제 1 강

부록 A1 : 물리학 배경지식
제 1 장 : 서론

삼성중공업 계약학과 선체저항

2013년도 봄학기

(2013. 3. 4)

담당교수 : 이 인 원

Fluid Mechanics ?

- **Everything flows, nothing stand still.**
  - Heraclitus (Greek Philosopher, 535~475 B.C.)

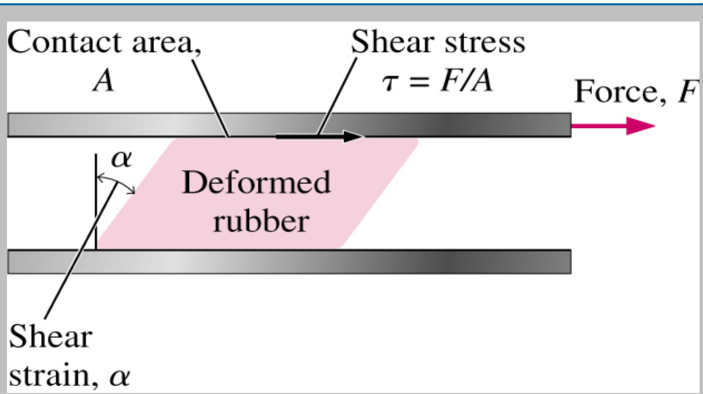
- **다음 방정식은 같은가, 다른가?**
  - Dynamics : $\vec{F} = m\vec{a}$
  - Solid Mechanics : $\frac{\partial \sigma_{xx}}{\partial x} + \frac{\partial \sigma_{yx}}{\partial y} + \frac{\partial \sigma_{zx}}{\partial z} = 0$
  - Fluid Mechanics : $\rho \frac{D\vec{V}}{Dt} = -\nabla p + \rho \vec{g} + \mu \nabla^2 \vec{V}$

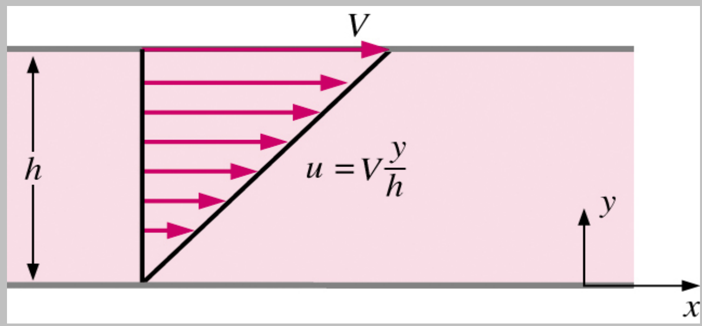
What is a fluid?

- **A fluid is a substance in the gaseous or liquid form**
- **Distinction between solid and fluid?**
  - Solid: can resist an applied shear by deforming. Stress is proportional to strain
  - Fluid: deforms continuously under applied shear. Stress is proportional to strain rate

