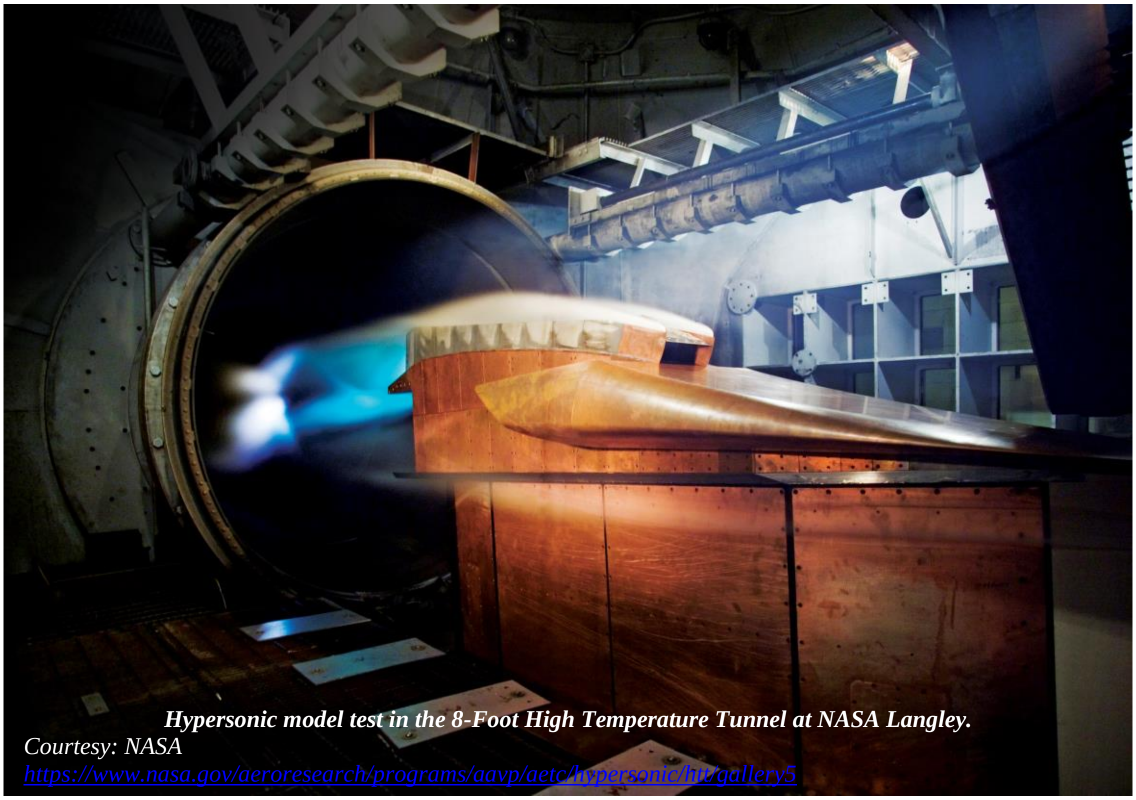
San José State University
Aerospace Engineering
AE164 – Aerothermodynamics – Fall 2017



Hypersonic model test in the 8-Foot High Temperature Tunnel at NASA Langley.
Courtesy: NASA
https://www.nasa.gov/aeroresearch/programs/aavp/aetc/hypersonic/htt/gallery5

Instructor:	Prof. Fabrizio Vergine
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Office Hours:	Tuesday & Thursday: 3pm – 4:30pm or by appointment
Class Days/Time:	Tuesday, Thursday and Friday / 1:30pm – 2:55pm
Classroom:	E164
Prerequisites:	"C" or better in PHYS 052 and AE 160

Faculty Web Page and MYSJSU Messaging

Course materials such as syllabus, handouts, notes, assignment instructions, etc. can be found on the Canvas Leaning Management System course login website at http://sjsu.instructure.com. You are responsible for regularly checking with the messaging system through MySJSU at http://my.sjsu.edu.

