ME 326 - Intermediate Fluid Mechanics

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Drag Force - Immersed Blunt Bodies

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Immersed Blunt Bodies

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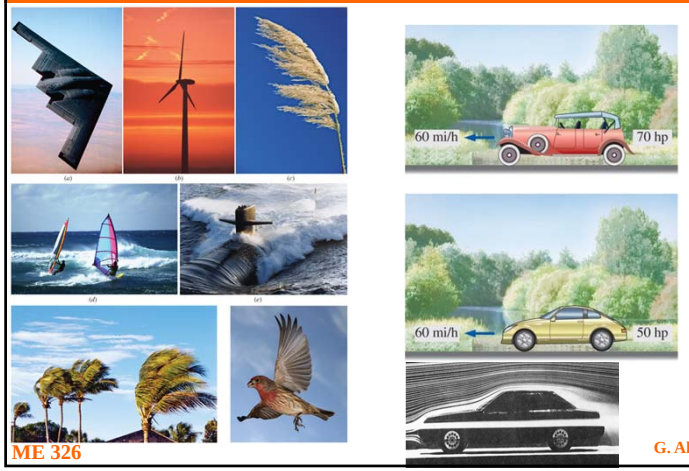

Drag Force

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Outline

- Forces and Toques
- Drag of Spheres
- Drag of Cylinders
- Drag Coefficient for 2D Objects
- Drag Coefficient for 3D Objects
- Lift Force for an Airfoil

Forces and Moments

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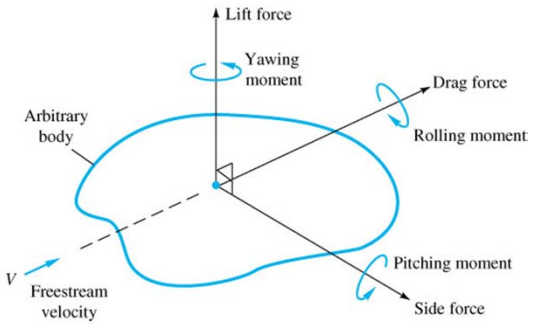

Drag Coefficient

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$$C_D = \frac{\text{Drag Force}}{\frac{1}{2}\rho V^2 A}$$

$$C_D = C_D(\text{Re}) \qquad \text{Re} = \frac{VL}{\nu}$$

$$C_D = C_{D,Press} + C_{D,Fric}$$

Drag Coefficient

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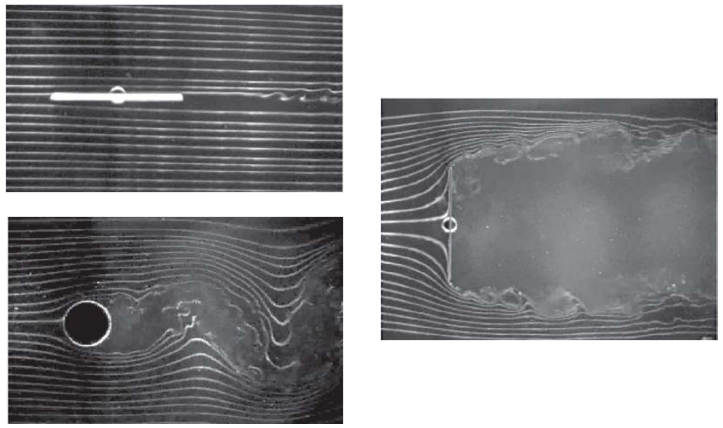

Drag Reduction

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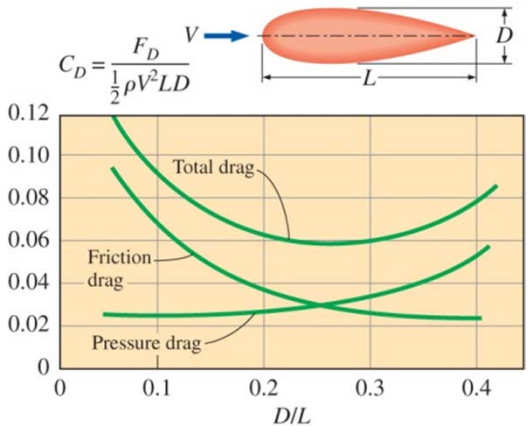

