52.6: Viscosity

Real fluids (especially liquids) exhibit a kind of internal friction called viscosity. Fluids that flow easily (like water and gasoline) have a fairly low viscosity; liquids like molasses that are "thick" and flow with difficulty have a high viscosity.

There are two different types of viscosity defined. The more common is dynamic viscosity; the other is kinematic viscosity. Both are described below.

Dynamic Viscosity

Recall from the study of elasticity (Chapter 50) that when a body is placed under transverse (shear) stress $\sigma = F_t/A$, the resulting strain ε is the tangential displacement x divided by the transverse distance l :

$$\sigma = E\varepsilon \tag{52.6.1}$$

$$\frac{F_t}{A} = S\frac{x}{l} \tag{52.6.2}$$

where S is the shear modulus. Fluid flow undergoes a similar kind of shear stress; however, with fluids, we find that the stress is not proportional to the strain, but to the rate of change of strain:

$$\frac{F_t}{A} = \mu\frac{d}{dt}\frac{x}{l} = \mu\frac{v}{l} \tag{52.6.3}$$

where v is the fluid velocity. The proportionality constant μ, which takes the place of the shear modulus, is the dynamic viscosity. The SI units of dynamic viscosity are pascal-seconds (Pa s). Other common units are the poise ($1\text{P} = 0.1$ Pa s) and the centipoise ($1\text{cP} = 0.001$ Pa s).

Viscosity, especially liquid viscosity, is temperature dependent. You've probably noticed this from everyday experience: refrigerated maple syrup is fairly thick (high viscosity), but if you warm it on the stove it becomes much thinner (low viscosity).

The following table shows dynamic viscosities of some common liquids at room temperature. A more extensive table is given in Appendix U.

Table 52.6.1 Viscosities of common liquids (room temperature).

Liquid	Dynamic viscosity μ (Pa s)	(cP)
gasoline	5×10^{-4}	0.5
water	8.9×10^{-4}	0.89
mercury	0.0016	1.6
olive oil	0.09	90
ketchup	1.3	1300
honey	5	5000
molasses	7	7000
peanut butter	250	250,000

Kinematic Viscosity

In addition to the dynamic viscosity μ, one sometimes encounters a kinematic viscosity ν. The kinematic viscosity is defined as the dynamic viscosity divided by the density:

$$v = \frac{\mu}{\rho}. \tag{52.6.4}$$

SI units for kinematic viscosity are m^2/s. Other common units are stokes ($1\mathrm{St} = 10^{-4}\ \mathrm{m}^2/\mathrm{s}$) and centistokes $\left(1\mathrm{cSt} = 10^{-6}\ \mathrm{m}^2/\mathrm{s}\right)$.
