



FLUID MECHANICS OF EXTERNAL FLOWS

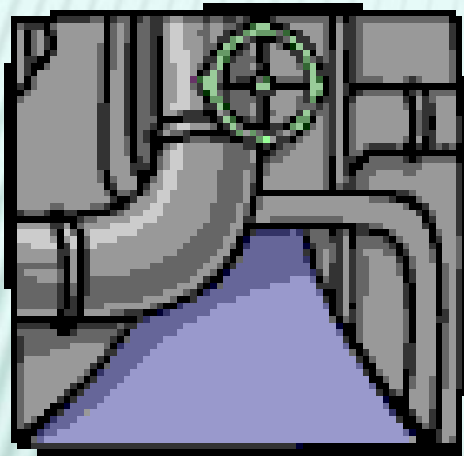
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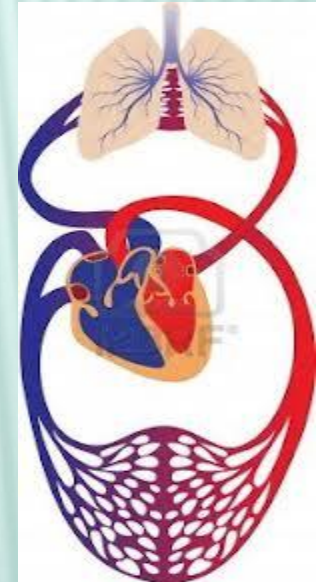
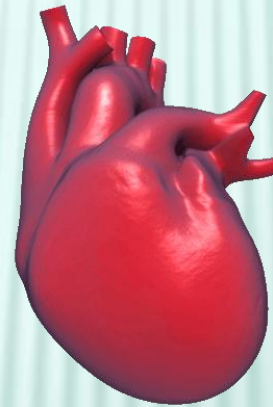
INTERNAL VS. EXTERNAL FLOWS

Internal Flow (flow through/in geometry):

Flow bounded on all sides by a solid surface



Flow in Pipes
and Ducts

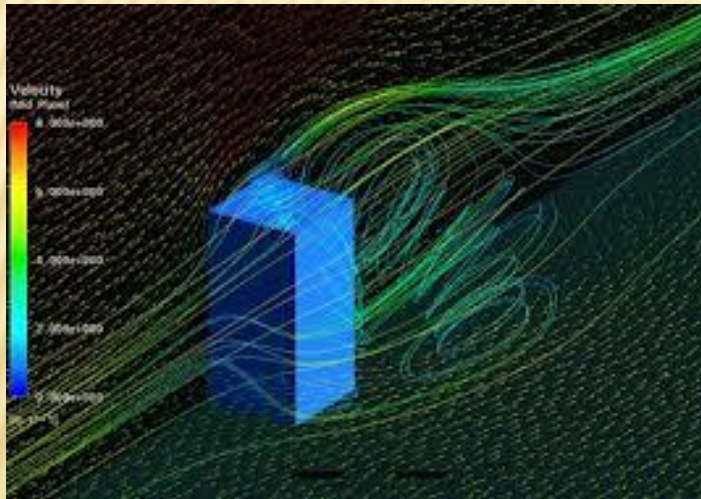


Flow in the Human
Circulatory System

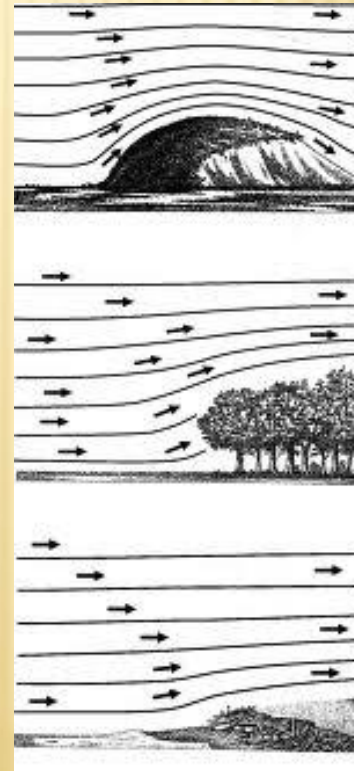
INTERNAL VS. EXTERNAL FLOWS

External Flow (flow over geometry):

