CHAPTER 5
THE STABILITY OF LAMINAR FLOWS

Laminar flows have a fatal weakness: poor resistance to high Reynolds numbers.

Stability:
A physical state which could withstand a disturbance and still return to its original state.

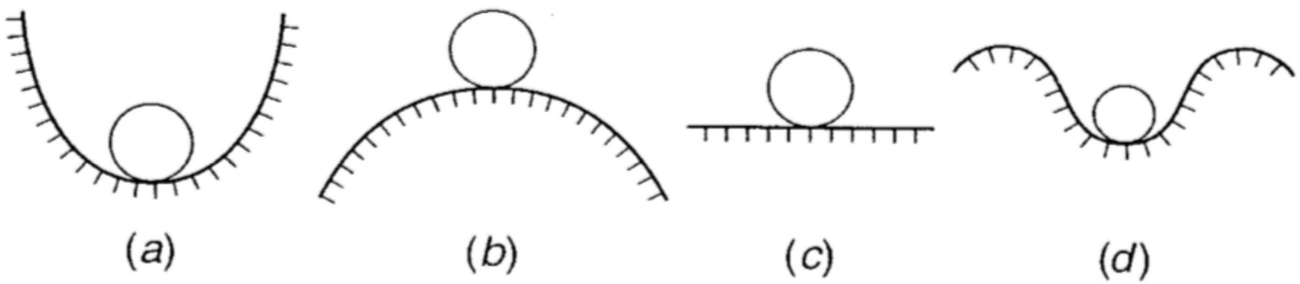


FIGURE 5-1
Relative stability of a ball at rest: (*a*) stable; (*b*) unstable; (*c*) neutral stability; (*d*) stable for small disturbances but unstable for large ones.

Transition:

The change, over space and time and a certain Reynolds number range, of a laminar flow into a turbulent flow.

