

exercise session 1

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Wind Energy Systems, Summer-Semester 2018

Albert-Ludwigs-University, Freiburg, Germany



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a question from you...



If we solve the question and we want to present it, do we have to check also the 10% box as well?



If we solve the question and we want to present it, do we have to check also the 10% box as well?

No.

The '10%-free points' are really 'free points'; you can take them or leave them as you wish, depending on how confident you are!

let's play a game...



concept questions!

for $\lambda = \infty$, which is the velocity triangle?

axes legend

\hat{x} : axial/downwind

\hat{t} : tangential

\hat{r} : radial

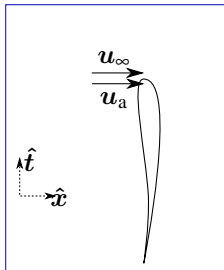
velocity legend

u_a : apparent/effective

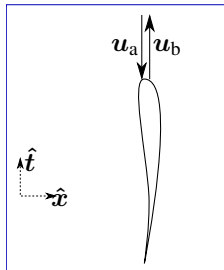
u_b : blade

u_∞ : freestream

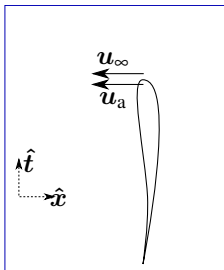
A)



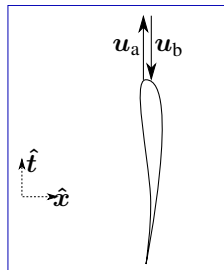
B)



C)



D)



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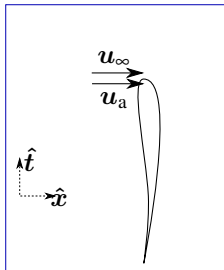
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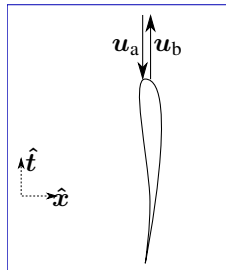
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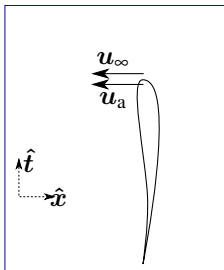
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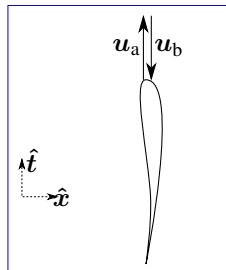
B)



C)

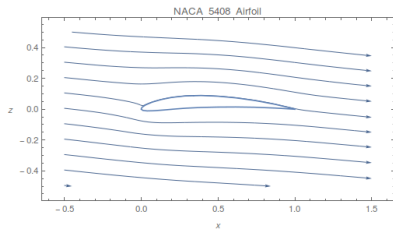


D)

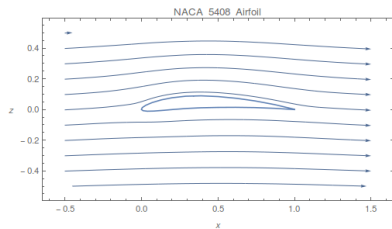


on which airfoil is c_l greatest?

