Hydraulics & pneumatics

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Phases of Matter

The three common phases of matter are solid, liquid, and gas.

A solid has a definite shape and size.

A liquid has a fixed volume but can be any shape.

A gas can be any shape and also can be easily compressed.

Liquids and gases both flow, and are called fluids.

Density and Specific Gravity

The density ρ of an object is its mass per unit volume:

$$\rho = \frac{m}{V},$$

The SI unit for density is kg/m^3.

Water at 4°C has a density of 1 g/cm^3 = 1000 kg/m^3.

The specific gravity of a substance is the ratio of its density to that of water.

Pressure in Fluids

Pressure is defined as the force per unit area.

Pressure is a scalar; the units of pressure in the SI system are pascals:

$$1 \text{ Pa} = 1 \text{ N/m}^2$$

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Pressure in Fluids

there is no component of force
parallel to any solid surface once again, if there were the fluid would flow.

The pressure at a depth *h* below the surface of the liquid is due to the weight of the liquid above it.

$$P = \frac{F}{A} = \frac{\rho A h g}{A}$$

$$P = \rho g h.$$

Atmospheric Pressure and Gauge Pressure

At sea level the atmospheric pressure is about 1.013×10^5 N/m^2; this is called one atmosphere (atm).

Another unit of pressure is the bar:

$$1 \text{ bar} = 1.00 \times 10^5 \text{ N/m}^2$$

Standard atmospheric pressure is just over 1 bar.

This pressure does not crush us, as our cells maintain an internal pressure that balances it.

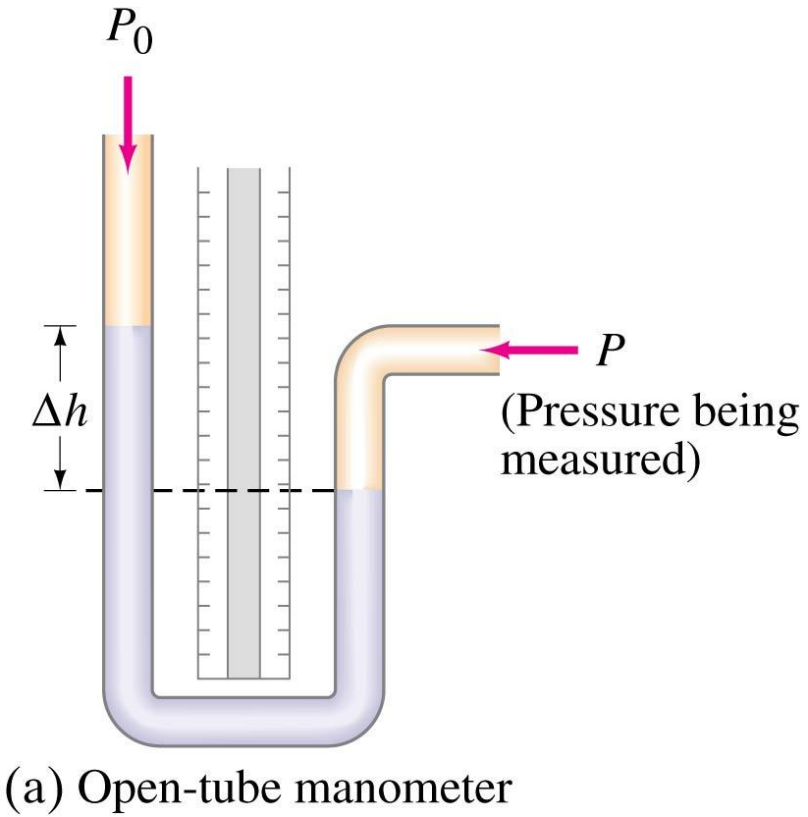
Atmospheric Pressure and Gauge Pressure

Most pressure gauges measure the pressure above the atmospheric pressure—this is called the gauge pressure.