Drag Reduction

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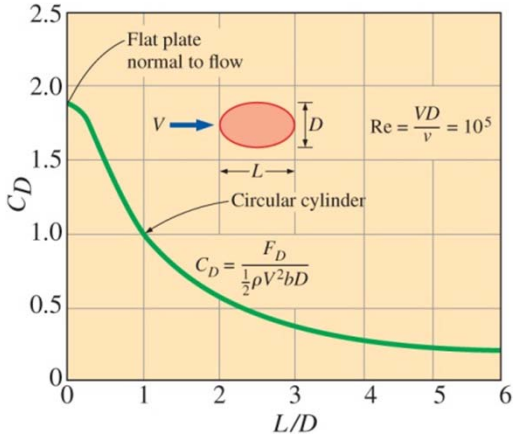

Flow Separation

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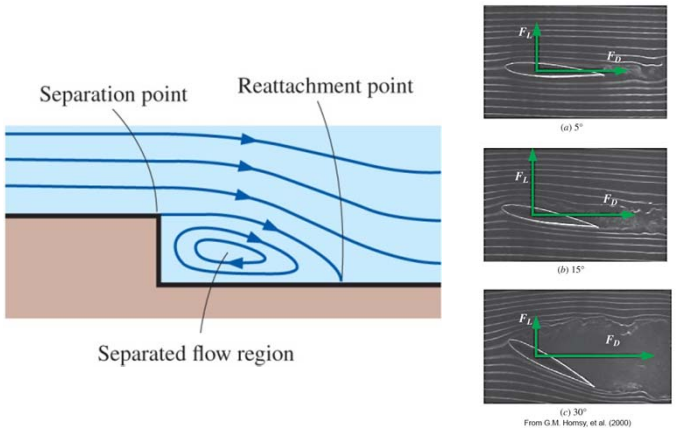

Drag Coefficients

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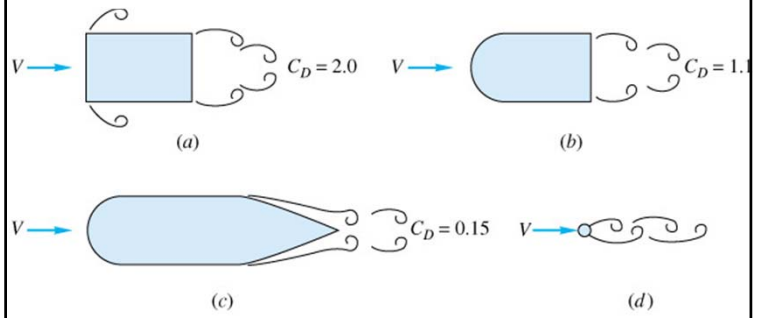

Drag Coefficients

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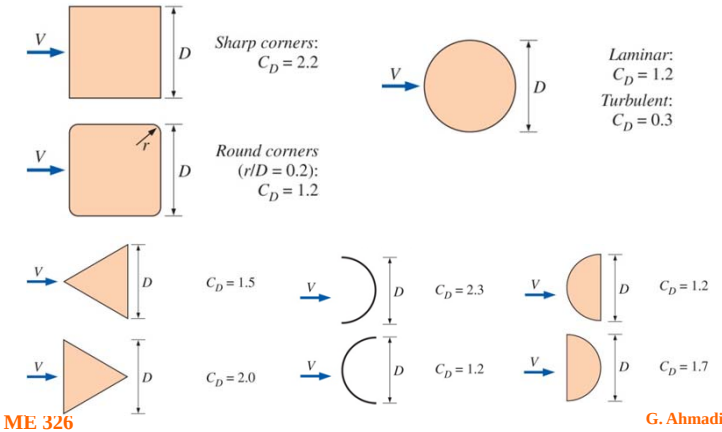