Solid

$$\tau = \frac{F}{A} \propto \alpha$$

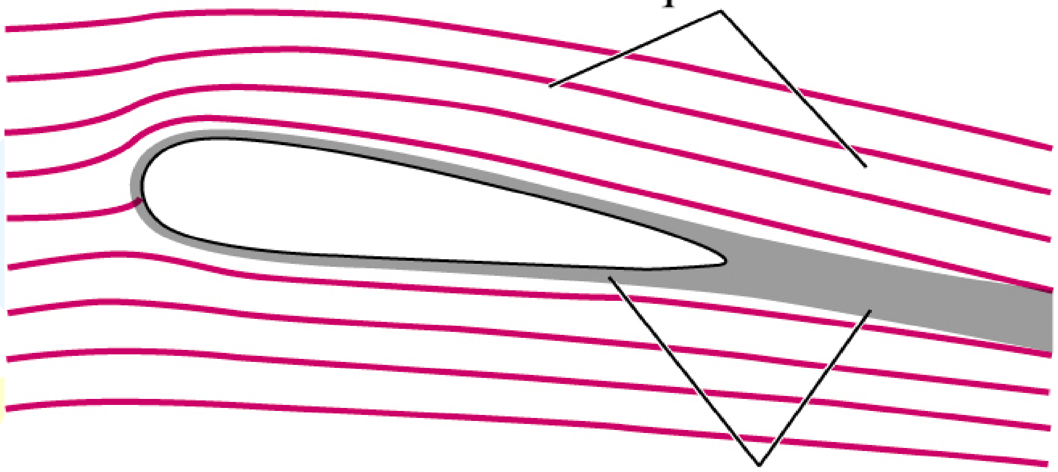




Fluid

$$\tau = \frac{F}{A} \propto \mu \frac{V}{h}$$

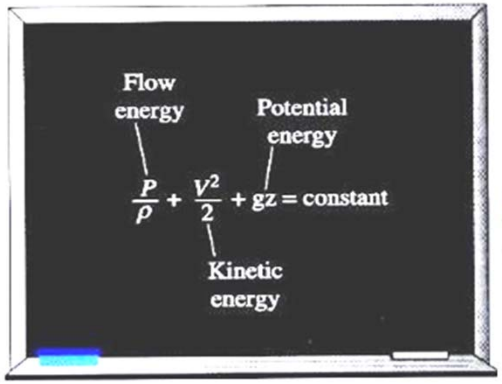
5.4 The Bernoulli Equation



- **The Bernoulli equation is an *approximate relation between pressure, velocity*, and *elevation and is valid in regions of steady, incompressible flow where net frictional forces are negligible.***
- **Equation is useful in flow regions outside of boundary layers and wakes.**

5.4 The Bernoulli Equation

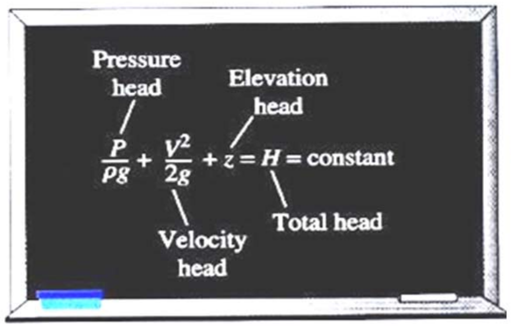
- **Interpretation of Bernoulli Equation**
  - Energy point of view : Conservation of mechanical energy
  - Pressure point of view : Conversion between static – dynamic – hydrostatic pressure
  - Head point of view : Conversion between pressure – velocity – elevation head



$$\frac{P}{\rho} + \frac{V^2}{2} + gz = C$$

그림 5-25
Bernoulli 방정식은 정상유동에서 유선을 따라 유체입자의 운동에너지, 위치에너지, 및 유동에너지의 합은 일정하다는 것을 나타내는 식이다.

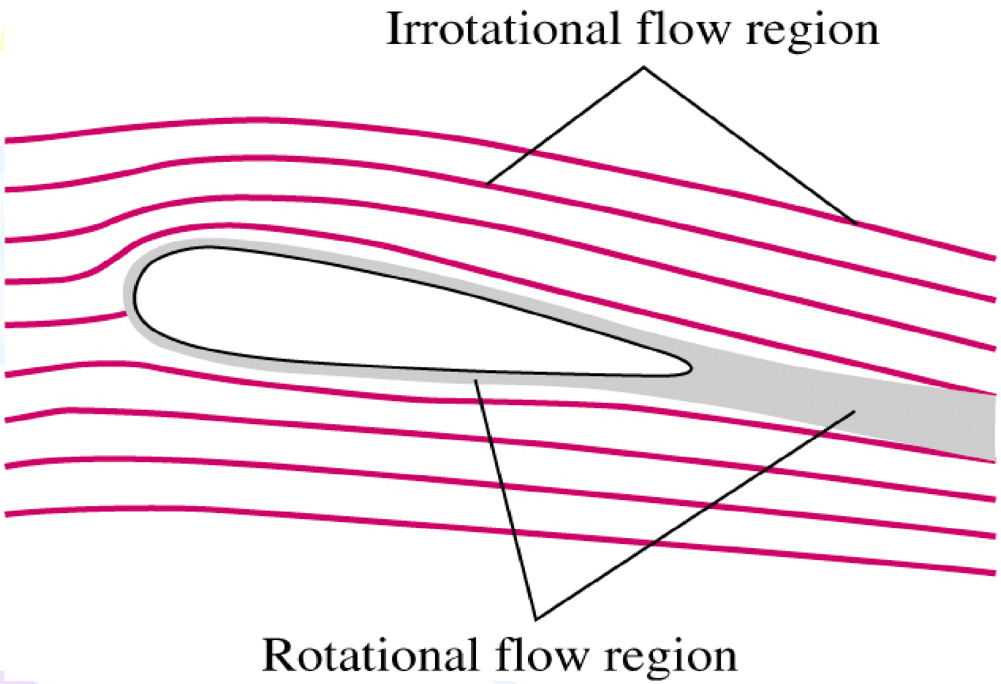
$$P + \frac{\rho V^2}{2} + \rho g z = C$$