Flow bounded on all at least one side by a solid surface



Flow over Buildings



Flow over Hills

Flow over Ground Vehicles





Flow over Aircraft and Marine Craft

IMPORTANT BASIC CONCEPTS

× Drag and Lift

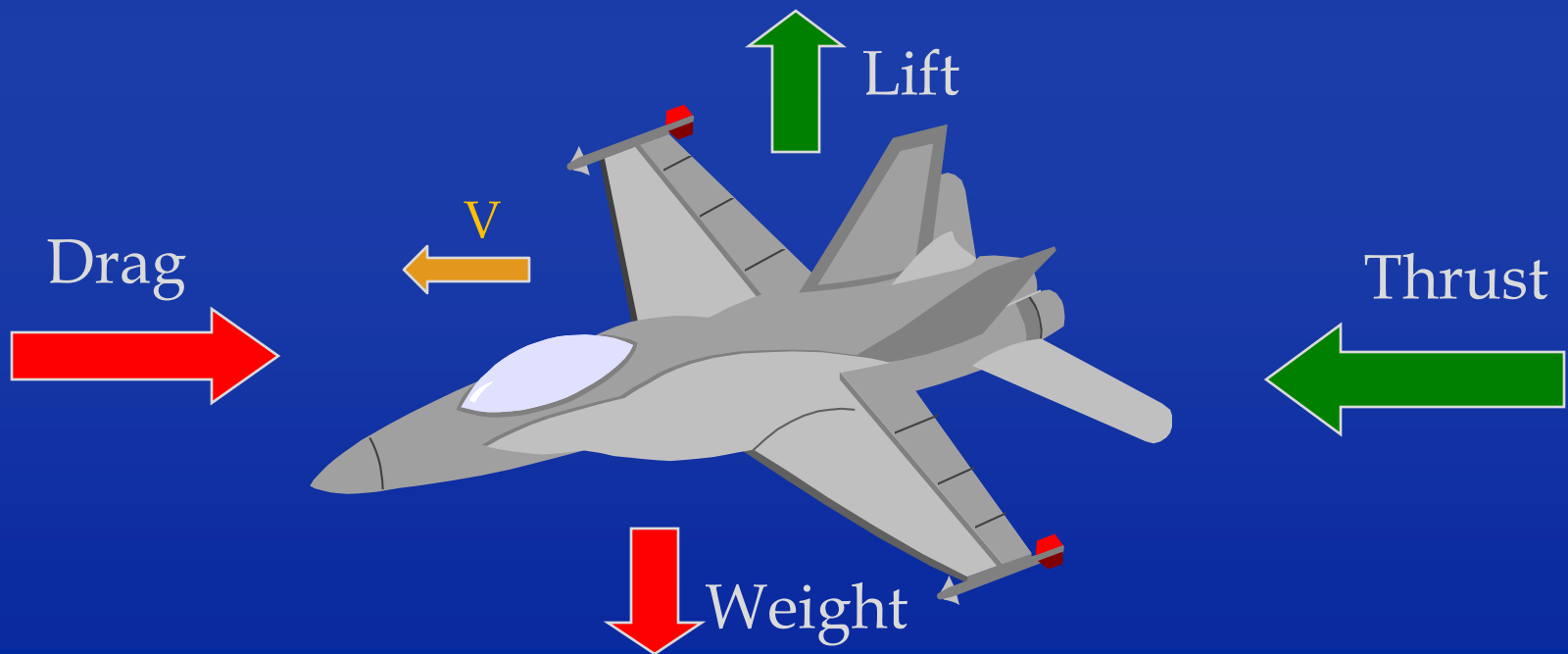
- + Drag: Force opposite the flow direction
- + Lift: Force normal to the flow direction

× Non-Dimensional Parameters

- + drag coefficient: $C_D = D / (\frac{1}{2} \rho V_\infty^2 S)$
- + lift coefficient: $C_L = L / (\frac{1}{2} \rho V_\infty^2 S)$
- + Reynolds number (ratio of inertial forces to viscous forces): $Re = \rho V_\infty L / \mu$

Application: Aerodynamics

- ✎ Aerodynamicists study the interaction of forces acting on vehicles moving in the atmosphere and the effect on translation
- ✎ These forces are thrust, drag, weight and lift



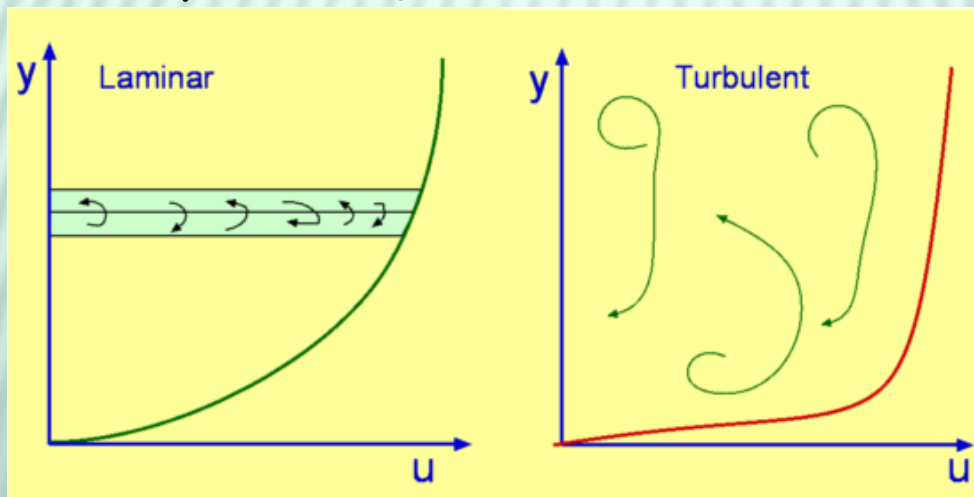
COMPONENTS OF DRAG

- ✕ Two main sources of drag are:
 - the pressure distribution over a body
and the friction between the fluid and
the body
- + pressure drag and friction drag

COMPONENTS OF DRAG

× Friction Drag

- + Due to the viscosity of a fluid...the resistance of a fluid to flow
- + The frictional force between a fluid and a solid boundary is based on the product of shear stress, τ , and surface area, S , where $\tau = \mu \, du/dy$ for a Newtonian fluid

