FLUID MECHANICS OF EXTERNAL FLOWS

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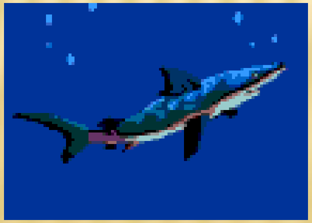
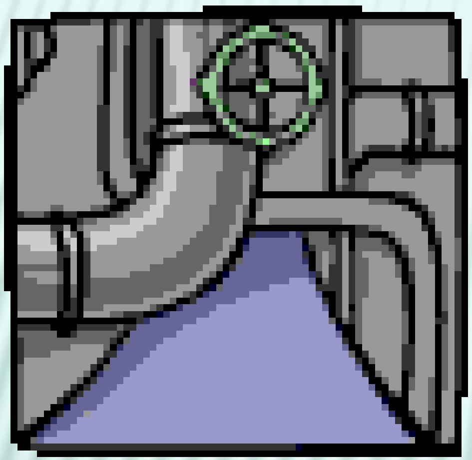
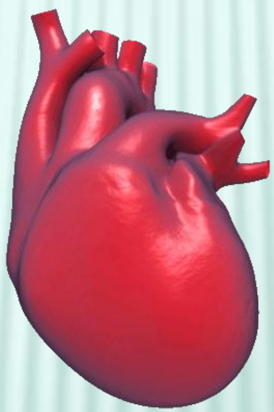


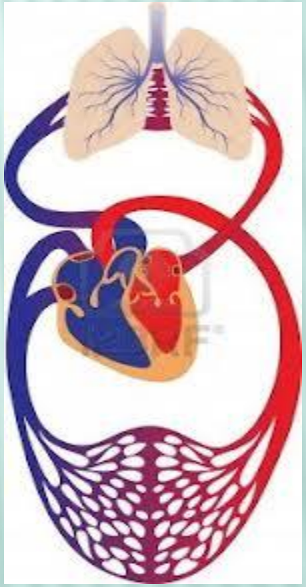
INTERNAL VS. EXTERNAL FLOWS

Internal Flow (flow through/in geometry):
Flow bounded on all sides by a solid surface