Course Description

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.

Course Goals

Introduce students to:

- *Accounting for energy and determining the efficiency of thermodynamic processes.*
- *Modeling of internal and external high-speed flows.*
- *Estimation of the aerodynamic forces on super/hypersonic vehicles.*
- *Estimation of aerodynamic heating on super/hypersonic vehicles.*
- *Aerothermodynamic design principles for super/hypersonic vehicles.*

Course Learning Outcomes (CLO)

Upon successful completion of this course, students will be able to:

1) *Use the 1^{st} and 2^{nd} laws of thermodynamics to calculate heat transfer, work done and entropy changes in a thermodynamic system.*
2) *Use the equation of state and the definition of enthalpy to calculate thermodynamic properties.*
3) *Calculate the isothermal and isentropic compressibility of a gas for given conditions.*
4) *Use thermodynamics and conservation equations to calculate flow parameters at various points of a flow field.*
5) *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.*
6) *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.*
7) *List the differences between a Mach wave and a shock wave.*
8) *Explain the conditions under which you get (a) a bow shock in front of a body or a compression corner, and (b) an oblique shock at the nose of a body or at a compression corner.*
9) *Explain the differences between the flow over a cone and the flow over a wedge.*
10) *Calculate the flow properties downstream of a Mach wave, an oblique shock wave, and a Prandtl-Meyer expansion wave.*
11) *Calculate the lift and drag on supersonic airfoils using shock-expansion theory.*
12) *Calculate the flow properties downstream of a reflected / refracted shock wave.*
13) *Explain mathematically and physically the relationship between flow cross-sectional area and local Mach (or flow speed).*
14) *Explain an (a) ideally expanded, (b) over-expanded and (c) under-expanded nozzle.*
15) *Calculate the flow properties at various locations of an (a) ideally expanded, (b) over-expanded and (c) under-expanded nozzle.*
16) *Calculate the location of a shock in a Laval nozzle (assuming there is one).*
17) *Design a supersonic / hypersonic wind tunnel (i.e. select the appropriate reservoir, throat and nozzle exit conditions to get the desirable test section conditions).*
18) *Identify when heat transfer occurs as conduction, convection, or radiation.*
19) *Setup and solve conduction problems using Fourier's Law.*
20) *Explain the difference between natural and forced convection, and the tradeoffs associated with them.*
21) *Setup and solve convection problems using Newton's Law of Cooling.*
22) *Estimate aerodynamic heating on supersonic and hypersonic vehicles.*

23) *Select appropriate nose shapes for different Mach numbers, and explain the tradeoffs associated with the different shapes.*
24) *Work effectively in a team to define and solve open-ended problems that combine compressible flow and jet / rocket engine performance.*

Course Relationship to BSAE Program Outcomes

	A	B	C	D	E	F	G	H	I
Learning Outcomes									
1 – 24	++	O		O	O			O	O

+: Skill level 1 or 2 in Bloom's Taxonomy
++: Skill level 3 or 4 in Bloom's Taxonomy
+++: Skill level 5 or 6 in Bloom's Taxonomy
O: Skill addressed but not assessed

Required Texts/Readings

Textbook

Anderson, J.D., Fundamentals of Aerodynamics, 6th edition, ISBN 978-1-259-12991-9

Other Readings

Instructor's notes posted on Canvas. Additional research material will be required for the completion of the project.

Course Requirements and Assignments

Workouts

Assigned problems will be solved during class time by groups of 4 students. Dates and times of the workouts will be communicated in class.

Quizzes

Individual quizzes will be provided during class times. Dates and times of the quizzes will be communicated in class.

Midterm exam

Individual midterm examination. The date of the midterm will be communicated in class.