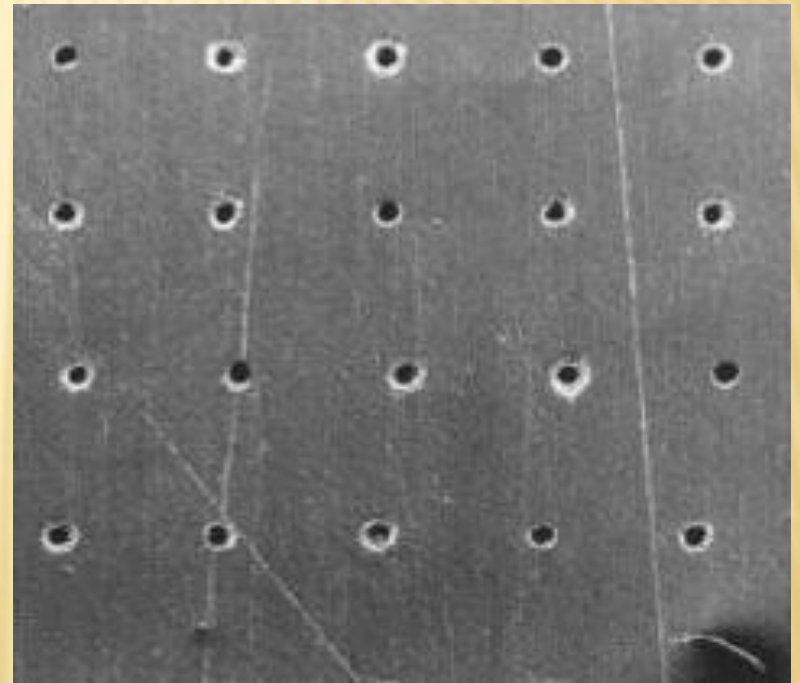
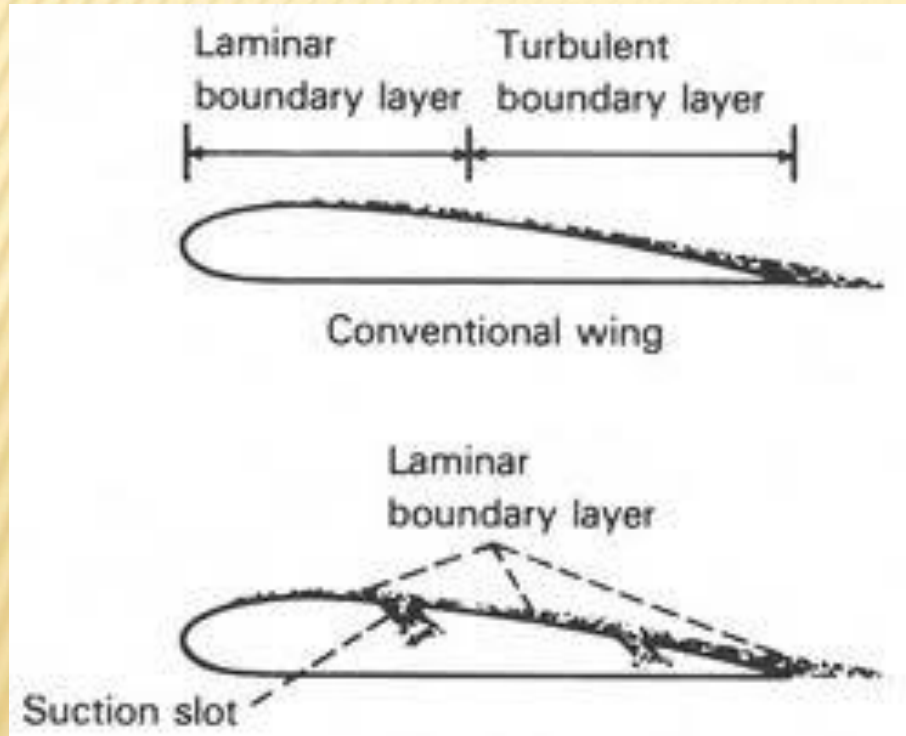


Generally,
 $(du/dy)_{\text{turbulent}} > (du/dy)_{\text{laminar}}$
and $\tau_{\text{turbulent}} > \tau_{\text{laminar}}$

FRICTION (VISCOUS) DRAG REDUCTION

✖ Applications

+ Aerodynamics of LFC Airfoils



Surface Suction Orifices

F-16XL WITH TITANIUM GLOVE USED TO INVESTIGATE LAMINAR-FLOW CONTROL



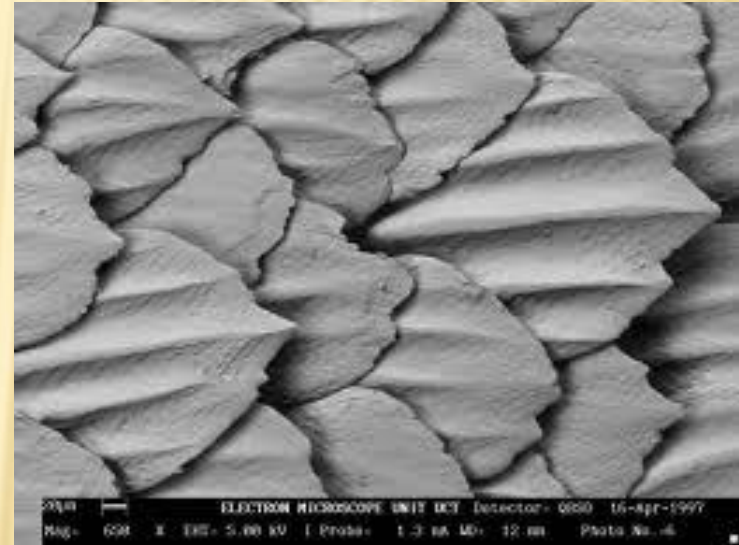
FRICTION (VISCOUS) DRAG REDUCTION

✕ Applications

+ Biofluidmechanics



Shark!



Surface Denticles

NEW SPEEDO SWIMSUIT



Speedo's new swimsuit being tested...the maker says the suit works like a shark's skin to aid hydrodynamics. Several materials tested in a wind tunnel at NASA Langley by an aerospace engineer.

SPEEDO'S FASTSKIN REDUCES DRAG BY 3%

Swimwear's new sleek design

Think of a shark and how efficiently it moves through the water. Speedo took a cue from nature and designed its Fastskin swimsuit to channel water away and reduce drag similar to a shark's skin.

How it works

Water doesn't adhere to the suit. The v-shaped ridges cause vortices of water to spiral off and flow away from the swimmer.

The fabric holds the body in, reducing muscle vibration which reduces fatigue.

