VISUAL PHYSICS ONLINE

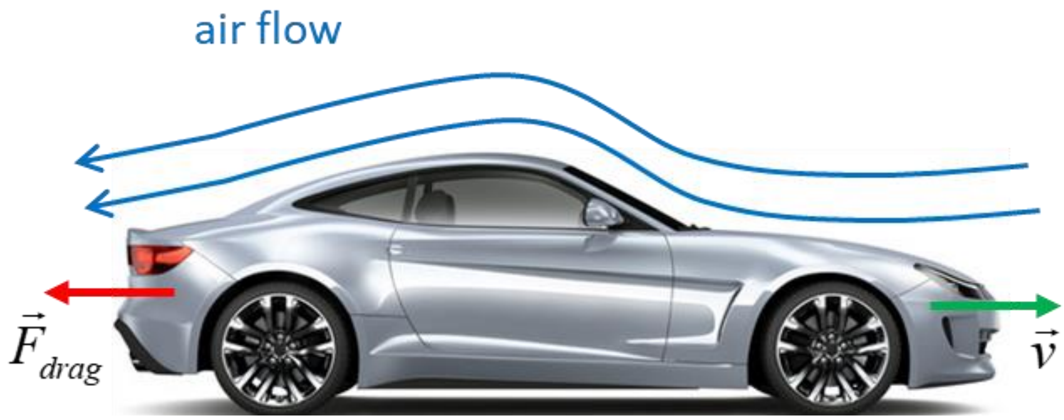
DYNAMICS

TYPES OF FORCES

VELOCITY DEPENDENT FORCES

ROLLING RESISTANCE

VELOCITY DEPENDENT FORCES



The force of **friction** acting on the object sliding along a surface is nearly independent of the speed of the object. However, other types of resistance to motion are velocity dependent. The resistance force of an object moving through a fluid is called the **drag force** $\vec{F}_D$.

Viscous drag $F_D \propto v$ low speeds

For a small object moving at low speeds through a fluid such as dust particles, to a good approximation, the resistive force is proportional to the velocity v of the object

$F_D = -\beta v$ viscous drag

- sign since force and velocity are in opposite directions

For the vertical motion of an object through a fluid, the forces acting on the object are the gravitational force F_G (weight) and the resistive force F_D. In our frame of reference, we will take down as the positive direction. The equation of motion of the object is determined from Newton's Second Law.

$$m\,a = m\frac{dv}{dt} = F_R = mg - \beta v \qquad a = g - \frac{\beta}{m}v$$

where *a* is the acceleration of the object at any instance.

The initial conditions are

$$t = 0 \quad v = v_0 \quad x = 0 \quad a = -\left(\beta / m\right) v_0$$

When $a = 0$, the velocity is constant $v = v_T$ where v_T is the **terminal velocity**

$$0 = m\,g - \beta\, v_T$$

$$v_T = \frac{m\,g}{\beta}$$ **terminal velocity**

The motion of a 2.0 kg object through a viscous fluid

m = 2.00 kg

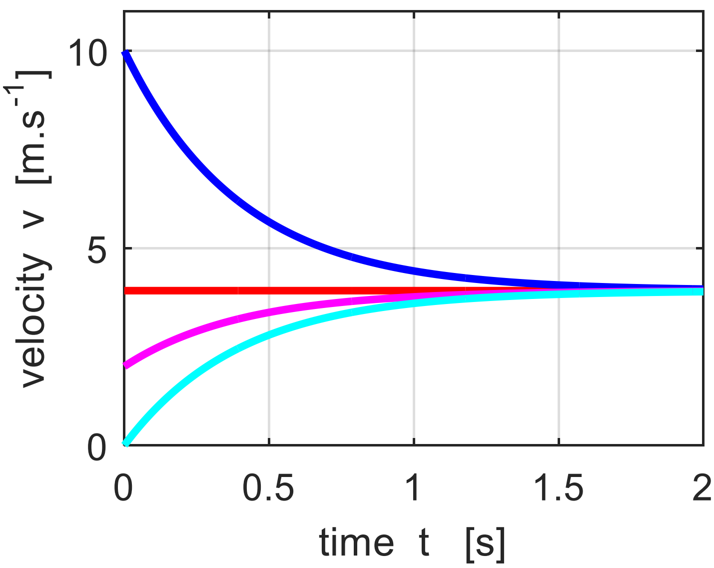
β = 5.00 kg.s^{-1}

g = 9.80 m.s^{-2}

v_T = 3.92 m.s^{-1}

Initial values for velocity v_0 [m.s^{-1}]