$$\frac{P}{\rho g} + \frac{V^2}{2g} + z = H$$

그림 5-33
수두로 표현한 다른 형태의 Bernoulli 방정식은 다음의 의미를 갖는다: 동일한 유선을 따라 압력수두, 속도수두, 및 위치수두의 합은 일정하다.

10-5 Irrotational Flow Approximation

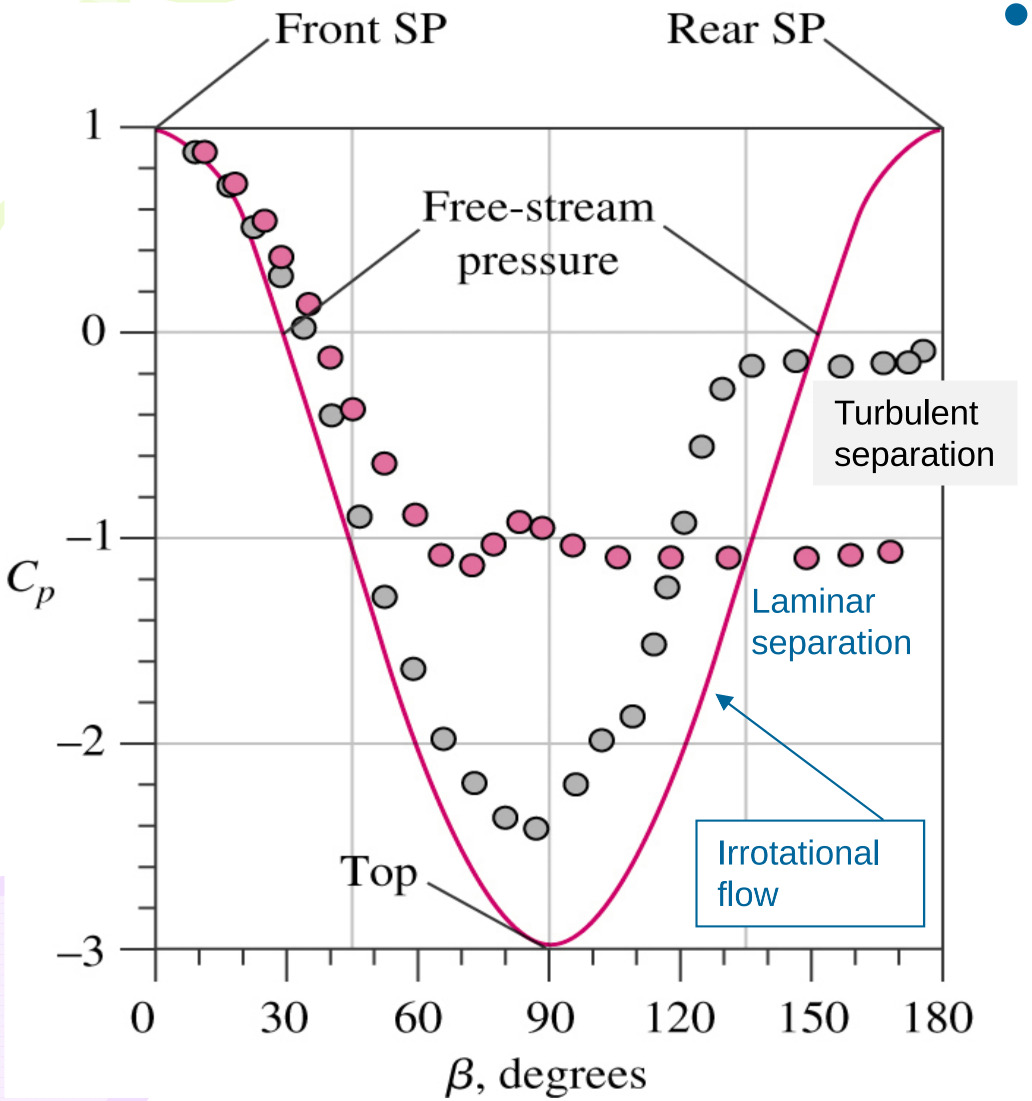


- **Irrotational approximation: vorticity is negligibly small**

$$\vec{\zeta} = \nabla \times \vec{V} \cong 0$$

- **In general, inviscid regions are also irrotational, but there are situations where inviscid flow are rotational, e.g., solid body rotation (Ex. 10-3)**