The absolute pressure is the sum of the atmospheric pressure and the gauge pressure.

$$P = P_A + P_G$$

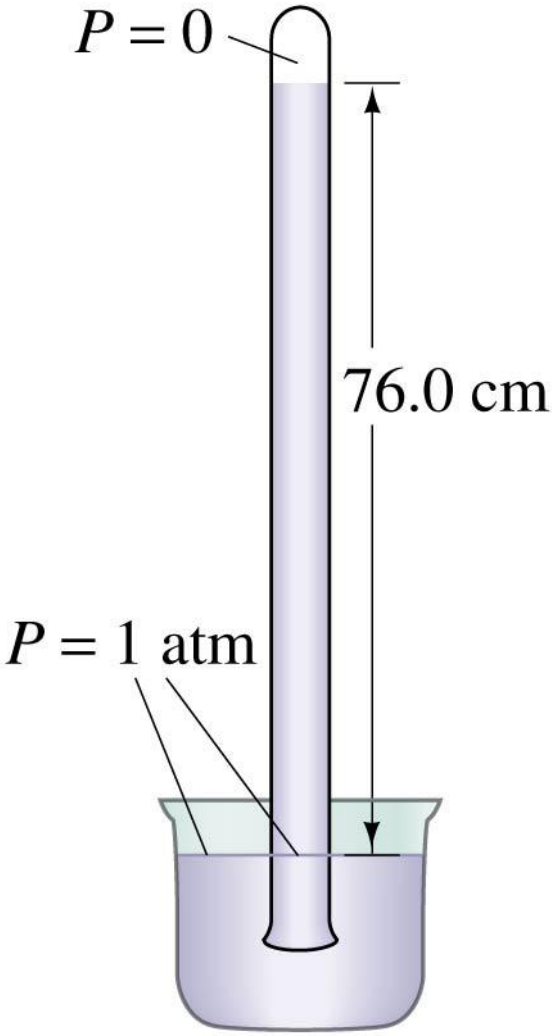
Measurement of Pressure; Gauges and the Barometer



(a) Open-tube manometer

There are a number of different types of pressure gauges. This one is an open-tube manometer. The pressure in the open end is atmospheric pressure; the pressure being measured will cause the fluid to rise until the pressures on both sides at the same height are equal.

10-6 Measurement of Pressure; Gauges and the Barometer



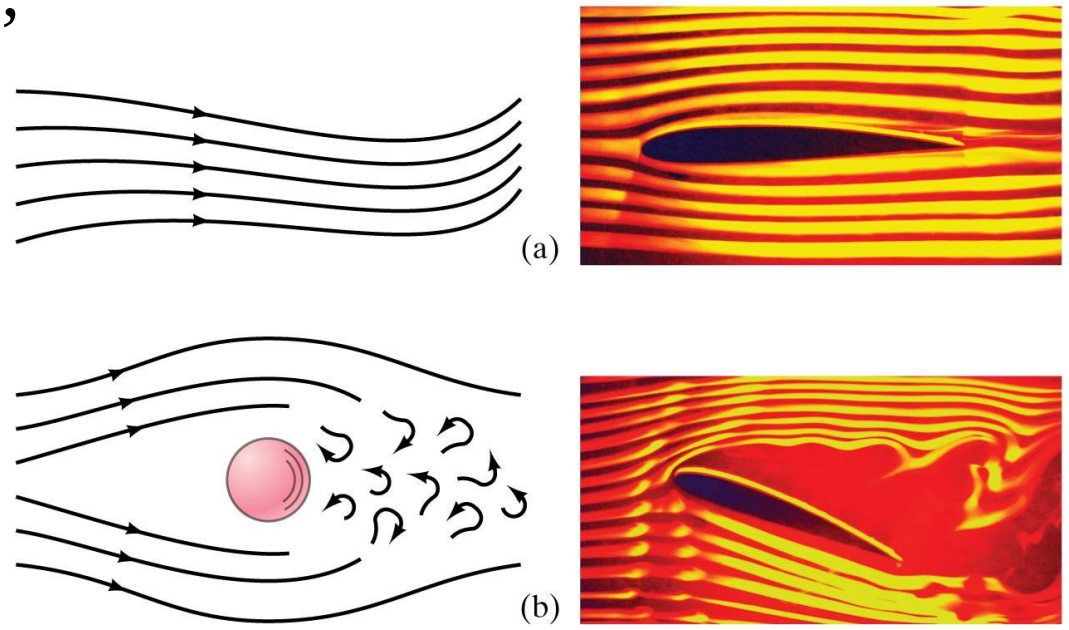
This is a mercury barometer, developed by Torricelli to measure atmospheric pressure. The height of the column of mercury is such that the pressure in the tube at the surface level is 1 atm.

Therefore, pressure is often quoted in millimeters (or inches) of mercury.

