52.8: Stokes's Law

Stokes's law gives the resistive force on a sphere moving through a viscous fluid. It was developed by the 19th century English physicist and mathematician George Stokes. Stokes's law states that the resistive force on the sphere is given by

$$F_R = 6\pi\mu r v, \tag{52.8.1}$$

where F_R is the resistive force on the sphere, r is its radius, μ is the dynamic viscosity of the fluid, and v is the relative velocity between the fluid and the sphere. This is generally valid for low Reynolds numbers ($\mathrm{Re} < 1$).

Notice that the Stokes's law force is of the form of a Model I resistive force described in Chapter 22 ($F_R \propto v$), with the resistance coefficient $b = 6\pi\mu r$. By Eq. 22.1.21 the terminal velocity for Model I is $v_\infty = mg/b$; so for a sphere moving through a viscous fluid, we have by Stokes's law

$$v_\infty = \frac{mg}{6\pi\mu r}. \tag{52.8.2}$$

Example 52.8.1

What is the terminal velocity of a steel ball of diameter 1 cm falling through a jar of honey? Solution. Taking the density of steel as $\rho = 7.86\ \mathrm{g/cm^3}$, we find the mass of the steel ball as

$$m = \rho V = \rho\left(\frac{4}{3}\pi r^3\right) = 4.115\ \mathrm{g} = 4.115\times 10^{-3}\ \mathrm{kg}. \tag{52.8.3}$$

Solution

From Table 52.6.1, the dynamic viscosity μ of honey is 5 Pa s ; the terminal velocity is then given by Eq. $52.8.2$

$$\begin{aligned} v_\infty &= \frac{mg}{6\pi\mu r} \\ &= \frac{\left(4.115\times 10^{-3}\ \mathrm{kg}\right)\left(9.80\ \mathrm{m/s^2}\right)}{6\pi(5\ \mathrm{Pa\ s})\left(0.5\times 10^{-2}\ \mathrm{m}\right)} \\ &= 8.56\ \mathrm{cm/s}. \end{aligned}$$