Flow in Pipes and Ducts



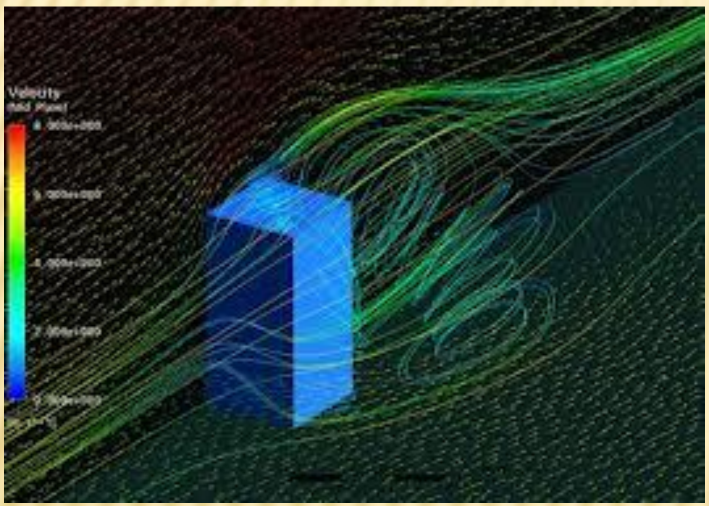


Flow in the Human Circulatory System

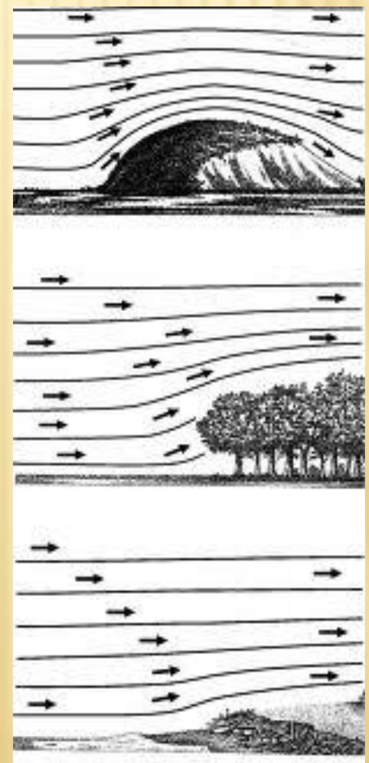
INTERNAL VS. EXTERNAL FLOWS

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

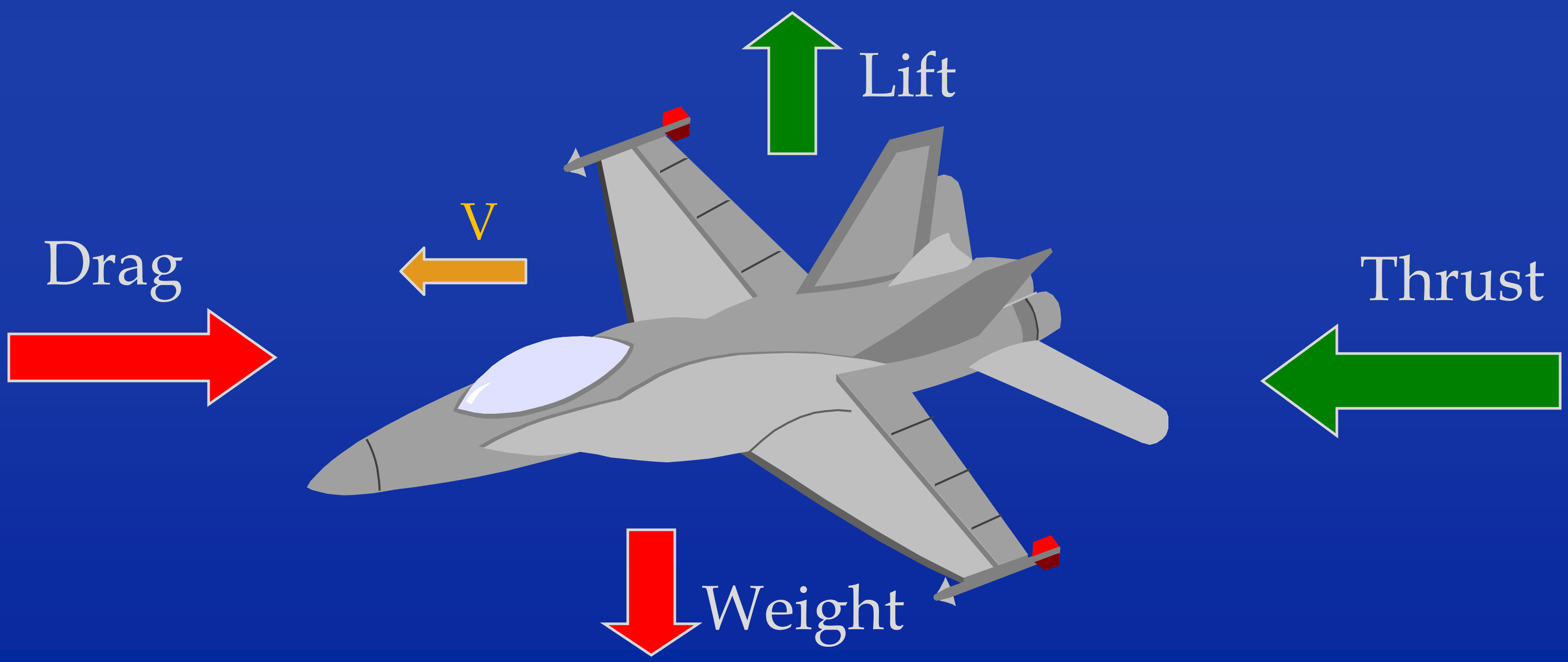
Flow over Aircraft and Marine Craft

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

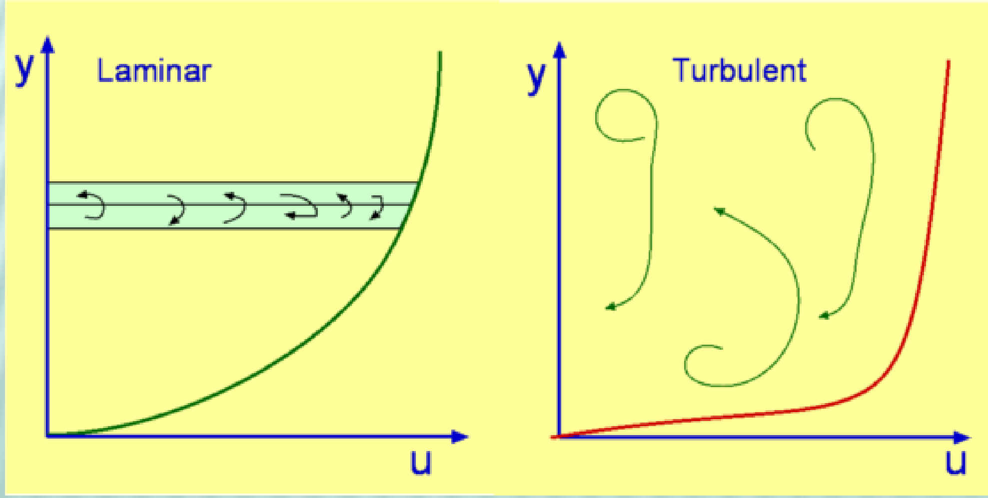
- Two main sources of drag are:

  the pressure distribution over a body and the friction between the fluid and the body