Seams crisscross the suit and hug body contours. Each 1-inch length of seam contains 52 inches of thread.



Chevron-shaped panels in the fabric stretch.

Made of Lycra and polyester.



The long-sleeve version

A tight mesh fabric (without ridges) runs inside the arm from wrist to just under the armpit. Water can permeate the mesh so the swimmer gets a better feel for the water and can moderate his or her stroke accordingly.

COMPONENTS OF DRAG

× Pressure Drag

- + Due to the pressure distribution around a body
- + Pressure drag is reduced by streamlining a body
- + Blunt bodies experience high levels of pressure drag

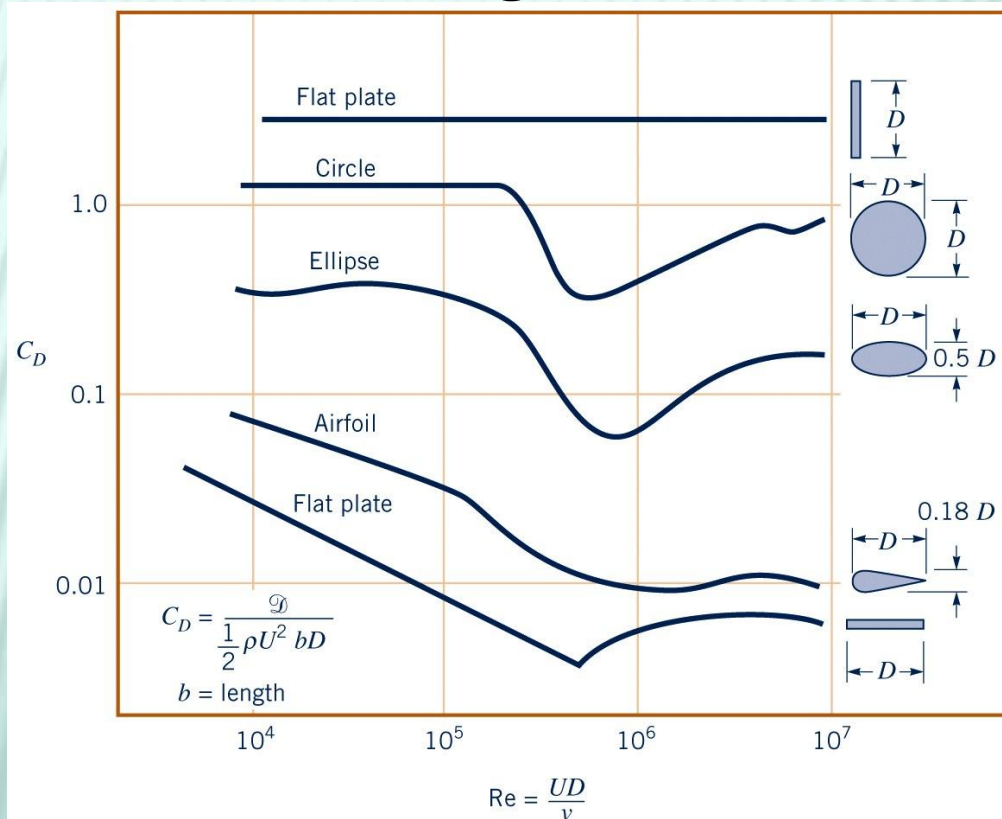


Figure 9.22
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PRESSURE DRAG REDUCTION

✖ Applications

+ Ground Vehicles



MAN/Krone Furturistic
Streamlined Truck



Conventional Truck
with Flow Deflector
and Gap Seal

PRESSURE DRAG REDUCTION

✖ Applications

+ Sports Aerodynamics – why does a golf ball have dimples?