Drag Coefficients

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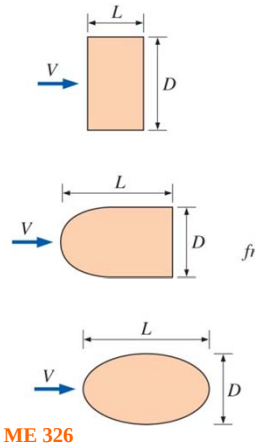

L/D	C_D
0	1.9
0.1	1.9
0.5	2.5
1.0	2.2
2.0	1.7
3.0	1.3

L/D	C_D
0.5	1.2
1.0	0.9
2.0	0.7
4.0	0.7

L/D	C_D Laminar	C_D Turb
2.0	0.6	0.2
4.0	0.35	0.15
8.0	0.25	0.1

Circular Cylinder - Karman Vortices

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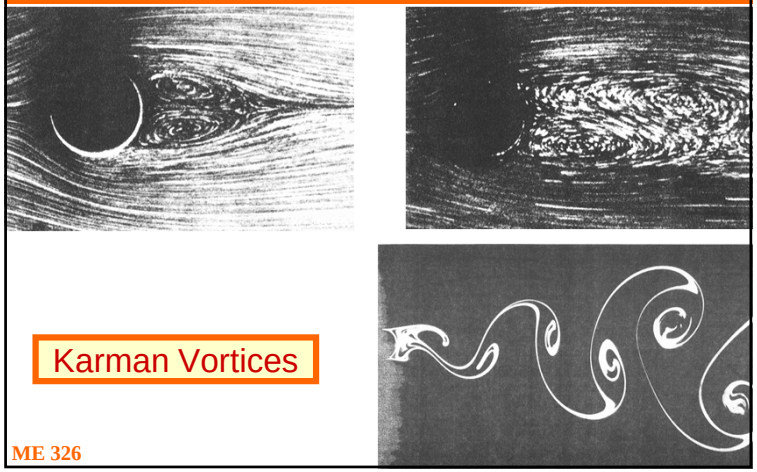

Karman Vortices

Circular Cylinder - Karman Vortices

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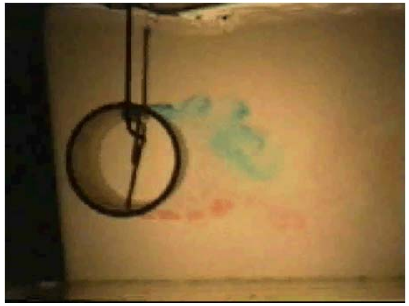
Karman Vortices



Flow Past Circular Cylinders

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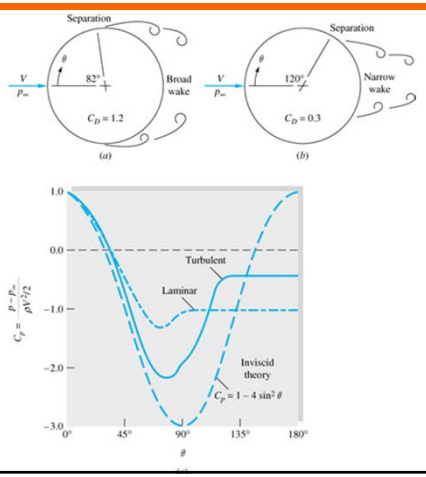

