North Carolina School of Science and Mathematics

EE4140 : Aerospace Engineering

Course Description: This course introduces students to the field of aerospace engineering, engineering design, and the core math and science concepts needed to solve problems related to aerospace and other engineering disciplines. The course is presented in a historical context with topics that include spatial reasoning, fluid statics and dynamics, thermodynamics, kinematics and the mechanics of flight. These principles are applied to the design and control of aircraft and spacecraft through small-scale physical design projects and computational modeling examples. Students have opportunities to experiment, calculate, compute, design and build as they explore and solve problems associated with flight, and are encouraged to earn course credit through aerospace-themed projects of their own design.

Instructor Name or Department:
Garrett Love
Engineering and Computer Science

Course Meeting Pattern:
Online - 1 day/week: 60 min remote webinar

Prerequisites/Corequisites: Math III or Integrated Math III with a B or higher. (Trigonometry)

Textbook(s): none required.
Online references include the Pilot's Handbook of Aeronautical Knowledge (https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/) and NASA Glenn Research Center - The Beginner's Guide to Aeronautics (https://www.grc.nasa.gov/www/k-12/airplane/)

Required Course Materials (including technology):
- Basic computer skills and daily access to a laptop/desktop computer.
- Internet access through a standard browser and electronic access to the Canvas Learning Management System
- A hand-held scientific calculator or calculator application.
- Writing materials such as notebooks, paper, pens/pencils for note taking.
- Standard office supplies including scissors, a metric ruler, rubber bands, paper clips, index cards, tape, string, a protractor, and a stapler
- Classroom "kit" materials (shipped to students) including a paper sky lantern, GLEIM Flight Calculator, model rocket parachute, balloons, a straw, twine,embroidery floss, a styrofoam toy glider, a 100 ml graduated cylinder, wooden and foam dowel lengths.

Learning Outcomes:
Upon successful completion of this course, students should be able to

- recall and discuss the relative importance of historic people and events in the development of flight and space exploration based on research gathered from a number of sources
- communicate relative locations, orientations and shapes of objects in 3-Dimensional Space both visually and quantitatively
- translate between graphical representations in two and three dimensions
- articulate the distinctions between various mechanical properties of fluids (volume, density, pressure, velocity, temperature, etc.) and determine quantitative values for these state variables in physical systems through measurement and application of state equations
- describe the motion of an object in 3-Dimensional space using a variety of representations: verbal, pictorial, numerical, graphical and with the use of kinematic equations
- demonstrate the relationships between the fundamental forces of flight (weight, thrust, lift and drag) and flight kinematics using numerical calculations and physical designs
- enumerate the control surfaces that might be found on an aircraft and apply the principles of flight dynamics to explain the function of each control surface in overcoming the weight, balance and drag inherent to the aircraft
- describe some of the key propulsion mechanisms for generating thrust and lift in terms of structure and physical principles of operation
- describe and apply the engineering design process in the context of a small scale flight design challenge
- work as an individual or in a team to design and construct flying mechanisms of various complexity and to communicate reasons for the effectiveness of the design

Grading Policy:
Point values for class assignments and activities are established to directly correspond with grade percentage points. Final letter grades will be awarded based on points accumulated according to the following scale: A: ≥ 90 B: < 90 and ≥ 80, C: < 80 and ≥ 70, D: < 70

10 points (and therefore 10% of the class grade) will be awarded based on webinar and other class participation activities.

The course is divided into eight content modules. Each module has two numbers associated with it, representing a baseline and a maximum number of points to be earned within each module, eg. (12-18).

- The *baseline* values sum to a total of 100 points, and provide a recommended target for a balanced approach to the course.
- You can personalize your learning by focusing more time and earning more credit within particular modules, but credit earned will be limited by the *maximum* value posted for that module.

Students are not required to complete **or even attempt** *all* of the posted assignments. Instead, you are encouraged to select assignments that are appropriate to both your skill and interest level in a particular module. Do note that partial completion of an assignment will likely result in earning only partial points. There is a total of at least 150 points of credit available in posted coursework.

Sample Weekly Schedule:

Week	**Content**	**Assessments** (* = standard course)
Week 1	*MODULE: SPATIAL REASONING* ● *3-D coordinate systems: Cartesian, Cylindrical, Spherical* ● *Absolute and Relative Coordinates* ● *Aircraft Principal Axes*	● *Drone Course Layout** ● *Drone Flight* ● *Knot-It! 3D plotting** ● *Rocky Mountain Quidditch* ● *Drop Design Project, intro** ● *History: Natural Flight*
Week 2	*MODULE: SPATIAL REASONING* ● *Drawing Orthographic Projections* ● *Isometric and Dimetric Drawing* ● *Engineering Design Process*	● *Orthographic Projection Exercises** ● *Iso to Ortho sketching** ● *Ortho to Iso sketching** ● *Plan a plane** ● *Drop Design Project, EDP** ● *History: Antiquity*
Week 3	*MODULE: FLUID STATICS* ● *Weight/Mass/Pressure conversions* ● *Pascal's Principle* ● *Proportional and Inverse Relationships: Boyle's Law* ● *Absolute and Relative Temperature* ● *Ideal Gas Law*	● *Fundamental and Derived Quantities Quiz ** ● *The Pressure of You! ** ● *<build a hydraulic jack>* ● *<Boyle's Law plotting> ** ● *Your Own Barometer* ● *Calculating Absolute Zero ** ● *Drop Design: brainstorm** ● *History: Hot Air*
Week 4	*MODULE: FLUID STATICS* ● *Deflate-gate: Ideal Gas Law* ● *Density and displacement* ● *Specific Weight & Specific Gravity* ● *Buoyancy: How much helium?* ● *Hydrostatic Pressure*	● *"Inflate"-gate ** ● *Combined Gas Law problems* ● *How Dense Are You?* ● *Density Lab** ● *Hovering Butter* ● *Buoyancy Practice* ● *Fluid Statics Section Quiz ** ● *Drop Design: peer feedback** ● *History: Lighter than Air*
Week 5	*MODULE: AIRCRAFT GEOMETRY* ● *Parts of an airplane* ● *Numerical integration of wing planforms* ● *NACA airfoil coding*	● *Aircraft parts & functions ** ● *Bird Wing Planform Area ** ● *NASA Balance activity* ● *Drop Design: prototype & iterate**

	• *Sigma Notation* • *Moment (torque)*	• *History: Blimps&Zeppelins*

Week 6 + Online Weekend	*DESIGN WEEK*
	• *Tian Deng Lantern reverse engineering*
	    ○ *Neutrally buoyant flight*
	    ○ *Deconstruction and measurement*
	    ○ *Scaling*
	    ○ *Buoyancy Calculations*
	    ○ *Rescaled design*
		• *Drop Design: document & peer review**
		• *Delta Design: group design work**
		• *Tian Deng Design Project*
		• *History:Gliding*

Week 7	*MODULE: AIRCRAFT GEOMETRY* • *Aircraft Weight & Balance* • *Centroid and CG calculations* • *Center of Pressure and Stability* • *Rocket Stability*	• *Aircraft Accident Case Study: Weight & Balance ** • *Get Mobile<mobile design> ** • *Pinewood Derby* • *Just Plane Stable <paper airplane CoP stability> ** • *Barrowman's Rocket CoP* • *Aircraft Geometry Quiz ** • *History: Learning to Fly*
Week 8	*MODULE: FLIGHT DYNAMICS* • *One-Dimensional Kinematics* • *Time-stepping and graphs* • *Velocity Vectors* • *Constant Velocity in 2-D (aircraft ascent, cruise, descent)* • *Vector Addition*	• *Unit Circles ** • *Flight Path Project ** • *Vector Guessing Game* • *Round Trip Design Project** • *History: First Planes*
Week 9	*MODULE: FLIGHT DYNAMICS* • *Ground and Airspeed in 2-D* • *Wind Correction Angle* • *WCA with a Flight Computer* • *Projectile Motion*	• *Vector Addition Practice ** • *Toss it up <projectile motion & derivative plotting>* • *Flight Computing* • *Flight Dynamics Quiz ** • *History: Flying Takes Off*
Week 10	*MODULE: AIRCRAFT FORCES* • *Linear Momentum* • *Newton's Laws of Motion* • *Video Game Controls & Newton* • *Thrust* • *Jet Engine Basics*	• *Cart & Brick <linear momentum calculations> ** • *Balloon propulsion activity* • *History: Commercial & WW2*
Week 11	*MODULE: AIRCRAFT FORCES* • *Model Rocket Propulsion* • *Drag* • *Parachute drag* • *Reynolds number*	• *1-D model rocket simulation* • *1-D model rocket sim update (add drag & parachute deployment)* • *Kind of a Drag <simulated*

		drag measurement> ● *Parachute Drag Measurement* ● *History: Jet Power*
Week 12	*MODULE: AIRCRAFT FORCES* ● *"Incorrect" Theories of Lift* ● *Lift Concepts* ● *Lift Factors* ● *Curve & Bended (Coanda effect)*	● *Gimme a lift <calculating lift for historic aircraft>* ● *History: Rocketry*
Week 13	*DESIGN WEEK* ●	● *Model Rocket Design* ● *Airfoil Surface Analysis* ● *History: The Space Race*
Week 14	*MODULE: SPACE FLIGHT* ● *Aero & Astro* ● *Circular and Satellite Motion* ● *Orbital Mechanics*	● *Stay on Track <orbital time-stepping>* ● *Spinning it Kepler Style <planetary orbits>* ● *NASA Spinoffs* ● *History: Space Missions*
Week 15	*MODULE: SPACE FLIGHT* ● *Math of Satellite Motion* ● *Space Flight*	● *Orbital Motion Problem Set* * ● *Orbital Simulation* * ● *Basics of Space Flight* * ● *Crowdsourced Space Research*