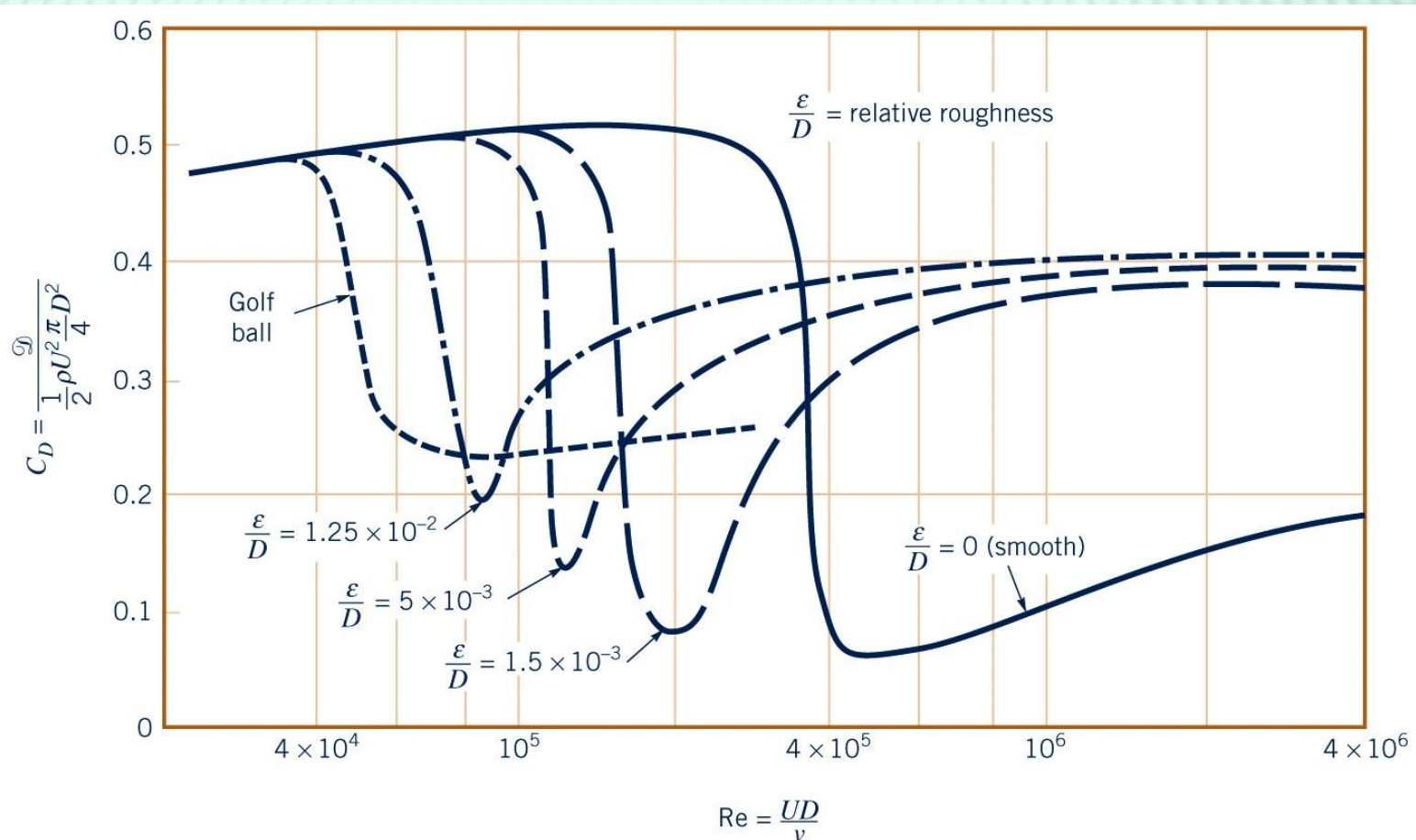


Figure 9.25

CYLINDERS IN CROSSFLOW

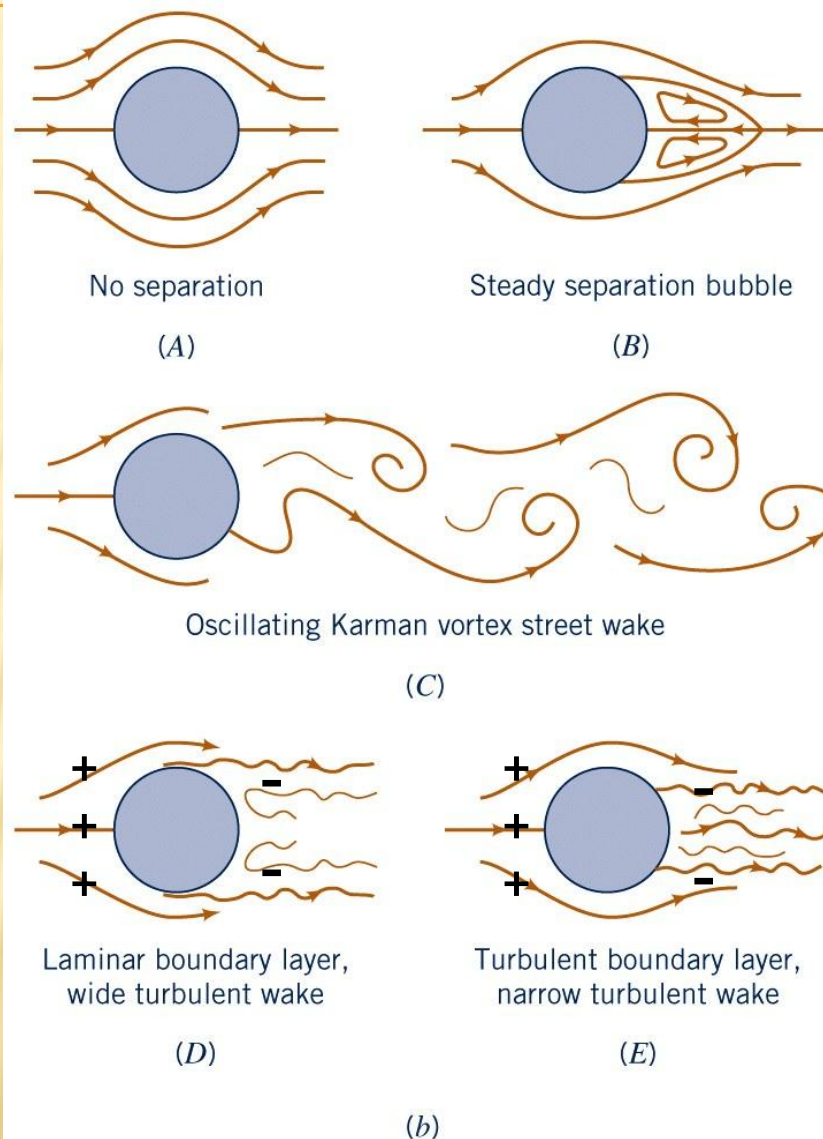
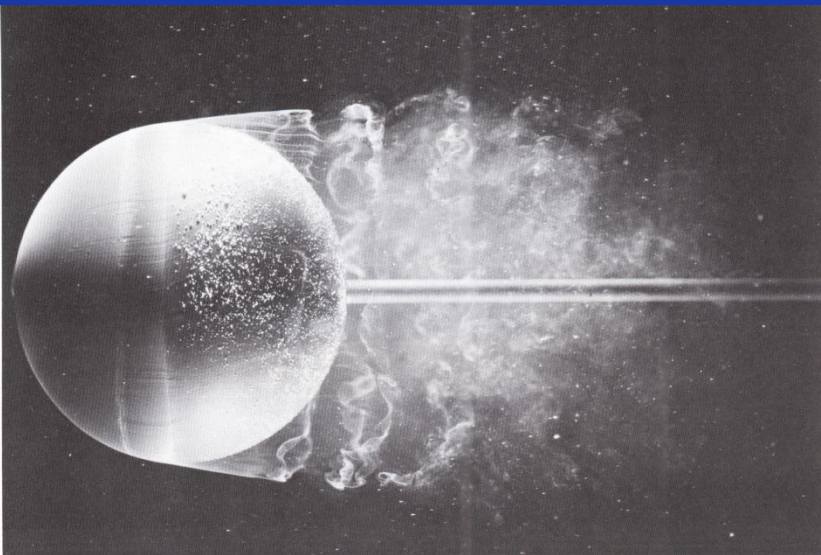