  - pressure drag and friction drag

COMPONENTS OF DRAG

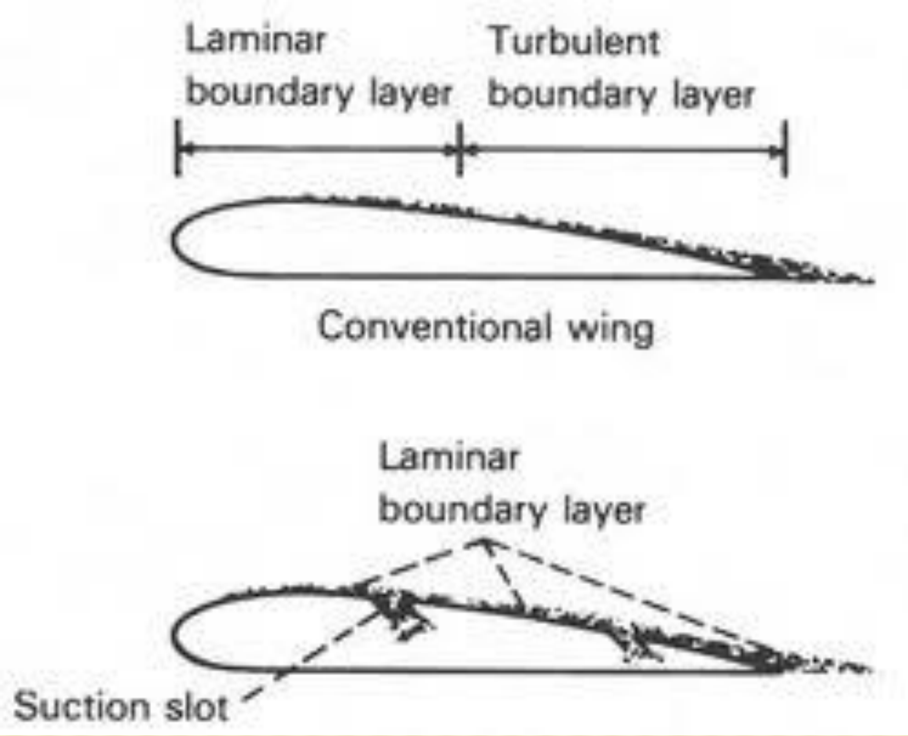
- Friction Drag
  - Due to the viscosity of a fluid…the resistance of a fluid to flow
  - The frictional force between a fluid and a solid boundary is based on the product of shear stress, τ, and surface area, S, where
    $\tau = \mu \, du/dy$ for a Newtonian fluid

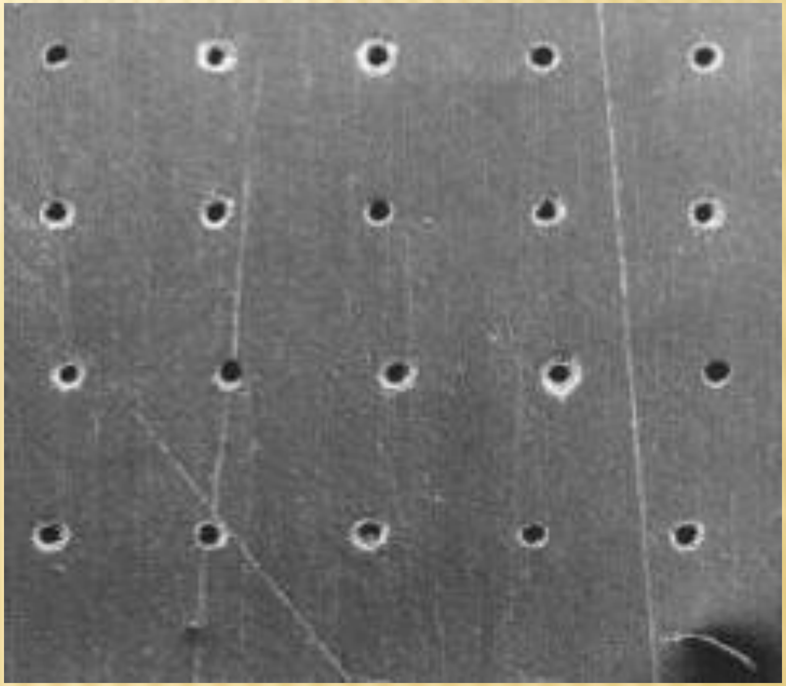


Generally,
$(du/dy)_{turbulent} > (du/dy)_{laminar}$
and $\tau_{turbulent} > \tau_{laminar}$

