AEM 313: Exam C Name: O'Neill

29th Sept 2016 75 minutes 5 Pages Closed books, Closed notes, Calculator

One page of notes.

100 total points **Read, think, plan, and then write.**

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Multiple Choice Problems: Circle **EVERY** correct answer [5 pts each]

1. A linearly tapered wing has a span of 40 feet, an aspect ratio of 8, and a root chord of 10 feet. What is the taper ratio? $S = b^2/AR = 40^2/8 = 200$ $\bar{c} = 200/40 = 5$ $\bar{c} = \frac{c_t + c_R}{2} = \frac{c_t + 10}{2} \Rightarrow c_t = 0$

$\lambda = \frac{0}{10} = 0$

A. 7/9	B. 1.0	C. 1.3	D. 0	E. None of the above

2. Estimate the SSL stall speed of a nearly empty Piper Tripacer (S=147 ft^2, W=1160 lbf) given the maximum lift coefficient is 2.2. $W = L = \frac{1}{2}\rho V^2 S C_{L_{max}} \Rightarrow V^2 = \frac{2W}{\rho S C_{L_{max}}} \Rightarrow V = \sqrt{\frac{2W}{\rho S C_{L_{max}}}}$

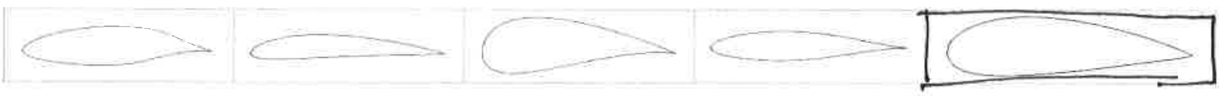
A. 64 ft/s	B. 41 mph	C. 55 ft/s	D. 33 mph	E. None of the above

$V^2 = \frac{2 \,|\, 1160\,lbf \,|\, ft^3 \,|\, \,|\, slug\ ft}{\,|\, 0.00237\,slug \,|\, 147\,ft^2 \,|\, 2.2 \,|\, lbf\,s^2}$

$V = 55\ ft/s$

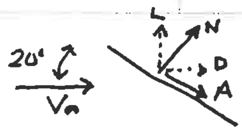
$= 55 \cdot \frac{60}{88} = 37\ mph$

3. Which airfoil is an NACA 4424? Hint: camber and thickness



4. In a wind tunnel, a wing is mounted at 20 degrees AOA. The normal force is 60 lbs. The axial force is 20 lbs. What is the lift to drag ratio?

A. 3.0	B. 1.6	C. 1.25	D. 0.79	E. None of the above



$L = N\cos(20°) - A\sin(20°)$
$D = N\sin(20°) + A\cos(20°)$ $= \frac{49.5\ lbf}{39.3\ lbf}$ $\frac{L}{D} = 1.26$

within 1% of 1.25 ✓

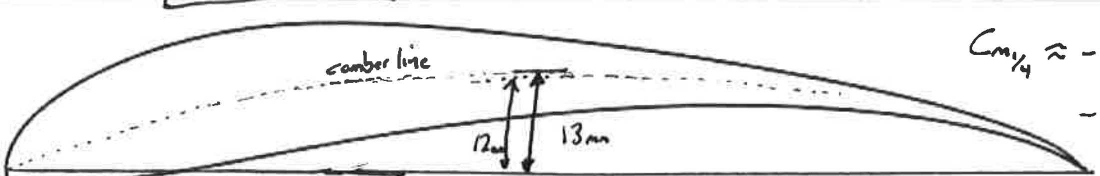
5. What is the air density in slug/ft^3 at standard sea level and 59F given 90% humidity?

A. 0.00219	B. 0.00236	C. 0.00237	D. 0.00238	E. None of the above

Increasing humidity decreases density... only A, B, E

6. Given the following Selig 1223 airfoil, estimate C_m at the quarter chord. After the exam, compare this estimate with the actual value to see amazing precision given the simple Joukowski estimate.