Figure 9.21b

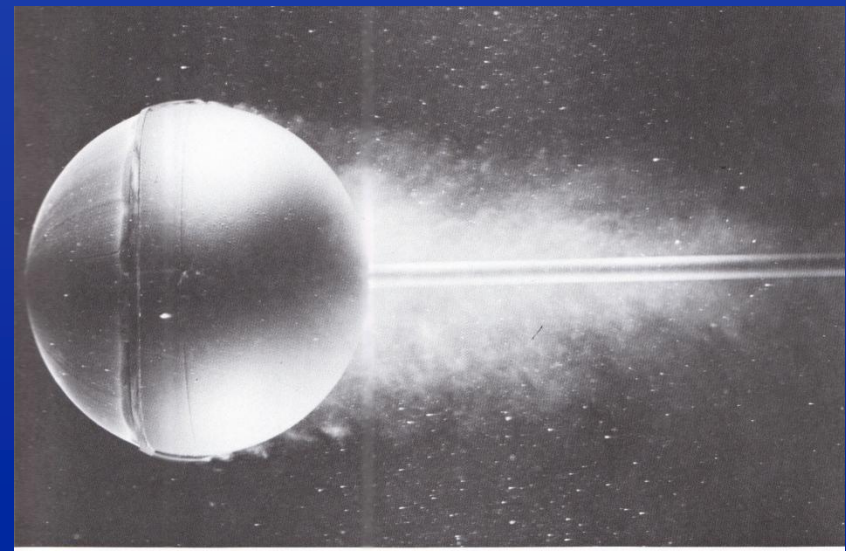
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Flow Visualization of Dye Flow Past a Stationary Sphere



Laminar Flow, $Re=15,000$

Turbulent Flow (trip wire),
 $Re=30,000$



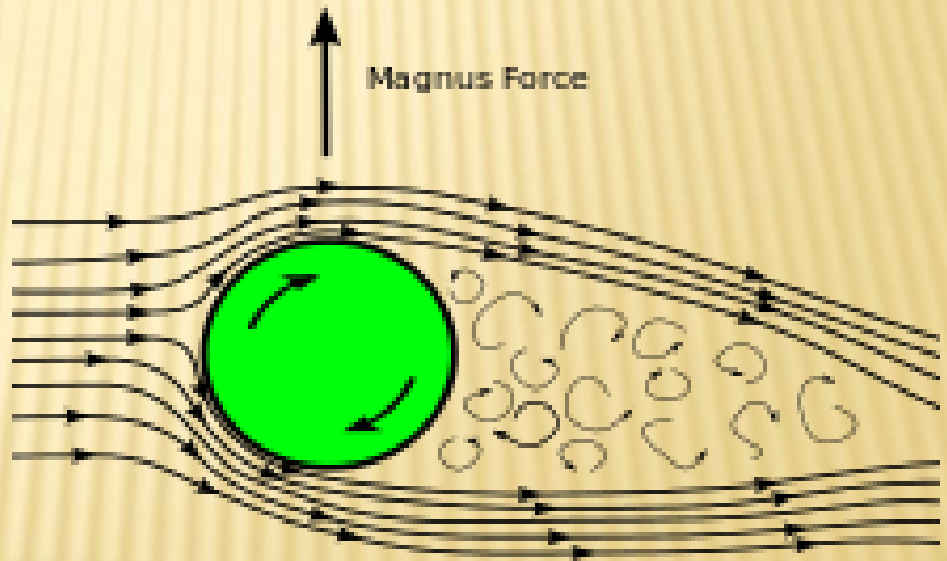
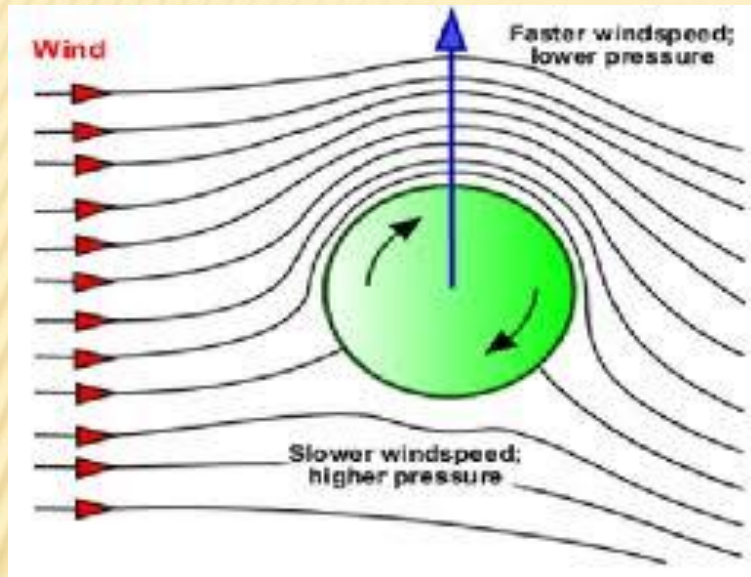
(Onera, Werle 1980)