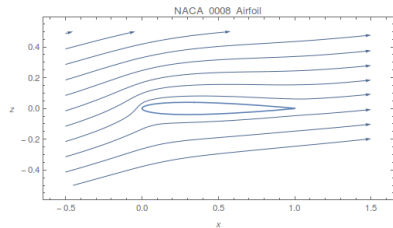
A) $\alpha = -5^\circ$



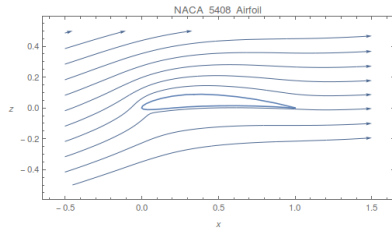
B) $\alpha = 0^\circ$



C) $\alpha = 10^\circ$

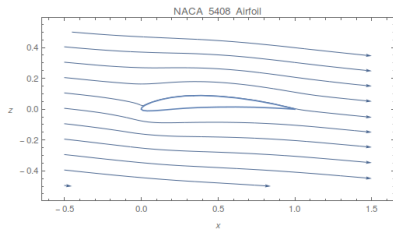


D) $\alpha = 10^\circ$

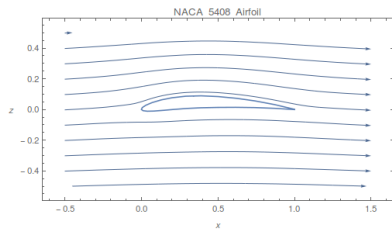


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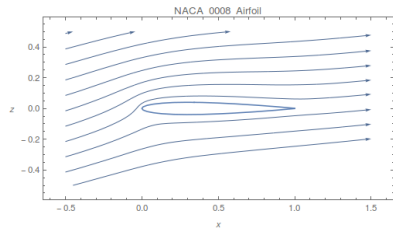
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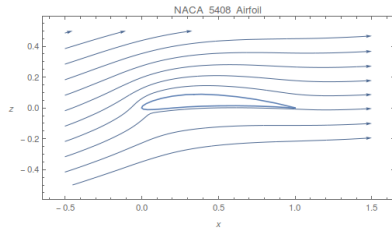
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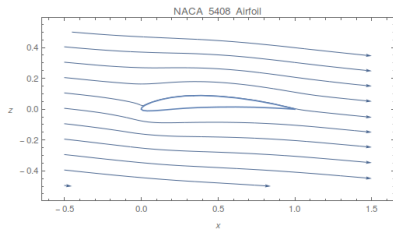


D) $\alpha = 10^\circ$

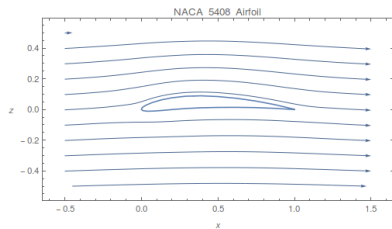


on which airfoil is c_d greatest?

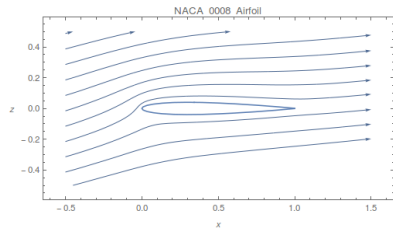
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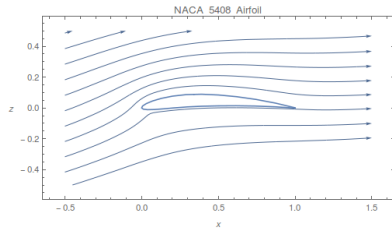
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C) $\alpha = 10^\circ$



D) $\alpha = 10^\circ$

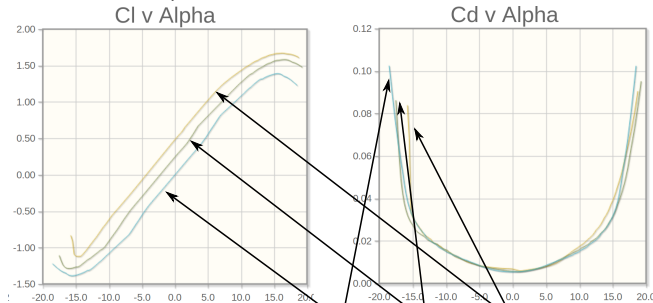


on which airfoil is c_d greatest?



thanks for pointing out an error!

c_d vs α relationship is similar for airfoils with different camber but same thickness at same Reynolds number. (but c_d is slightly higher for less-cambered airfoils!)



max camber at 40% chord: 4% 2% 0% (symmetric)
(NACA airfoils with max. thickness 12% at 30% chord at $Re = 10^6$.)

on which airfoil is c_d greatest?



to clarify (hopefully without causing too much confusion)...

the original solution would have been correct **if** I had asked about C_D rather than c_d , where:

$$\begin{array}{ll} C_D & \text{3D (whole wing) coefficient} & \mathbf{D} = C_D \frac{1}{2} \rho \|\mathbf{u}\|_2^2 S \hat{\mathbf{d}} \\ c_d & \text{2D (profile/cross-section) coefficient} & \mathbf{D}' = c_d \frac{1}{2} \rho \|\mathbf{u}\|_2^2 c \hat{\mathbf{d}} \end{array}$$

where:

\mathbf{D} : the drag force (vector)

\mathbf{D}' : the drag force (vector) per unit span

ρ : fluid density

\mathbf{u} : wind velocity

S : wing area (typically when looking down onto the wing)

c : chord of the wing

$\hat{\mathbf{d}}$: unit vector in the direction of the wind velocity = $\mathbf{u} / \|\mathbf{u}\|_2$

on which airfoil is c_d greatest?