10-5 Examples of Superposition



- **Compute pressure using Bernoulli equation and velocity on cylinder surface**

$$\frac{P}{\rho}+\frac{V^2}{2}=\frac{P_\infty}{\rho}+\frac{V_\infty^2}{2}$$

$$C_P=\frac{P-P_\infty}{\frac{1}{2}\rho V_\infty^2}=1-\frac{V^2}{V_\infty^2}$$

$$V^2=U_r^2+U_\theta^2=0^2+(2V_\infty\sin\theta)^2=4V_\infty^2\sin^2\theta$$

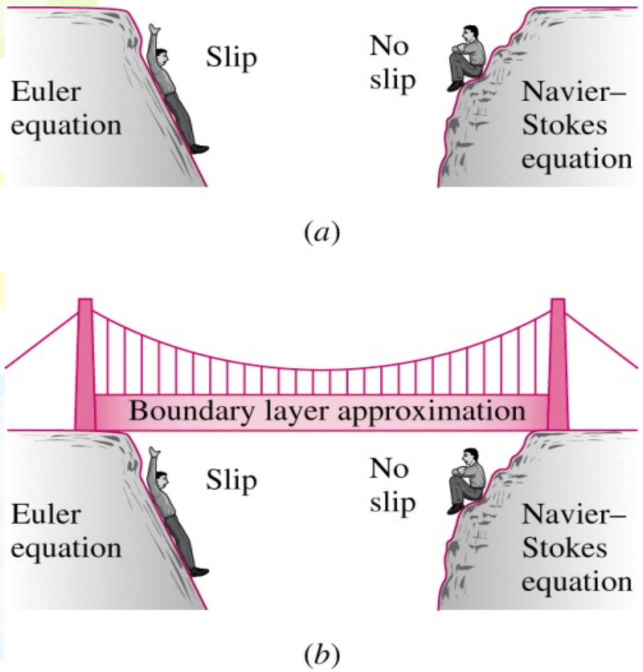
$$C_P=1-4\sin^2\theta=1-4\sin^2\beta$$

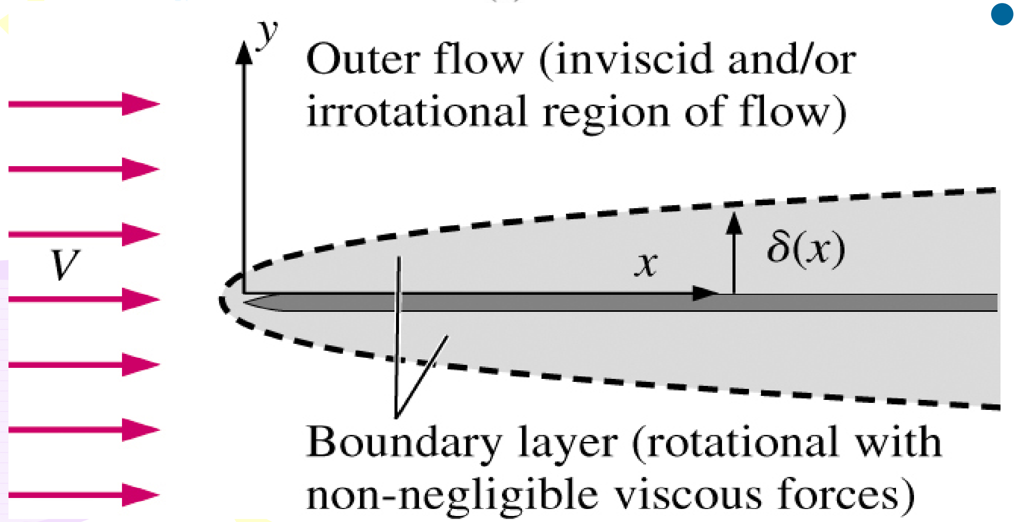
$$\beta=\pi-\theta$$

10-5 Examples of Superposition

- ***D'Alembert's Paradox*** **: Integration of surface pressure (which is symmetric in x), reveals that the DRAG is ZERO.   not true !!!!**
  - For the irrotational flow approximation, the drag force on ***any*** non-lifting body of ***any*** shape immersed in a uniform stream is **ZERO.**
