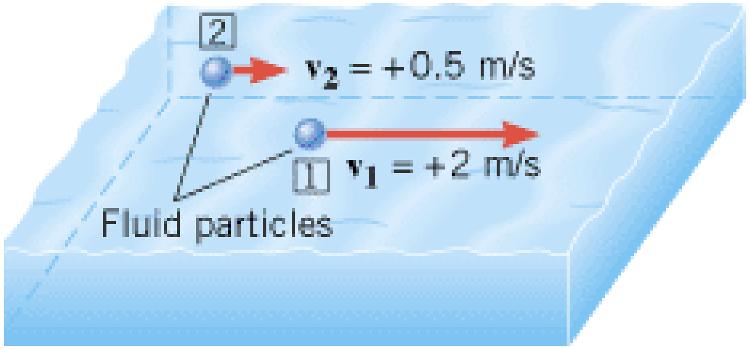
Steady or Unsteady Fluid Flow



In ***steady flow*** the velocity of the fluid particles at any point is constant as time passes.

Unsteady flow exists whenever the velocity at a point in the fluid changes as time passes.

Fluids in Motion

Fluids can move or flow in many ways.

Water may flow smoothly and slowly in a quiet stream or violently over a waterfall.

The air may form a gentle breeze or a raging tornado.

To deal with such diversity, it helps to identify some of the basic types of fluid flow.

Turbulent Flow

Turbulent flow is an extreme kind of unsteady flow and occurs when there are sharp obstacles or bends in the path of a fast-moving fluid.

In turbulent flow, the velocity at a point changes erratically from moment to moment, both in magnitude and direction.

Compressible or Incompressible Fluid Flow

Most liquids are nearly incompressible; that is, the density of a liquid remains almost constant as the pressure changes.

To a good approximation, then, liquids flow in an incompressible manner.

In contrast, gases are highly compressible. However, there are situations in which the density of a flowing gas remains constant enough that the flow can be considered incompressible.

Viscous or Nonviscous Fluid Flow

A viscous fluid, such as honey, does not flow readily and is said to have a large viscosity.

In contrast, water is less viscous and flows more readily; water has a smaller viscosity than honey.

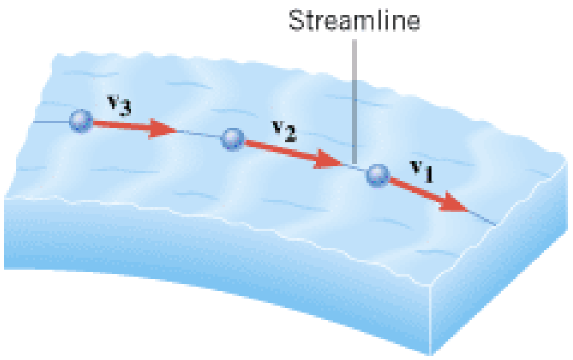
The flow of a viscous fluid is an energy-dissipating process.

A fluid with zero viscosity flows in an unhindered manner with no dissipation of energy.

Although no real fluid has zero viscosity at normal temperatures, some fluids have negligibly small viscosities.

