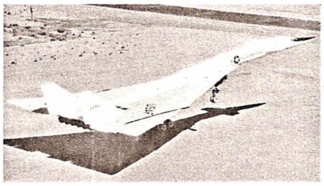 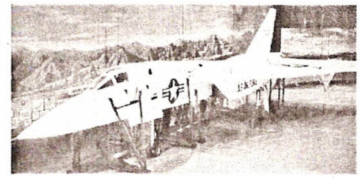

UNITED STATES AIR FORCE ACADEMY
DEPARTMENT OF AERONAUTICS

AE 315 – Fundamentals of Aerodynamics

Fall 2007	**GR #2**	Lesson 33 – 13,14 November 2007
124 points	**CLOSED BOOK/NOTES**	

ACADEMIC TESTING MATERIAL

THIS EXAMINATION IS NOT RELEASED FROM ACADEMIC SECURITY UNTIL *1420, 16 November 07, Lesson 34.*
DO NOT REVEAL ITS CONTENTS TO, OR DISCUSS IT WITH ANYONE UNTIL THEN.

Allowed Reference Materials
(1) Calculators – definitions, concepts, equations (any text) input into calculators is prohibited.
(2) Aero 315 Supplemental Data Book
(3) Both sides of a 3x5" Note Card
(4) Ruler or Straight Edge

Name: Gabriel Staples T4A   TOTAL SCORE (125 pts): 95   76%

+6

21
3.5
24.5

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>M (<M

V ↓ ρ ↑ T ↑

(blunt)

As air passes through a normal shock, temperature **1.** _________. This is due to the fact that **2.** ___________ increases. A shock is a bunch of pressure waves on top of each other, but **3.** ___________ decreases because the change in **4.** ___________, which is squared in this term, is the dominate effect.

+ 1. (4 points)
a. increases
b. decreases
c. is constant
d. doesn't matter

2. (4 points)
a. velocity
b. Mach number
c. dynamic pressure
d. static pressure

3. (4 points)
a. density
b. temperature
c. dynamic pressure
d. static pressure

4. (4 points)
a. density
b. temperature
c. velocity
d. static pressure

+ 5. (4 points) (True or False) Since speed of sound is a function of altitude, all we need is the altitude of a plane and we will know the plane's velocity.
a. True
b. False

+ 6. (4 points) You are to designing a next generation light-weight, low-speed, (M <.6) troop transport aircraft for Special Operations. While trying to decide what type of engine to use, you remember your days in Aero 315. For this low speed, lightweight aircraft, a _______________ is the best choice based on its balance of efficiency and power.
a. low bypass turbo-fan
b. rocket
c. turbojet
d. turbo-prop
e. SCRAMjet

7. (4 points) While coming back from a glider flight, the tower informs you that they are having some issues with clearing the runway of another aircraft and you will have to wait until they are done to land. In response you:

a. slow down. You were flying at range max for your glider which occurs at the best range airspeed. Now you will slow down to $(L/D)_{max}$ so that you can fly at $V_{minsink}$.

b. speed up. You were flying at range max for your glider which occurs at $V_{minsink}$. Now you will speed up to the velocity for $(L/D)_{max}$.

\+ **c.** slow down. You were flying at range max for your glider which occurs at the velocity for $(L/D)_{max}$. Now you will slow down to $V_{minsink}$ to maximize the time you can stay aloft.

d. speed up. You were flying at range max for your glider which occurs at the velocity for $(L/D)_{max}$. Now you will speed up to $V_{minsink}$ to maximize the time you can stay aloft.