FRICTION (VISCOUS) DRAG REDUCTION

- Applications
  - Aerodynamics of LFC Airfoils





Surface Suction Orifices

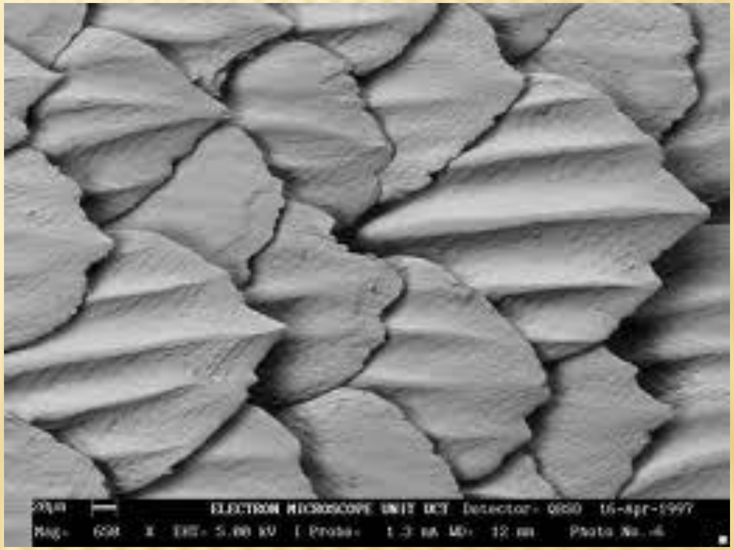
F-16XL WITH TITANIUM GLOVE USED TO INVESTIGATE LAMINAR-FLOW CONTROL

NASA Dryden Research Center

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%

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

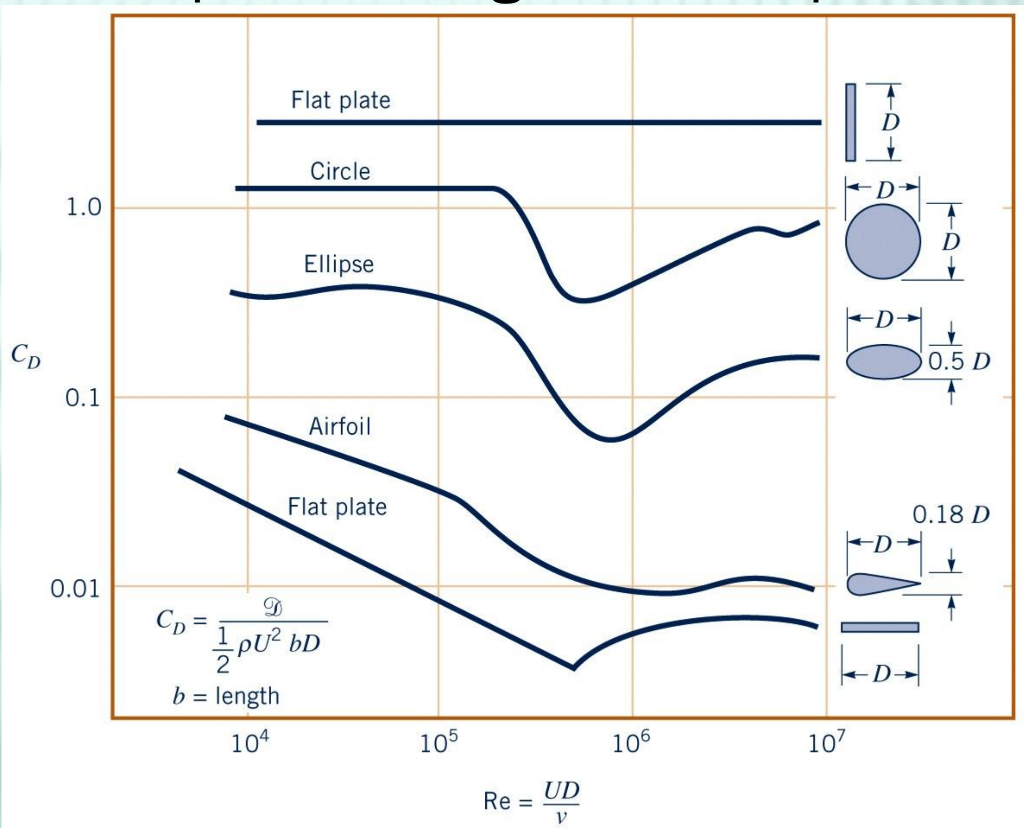


Figure 9.22

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?