An incompressible, nonviscous fluid is called an ***ideal fluid.***

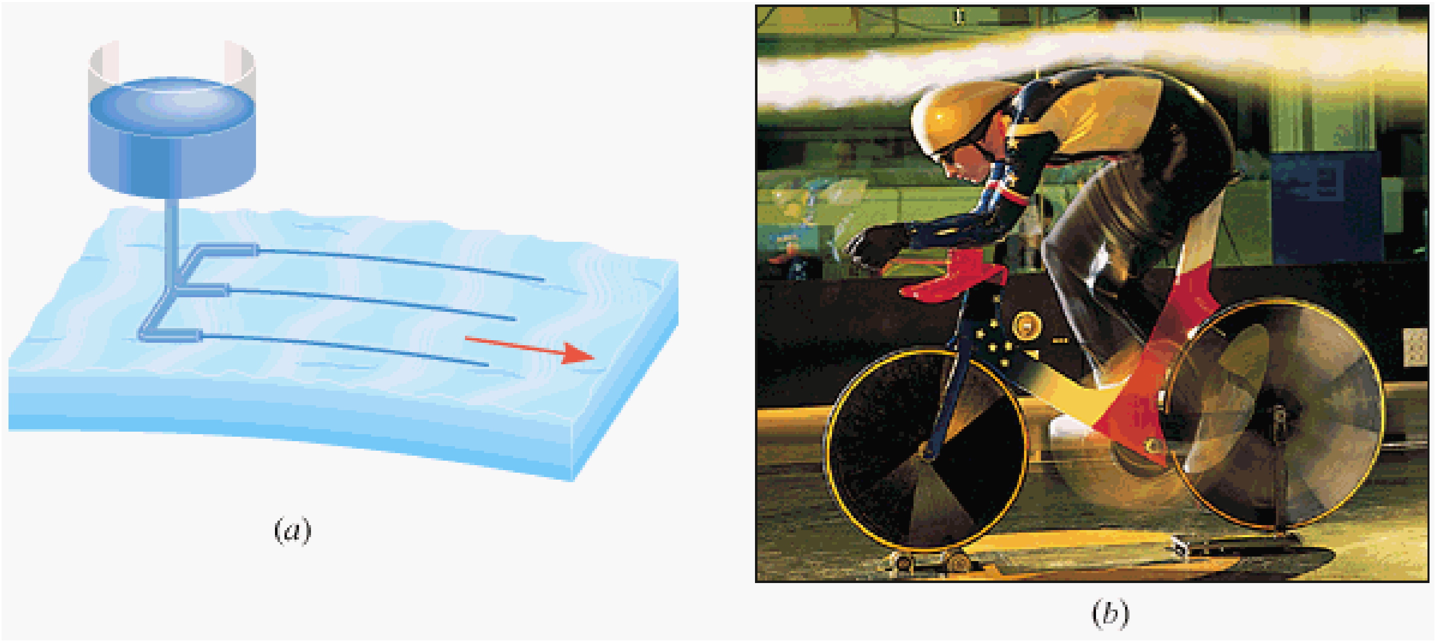
Streamline Flow



When the flow is steady, ***streamlines*** are often used to represent the trajectories of the fluid particles.

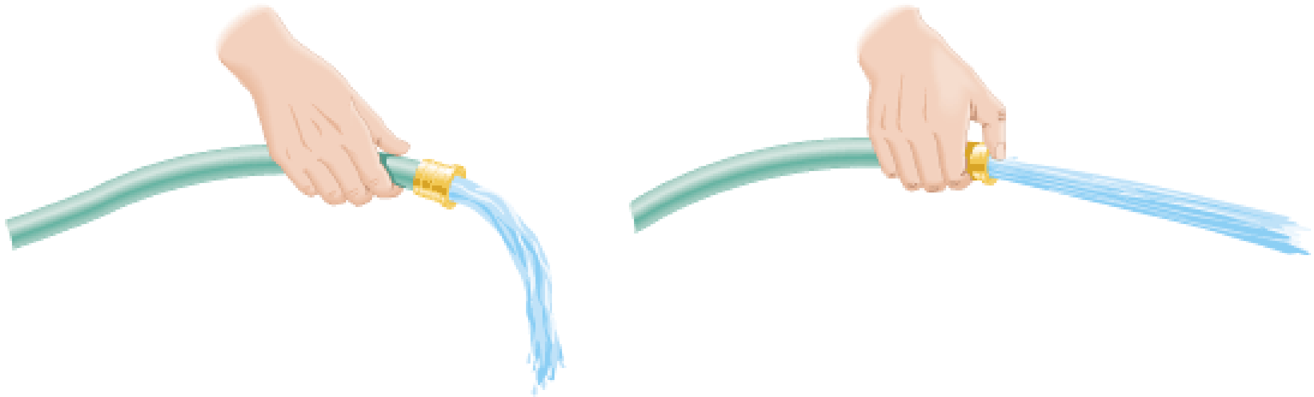
A streamline is a line drawn in the fluid such that a tangent to the streamline at any point is parallel to the fluid velocity at that point.