Project

Teams of 4 students will be required to choose an aerothermodynamics topic among the following:
1) *Analysis of the aerodynamic characteristics of a supersonic/hypersonic aircraft in different flight conditions specified by the students (i.e., various altitudes, Mach numbers, angles of attack…).*
2) *Design of a hypersonic wind tunnel.*
3) *Define an aerothermodynamics topic with possible application in a real-life supersonic aircraft.*

All groups must submit a "project proposal" which should include:
- *Abstract.*
- *Project objectives and expected outcomes.*

- *An outline of the project with a tentative schedule of the various steps required for completion and the description of the simplifications and assumptions to be made.*
- *Names of the team members with a clear and balanced assignment of tasks.*
- *Appropriate literature survey.*

Once the proposals are reviewed and approved (adjustments may be required), it is the responsibility of each group to organize meeting times and work schedule.
Additional required material includes:

- *A written midterm report (dates and times TBD).*
- *A final written report due on the last day of class.*
- *A presentation of the work (dates and times TBD)*

Extra credit (up to max 10% of the final grade) can be assigned based on the quality of the work and the depth reached in the analysis.

Final Exam

Individual final examination.

Grading Information

- ***Workouts***	*10%*
- ***Quizzes***	*15%*
- ***Midterm exam***	*20%*
- ***Final exam***	*30%*
- ***Project***	
Project proposal	*2%*
Midterm report	*5%*
Final report	*10%*
Final presentation	*8%*

A+	> 100%
A	93% - 100%
A-	90% - 92%
B+	88% or 89%
B	83% - 87%
B-	80% - 82%
C+	78% or 79%
C	73% - 77%
C-	70% - 72%
D	60% - 69%
F	< 60%

Both for workouts and project: each individual in a group will receive the same grade as the group as a whole.
For workouts only: in order to evaluate a group's performance, I will periodically and randomly call students to explain the solution of the problem/problems solved by the group as a whole.
You must average at least 73% to receive a passing grade in the course ("C" or "C +").

Classroom Protocol

No cellphone use is permitted in class. Respect for others is required and expected.

University Policies

Per University Policy S16-9, university-wide policy information relevant to all courses, such as academic integrity, accommodations, etc. will be available on Office of Graduate and Undergraduate Programs' [Syllabus Information web page](http://www.sjsu.edu/gup/syllabusinfo/) at http://www.sjsu.edu/gup/syllabusinfo/.

AE Department *and SJSU policies are also posted at* http://www.sjsu.edu/ae/programs/policies/

Course Schedule

Week	Date	Topics, Readings, Assignments, Deadlines
1	8/24 - 8/25	Fundamentals of thermodynamics
2	8/29 - 8/31 - 9/1	Fundamentals of thermodynamics
3	9/5 - 9/7 - 9/8	Fundamentals of thermodynamics
4	9/12 - 9/14 - 9/15	1D compressible flows: total and critical quantities, speed of sound
5	9/19 - 9/21 - 9/22	1D adiabatic compressible flows: normal shocks
6	9/26 - 9/28 - 9/29	1D non-adiabatic, inviscid compressible flows: Rayleigh flow
7	10/3 - 10/5 - 10/6	1D adiabatic viscous compressible flows: Fanno flow
8	10/10 - 10/12 - 10/13	2D adiabatic supersonic flows: oblique shocks
9	10/17 - 10/19 - 10/20	2D isentropic supersonic flows: Prandtl-Meyer expansion waves
10	10/24 - 10/26 - 10/27	Supersonic airfoil theory
11	10/31 - 11/2 - 11/3	Quasi 1D flow: de Laval nozzles, diffusers and supersonic wind tunnels
12	11/7 - 11/9 - 11/10	Heat transfer: conduction
13	11/14 - 11/16 - 11/17	Heat transfer: convection
14	11/21 - 11/23 - 11/24	Heat transfer: radiation
15	11/28 - 11/30 - 12/1	Elements of hypersonic flows
16	12/5 - 12/7 - 12/8	Aerodynamic heating on hypersonic vehicles
Final Exam	Tuesday, December 19	ENGR 164 at 12:15pm – 2:30pm