A. 0.086	B. -0.272	C. -0.149	D. -0.226	E. None of the above



I averaged two measurements of max f/c. $c = 142\,mm$

$C_{m_{c/4}} \approx -\pi \frac{f}{c}$

$-\pi \frac{12}{142} = -0.265$ lower bound

$-\pi \frac{13}{142} \approx -0.287$ upper bound

7. In a 2D flow, you notice a particle rotating at 1 rad/s. What is the vorticity?

A. 0	B. 1/2	C. 1	D. 2	E. None of the above

Twice angular rate

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8. For an NACA 64_3-418 airfoil at Re=6 million, what is the drag coefficient at -6 degrees AOA? The experimental data is plotted below (source: Theory of Wing Sections)

A. 60 counts	B. 140 counts	C. 80 counts	D. 95 counts	E. None of the above

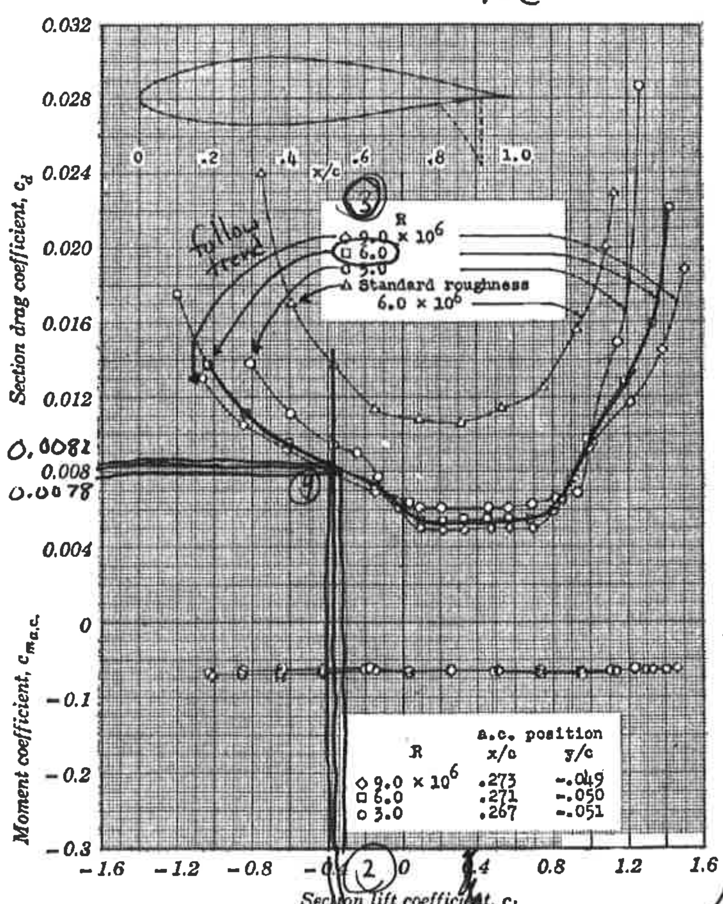
9. Given a **steady** flow, which of the following visualizes a trace of all fluid elements that flowed through a fixed location? Steady flow indicates d/dt=0.