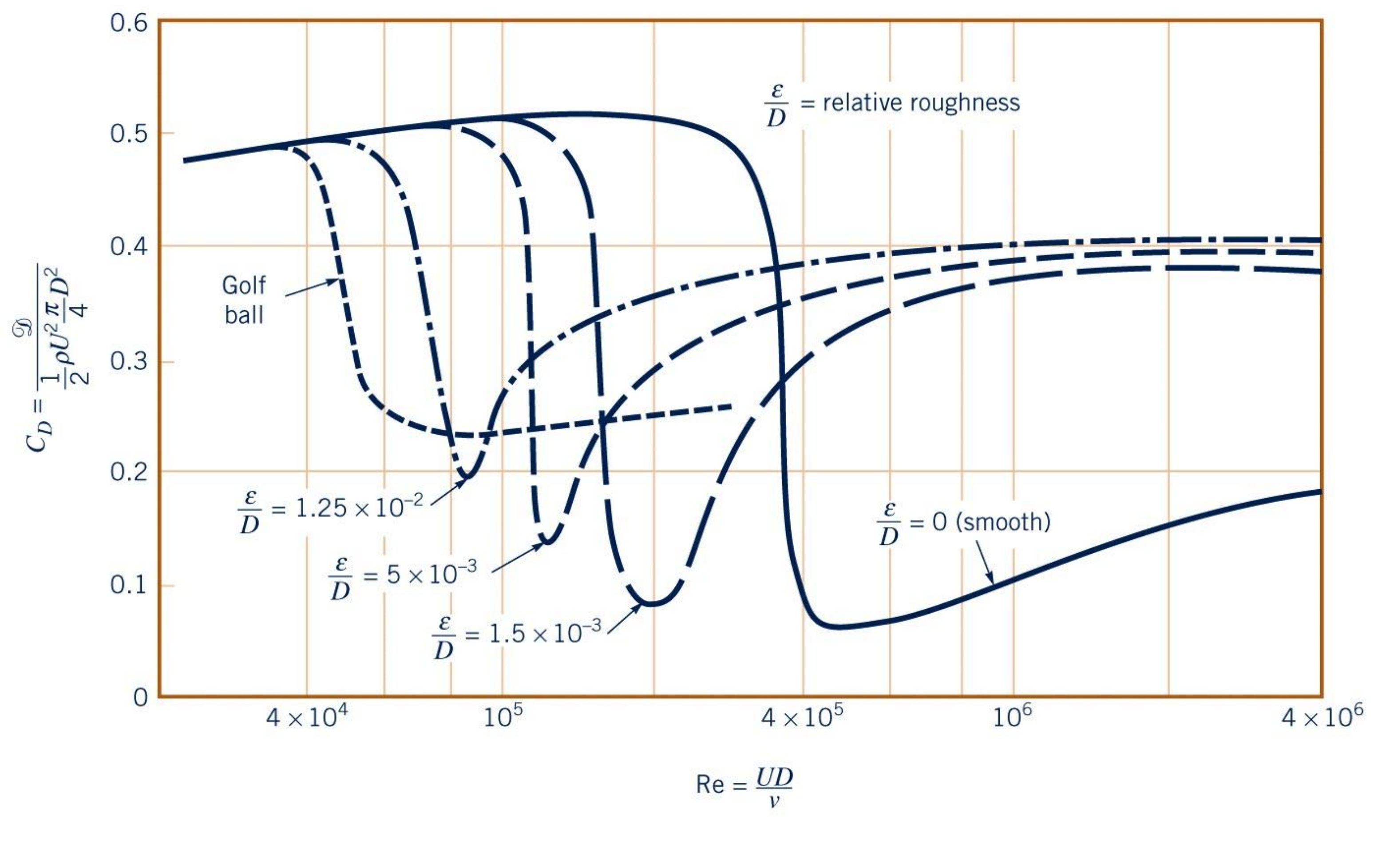


Figure 9.25

CYLINDERS IN CROSSFLOW

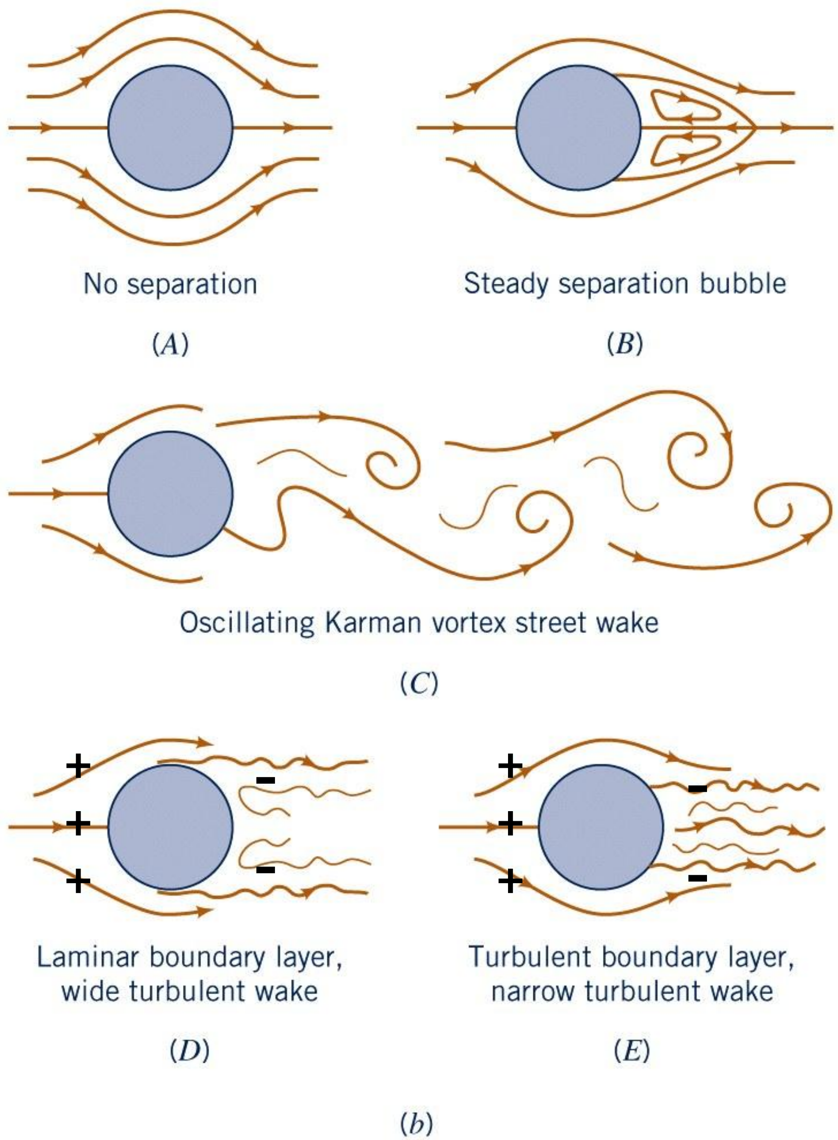
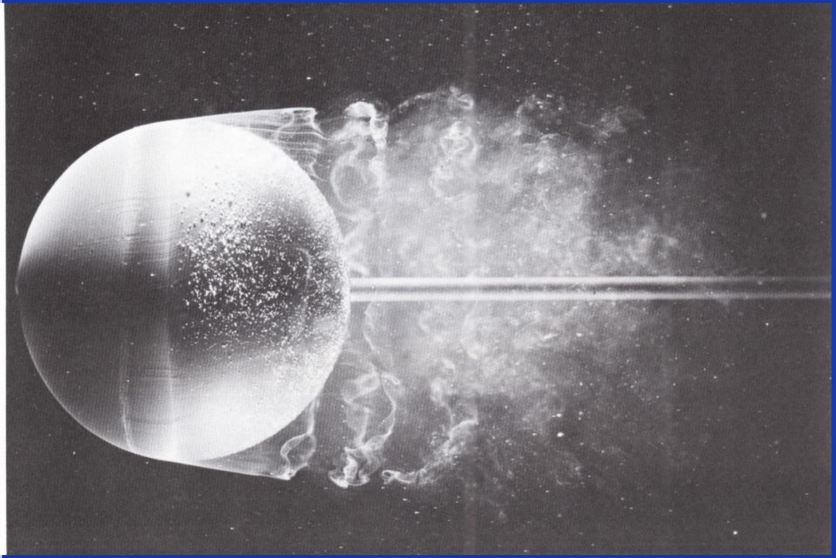