Fluids in Motion; Flow Rate and the Equation of Continuity

If the flow of a fluid is smooth, it is called streamline or laminar flow

Above a certain speed, the flow becomes turbulent
Turbulent flow has eddies; the viscosity of the fluid is much greater when eddies are present.



Equation of Continuity

We will deal with laminar flow.

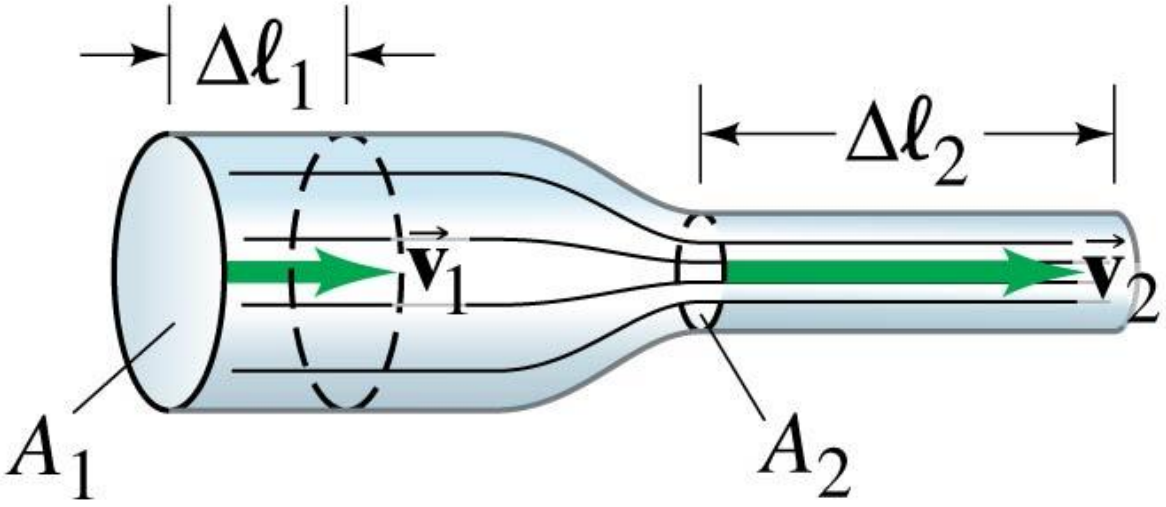
The mass flow rate is the mass that passes a given point per unit time. The flow rates at any two points must be equal, as long as no fluid is being added or taken away.

This gives us the equation of continuity:

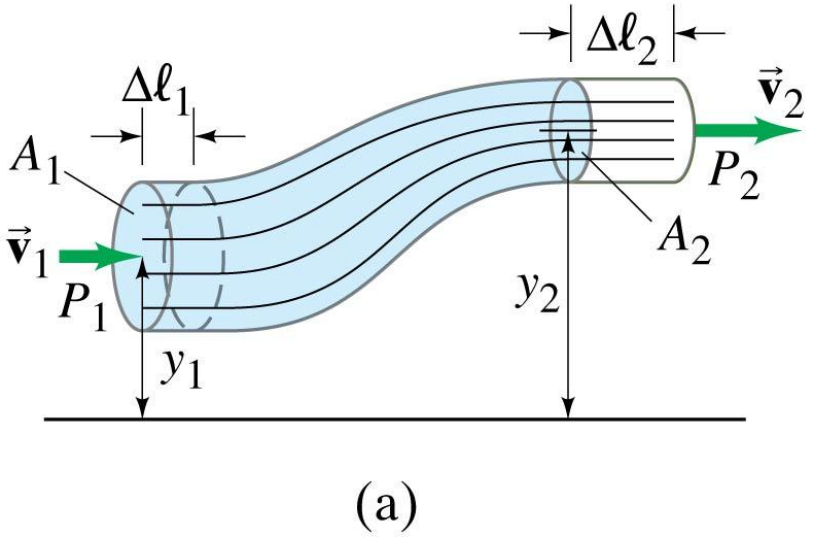
$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2 .$$

Fluids in Motion; Flow Rate and the Equation of Continuity

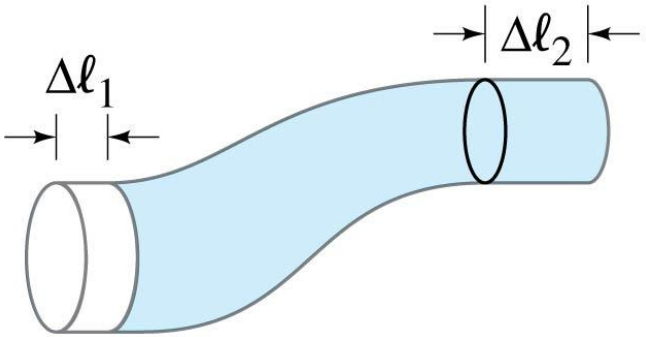
If the density doesn't change—typical for liquids—this simplifies to $A_1 v_1 = A_2 v_2$. Where the pipe is wider, the flow is slower.



