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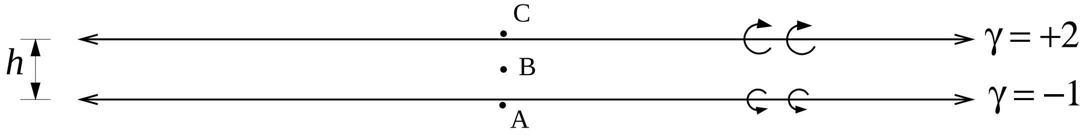
Unified Engineering
Fall 2004

Problem Set #14
(Optional)

F18
F19
F20
F21
M19
M20
M21

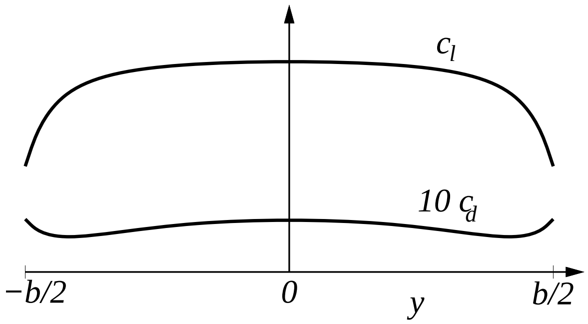
Two very long vortex panels of strengths $\gamma = +2$, $\gamma = -1$, as shown, are located at distance h apart. Determine the velocities at points A, B, C.

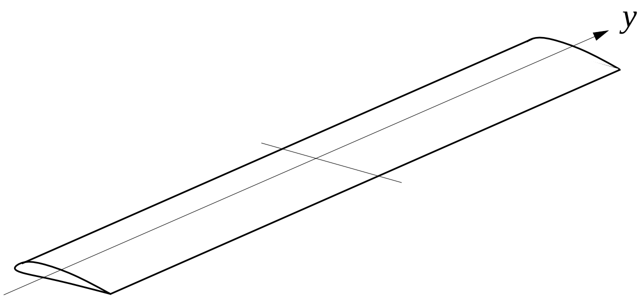


Unified Engineering Fall 2004
Fluids Problems F19

A long rectangular wing has span b and constant chord c, and hence the wing area is $S = bc$. Because of "tip effects", the local lift and drag coefficients $c_\ell(y)$ and $c_d(y)$ tend to vary across the span. Determine how these local $c_\ell(y)$ and $c_d(y)$ distributions relate to the wing's overall C_L and C_D.

(Hint: Determine L' and D', then get L and D, then from these determine C_L and C_D).





(Note: Using only the airfoil's c_d ignores other contributions such as induced drag, which become especially significant at low flight speeds!)

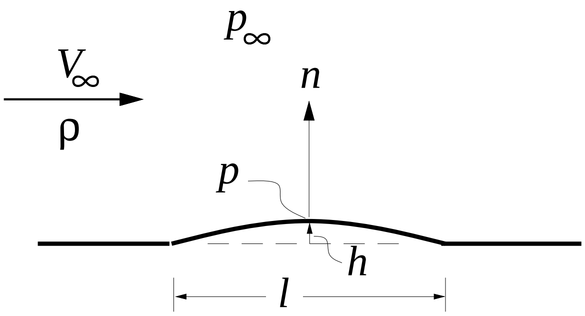
Unified Engineering Fall 2004
Fluids Problem F20

A wall with air flowing over it has a shallow parabolic bump of length l and height h.

a) Determine the curvature κ of the bump, and the resulting normal pressure gradient $\partial p / \partial n$ over the center of the bump.

b) Assume that the pressure gradient extends some height Δn into the flow. What is the resulting overpressure $\Delta p \equiv p - p_\infty$ at the center of the bump? Specify the sign of Δp.

c) Experiments indicate that Δp is very nearly proportional to the bump's h/l ratio. How must Δn relate to the bump geometry? (i.e. how far does the bump's pressure disturbance reach into the flow?)



Unified Engineering
Fluids Problem F21

Fall 2004

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a) The flight power needed to overcome drag is

$$P = V_\infty \, D$$

Derive a formula for P in level flight, in terms of the following quantities:

ρ	air density
W	aircraft weight
S	wing area
C_L	lift coefficient
C_D	drag coefficient

b) How does flight power vary with air density (e.g. via changed altitude)? Explain your seemingly paradoxical result.

c) If C_D is reduced by 1%, how much does flight power decrease percentagewise?

d) If W is reduced by 1%, how much does flight power decrease percentagewise?

Unified Engineering Problem Set #14 — Units M3.3, M3.4
Fall, 2004

M19 A material has a rectangular crystal lattice. The potential energy of the two atoms in the lattice, a distance r apart, is :

$$U = -A/(r^m) + B/(r^n)$$

with values of the two exponents of 2 for m and 10 for n. It is known that the atoms form a stable pair at a separation of 0.3 nm with an energy of -4 eV.

(a) Determine the values of the constants A and B.

(b) Making no further assumptions (i.e. just use this single bond model), estimate the extensional modulus, E, of the material.

(c) Comment on possible discrepancies between the estimated value of the modulus and an actual measured value for the material

M20 A unidirectional composite material is to be made of graphite fibers with a fiber modulus of 230 GPa and an epoxy matrix with a modulus of 10 GPa. Determine estimates for the composite ply modulus along and perpendicular to the fiber direction as a function of the fiber volume fraction v_f. Plot these estimates.

M21 Crystalline aluminum and titanium have face-centered cubic and close-packed hexagonal structures, respectively.

(a) Assuming that the atoms can be represented as hard spheres, calculate the percentage of the volume occupied by atoms in each material.

(b) Starting from basic principles, determine the dimensions of the unit cell for each material. Note that the density of aluminum is 2.70 Mg/m^3; that of titanium is 4.51 Mg/m^3.