10/23/2012

SYLLABUS FOR THE WRITTEN PRELIMINARY EXAMINATION IN THE CONCENTRATION OF AEROHYDRODYNAMICS.

The exam will be open book and notes. Students are also allowed to use a computer, calculator, any references or written materials as they see fit. Students may also find software referenced at www.aoe.vt.edu/research/onlinesoftware.html useful in solving some prelim problems. Students' solutions must be strictly their own. No communication of any type, implicit or explicit, is allowed during the exam. The honor code will be strictly enforced.

Students are required to answer four questions from a pool of seven to eight questions. Questions will require the student to effectively apply their knowledge from across the area of concentration to familiar and unfamiliar situations. Questions may address a single topic, or integrate material from different areas. Questions will draw on material contained within the recommended texts/resources listed below.

LIST OF RECOMMENDED TEXTS/RESOURCES

Text: Karamcheti, K., 1980, *Principles of Ideal Fluid Aerodynamics*, 2nd Edition, Kreiger, Malabar.
Sections: All chapters except 7 and 20.

Text: Grossman, B., 2000, *Fundamental Concepts Of Real Gasdynamics*, Lecture notes version 3. Also available at: www.aoe.vt.edu/graduate/forms/lectnotes3-09All101812.pdf
Sections: All.

Text: Anderson, J. D., 2003, *Modern Compressible Flow with Historical Perspective*, 4th Edition, McGraw-Hill, New York.
Sections: Chapters 1-10 and 11.1-11.7, 14.1-14.2, 15.1-15.4, 16.8-16.12, 17.1-17.6.

Text: Bertin, J.J, 2002, *Aerodynamics for Engineers*, 3rd Edition, Prentice-Hall, Englewood Cliffs.
Sections: Chapters 1-7.

Text: Schetz, J.A. and Bowersox, R.D.W., 2011, *Boundary Layer Analysis*, 2nd Edition, Prentice Hall, Englewood Cliffs.
Sections: Chapters 1 (except 1-8), 2 (except 2-9), 3, 4 (except 4-6 and 4-7-5), 5 (except 5-7, 5-9, 5-10, 5-12 and 5-14), 6 (except 6-6-6 and 6-6-8), 7 (except material on suction and injection), 8 (except 8-2-3, 8-2-4, 8-4-3, 8-4-4 and 8-5), 10 (except 10-4).

Text: Hill, P.G., and Peterson, C.R., 1992, *Mechanics and Thermodynamics of Propulsion*, 2nd Edition, Addison-Wesley.
Sections: Chapters 1-6, 7.1-7.5, 10, 11, 12.1-12.3, 14.

Text: Ames Research Staff, 1953, *Equations Tables and Charts for Compressible Flow*, NACA Report 1135, published by AMTEC Engineering, Bellevue WA. Also available at: ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19930091059_1993091059.pdf
Sections: All.

Example Aero/Hydro Prelim from 2010

WRITTEN Ph.D. PRELIMINARY EXAMINATION IN THE CONCENTRATION OF AEROHYDRODYNAMICS.

Department of Aerospace and Ocean Engineering
September 20, 2010

This exam is open book and notes. Students are also allowed to use a computer, calculator, any references or written materials as they see fit. However, students' solutions must be strictly their own. No communication of any type, implicit or explicit is allowed during the exam. The honor code will be strictly enforced.

Students are required to answer four of seven questions, as follows:

- at least **one** of questions 1, 2, and 3
- at least **two** of questions 4, 5, 6 and 7.

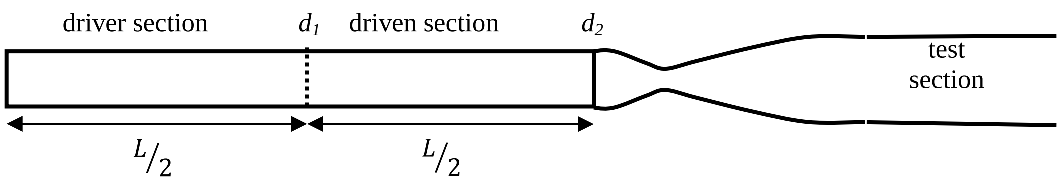
Start each question on a new sheet of paper. Write your name at the top of all answer sheets. <u>Do not hand in solutions to more than four questions.</u> Complete and sign the honor code pledge below. Hand in this completed cover page with your solutions.

Printed Name.....................................   Student ID....................................

I pledge that this assignment has been completed in compliance with the Graduate Honor Code and that I have neither given nor received any unauthorized aid on this assignment

Signature...