  - Why?
    - Viscous effects have been neglected. Viscosity and the no-slip condition are responsible for
      - Flow separation (which contributes to pressure drag)
      - Wall-shear stress (which contributes to friction drag)

10-7 Boundary Layer (BL) Approximation

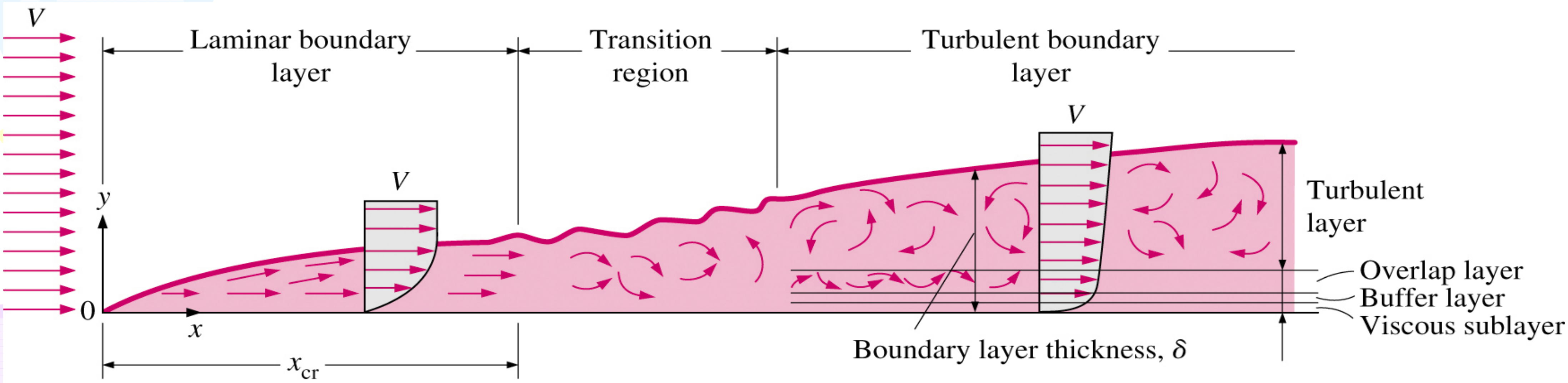




- **BL approximation bridges the gap between the Euler and NS equations, and between the slip and no-slip BC at the wall.**
- **Prandtl (1904) introduced the BL approximation**

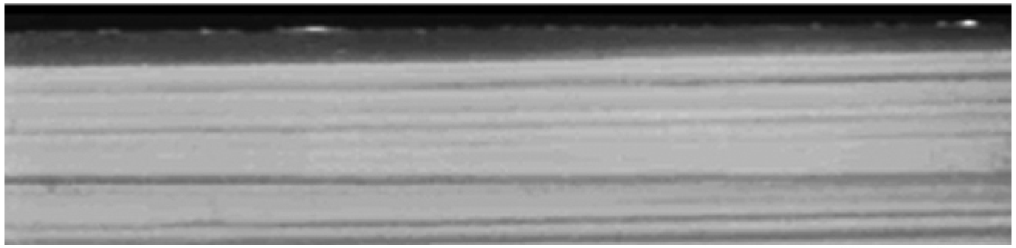
11-5 Flat Plate Drag

- **Drag on flat plate is solely due to friction created by laminar, transitional, and turbulent boundary layers.**