Flows Around a Circular Cylinder

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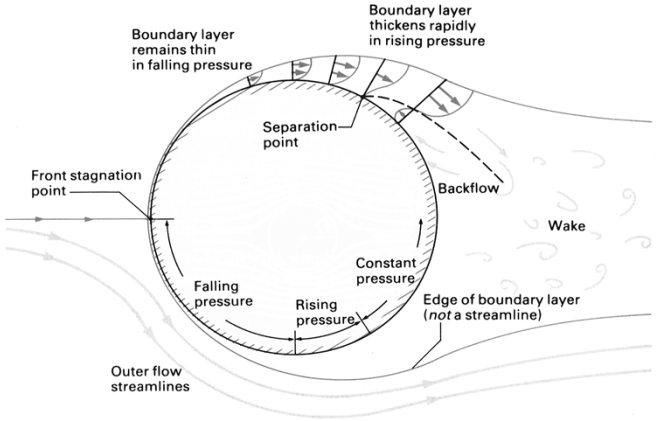

Drag Coefficients

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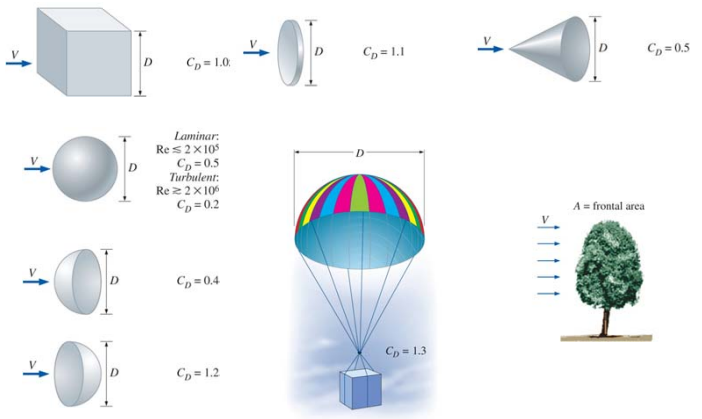
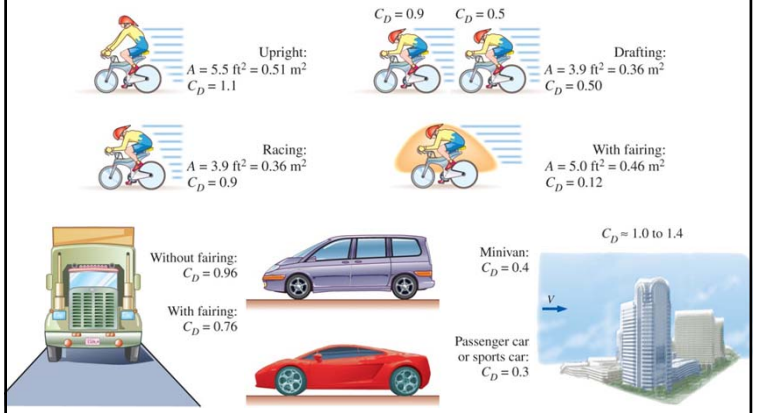


Drag Coefficients

Clarkson University



Drag Coefficients for 3D Bodies at low Reynolds Number

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Viscous drag coefficients
for low Reynolds number flow (valid for $\mathbf{R} < 1$).

Shape	Reference Length	C'_D
Sphere	D	3π
Hemisphere	D	8.7
Normal disc	D	8
Parallel disc	D	$\frac{16}{3}$
Normal rod	L	$\frac{4\pi}{\ln(2L/D) + 0.5}$
Parallel rod	L	$\frac{2\pi}{\ln(2L/D) - 0.72}$

Drag Coefficients

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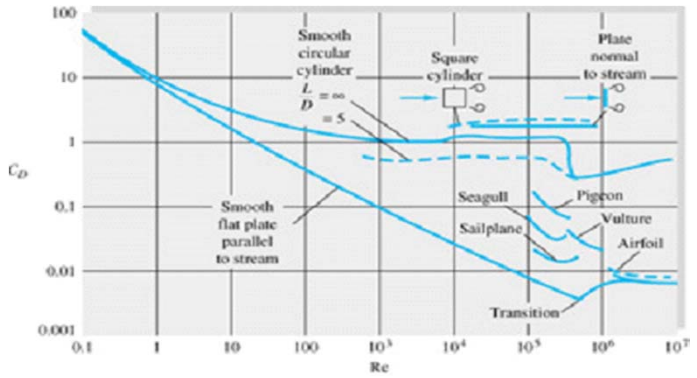