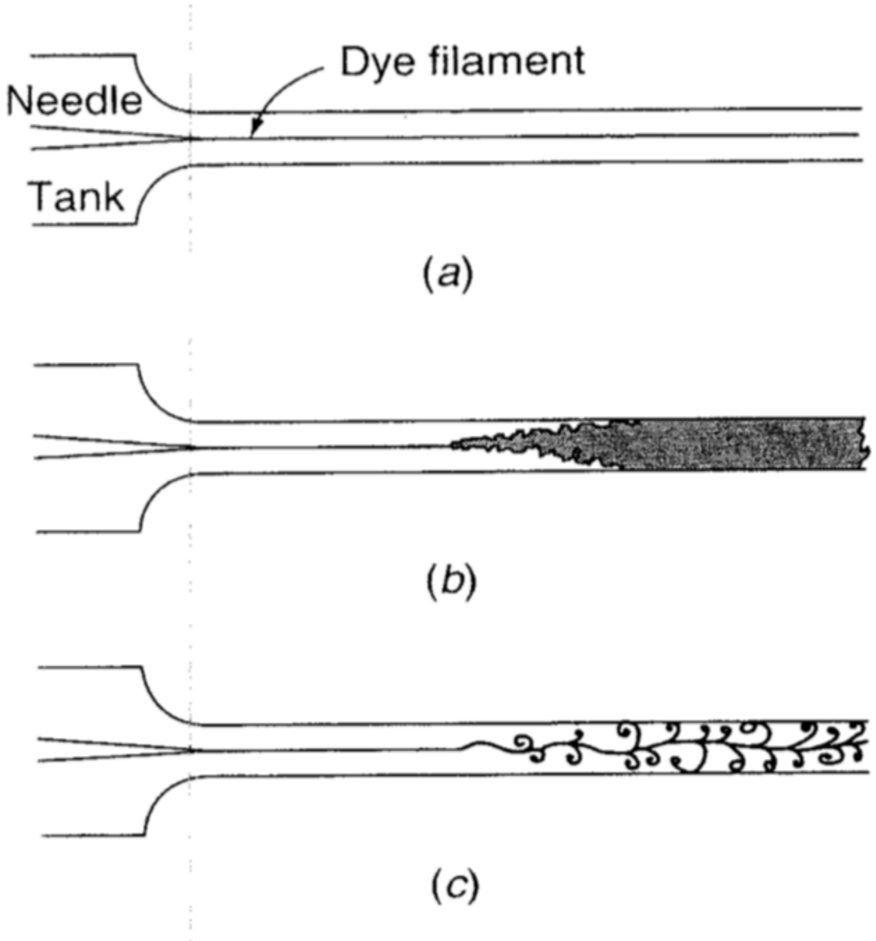
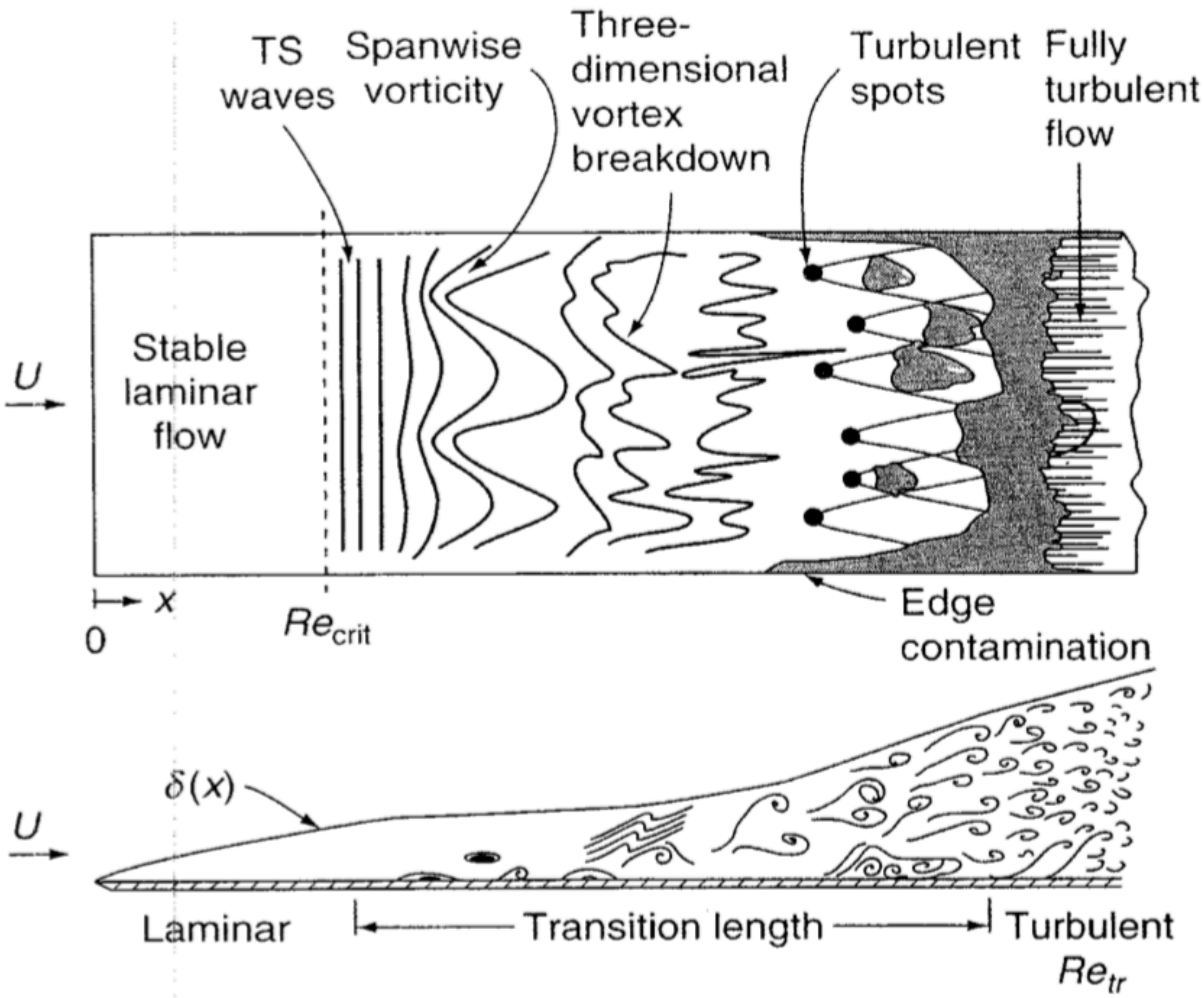
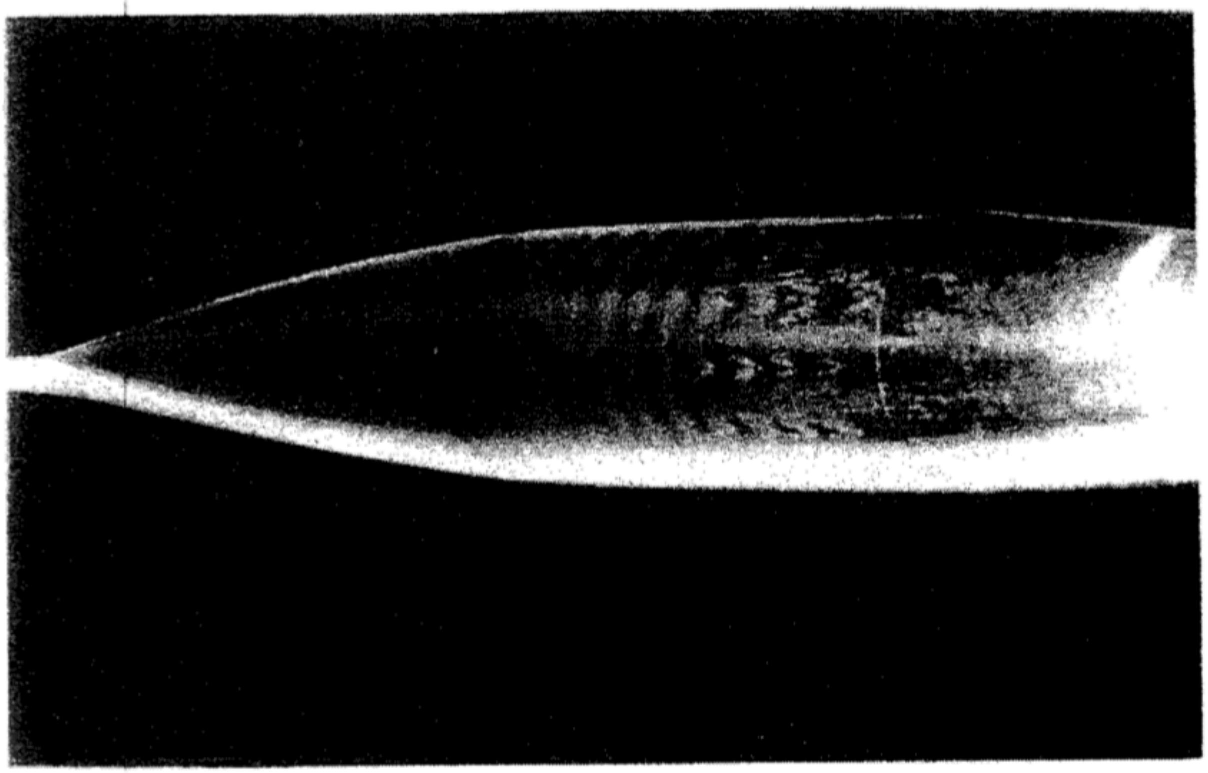