1. A simple hypersonic wind tunnel is designed by combining a shock tube with a converging-diverging nozzle as shown below. The driver section is set to a pressure higher than that of the driven section, and both sections contain dry air at an initial temperature of 300 K. At time $t = 0$, the diaphragm d_1 separating the two sections is ruptured, causing a shock wave to move from the diaphragm towards the nozzle. The nozzle and test section are initially evacuated ($p \approx 0$), and a second diaphragm d_2 ruptures when it encounters the shock wave. The nozzle is designed to achieve Mach 5 with a static pressure of 10 kPa in the test section. As the shock wave moves through the driven section, the pressure ratio *across the shock* is found to be four (4.0).



Assume 1D, inviscid flow of a calorically perfect gas.

a) Find the initial pressure ratio between the driver and driven section $\frac{p_{driver}}{p_{driven}}$.

b) Find the initial pressure in the driven section required to achieve the above specified static pressure in the test section.

c) Determine the approximate length of the shock tube L required to achieve a run time of 0.005 s.

2. Consider the steady flow of air in diverging duct. The air is very hot and at station 1, where the duct area is 1.0 m^2, the temperature T_1 is 1800K. The pressure p_1 is 0.1 atm and the flow velocity u_1 is 500 m/sec. We wish to determine conditions at station 2 downstream where the area is 1.25 m^2. You may assume the flow to be inviscid and adiabatic.

   a) Considering the flow between stations 1 and 2 in chemical and thermodynamic equilibrium, write down (and name) the governing algebraic equations needed to determine p_2, T_2 and velocity u_2. (You may give any state equations in functional form)

   b) Approximately solve the system and evaluate the flow velocity u_2 at station 2 using the Thermodynamics of Air calculator (EQAIR) on www.engapplets.vt.edu

   c) Also solve the problem assuming air to be a perfect gas with γ=1.4.

(Show all your work and any intermediate calculations)

3. Work the following two problems (equal weighting for each).

3A. A rocket has the following operating data:

Combustion temperature T_0=2400K

MW of propellant gases=25

γ=1.3

Exit Mach number M_e=3

Assuming p_e=p_a, estimate the I_{sp} of the rocket. (g=9.81 m/sec^2)

3B. A rocket fuel system is proposed based on methane (CH_4) and hydrogen (H_2) with oxygen (O_2) as the oxidizer.

a. Write the chemical combustion equation for the stoichiometric reaction of CH_4, H_2 and O_2 in terms of unknown molar coefficients on the reactants and products. (Remember that stoichiometric means that the products of combustion are fully oxidized with no fuel or oxidizer left over.)
b. If the mass flow ratio of CH_4/H_2=4/1, balance the chemical equation.
c. What is the stoichiometric fuel/oxidizer mass ratio?
d. Write the chemical equation for an equivalence ratio of $\phi=0.5$. (neglect dissociation of the products)
e. Use the 1st Law to estimate the combustion temperature of the $\phi=0.5$ reaction. Assume that the reactants are gases at the reference temperature (298K). Use the following data:

Heat of formation at 298K

CH_4 gas	-74,000 kJ/kg mol
CO_2 gas	-393,000 kJ/kg mol
H_2O gas	-241,000 kJ/kg mol

Specific Heat C_p of combustion product gases

C_p CO_2	47 kJ/kg mol K
C_p O_2	37 kJ/kg mol K
C_p H_2O	52 kJ/kg mol K

f. Calculate the average C_p of the combustion product gases, and use the result to find γ_{avg}. Use R_{univ}=8,314 J/kmol K.

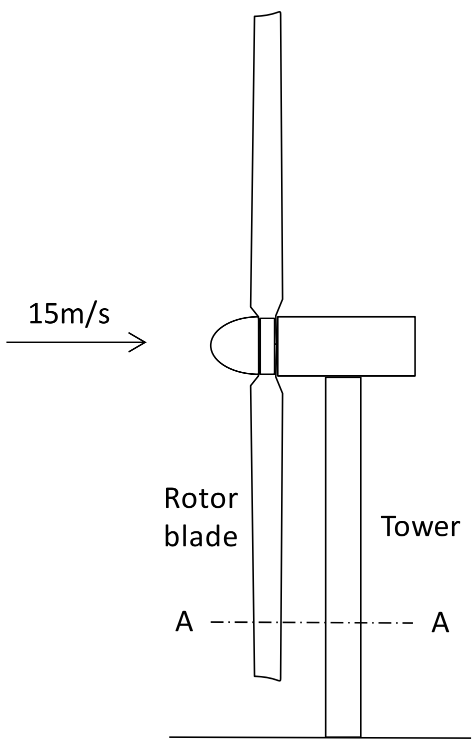
4. An off-shore wind turbine has blades that, in the outer part of the span, are 1m in chord and have a zero lift angle of attack of -2^o. The blade is mounted with a 68 degree angle between the chord line and the axis of the wind turbine. Consider a day when the wind speed is 15m/s and the blade is rotating with a speed of 30m/s at section A-A, as shown in the figure.