blue: 10 red: v_T magenta: 2 cyan: 0



When you consider the viscous drag acting upon falling objects, heavier objects do fall faster than lighter objects.

Drag at high speeds $F_D \propto v^2$

For objects moving at high speeds, such as, aeroplanes, cricket balls, cars or bikes, the resistance force to a good approximation is proportional to the square of the velocity

$$F_D = -\alpha v^2$$

For the vertical motion of an object through a fluid, the forces acting on the object are the gravitational force F_G (weight) and the resistive force F_D. In our frame of reference, down is the positive direction. The equation of motion of the object is determined from Newton's Second Law.

$$m\,a = m\frac{dv}{dt} = F_G - F_R = mg - \alpha v^2 \left(v/|v|\right) \qquad a = g - \frac{\alpha}{m} v^2 \left(v/|v|\right)$$

where *a* is the acceleration of the object at any instance.
The initial conditions are

$$t = 0 \quad v = v_0 \quad x = 0 \quad a = g - \left(\alpha / m\right) v_0^{\;2} \left(\frac{v_0}{|v_0|}\right)$$

When $a = 0$, the velocity is constant $v = v_T$ where v_T is the **terminal velocity**

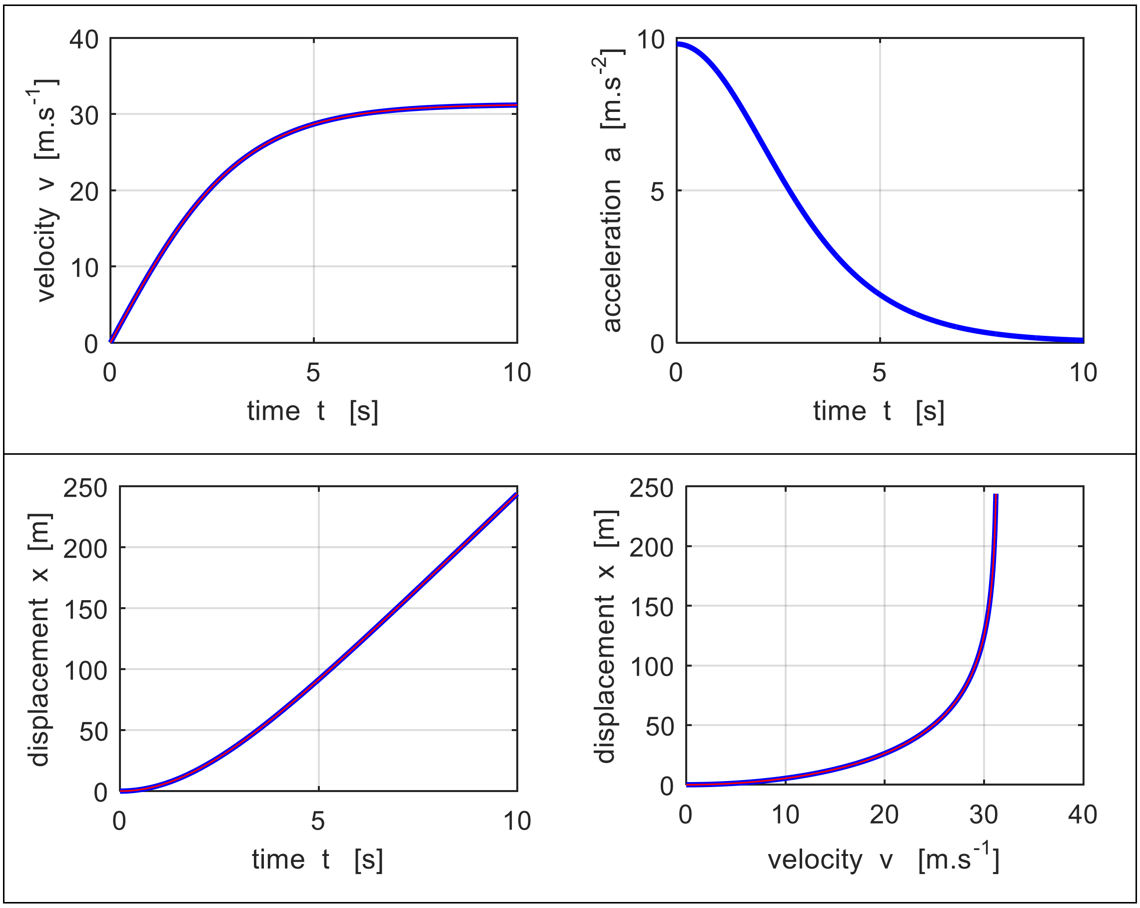
$$0 = m\,g - \alpha\, v_T^{\;2} \quad v_T^{\;2} = \frac{m\,g}{\alpha}$$

