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AAE519 Hypersonic Aerothermodynamics: Final Exam
Wed. 14 Dec. 2011 RAWL 1057 1-3pm

Open Textbook and Notes (in your own handwriting) plus calculator

Short Answer Section (13 points total). Each question is worth 1 point.

1. Hypersonic flow along a flat plate parallel to the stream enters a compression corner, where an oblique shock forms and boundary-layer separation occurs. The incoming boundary layer might be laminar or it might be turbulent. Which case results in a larger separation bubble? Circle the correct answer:

a) Laminar b) Turbulent

2. A vehicle with a 1-m-dia. hemispherical nose is flying at 7 km/s, near 50km altitude, in the Earth's atmosphere. An aerothermodynamics engineer needs to estimate the heat transfer to the nose at this condition. What chemical species should he or she consider when analyzing the air?

(List the species) ____

3. For the vehicle in question (2), the Materials group is considering thermal protection systems with two surface materials: a) copper, used as a heat sink, and b) standard black Shuttle tiles, as were installed on the majority of the lower surface of the Shuttle orbiter. Which of these materials would result in a higher heat-transfer rate?

a) copper b) black Shuttle tiles

4. In one sentence, explain the reasoning behind your answer for question (3):

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5. Your group is analyzing the aeroheating to a modified version of the X-43A (Fig. 1.9 in the text). The controls group wants to increase the height of the vertical fins on the upper surface, to improve control authority. If the fins get too high, what new physical effect might occur, dramatically increasing the heat transfer to the fins?

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6. The Marketing Department has been looking for new uses for the vehicle described in question (2). They think they can sell it to NASA for a mission that involves returning samples from one of Saturn's moons. This involves performing an Earth reentry at 20 km/s, instead of 7 km/s. What new physical effects must be considered when analyzing this higher-speed reentry?

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7. Marketing is also trying to sell a quarter-scale version of the vehicle described in question (2). For the quarter-scale vehicle, at the same 7 km/s and 50 km altitude, how does the stagnation-point heat transfer compare? Circle the ratio of the stagnation-point heat transfer for the quarter-scale design, divided by the result for the original design:

1/4 1/2 1 2 4 8

8. For the quarter-scale vehicle in question (7), is the overall heating to the whole hemispherical nose higher or lower than it is for the full-scale vehicle?

higher lower

9. For the vehicle in question (3), the Materials group is now considering the use of an ablating carbon-carbon nose. How will this affect the heat transfer to the nose? Summarize the key factors in a sentence or two.

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10. Air at 50km passes through a normal shock at 6 km/s. In the region behind the shock, as you look farther and farther downstream, does the concentration of oxygen atoms rise or fall?

rises falls

11. For the conditions of question (10), in the region behind the shock, which species has a higher concentration?

atomic nitrogen atomic oxygen

12. What species forms within a hypervelocity shock layer to create the phenomena known as 'blackout'?

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13. The Stardust sample return capsule performed an Earth reentry at about 13 km/s. Marketing is trying to sell it for a Mars entry mission at the same 13 km/s. What differences in the flow physics must be considered to evaluate whether the heatshield design needs to change?

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Short Essay Section (12 points total). Each question is worth 3 points.

11. The aerothermodynamics group is tasked with predicting the heat transfer to the shuttle-like lifting-body vehicle described in question (2). In a few sentences, describe the benefits and limitations of predicting the heat transfer using a computational simulation:

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12. The aerothermodynamics group is also considering the use of ground testing to help in predicting the heat transfer to the vehicle described in questions (2) & (11). In a few sentences, describe the benefits and limitations of performing ground tests. What facilities would you recommend using?

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13. The X-38 vehicle was a lifting body with body flaps on the rear portion of the windward surface, see the following image (NASA EL-1997-00310):

As the vehicle descends in a Shuttle-like trajectory from above 300km and 7 km/s, it will eventually begin to maneuver using aerodynamic forces. Drawing on the Space Shuttle program history, discuss some of the aerothermochemistry effects that might affect the pitching moment and the body-flap effectiveness. How would you propose to analyze these effects?

14. The same X-38 vehicle flying the same trajectory would later encounter higher densities and Reynolds numbers as it descends. What other physical processes should be investigated to ensure good control of the pitch-plane aerodynamics as the vehicle continues to descend? How would you investigate these processes?