Steady flow is often called ***streamline flow.***



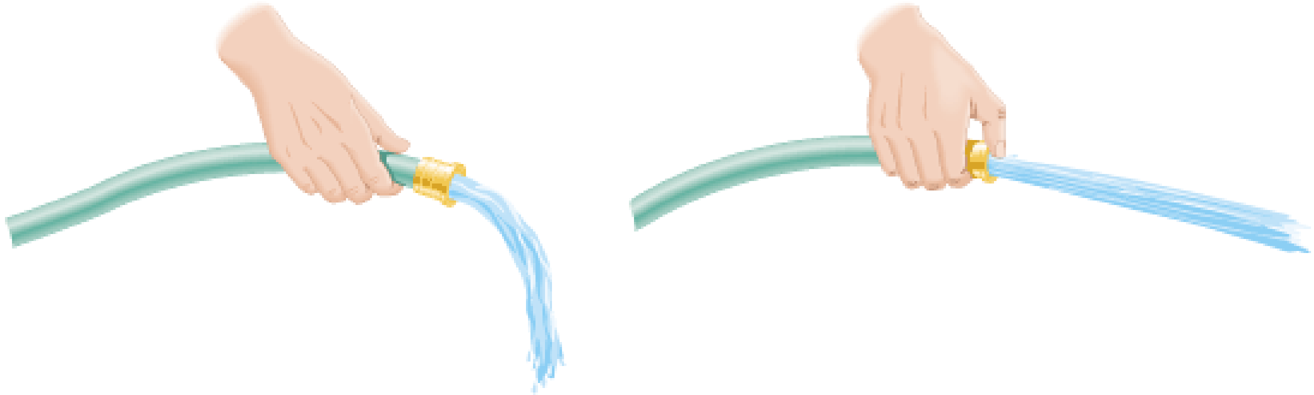
(a) In the steady flow of a liquid, a colored dye reveals the streamlines. *(b)* A smoke streamer reveals a streamline pattern for the air flowing around this pursuit cyclist, as he tests his bike for wind resistance in a wind tunnel.

11.8 The Equation of Continuity



Q: Have you ever used your thumb to control the water flowing from the end of a hose?

11.8 The Equation of Continuity

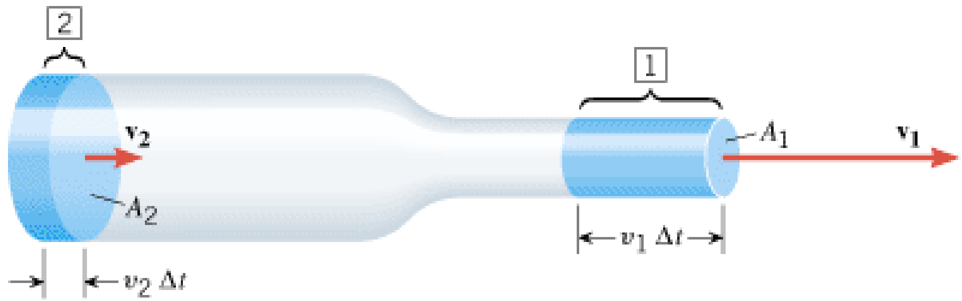


Q: Have you ever used your thumb to control the water flowing from the end of a hose?

A: When the end of a hose is partially closed off, thus reducing its cross-sectional area, the fluid velocity increases.