Bernoulli's Equation



(a)



(b)

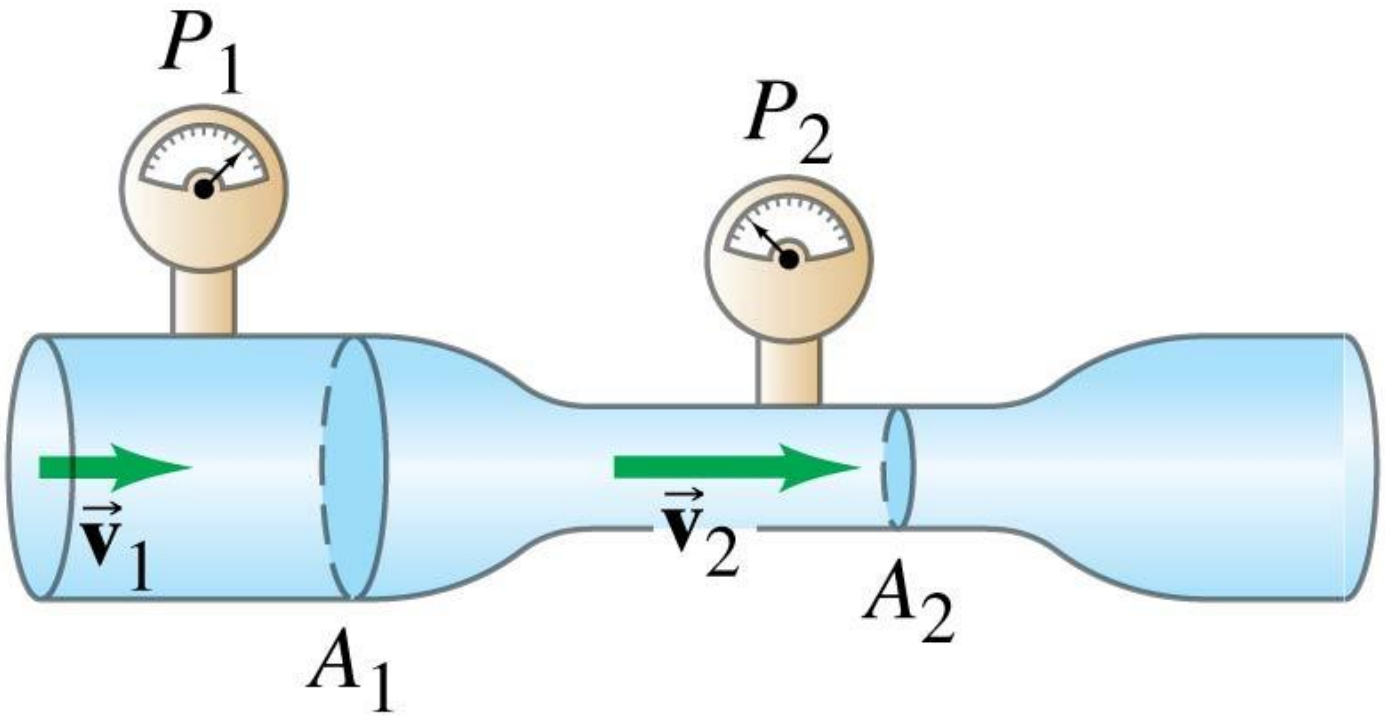
A fluid can also change its height. By looking at the work done as it moves, we find:

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

This is Bernoulli's equation. One thing it tells us is that as the speed goes up, the pressure goes down.

Venturi Meter

A venturi meter can be used to measure fluid flow by measuring pressure differences.



Viscosity

Real fluids have some internal friction, called viscosity.

The viscosity can be measured.

$$F = \eta A \frac{v}{\ell}.$$

where η is the coefficient of viscosity.