F. Pathline	G. Streakline	H. Timeline	I. Streamline	J. None of the above

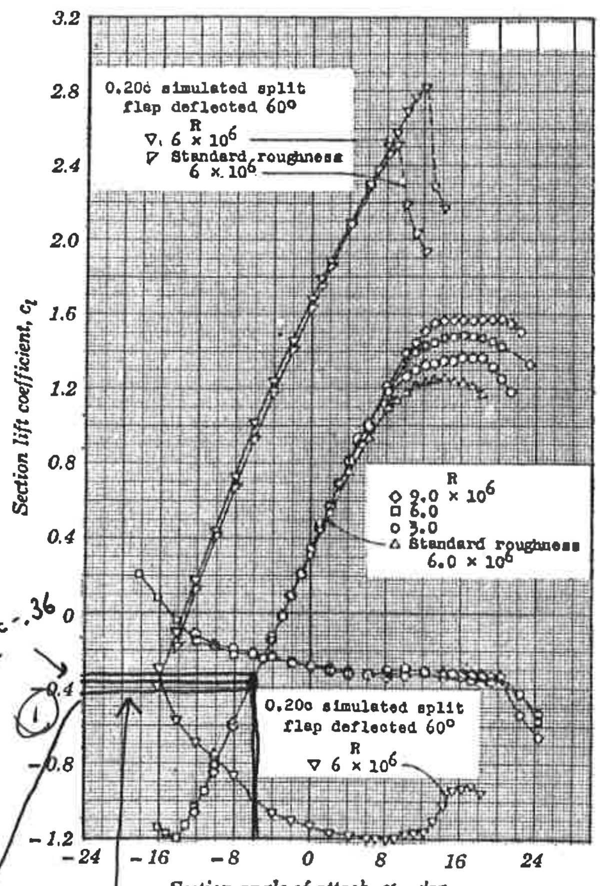
10. Given a 15% thick symmetrical Joukowski airfoil at 10 degrees AOA, estimate $C_{l\alpha}$ [1/rad]?

K. 6.9	L. 20π	M. 0.12	N. 2π	O. None of the above

$C_{l_\alpha} \approx 2\pi \frac{1+\epsilon}{1+\epsilon^2}$ with $\epsilon \approx 0.77 \cdot 15\% \Rightarrow C_{l_\alpha} \approx 6.9$



NACA 64_3-418 Wing Section (Continued)



NACA 64_3-418 Wing Section

Uncertainty band to ensure that I bound the correct value.

When you are working with experimental hard-to-read data, improve your estimate with multiple samples.

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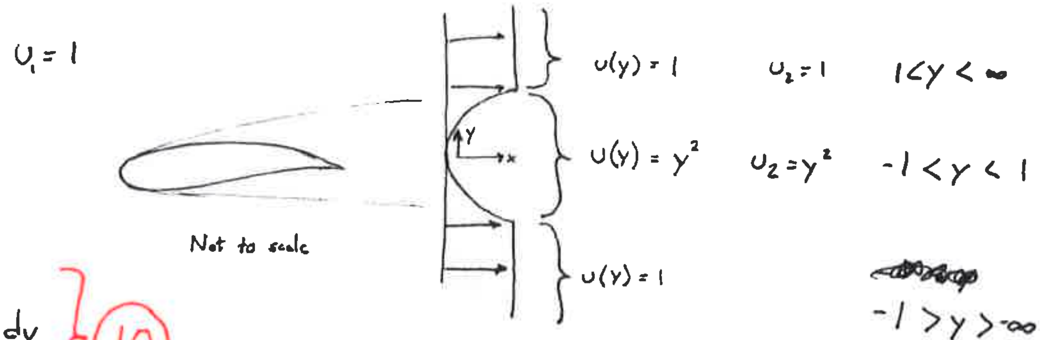
11. [25 pts] An airfoil with a 100 inch chord creates the following velocity profile measured in inches. The upstream velocity is $U_1=1$. Determine the sectional drag coefficient C_d.



$$D = \int_{-\infty}^{\infty} \rho_2 u_2 (u_1 - u_2)\, dy$$ (10)

Notice that the profile is symmetric about $y=0$

$$D = \int_{-\infty}^{\infty} (\cdots) = 2\int_0^{\infty} (\cdots)$$

Notice that the u_2 function switches from y^2 to 1 at $y^2=1 \Rightarrow y = \pm 1$. New integration limits/functions are:

split into two portions ≈ 3pt

$$D_{1/2} = \int_0^1 \rho_2 y^2 (1-y^2)\, dy + \int_1^{\infty} \rho_2 \cdot 1 \cdot (1-1)\, dy = \int_0^1 \rho_2 y^2 (1-y^2)\, dy$$

apply velocities and deficit ≈ 3pts

$$= \rho_2 \int_0^1 (y^2 - y^4)\, dy = \rho_2 \left(\frac{y^3}{3} - \frac{y^5}{5} \right)\Bigg|_0^1 = \rho_2 \left(\frac{1}{3} - \frac{1}{5} \right) = \rho_2 \frac{2}{15}$$