8. (4 points) When we assume SLUF, we are able to simplify our force balancing and say the L = W, and T = D. One assumption that is **required** for this is that

a. $\alpha_T = \alpha$

\+ **b.** $\gamma = 0$

c. $\alpha_T = V$

d. $\alpha_T = 57.3^o$

9. (4 points) In SLUF, to fly at $(L/D)_{max}$, we have to:

a. maximize lift

b. minimize drag

You can't maximize Lift and Stay in SLUF, 'cuz you will rise.

c. maximize lift and minimize drag

d. fly as fast as the plane will go

e. reduce the weight of the aircraft

① 

② 

W↓, so V↓

10. (4 points) After dropping off supplies at a forward air base in your C-17 you have to take-off to head back to your base. The runway is extremely short, and at the end you must climb over a large rock formation. After you take-off and are climbing over the rock formation, your C-17 is struck by ground fire. Your Fuel gauge suddenly shows empty as you see your fuel draining from the wings and your engines shut down. There are trees and rock formations beneath you and you know that your only option is to try and make it to the clearing you see ahead of you in the jungle. What airspeed should you fly at to accomplish this?

a. The same airspeed you used to clear the rock formation. Max climb angle and best glide range both occur at the airspeed for $(L/D)_{max}$.

b. A faster airspeed than you used to clear the rock formation. Max climb angle and best glide range both occur at the airspeed for $(L/D)_{max}$, but you lost a lot of weight when you lost fuel, so the velocity for $(L/D)_{max}$ is now faster.

c. A slower airspeed than you used to clear the rock formation. Max climb angle and best glide range both occur at the airspeed for $(L/D)_{max}$, but you lost a lot of weight when you lost fuel, so the velocity for $(L/D)_{max}$ is now slower.

d. A slower airspeed than you used to clear the rock formation. Max climb angle occurs at the velocity for P_{xmax} and best glide range occurs at the airspeed for $(L/D)_{max}$. The velocity for P_{xmax} is faster than the velocity for $(L/D)_{max}$. Also, you lost a lot of weight when you lost fuel, so the velocity for $(L/D)_{max}$ is now slower than it was on take-off.

e. A faster airspeed than you used to clear the rock formation. Max climb angle occurs at the velocity for P_{xmax} and best glide range occurs at the airspeed for $(L/D)_{max}$. The velocity for P_{xmax} is slower than the velocity for $(L/D)_{max}$. Also, you lost a lot of weight when you lost fuel, so the velocity for $(L/D)_{max}$ is now faster than it was on take-off.

11. (4 points) When designing a new Reconnaissance UAV for the Air Force, you are trying to help create the maximum loiter time possible, while still allowing it to cover as much ground as possible. To do this you:

a. suggest high AR wings with winglets and flying at a lower altitude. This will reduce the induced drag and increase the velocity for $(^L/_D)_{max}$

b. sweep the wings back to reduce wave drag. You will be to loiter longer if you can fly faster, which allows you to cover more ground also.

c. increase the thrust of the engine. Everybody knows more thrust fixes everything.

d. dimple the wings. You are worried about pressure drag and want to prevent separation which helps you fly faster and longer.

+ e **~~d~~.** suggest high AR wings with winglets and flying at a higher altitude. This will reduce the induced drag and increase the velocity for $(^L/_D)_{max}$.

12. (4 points) If a fighter aircraft is cruising along in SLUF, what would be a good estimate for lift and drag?

+ **a.** Lift = 50,000 lbs, Drag = 5,000 lbs

b. Lift = 50,000 lbs, Drag = 50,000 lbs

c. Lift = 5,000,000 lbs, Drag = 50,000 lbs

d. Lift = 5,000 lbs, Drag = 50,000 lbs

e. Lift = 100,000 lbs, Drag = 5,000 lbs

13. (4 points) After one of the guys you hang out with shows off his nunchuck skills, you decide it is time to impress your friends with your Aero "skills". You decide to explain energy height to them and say:

a. Energy height is simply the potential and kinetic energy of an aircraft.

b. Energy height is simply the potential and kinetic energy of an aircraft divided by its weight.

c. Energy height is simply a measure of excess power versus weight.

d. Energy height is simply how quickly the aircraft can change altitude and/or airspeed.