$$v_T = \sqrt{\frac{m\,g}{\alpha}}$$

Example Small rock dropped from rest:

$m = 0.010$ kg $\alpha = 1.00\times10^{-4}$ kg.m^{-1}

$v_0 = 0$ m.s^{-1} $\Rightarrow$ $v_T = 31.3$ m.s^{-1}



VIEW

Interest only article on the motion of falling objects with resistance

The ferrari has a small frontal area and shaped to reduce **air drag** to give better acceleration and fuel efficiency.

The bike, clothing and helmet are designed to reduce **air drag** which opposes the forward motion of the bike and rider.

ROLLING RESISTANCE

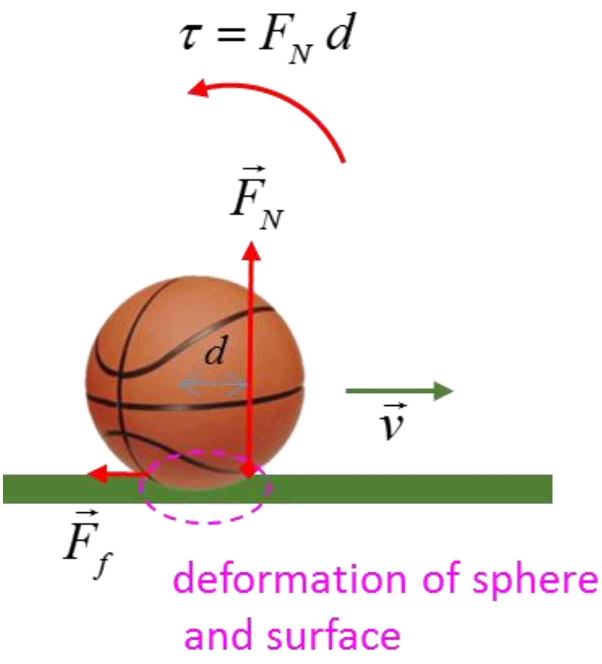
Rolling resistance (**rolling friction** or **rolling drag**) is the force resisting the rolling motion when a body such as a ball, tire, or wheel on a surface. It is mainly caused by non-elastic effects where some of the kinetic energy is dissipated as the object rolls along the surface.

In analogy with sliding friction, rolling resistance force F_R is often expressed as a coefficient μ_R times the normal force F_N.

$$F_R = \mu_R F_N$$

The coefficient of rolling resistance μ_R is generally much smaller than the coefficient of sliding friction μ_S.

Why does a rolling sphere slow down?



Because of the deformations of sphere and surface in the contact region, the normal force F_N does not pass through the centre of mass of the sphere and the normal force acts over an area and not a point as in an idealized case. A **torque** τ is produced by the normal force F_N which **slows** down the sphere and then stops it.

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If you have any feedback, comments, suggestions or corrections please email:

Ian Cooper   School of Physics   University of Sydney

ian.cooper@sydney.edu.au