This kind of fluid behavior is described by the ***equation of continuity.***

Equation of Continuity

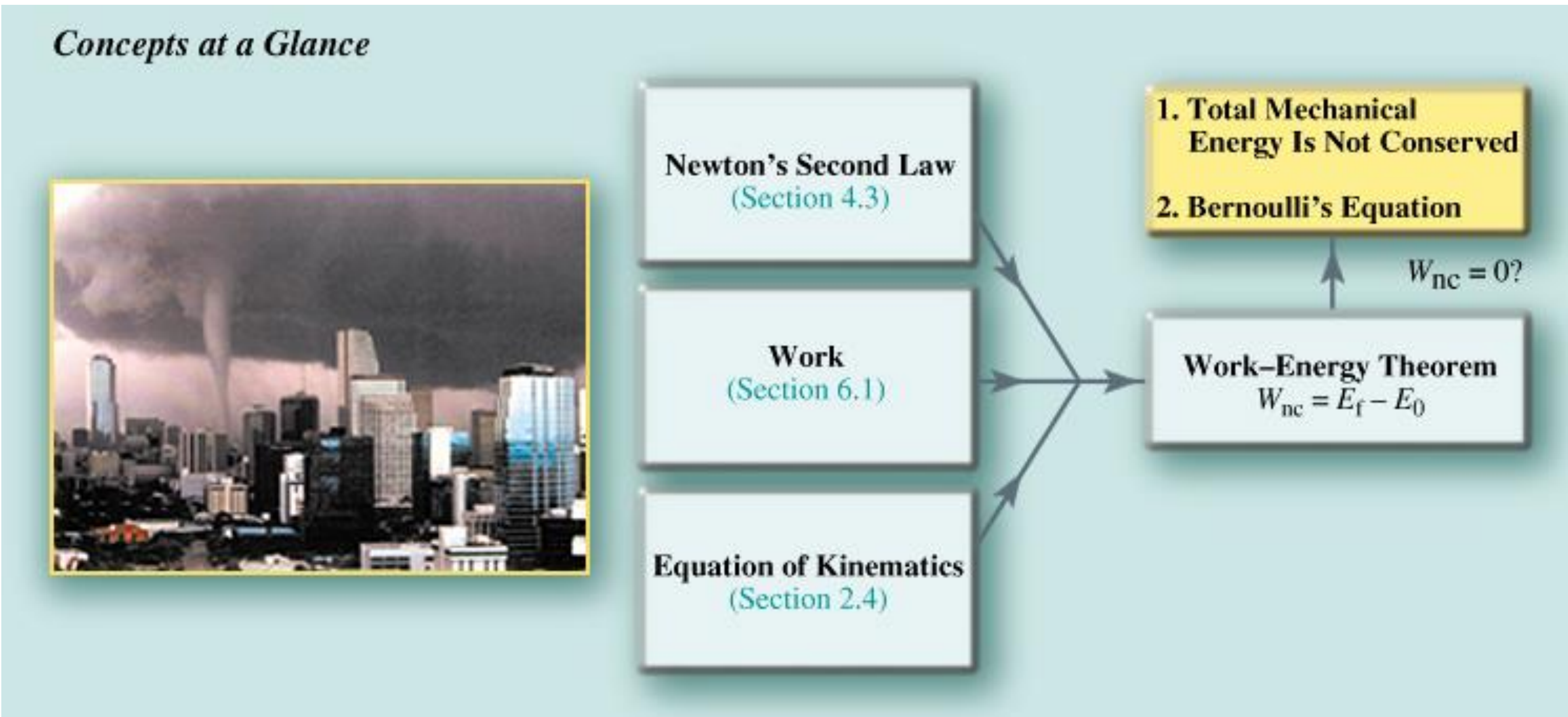


Mass flow rate at position 2 $= \dfrac{\Delta m_2}{\Delta t} = \rho_2 A_2 v_2$

Mass flow rate at position 1 $= \dfrac{\Delta m_1}{\Delta t} = \rho_1 A_1 v_1$

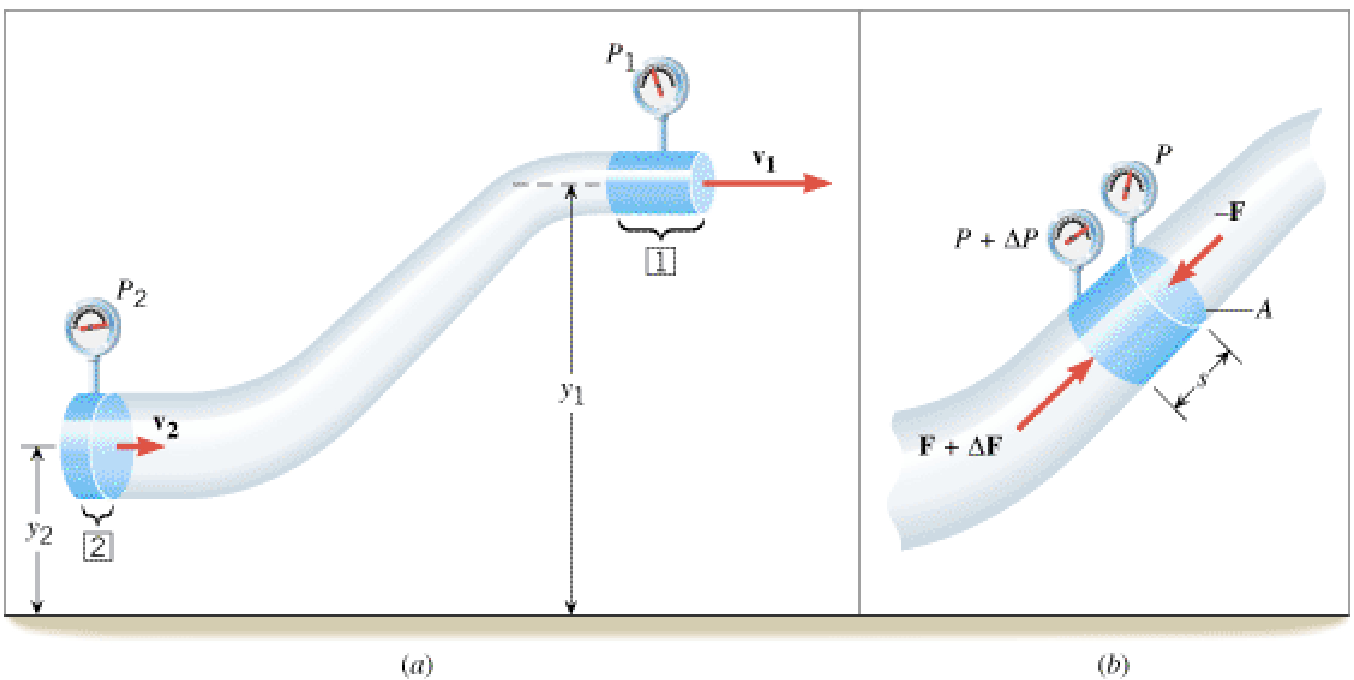