PRESSURE DRAG REDUCTION

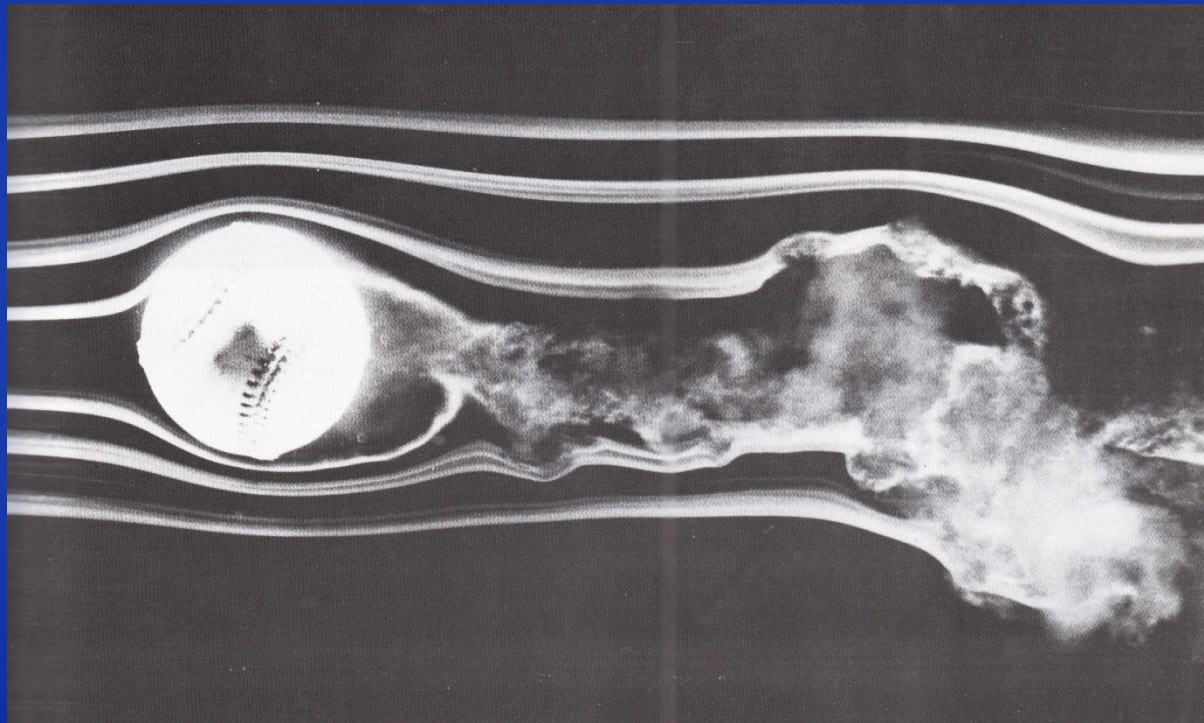
Why does a curveball curve? Why does a knuckleball move erratically?



MAGNUS FORCE ON A SPINNING BALL



Flow Visualization of Smoke Flow Past a Spinning Baseball

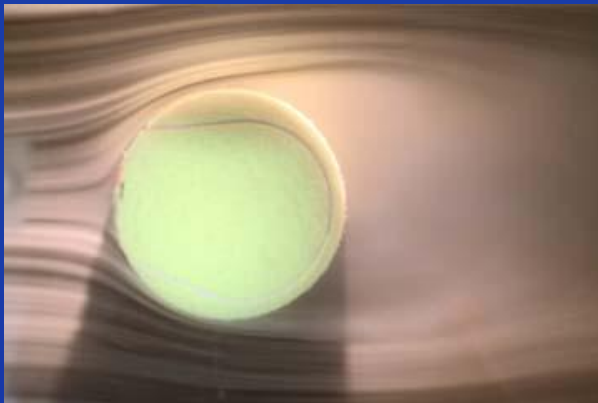


$$V = 77 \text{ ft/s}, \omega = 630 \text{ rpm}$$

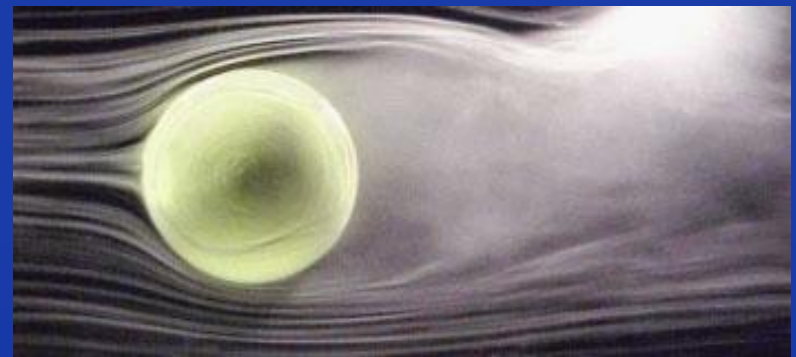
(Univ. Notre Dame, Brown 1971)

Flow Visualization of Smoke Flow Past a Tennis Ball at $Re=167,000$

Why does a tennis ball have fuzz?