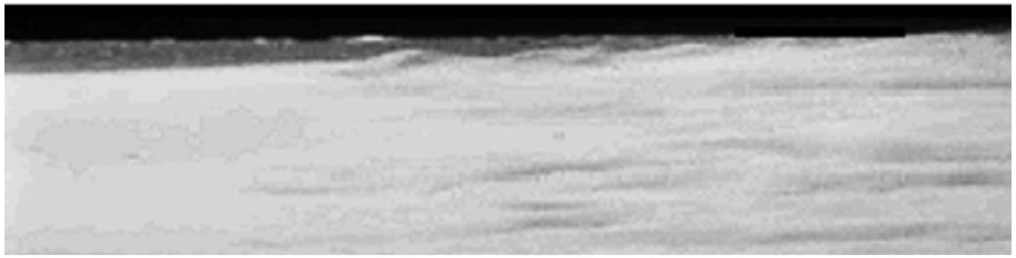


Laminar vs. Turbulent Flow

- **Laminar: highly ordered fluid motion with smooth streamlines.**
- **Turbulent: highly disordered fluid motion characterized by velocity fluctuations and eddies.**
- **Transitional: a flow that contains both laminar and turbulent regions**
- **Reynolds number, Re= $\rho UL/\mu$ is the key parameter in determining whether or not a flow is laminar or turbulent.**



Laminar



Transitional

Turbulent

10-7 Pressure Gradients

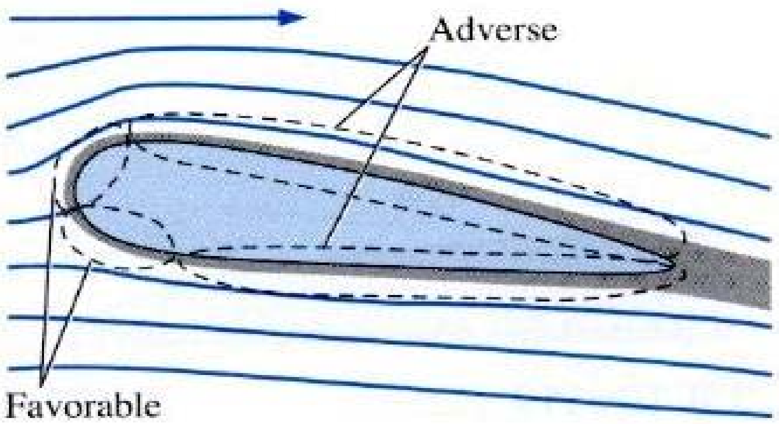
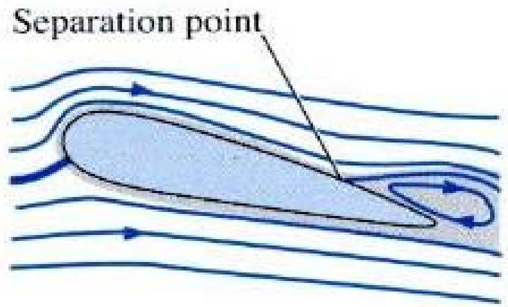
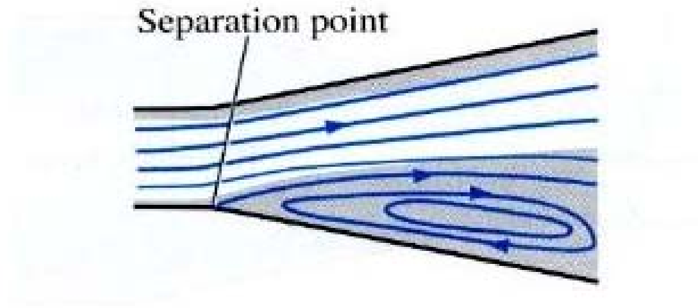


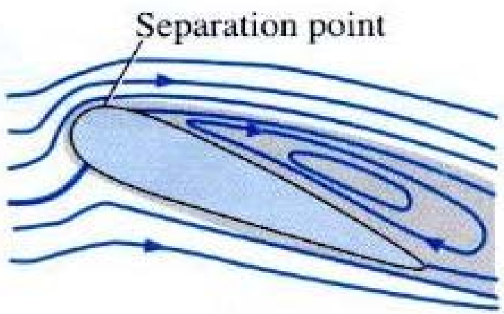
그림 10-121
자유유동에 노출된 물체 표면을 따라 생기는 경계층에서, 앞에서는 순압력 구배, 뒤에서는 역압력 구배가 나타난다.