FIGURE 5-24
The classic pipe-flow dye experiment of Reynolds (1883): (*a*) low speed: laminar flow; (*b*) high speed: turbulent flow; (*c*) spark photograph of condition (*b*).

Laminar and turbulent flow on flat surface

The idealized sketch of laminar and turbulent flow on flat plate surface is shown below.





(*b*)

FIGURE 5-28
Description of the boundary-layer transition process: (*a*) idealized sketch of flat-plate flow; (*b*) smoke-flow visualization of flow with transition induced early by acoustic input at $Re_L = 814{,}000$ and 500 Hz. (*Courtesy of J.T. Kegelman and T. J. Mueller, University of Notre Dame.*)

Falkner-Skan solution

$$\theta^{*} = \theta\sqrt{\frac{(m+1)}{2}\frac{U}{\upsilon x}}$$

Thwaites solution

$$\frac{\theta^{2}}{\upsilon} = \frac{0.45}{U^{6}}\int_{0}^{x} U^{5}dx$$

Michel solution

$$Re_{\theta} = \frac{U(x)\theta(x)}{\upsilon} = 2.9{Re_{x}}^{0.4}$$

Wazzan solution

$$\log_{10}(Re_{x-tr}) = -40.4557 + 64.8066H - 26.7538H^2 + 3.3819H^3$$

Van Driest & Blumer solution

$$\frac{1690}{\sqrt{Re_{x.tr}}} = 0.312(m + 0.11)^{-0.528} + 1.6(\eta_\delta)^2(Re_{x.tr})^{1/2}(T^2)$$

Dunham solution

$$Re_{\theta-tr} = (0.27 + 0.73e^{-80T})\left[550 + \frac{680}{(1 + 100T - 21\lambda_{tr})}\right]$$