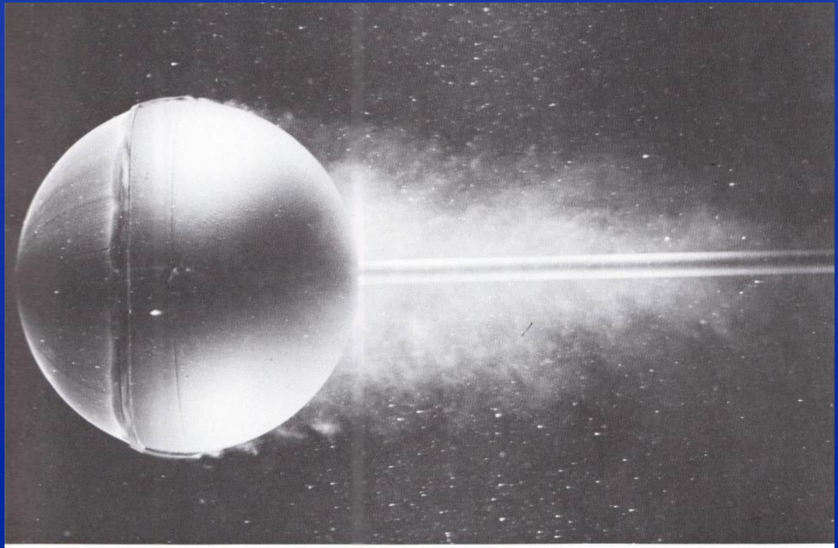
Figure 9.21b

Flow Visualization of Dye Flow Past a Stationary Sphere



Laminar Flow, Re=15,000

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

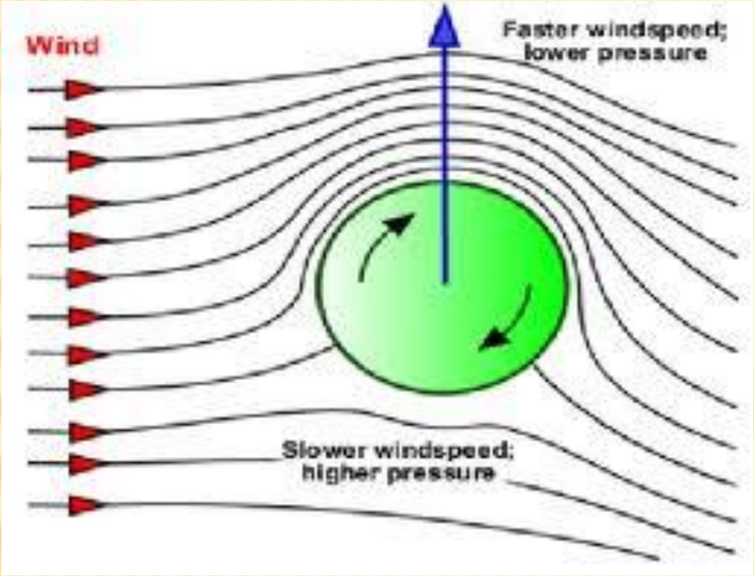


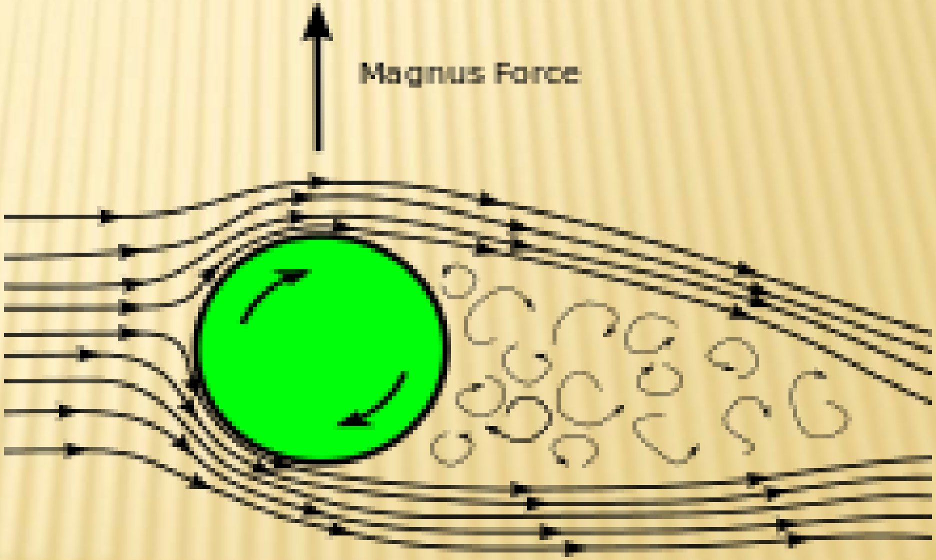
(Onera, Werle 1980)