Integral 3pts; Value 1pt

$0.2667 \rho_2$

Integral (10)

Non-dim

$$C_d = \frac{2D_{1/2}}{\frac{1}{2}\rho V^2 c} = 2\, \frac{\rho_2\, 2}{15} \,\Big|\, \frac{2}{\rho V_1^2} \,\Big|\, \frac{1}{100} = \frac{1}{375} = \frac{8}{15}\frac{1}{100}$$

(5)

$$\boxed{C_d = \frac{2}{375} \approx \text{~~26~~ counts}}$$

53 counts

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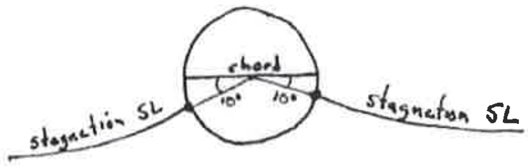
Challenge problem.

[25 pts] Given a cylinder of radius 10 inches in a freestream flow of 100 ft/s at SSL, you measure stagnation points at -10 degrees below the chordline. What is the pressure coefficient at the leading edge of the cylinder where r=10 and $\theta = \pi$?



Streamfunction:

$$\psi = V_\infty r \sin\theta \left(1 - \frac{R^2}{r^2}\right) + \frac{\Gamma}{2\pi} \ln\left(\frac{r}{R}\right)$$ (5)

Velocity at stagnation pt is zero. On surface, $V_r = 0$ already. We want $V_\theta = 0$ too.

(5)

$$V_\theta = -\frac{d\psi}{dr} = -V_\infty \sin\theta\left(1 - \frac{R^2}{r^2}\right) - V_\infty r \sin\theta\left(+\frac{2R^2}{r^3}\right) - \frac{\Gamma}{2\pi}\frac{1}{r}$$

$$= -V_\infty \sin\theta\left(1 - \frac{R^2}{r^2} + \frac{2R^2}{r^2}\right) - \frac{\Gamma}{2\pi}\frac{1}{r}$$

$$= -V_\infty \sin\theta\left(1 + \frac{R^2}{r^2}\right) - \frac{\Gamma}{2\pi r}$$

(5)

$$V_\theta(\theta = -10°) = 0 = -V_\infty \sin(-10°)(1+1) - \frac{\Gamma}{2\pi\, 10}$$

$$\Gamma = -V_\infty \sin(-10°)(2)(2\pi)(10 \text{ inches})$$

$$= -100\,\frac{ft}{s} \cdot -0.1736 \cdot 4\pi \cdot \frac{10}{12}\,ft = 181.8\,\frac{ft^2}{s}$$

Pressure Coefficient

(3)

$$C_p = 1 - \frac{V^2}{V_\infty^2}$$

(5)

$$V_\theta = -V_\infty \sin(\pi)\left(1 + \frac{R^2}{r^2}\right) - \frac{\Gamma}{2\pi r} = -\frac{\Gamma}{2\pi r} = -\frac{181.8\,ft^2}{s}\,\frac{1}{2\pi}\,\frac{1}{10\,in}\,\frac{12\,in}{ft}$$

$$= 34.7\,\frac{ft}{s}$$

$$C_p = 1 - \frac{34.7^2\,ft^2/s^2}{100^2\,ft^2/s^2} = 0.88$$

(2)

$$\boxed{C_p = 0.88}$$

Alternative worth 15 pts

Shortcut:

$$C_p = 1 - 4\sin^2\theta - \frac{2\Gamma}{\pi R V}\sin\theta - \frac{\Gamma^2}{4\pi^2 R^2 V^2}$$

$$= 1 - 0.12$$

$$= \underline{0.88}$$