Two-Dimensional Bodies

Drag Coefficients

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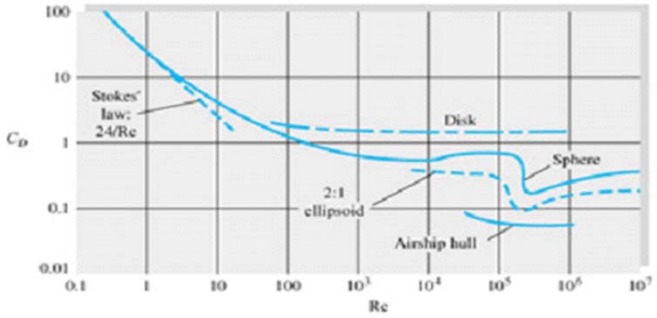

Three-Dimensional Bodies

Drag Force for a Sphere

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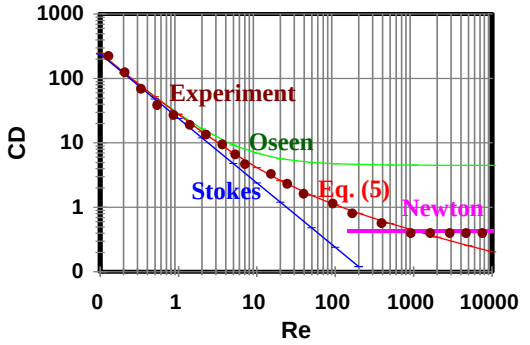

Drag Coefficient for a Sphere

Drag Coefficients for Cars

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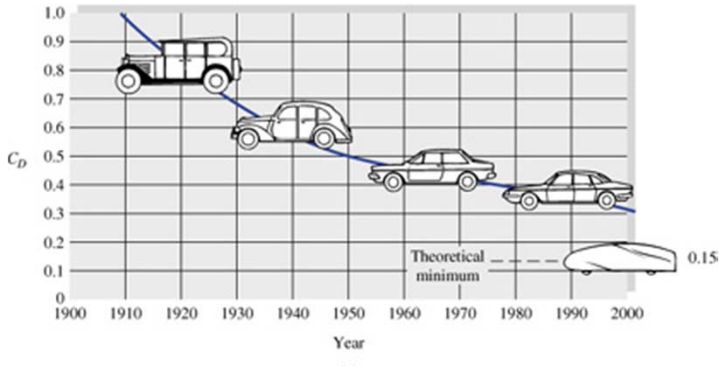

Drag Coefficients for Trucks

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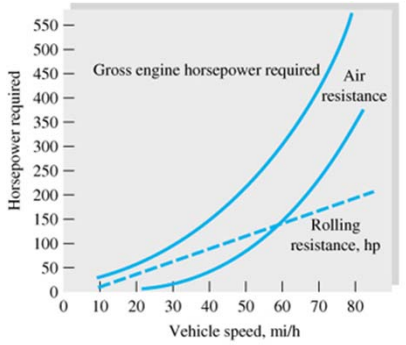

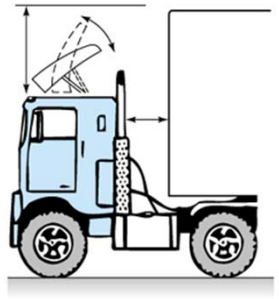

Drag Reduction

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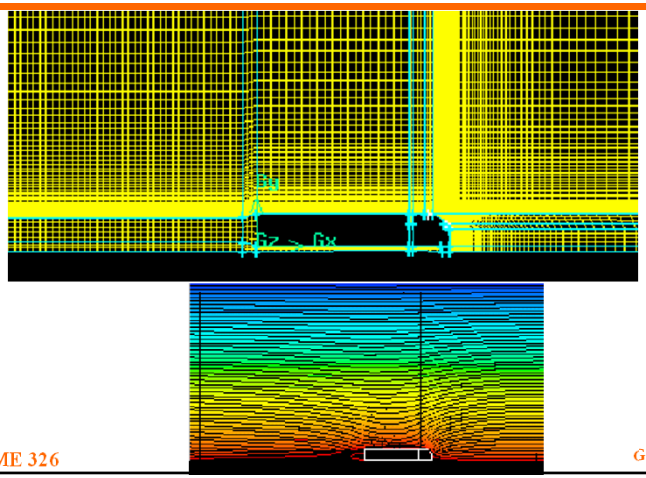