$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

11.9 Bernoulli's Equation

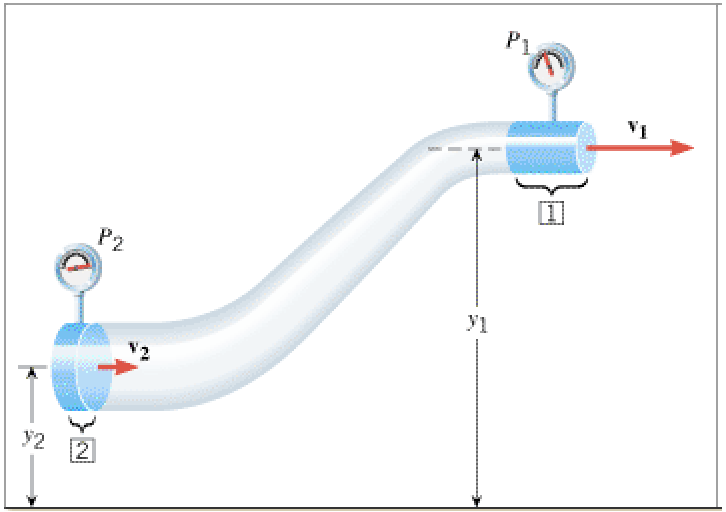


Bernoulli's Equation

For *steady flow*, the speed, pressure, and elevation of an *incompressible and nonviscous* fluid are related by an equation discovered by Daniel Bernoulli (1700–1782).