14. (4 points) (True or False) When comparing the Thrust Required and Power Required Graphs for the same A/C, altitude, weight, and configuration, the maximum velocity an aircraft can achieve will be lower on the Power graph due to the quote "back side of the power curve".

a. True

b. False

15. (4 points) Deciding to play a practical joke on your fellow pilot-school classmates, you put very thick and viscous syrup out on the runway at night on a 40° F night.

a. This is a great practical joke because it will have no effect on airplanes since they fly through the air, and the worst that could happen is that one of your fellow students gets a little "squirrelly".

b. This might not be the best joke, but it is has little to no effect on the operations of the planes. Take-off distance and landing distance decrease when there is more friction between the wheels and the runway, so there won't be any problems.

\+ **c.** This might not be the best joke, but it will have a slightly negative on the operations of the planes. Take-off distance will increase, but landing distance decrease since there is more friction between the wheels and the runway.

d. This is dangerous. That syrup will induce large herds of Wooly mammoths, known for their love of syrup (and incredible "squirrellyness" under the influence of syrup), to stampede onto the runway. This will halt runway operations and possibly harm innocent bystanders.

16. (4 points) If you are given the option of taking-off when density is double standard day at your altitude, or mounting a second engine and taking-off at standard day density, which should you choose?

$S_{TO} = \frac{\;}{\rho} \cdot \frac{\;}{\rho}$

$\frac{1}{\rho^2 2^2} \rightarrow \frac{1}{4}$

a. I would definitely get a second engine. This will reduce my take-off roll to ¼ it's normal distance.

b. I would definitely get a second engine. This will reduce my take-off roll to $^1/_{16}$ it's normal distance.

c **a.** I would definitely take-off at the higher density. This will reduce my take-off roll to ¼ it's normal distance.

d **b.** I would definitely take-off at the higher density. This will reduce my take-off roll to ½ it's normal distance.

$\frac{1}{\rho}$ $\left(\frac{1}{2\rho}\right)$

17. (4points) While V-n diagrams are useful, most of the time maneuverability diagrams are used to compare two different aircrafts' capabilities instead. This is because:

a. A V-n diagram is only good for one load factor whereas a maneuverability diagram shows multiple load factors.

b. A V-n diagram is only good for one altitude whereas a maneuverability diagram shows multiple altitudes.

c. A V-n diagram shows multiple weights whereas a maneuverability diagram only illustrates one weight.

\+ **d.** A V-n diagram shows instantaneous performance whereas a maneuverability diagram shows sustainable and instantaneous performance.

18. (4 points) While flying your T-38 in mil power at an altitude of 15,000 ft, you need to perform a minimum radius turn that maintains +50 ft/s P_S throughout. If you are carrying 2000 lbs of fuel, what is the radius?

a. 6000 ft

b. 5000 ft

c. 8000 ft

d. 3000 ft

$r = \frac{V^2}{\;}$

19. (4 points) While filling out the decision matrix for your RASP, you realize you still need to normalize the cost measure of merit. The cost measure of merit is weighted 0.2. You have 4 configurations, red, black, white, and gray, and they cost \$150, \$121, \$178, and \$116 respectively. Once normalized and weighted, they should have values of:

$\frac{150}{178}(.2) = .17$

a. red = 0.26, black = 0.21, white = 0.31, gray = 0.20

b. red = 0.17, black = 0.14, white = 0.2, gray = 0.13   .136

c. red = 0.15, black = 0.19, white = 0.13, gray = 0.20   .2

d. red = 0.13, black = 0.18, white = 0.10, gray = 0.20   .130

20. (4 points) The minimum velocity of most aircraft will be _______________ at sea-level whereas it will be _______________ when the aircraft is nearing its absolute ceiling.

a. power-limited, thrust-limited

b. stall-limited, power-limited

c. thrust-limited, stall-limited

+ **d.** stall-limited, thrust-limited

e. power-limited, stall-limited

The next few pages contain different work-out problems. You may choose **ANY TWO** work-out problems (***Only two will be graded, so if you do more, mark which ones are to be graded***). Each problem will be worth 22.5 points, so both together are worth 45 points. Also, some of the work-out problems have bonuses. You may do any of the bonuses for extra credit, whether you did the work-out problem for points or not. **DO NOT FORGET TO INCLUDE ALL THE EXTRA STEPS REQUIRED FOR MAX POINTS.**