(*a*)



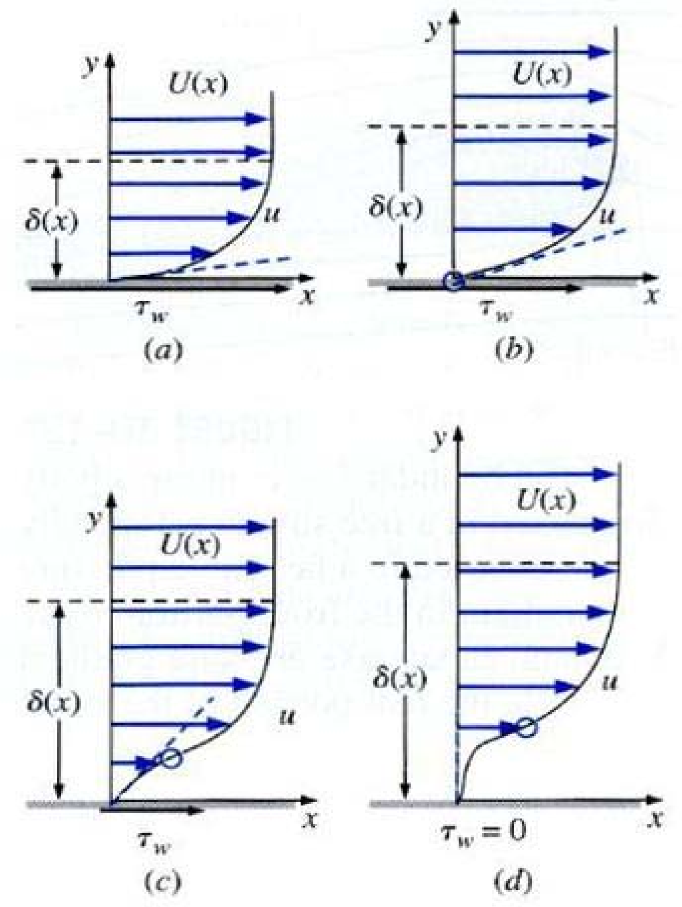
(*c*)



(*b*)

그림 10-122
역 압력 구간에서 박리되는 경계층의 예: (*a*) 일반적인 영각의 비행기 날개 (*b*) 높은 영각을 갖는 동일한 비행기 날개 (*c*) 넓은 각을 가진 디퓨저에서는 경계층이 부착되지 못하고 박리된다.