PRESSURE DRAG REDUCTION

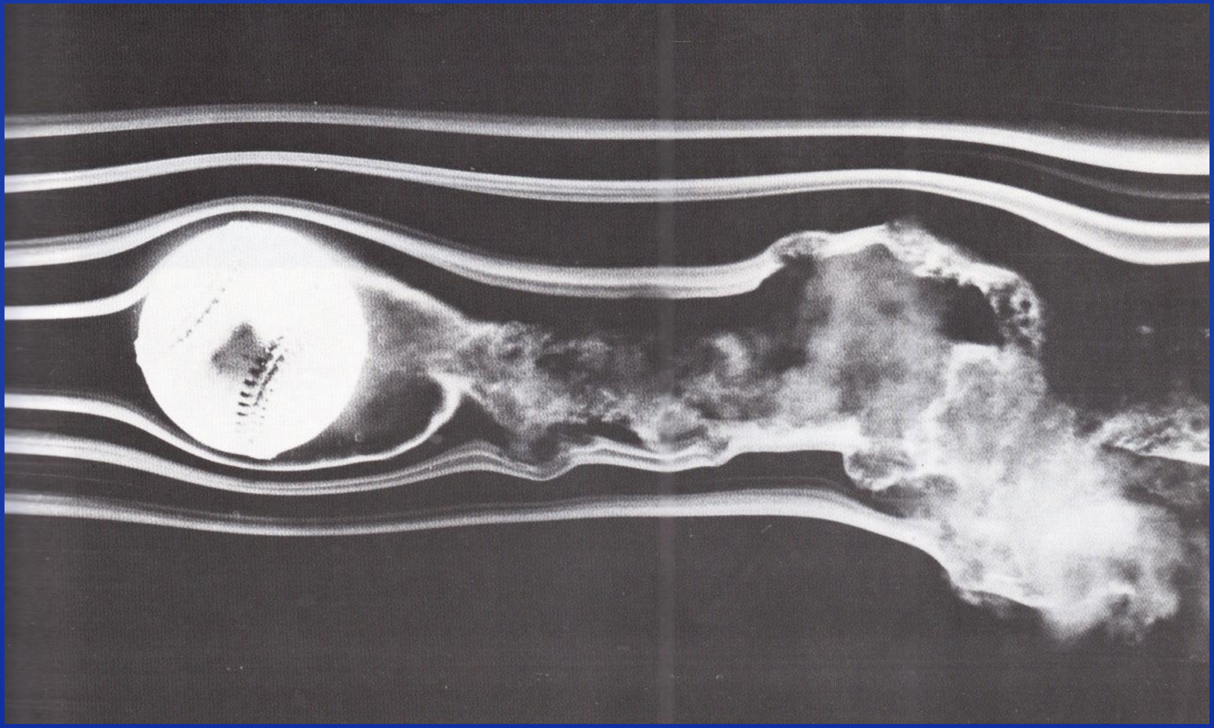
Why does a curveball curve? Why does a knuckleball move erratically?

MAGNUS FORCE ON A SPINNING BALL





Flow Visualization of Smoke Flow Past a Spinning Baseball

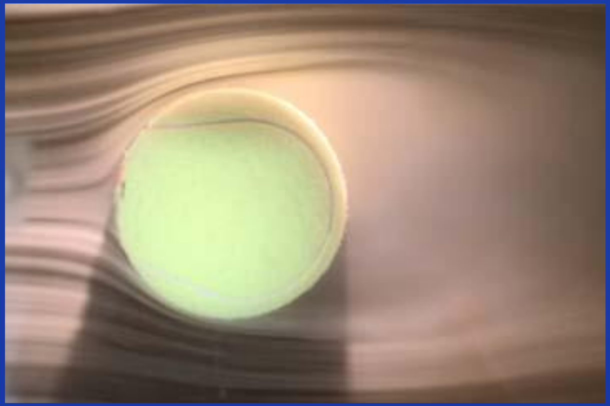


V = 77 ft/s, ω = 630 rpm

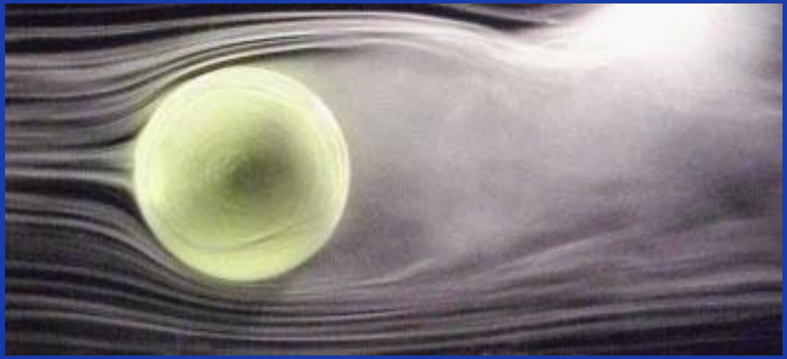
(Univ. Notre Dame, Brown 1971)

