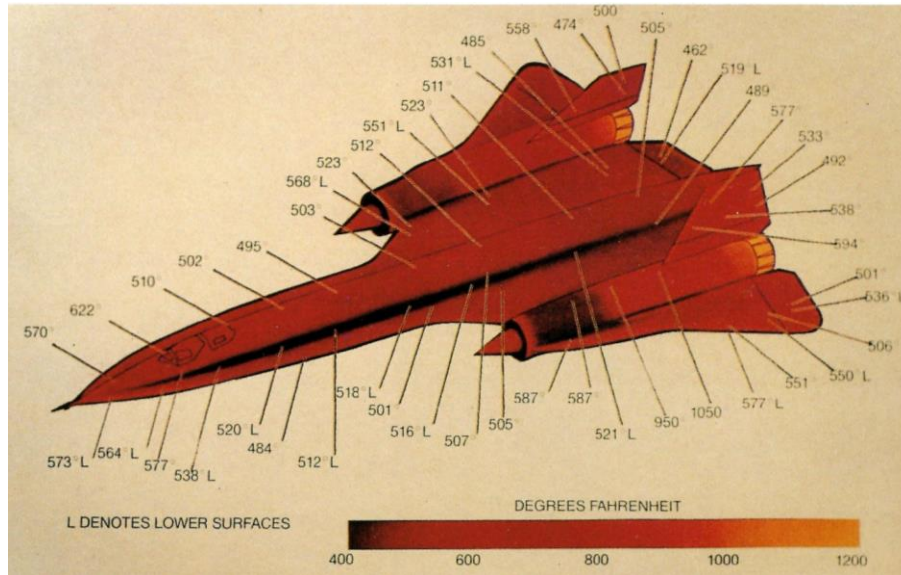


AE 164 – Aerothermodynamics

Term	Spring 2019
Instructor Info	Professor Sean Montgomery sean.montgomery@sjsu.edu or sean5montgomery@gmail.com Office Hours: After class on Tuesdays and Fridays
Credit	5 units
Class Time	Tu/Th 3:00 – 4:15 pm, Fri 4:30 – 6:10 pm
Final Exam	Tuesday, May 21 2:45 – 5:00 pm
Classroom	ENGR 401
Prerequisites	“C-” or better in AE160 or equivalent
Textbook	Fundamentals of Aerodynamics by John D. Anderson, 5 th or 6 th ed.
Course Website	SJSU Canvas < http://www.sjsu.edu/at/ec/canvas/ >

Description

1st and 2nd Thermodynamic laws. Shock and expansion waves with applications to supersonic airfoils and wings. Nozzle flow. Flow with heat addition and friction. Aerodynamic heating. Conduction, convection and radiation heat transfer.

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Goals Introduce students to:

- (a) Accounting for energy and determining the efficiency of thermodynamic processes.
- (b) Modeling of internal and external high-speed flows.
- (b) Estimation of the aerodynamic forces on super/hypersonic vehicles.
- (c) Estimation of aerodynamic heating on super/hypersonic vehicles.
- (c) Aerothermodynamic design principles for super/hypersonic vehicles.
- (d) Develop, practice, and improve communication and team skills.

Learning Objectives

Students completing AE164 should be able to:

1. Define and explain physically the following: (a) Conservation law, (b) Energy and internal energy (c) Entropy, (d) Equilibrium state, (e) Time-reversible and time-irreversible process, (f) Enthalpy, (g) Real gas, (h) Perfect gas, (i) Thermally perfect gas, (j) Calorically perfect gas, (k) Adiabatic process, (l) Isentropic process, (m) Compressibility and compressible flow.
2. Use the 1st and 2nd laws of thermodynamics to calculate heat transfer, work done and entropy changes in a thermodynamic system.
3. Use the equation of state and the definition of enthalpy to calculate thermodynamic properties.
4. Calculate the isothermal and isentropic compressibility of a gas for given conditions.
5. Define and explain physically the following: (a) Speed of sound and Mach number, (b) Stagnation and sonic (critical) conditions for isentropic flow, (c) Stagnation and sonic (critical) conditions for flow with heat addition.
6. Derive the conservation equations for 1-D compressible flow (isentropic, adiabatic, with heat addition, with friction).
7. Use thermodynamics and conservation equations to calculate flow parameters at various points of a flow field.
8. Calculate stagnation and critical conditions at various points of a flow field for isentropic flow, adiabatic flow, flow with heat addition and flow with friction.
9. Explain physically what happens to flow parameters when the flow (a) crosses a normal shock wave, (b) is heated or cooled and (c) is subjected to friction.
10. List the differences between a Mach wave and a shock wave.
11. Explain the conditions under which you get a bow shock in front of a body or a compression corner.
12. Explain the conditions under which you get an oblique shock at the nose of a body or at a compression corner.
13. Explain the differences between the flow over a cone and the flow over a wedge.
14. Calculate the flow properties downstream of a Mach wave, an oblique shock wave, and a Prandtl-Meyer expansion wave.
15. Calculate the lift and drag on supersonic airfoils using shock-expansion theory.
16. Calculate the flow properties downstream of a reflected / refracted shock wave.
17. Define quasi 1-D flow.