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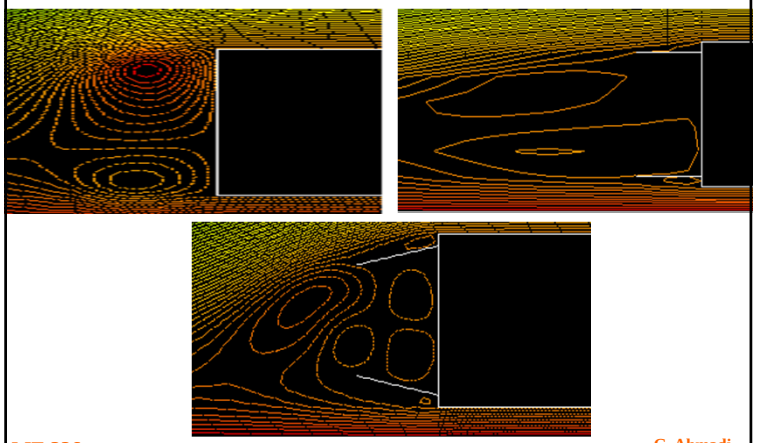

Drag Control

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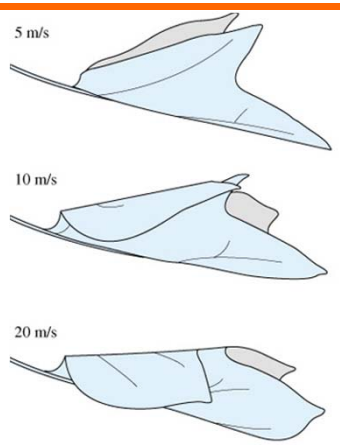
Shape Variation for Drag Reduction

Leaf Curls with Wind Speed



Flow over an Airfoil

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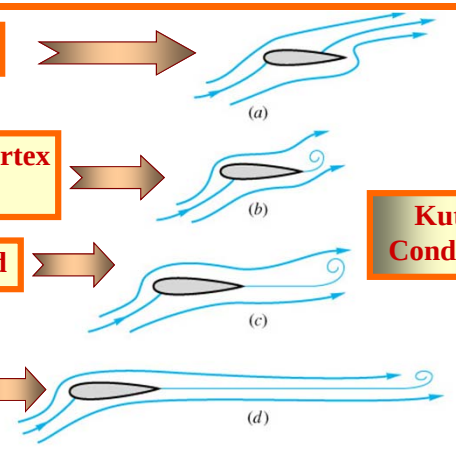
Start-Up

Separation/ Vortex Formation

Vortex is Shed

Full Lift

Kutta Condition



Flow over an Airfoil

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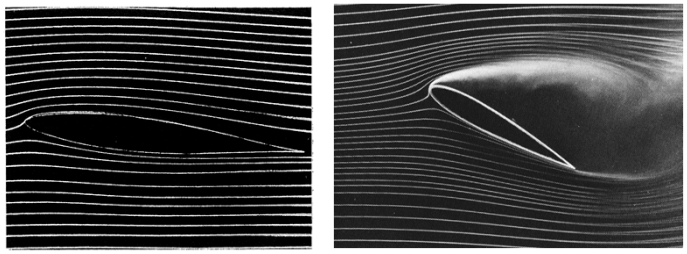
Flow Visualization