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

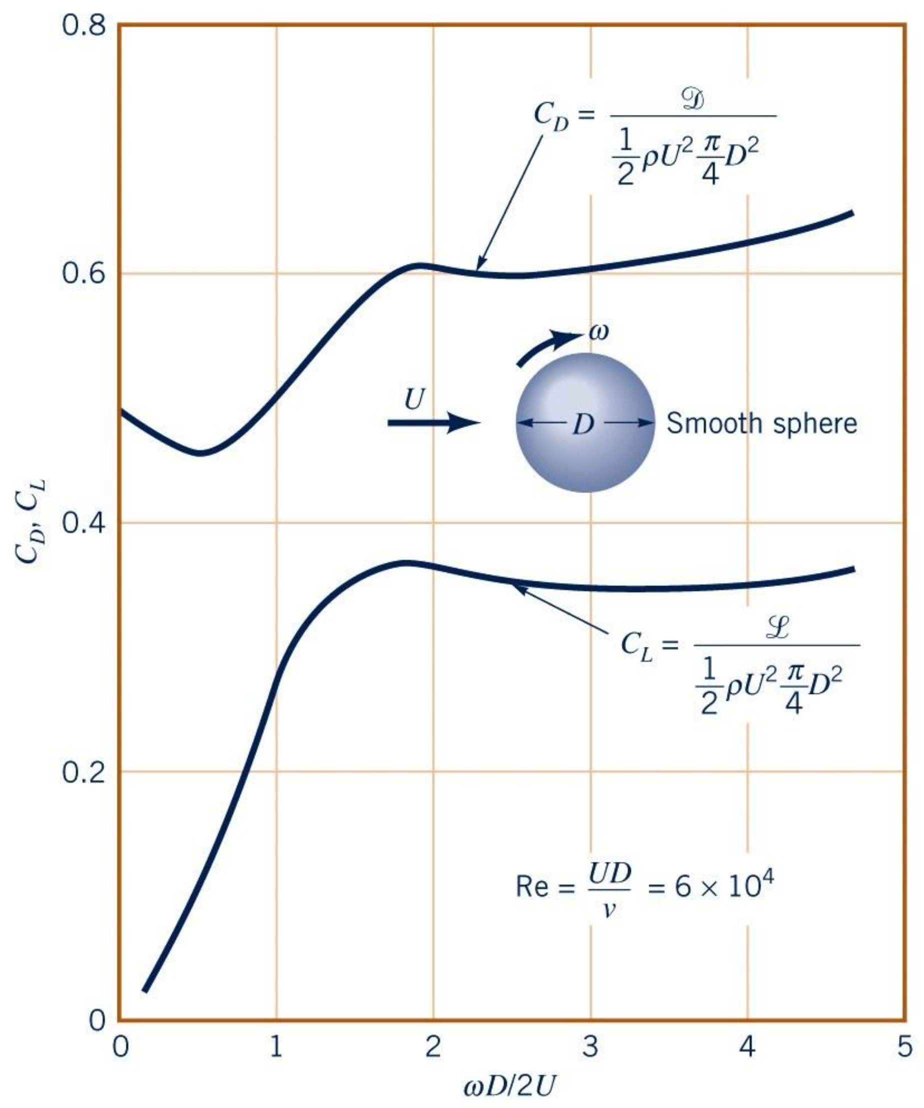
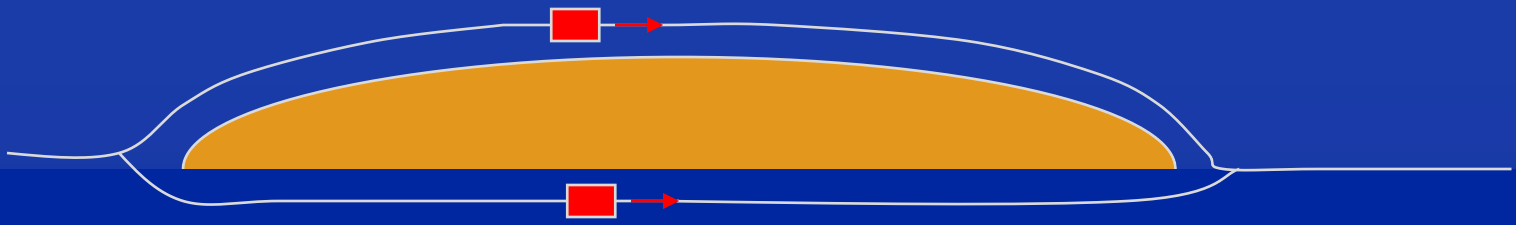


Figure 9.39

The Bernoulli Principle

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

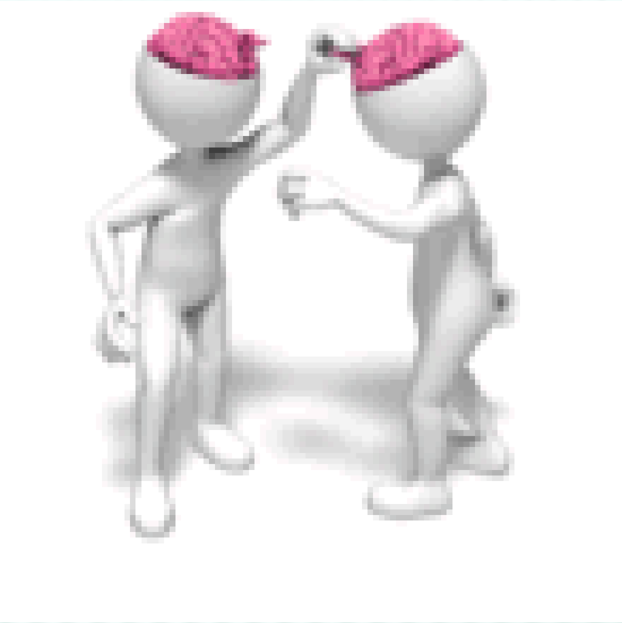


- The Bernoulli Principle states that the faster the flow, the lower the pressure, since

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

DEMONSTRATION: THE BERNOULLI PRINCIPLE

QUESTIONS? QUESTIONS? QUESTIONS?



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