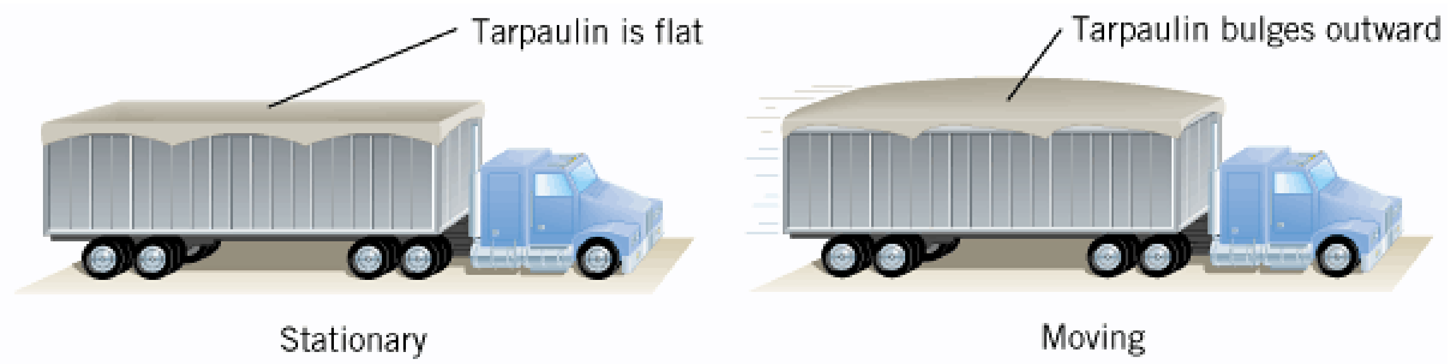
Bernoulli's Equation



In the steady flow of a nonviscous, incompressible fluid of density ρ, the pressure P, the fluid speed v, and the elevation y at any two points (1 and 2) are related by

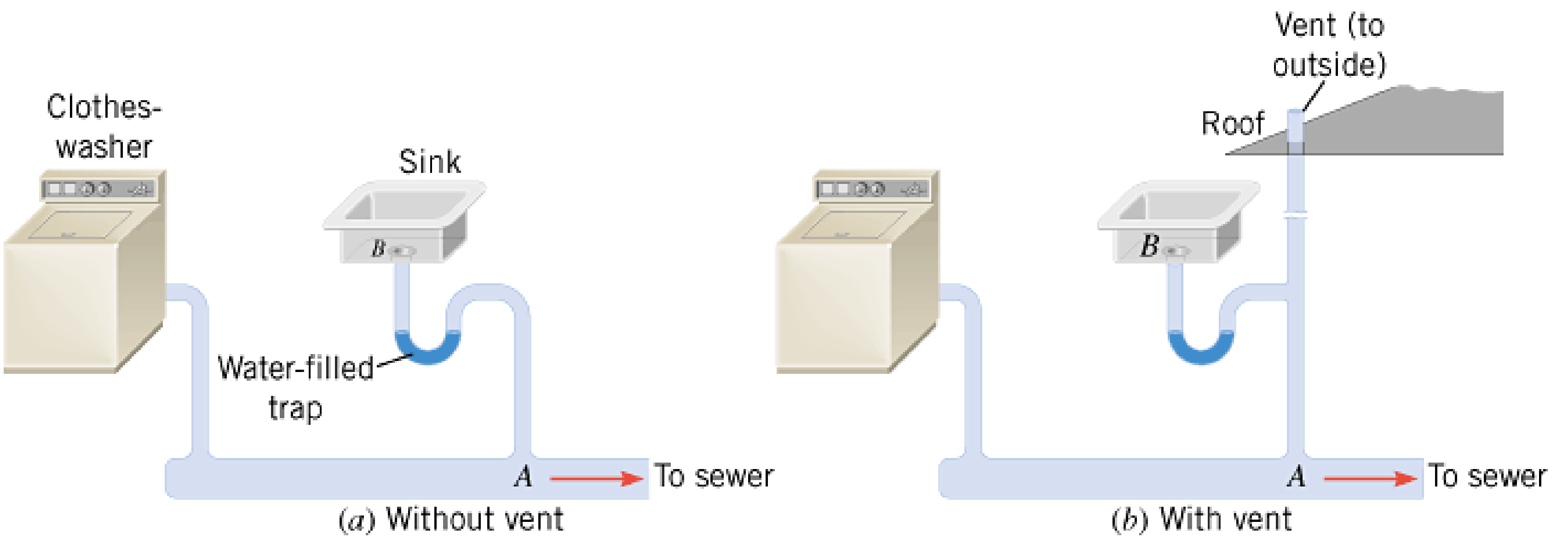
$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

11.10 Applications of Bernoulli's Equation



The tarpaulin that covers the cargo is flat when the truck is stationary but bulges outward when the truck is moving.

Household Plumbing



In a household plumbing system, a vent is necessary to equalize the pressures at points *A* and *B*, thus preventing the trap from being emptied. An empty trap allows sewer gas to enter the house.

Curveball Pitch