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18. Explain mathematically and physically the relationship between flow cross-sectional area and local Mach (or flow speed).
19. Explain what we mean by "choked flow".
20. Describe what happens to the flow inside a Laval nozzle as we change the exit pressure and / or the reservoir pressure.
21. Explain an (a) ideally expanded, (b) over-expanded and (c) under-expanded nozzle.
22. Calculate the flow properties at various locations of an (a) ideally expanded, (b) over-expanded and (c) under-expanded nozzle.
23. Calculate the location of a shock in a Laval nozzle (assuming there is one).
24. Design a supersonic / hypersonic wind tunnel (i.e. select the appropriate reservoir, throat and nozzle exit conditions to get the desirable test section conditions).
25. Explain what we mean by an "unstarted" supersonic wind tunnel.
26. Identify when heat transfer occurs as conduction, convection, or radiation.
27. Explain what affects conduction heat transfer.
28. Explain the difference between thermal conductivity and thermal diffusivity.
29. Setup and solve conduction problems using Fourier's Law.
30. Explain the difference between natural and forced convection, and the tradeoffs associated with them.
31. Explain what affects convection heat transfer.
32. Explain how the boundary layer affects convection heat transfer rates.
33. Explain what the thermal boundary layer is and how it compares to the viscous boundary layer.
34. Explain the significance of the Nusselt number and Prandtl number.
35. Setup and solve convection problems using Newton's Law of Cooling.
36. Explain what affects radiation heat transfer.
37. Explain how emissivity and other material properties affect radiation heat transfer.
38. Estimate aerodynamic heating on supersonic and hypersonic vehicles.
39. Select appropriate nose shapes for different Mach numbers, and explain the tradeoffs associated with the different shapes.
40. Work effectively in a team to define and solve open-ended problems that combine compressible flow and jet / rocket engine performance.

Approximate Weekly Schedule

<u>Week</u>	<u>Topic(s)</u>
01	Introduction; why we need thermodynamics to analyze high-speed flows
02	Thermodynamic laws
03	Thermodynamic laws
04	1-D compressible flow
05	Normal shocks
06	Flow with heat addition
07	Flow with friction
08	Mach waves, oblique shock waves and expansion (Prandtl-Meyer) waves
09	Supersonic airfoil theory
10	Quasi 1-D flow; supersonic nozzles, diffusers and wind tunnels
11	Linearized subsonic and supersonic flow

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12	Hypersonic flow
13	Aerodynamic heating
14	Conduction
15	Convection
16	Radiation heat transfer
17	<u>FINAL EXAM</u>

Grading	5 Exams	50% (>70% on each exam required for C-)
	Final Exam	20% (>70% required for C-)
	Homework Problems	10%
	In Class Workout Problems	10%
	Team Project	10%

To earn a passing grade you must score 70% or higher on all of the exams!

Workout problems are practice problems for the exams. Solutions to workout problems will be provided in class or posted online.

Grade Criteria:

A+	Depends on how much extra credit is offered (roughly >97% of all points possible including extra credit)
A	≥ 92% and doesn't satisfy criteria for A+
A-	90% - 92%
B+	88% - 90%
B	82% - 88%
B-	80% - 82%
C+	78% - 80%
C	72% - 78%
C-	70% - 72%
D	60% - 70%
F	< 60%

Project

Work in teams of no more than 4 students. Select one of the choices below. You must obtain verbal approval of your project before May. At the end of the semester you will give a 10 minute group presentation on the results of your project.

- Research a topic you are interested in involving aerothermodynamics (historic aerospace vehicles, proposed ideas, specific components or systems, etc.).
- An escape system for the pilot of an aircraft traveling faster than Mach 3.0
- An escape system for astronauts on a rocket travelling faster than Mach 3.0 (your system may be for launch, landing, or both)
- Define an aerothermodynamics problem of your choice and investigate how to solve it (perhaps with applications to your aircraft / spacecraft design project).