... and C_D increases (approximately) with the square of (3D) wing lift coefficient C_L^2 :

$$C_D \approx C_{D0} + \kappa C_L^2$$

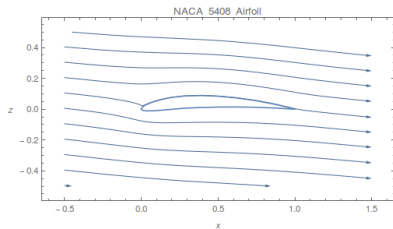
because of a penalty (induced drag) due to the lift.

(the 'you don't get anything for free' explanation that I made a mess of today...)

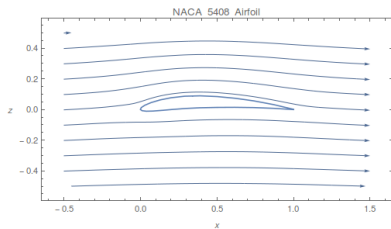
I'll try to motivate this all properly during my lecture (next week).

[SO!] on which airfoil is c_d greatest?

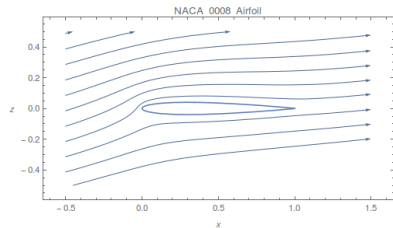
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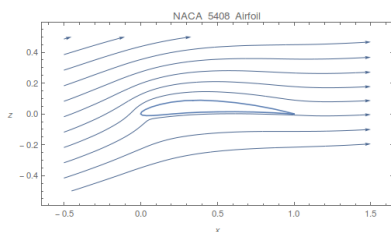
B) $\alpha = 0^\circ$



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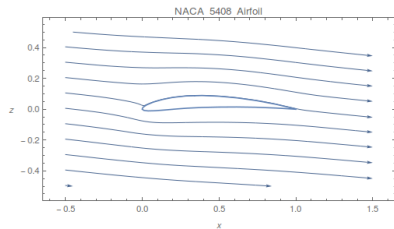


~~D) $\alpha = 10^\circ$~~

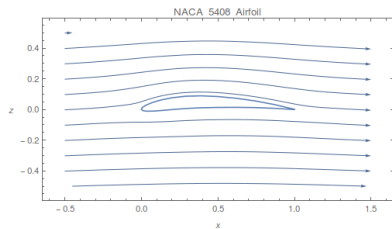


on which airfoil could $c_l = 0$?

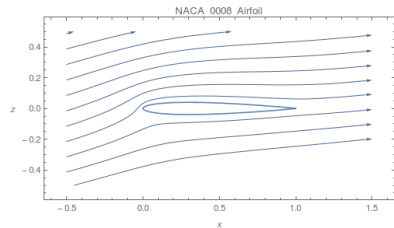
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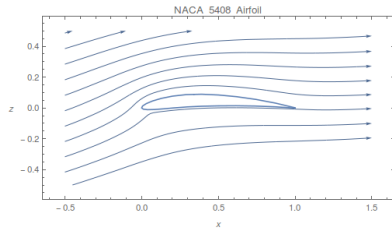
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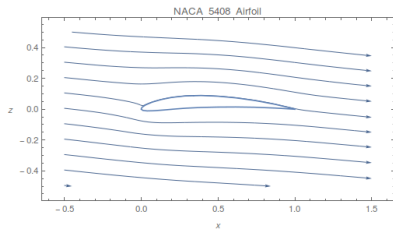


D) $\alpha = 10^\circ$

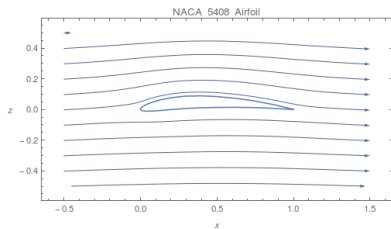


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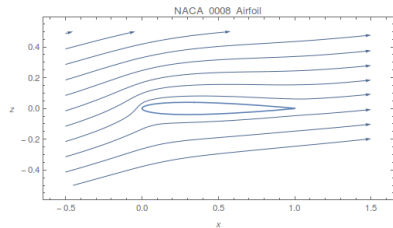
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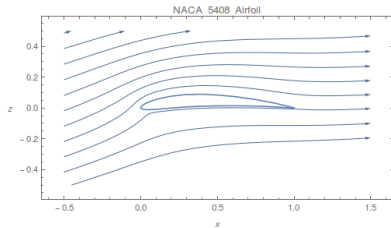
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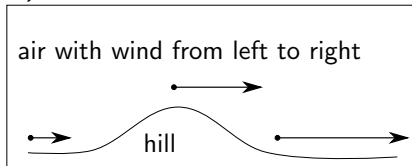


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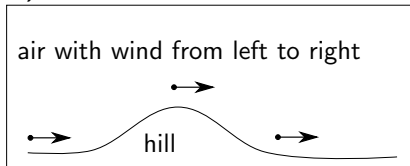


what does the wind over a hill look like?

