eighth classes will be sent out the day of class upon tuition receipt. Since it is not yet known how many classes we will have, tuition payment will be managed in this manner until the end of the course.

That is, if we begin Wednesday, Janurary 22, 2025

$150 is due immediately to secure your spot in the class
$375 due by 11:59 pm on Feburary 4, 2025 (just prior to third class)
$375 due by 11:59 pm on March 11, 2025 (just prior to eighth class) – this would take us through the class on April 16, 2025.

One additional block of around 3 to 6 classes is likely, but due to lack of information on the preferred learning speed of the students, the exact number of classes cannot be determined.

VI. Textbook

There will be no textbook. Lectures will be based on my lecture notes which will be provided.

VII. Online meeting platform

We will be using an application that I have access to that does not require any software for the student. It is very easy to use. All the student needs is an internet connection, a browser, microphone and camera. The student will merely click on a link sent via email and allow access to their microphone and camera, then they will join the meeting. Most browsers work with this platform.

VIII. General Expectations

Given that this class is open to all ages, I must emphasize that students must behave in a manner that is appropriate to all ages during the class. That is, older students must refrain from speaking about any topics that are inappropriate for younger students. This rule will be strictly enforced.

I will not wait more than two minutes for tardy students, and prefer getting started as early as possible. Please try to come to class on time.

I do take attendance, and while it is not a large component of your grade, it can make the difference between an A and a B. I will deduct points if you are not in class and do not have an excuse. Please let me know beforehand if you cannot make class.