10-7 Pressure Gradients



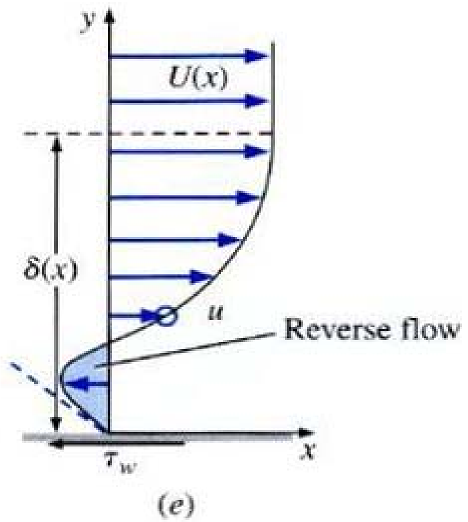
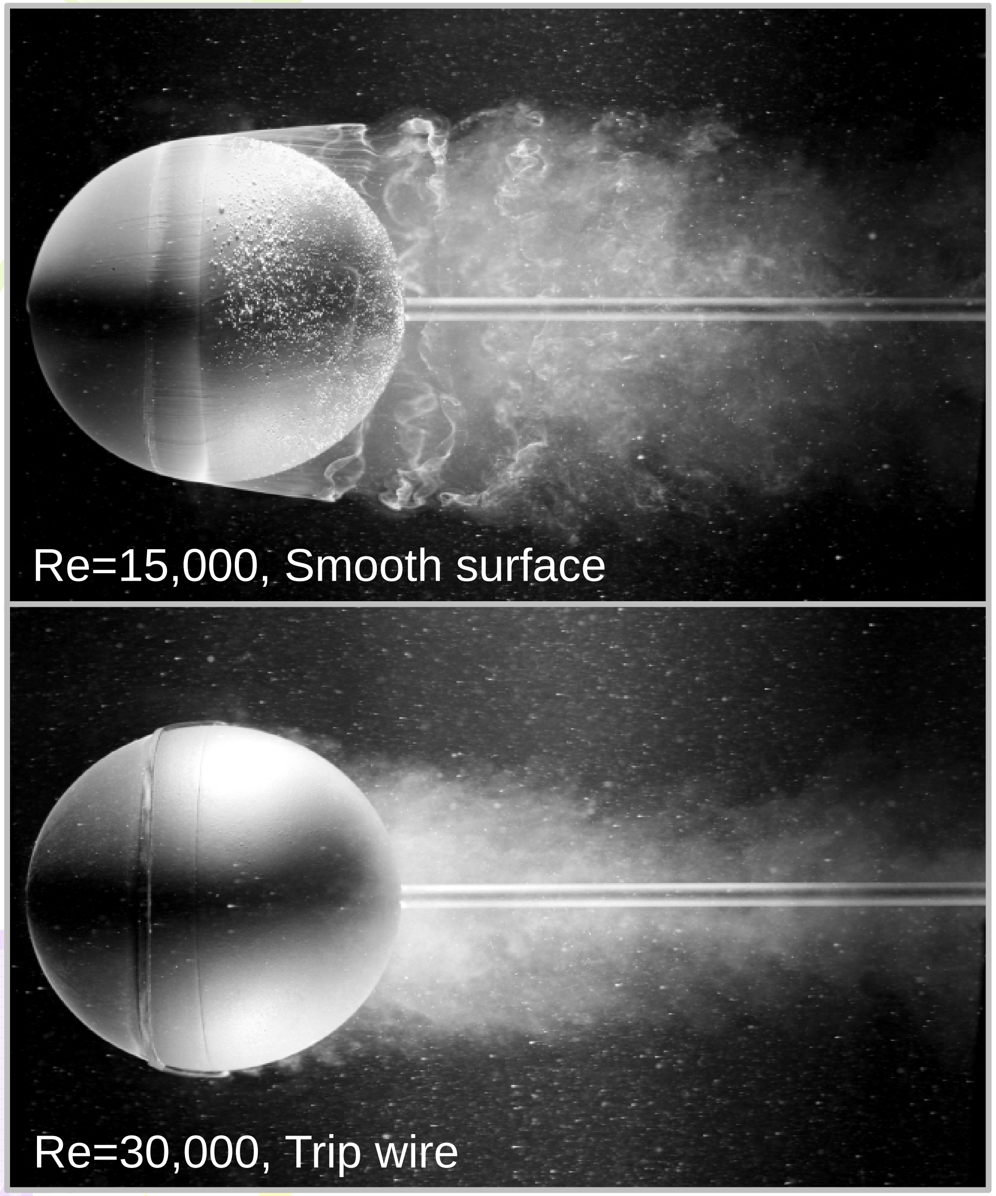


FIGURE 10–123
Comparison of boundary layer profile shape as a function of pressure gradient ($dP/dx = -U\, dU/dx$): (*a*) favorable, (*b*) zero, (*c*) mild adverse, (*d*) critical adverse (separation point), and (*e*) large adverse; inflection points are indicated by blue circles, and wall shear stress $\tau_w = \mu\,(\partial u/\partial y)_{y=0}$ is sketched for each case.

- **Shape of the BL is strongly influenced by external pressure gradient**
  - (a) favorable ($dP/dx < 0$)
  - (b) zero
  - (c) mild adverse ($dP/dx > 0$)
  - (d) critical adverse ($\tau_w = 0$)
  - (e) large adverse with reverse (or separated) flow

11-6 Cylinder and Sphere Drag



- **Flow is strong function of Re.**
- **Wake narrows for turbulent flow since TBL (turbulent boundary layer) is more resistant to separation due to adverse pressure gradient.**

□ $\theta_{sep,lam} \approx 80^{o}$

□ $\theta_{sep,lam} \approx 140^{o}$

11-6 Effect of Surface Roughness