Stationary



Spinning (CCW)

(NASA Ames 2008)

LIFT COEFFICIENT VS. ANGULAR VELOCITY

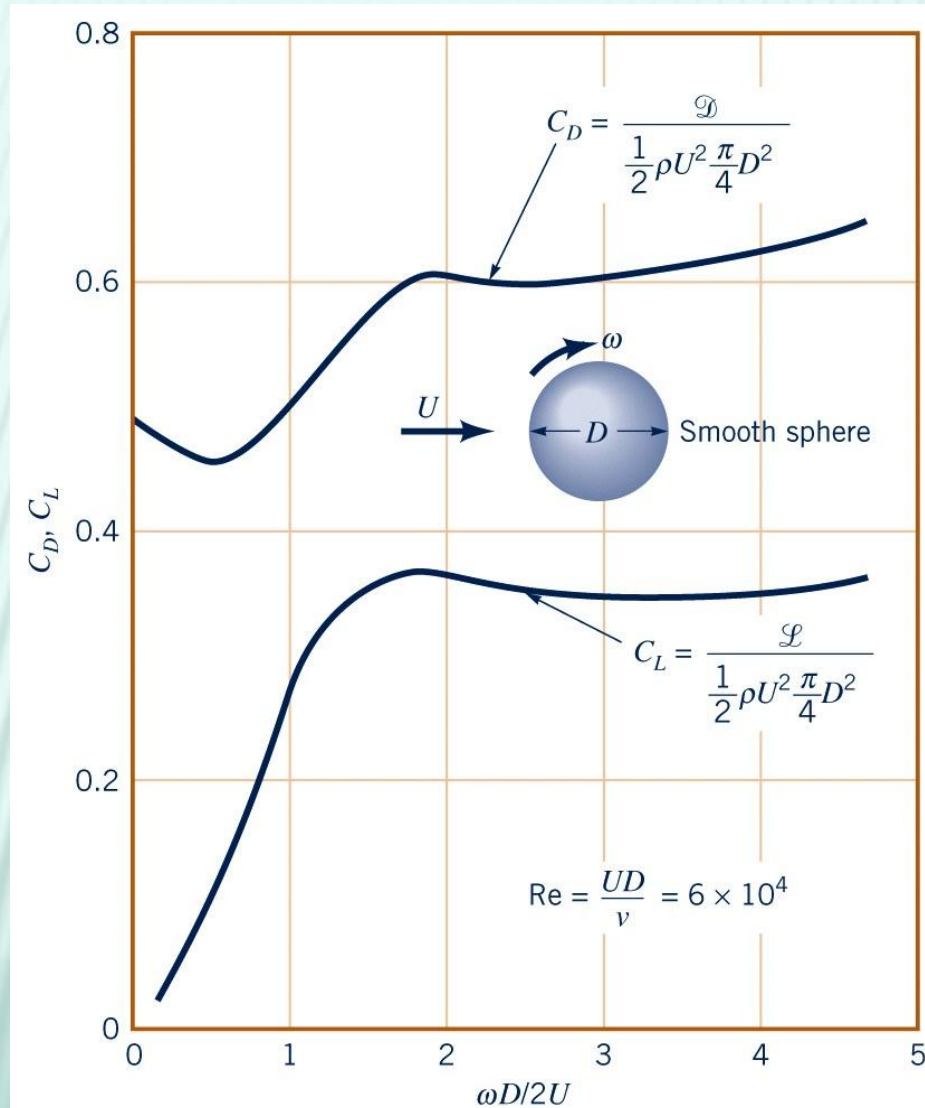
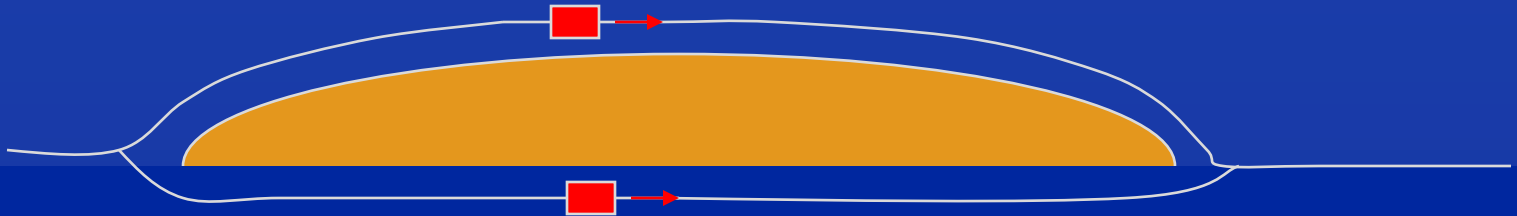


Figure 9.39

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The Bernoulli Principle

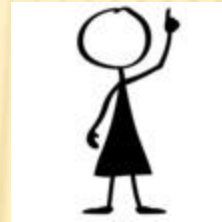
✎ The Bernoulli Principle helps explain how airplanes fly and the Magnus force



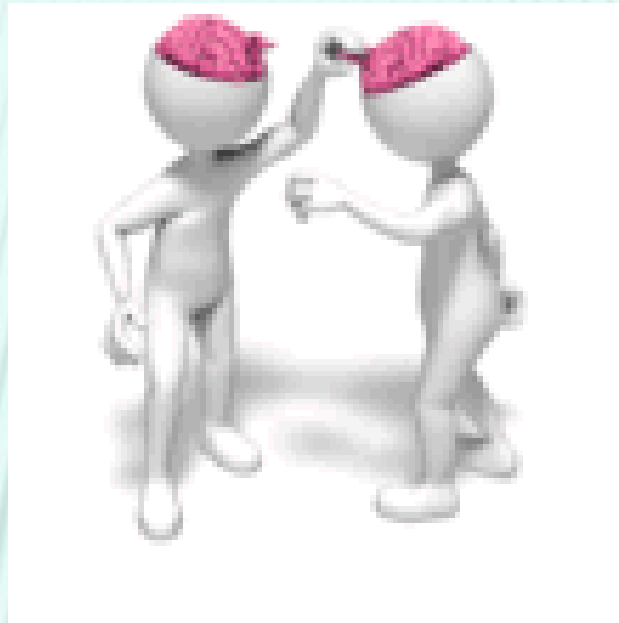
✎ The Bernoulli Principle states that the faster the flow, the lower the pressure, since

$$P + \frac{1}{2} \rho V^2 + \gamma Z = \text{const.}$$

DEMONSTRATION: THE BERNOULLI PRINCIPLE



QUESTIONS? QUESTIONS? QUESTIONS?



References

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