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Problem 1 (22.5 points). The Air force is finishing off the design of a new hypersonic bomber. It will be operating at 150,000 ft where the air temperature is 21.05° F and the density is $3*10^{-6}$ sl/ft^3. The plane has a drag polar of $0.05 + 0.078C_L^2$ and a wing area of 6,280 ft^2. TSFC at sea level for this engine is 1.8 /hr. Please answer the next few questions about the plane.

✓ - With an initial weight of 724,223 lbs (100,000lbs of fuel), what Mach number does the plane need to fly at for max powered range?

✓ - What is the range in nautical miles?

- How much drag does the aircraft experience at this flight condition?

(5 points) Bonus: How much thrust would the engines have to produce at sea-level for the above aircraft to fly in SLUF at the max powered range velocity? (Assume the bomber's engines behave like a fighter's engine in afterburner)

in SLUF, Th=D

Given: $h = 150{,}000$ ft

$T = 21.05°F + 460° = 481.05°R$

$\rho = 3\times10^{-6}\ \frac{sl}{ft^3}$

$C_D = C_{D_0} + kC_L^2 = \underbrace{.05}_{C_{D_0}} + \underbrace{.078}_{k} C_L^2$

$S = 6280\ ft^2$

$C_{t_{SL}} = 1.8/hr \cdot \frac{1hr}{3600\ sec} = \frac{.0005}{sec}$

$W_1 = 724{,}223$ lbs

$W_f = 100{,}000$ lbs

Find: M for max powered range

Assume: std. atmosphere, SLUF

Sketch:

V →

Estimate: hypersonic so $M > 5$

check: $M = 12$ ✓

$C_{t_{alt}} = ?$ -0.5

Solution: $V = \sqrt{\frac{2nW}{\rho S C_L}}$

$C_{D_0} = 3kC_L^2$

$C_L = \sqrt{\frac{C_{D_0}}{3k}} = \sqrt{\frac{.05}{3(.078)}} = .462$ ✓

$V = \sqrt{\frac{2(724{,}223)}{3\times10^{-6}(6280)(.462)}} = 12{,}900\ \frac{ft}{s}$ ✓

$M = \frac{12{,}900}{1075} = \boxed{12}$ ✓

$M = \frac{V}{a}$

$a = \sqrt{\gamma R T} = \sqrt{1.4\left(1716\ \frac{ft\,lb}{slug\,°R}\right)(481.05)} = 1075\frac{ft}{s}$ ✓ $\div \frac{6076\ ft}{naut\ mile} = 0.1769$

$E = \frac{1}{C_t}\frac{C_L}{C_D}\ln\left(\frac{W_1}{W_2}\right) = \frac{1}{.0005/sec}\ \frac{.462}{.0666}\ln\left(\frac{724{,}223}{624{,}223}\right) = 2061.5\ sec$

$C_D = .0666$ ✓

$\times\ \cancel{1075}\frac{ft}{sec} \cdot \frac{1\ n\ mile}{6076\ ft} = \boxed{364.7\ n\ miles}$

↑ -0.5

$V = 12900\frac{ft}{s}$

$D = C_D q S = .0666(1.\cancel{733})(6280) = \boxed{724.8\ lbs\ drag}$

$q = \frac{1}{2}\rho V^2 = \frac{1}{2}(3\times10^{-6})(10\cancel{75}\ \frac{ft}{s})^2 = 1.733$

-0.5

3.5

Problem 2 (22.5 points). In 1902, the Wright Brothers built their second glider in an effort to reach their end goal of powered flight (achieved in 1903). This glider, much improved over their first attempt, had a wing area of 303 ft^2 and a weight of 225 lbs. Studies conducted on a replica of the glider in 2002 found the aircraft to have a drag polar of $C_D = 0.07 + 0.08C_L^2$. For the next 5-10 minutes, you have been miraculously transported back to 1902 in order to help Orville and Wilbur with their first flights.

