The chemist's toolkit 10 Classical mechanics

The **speed**, v, of a body is defined as the rate of change of position. The **velocity** specifies the direction of travel as well as its rate, and particles travelling at the same speed but in different directions have different velocities. The **linear momentum**, p, is defined as

$$p = mv \qquad \text{Linear momentum [definition]}$$

Momentum also mirrors velocity in having a sense of direction; bodies of the same mass and moving at the same speed but in different directions have different linear momenta.

Acceleration, a, is the rate of change of velocity. A body accelerates if its speed changes. A body also accelerates if its speed remains unchanged but its direction of motion changes: a body moving in a circle at constant speed is ceaselessly accelerating. According to Newton's **second law of motion,** the acceleration of a body of mass m is proportional to the force, F, acting on it:

$$F = ma \qquad \text{Force}$$

The **law of conservation of momentum** states that the momentum of a body is constant in the absence of a force acting on it.

The **energy**, E, of a body is the sum of its kinetic energy, E_k, and its potential energy, E_p (and commonly V). The **kinetic energy** is the energy a body possesses due to its motion. For a body of mass m travelling at a speed v:

$$E_k = \tfrac{1}{2}mv^2 \qquad \text{Kinetic energy [definition]}$$

The potential energy is the energy a body possesses due to its position. The expression for the potential energy depends on the nature of the force acting on the body. For a body of mass m at a height h above (but close to) the surface of a planet:

$$E_p = mgh \qquad \text{Potential energy [gravitational]}$$

Here, g is the *acceleration of free fall*; its standard value on Earth is 9.81 m s^{-2}. The potential energy of a spring (and a chemical bond) stretched through a distance x is

$$E_p = \tfrac{1}{2}k_f x^2 \qquad \text{Potential energy [spring]}$$

Here, k_f is the *force constant*, a measure of the spring's stiffness. The only other type of potential energy of interest in biochemistry is the *Coulomb potential energy* of a charge Q_1 at a distance r from another charge Q_2:

$$E_p = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r} \qquad \text{Potential energy [Coulomb]}$$

Here, ε_0 is the *electric constant*, a fundamental constant (see inside front cover). The **law of conservation of energy** states that the total energy ($E = E_k + E_p$) of an isolated body is constant.