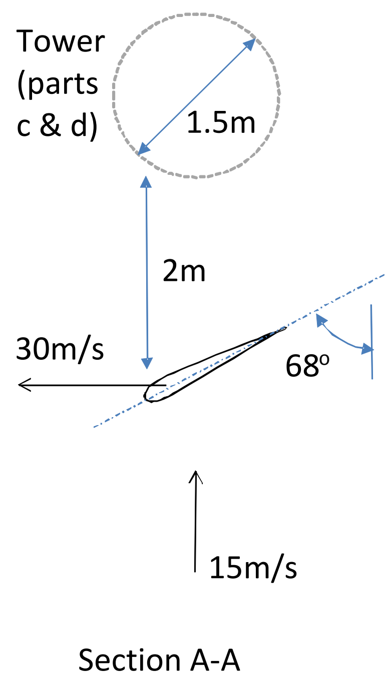
(a) Assuming that the airfoil section is thin and the trailing edge sharp estimate the lift and drag generated by the blade at A-A, in Newtons per meter of span.

(b) An engineer suggests using an airfoil with a blunt trailing edge instead (such airfoils may be used to reduce the sensitivity of the blade to fouling). The blunt trailing edge would be 10% of the chord in thickness. Revise your drag estimate to account for this. Estimate the power that would be lost per blade to the turbine due to the drag in this case (in Watts per meter of span at A-A).

(c) At the bottom of its stroke the blade passes in-front of the tower that supports the turbine, which has a circular cross section 1.5m in diameter. The blade passes 2m in front of the tower. Estimate the amplitude of the change in lift experienced by the blade as it passes the tower.

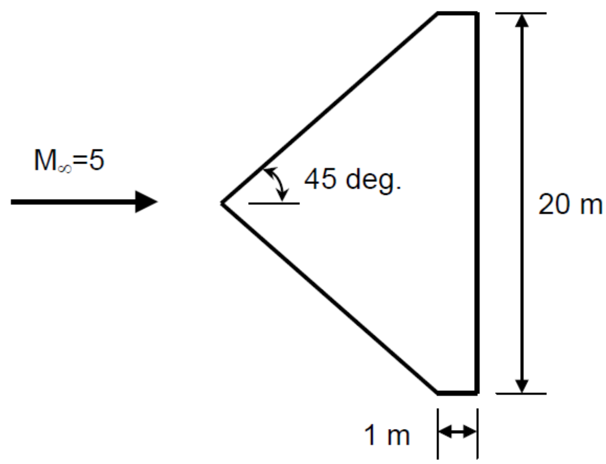
(d) The fluctuating lift in part (c) generates sound with intensity proportional to the square of the lift amplitude. What should the distance between the blade and tower be for the sound to be half that generated in part (c).





5. A supersonic vehicle has a thin wing planform as shown below. The vehicle is cruising at Mach 5 and 5 deg. angle of attack at an altitude of 50,000 ft (15.24 km). You may assume locally 2D flow.

Top View



a) Compute the lift coefficient for this vehicle.

b) Compute the drag coefficient for this vehicle including viscous drag (you may assume laminar flow).

c) Calculate the percentage drag due to viscous effects.

Make sure to justify any assumptions.

6. Consider the flow over the wing of a long-duration sensor craft that loiters at 30 m/sec at 30 km. The airfoil of the high-aspect-ratio wing is an NACA 4412, the angle of attack is 0.0 deg. and the chord is 2.0 m. When the sun shines on the vehicle, it produces a 50 C surface temperature increase on the wing starting abruptly at x/c=0.2. There is a sensitive instrument in the wing at x/c=0.3, and there is a concern about thermal effects. Estimate the heat transfer at that location. Justify all assumptions.

7. The tailplane of the aircraft shown in the figure is located a distance X downstream of the unswept main wing center of pressure and in the horizontal plane of the main wing trailing vortices. The spanwise untwisted chord of the main wing has an angle of attack of α to the approaching flow and the spanwise circulation distribution produces a minimum induced drag on the main wing.

   a) What is the downwash angle ε of the flow that approaches the tail at X and y = 0? What is this downwash angle ε in terms of the main wing lift coefficient C_L?

   b) What is the sensitivity of ε with respect to the angle of attack of the main wing? In other words, what is $d\varepsilon/d\alpha$?