A. For his first flight, Wilbur decides that he wants to make an attempt at maximum range. At what airspeed (in Knots) should he fly? (Wilbur was a small man, weighing about 145 lbs)

Given: $S = 303\ ft^2$ +1.5 $V = \sqrt{\frac{2W}{\rho S C_L}}$ ✓ $C_L = \sqrt{\frac{C_{D_0}}{K}}$ ✓ $= \sqrt{\frac{.07}{.08}} =$

$W = 225\ lbs$

$C_D = .07 + .08C_L^2$

+2

Find :

Assume: $\cancel{SLUF}$

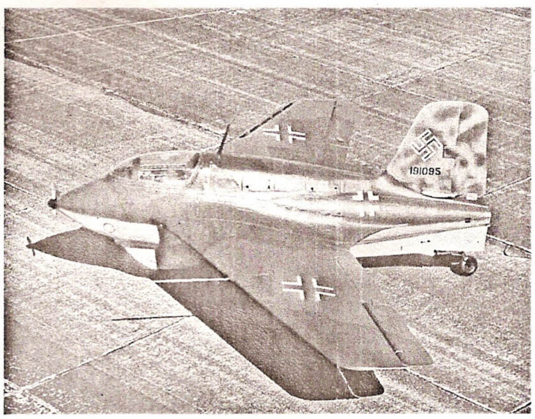
B. If he begins the flight in A. from a height of 100 ft, how far do you predict he will be able to fly before landing safely (hopefully) on the ground?

C. For the next flight, Orville decides he wants to make an attempt for maximum endurance. What airspeed (in Knots) would you advise him to fly for this attempt? Orville weighs the same as Wilbur.

D. For the flight in C., what is the glide path angle?

(5 points) Bonus: How much longer was Orville's flight than Wilbur's? Assume Orville took off from the same height.

Problem 3 (22.5 points). The German Me-163 Komet, a rocket-powered glider attack plane, was one of the least successful aircraft of WWII. It's standard profile included taking off, climbing at an 80° angle for 3.5 minutes to its service ceiling (shooting at allied bombers on the way by), flying until its fuel ran out (4.5 minutes later), and then gliding down (shooting at allied bombers on the way by). They crashed far more airplanes than shot down (it was one of the allies best weapons). Answer the following questions about it:



a) Given an average (or constant) P_s of 11,730 ft/min, to what altitude does the Komet reach in its climb?

b) What horizontal distance does it cover in its climb?

c) If it continues in a straight line for its level cruise phase, what is its $L/D)_{max}$ as it tries to stay up as long as possible to shoot at bombers? (assume it is the jet-engine version of the Komet with ct = 2.41/hr, weight at the beginning of cruise of 4263 lb, using 63 lb of fuel).

d) At a speed of 550 mph, what horizontal distance does it cover in its cruise phase?

e) Draw the Komet's flight profile here (assuming it always travels in a straight line)-- include altitudes and horizontal distances as you solve for them

f) The adjoining base that the Komet is scheduled to land at is 130 nm from where it took off. Can it make it?

Problem 4 (22.5 points). You are flying a T-38 in SLUF at 10,000 ft with a weight of 10,000 lb. You have the appropriate performance diagrams.

a) What TAS should you use for maximum endurance?
b) If your actual Mach number is 0.6, what is your maximum level acceleration?
c) If you were to zoom climb from this condition (with thrust equal to drag), what altitude would you reach?
d) You climb to 15,000 ft and burn off 400 lbs of fuel. You decide to do a sharp level turn. What is your maximum bank angle for level flight?
e) What is the stall speed for this bank angle?

(5 points) Bonus: What is your minimum turn radius at this new altitude and weight?

Extra Page for Calculations