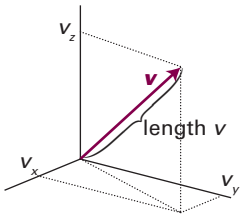
THE CHEMIST'S TOOLKIT 3 Momentum and force

The **speed**, v, of a body is defined as the rate of change of position. The **velocity**, $\boldsymbol{v}$, defines the direction of travel as well as the rate of motion, and particles travelling at the same speed but in different directions have different velocities. As shown in Sketch 3.1, the velocity can be depicted as an arrow in the direction of travel, its length being the speed v and its components v_x, v_y, and v_z along three perpendicular axes. These components have a sign: $v_x = +5\,\mathrm{m\,s^{-1}}$, for instance, indicates that a body is moving in the positive x-direction, whereas $v_x = -5\,\mathrm{m\,s^{-1}}$ indicates that it is moving in the opposite direction. The length of the arrow (the speed) is related to the components by Pythagoras' theorem: $v^2 = v_x^2 + v_y^2 + v_z^2$.



Sketch 3.1

The concepts of classical mechanics are commonly expressed in terms of the linear momentum, $\boldsymbol{p}$, which is defined as

$$\boldsymbol{p} = m\boldsymbol{v} \qquad \text{Linear momentum [definition]} \qquad (3.1)$$

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, $\boldsymbol{a}$, 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. According to Newton's **second law of motion**, the acceleration of a body of mass m is proportional to the force, $\boldsymbol{F}$, acting on it:

$$\boldsymbol{F} = m\boldsymbol{a} \qquad \text{Force} \qquad (3.2)$$

Because $m\boldsymbol{v}$ is the linear momentum and $\boldsymbol{a}$ is the rate of change of velocity, $m\boldsymbol{a}$ is the rate of change of momentum. Therefore, an alternative statement of Newton's second law is that the force is equal to the rate of change of momentum. Newton's law indicates that the acceleration occurs in the same direction as the force acts. If, for an isolated system, no external force acts, then there is no acceleration. This statement is the **law of conservation of momentum**: that the momentum of a body is constant in the absence of a force acting on the body.