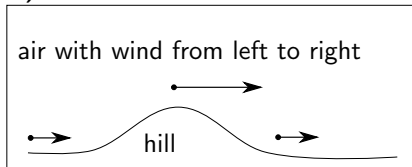
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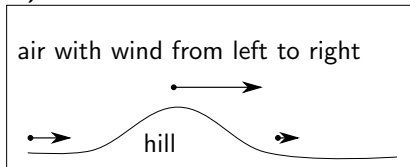
B)



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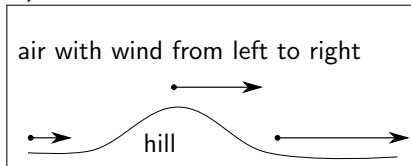


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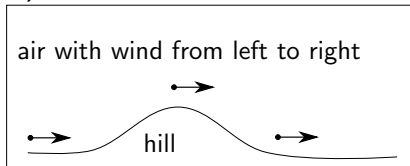


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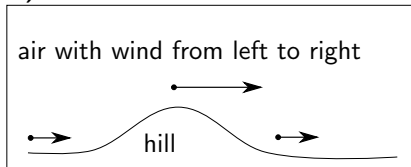
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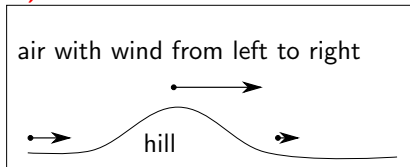
B)



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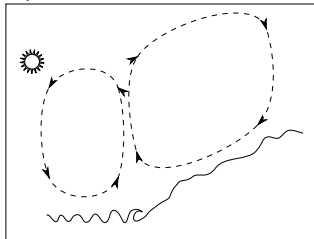


D)

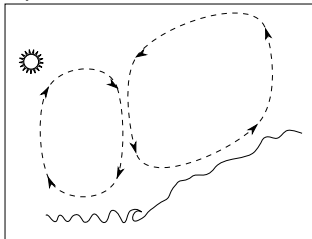


what does the 'sea-breeze' look like?

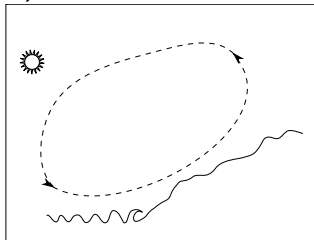
A)



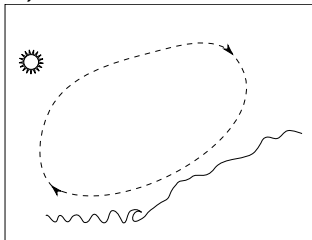
B)



C)

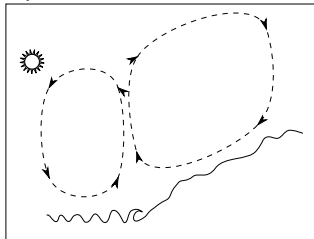


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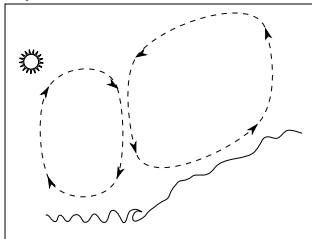


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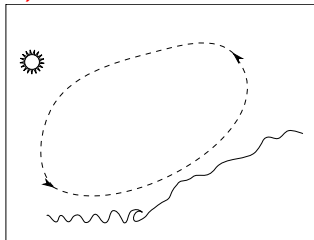
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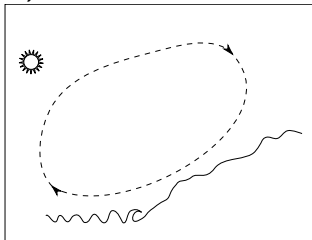
B)



C)



D)



another game!



presenting the homework solutions...