Small Angle of Attack **High Angle of Attack**

Lift and Drag

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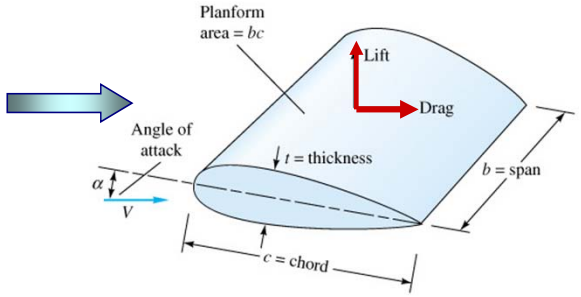

Lift and Drag Coefficients

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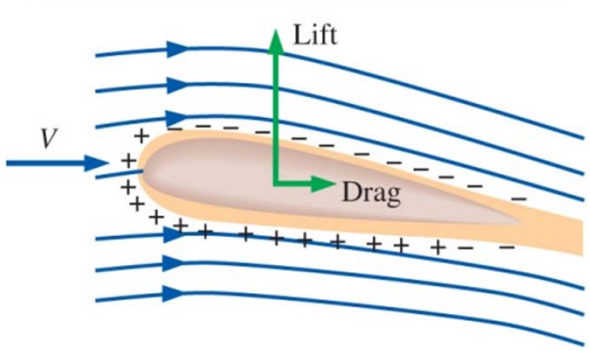

Lift and Drag Coefficients

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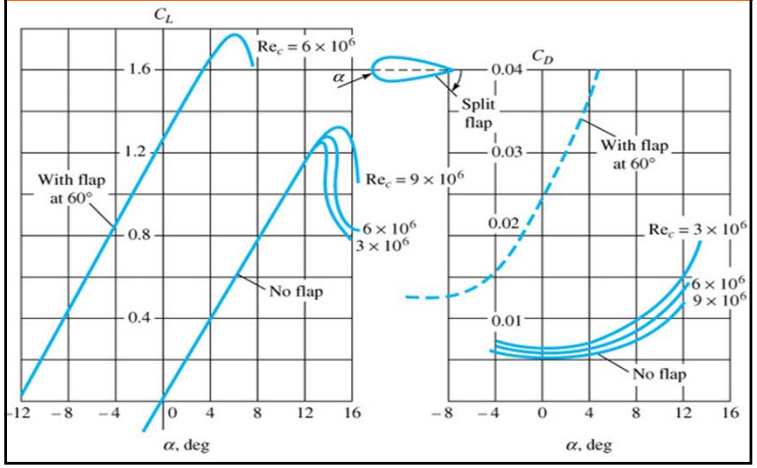

Lift and Drag Coefficients

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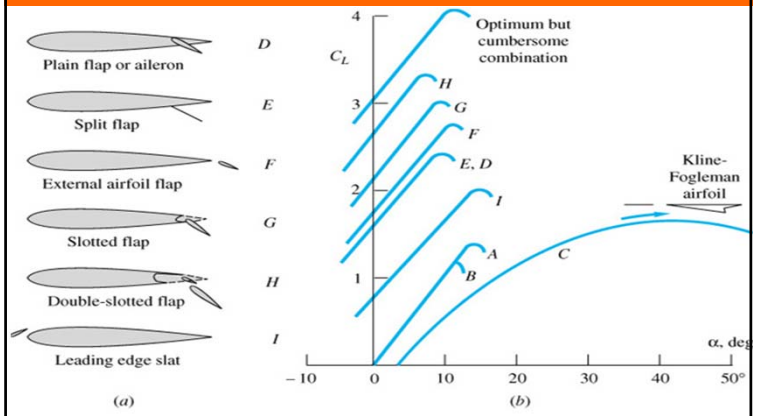

Drag Force

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Concluding Remarks

- Forces and Toques
- Drag of Spheres
- Drag of Cylinders
- Drag Coefficient for 2D Objects
- Drag Coefficient for 3D Objects
- Lift Force for an Airfoil

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Thank you!

Questions?