Acceleration

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Last updated: 2014

DOI: https://doi.org/10.1036/1097-8542.002500 (https://doi.org/10.1036/1097-8542.002500)

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The time rate of change of velocity. Since velocity is a directed or vector quantity involving both magnitude and direction, a velocity may change by a change of magnitude (speed) or by a change of direction or both. It follows that acceleration is also a directed, or vector, quantity. If the magnitude of the velocity of a body changes from υ_1 ft/s to υ_2 ft/s in t seconds, then the average acceleration $\overline{a}$ has a magnitude given by Eq. (**1**).

$$\overline{a} = \frac{\text{velocity change}}{\text{elapsed time}} = \frac{\upsilon_2 - \upsilon_1}{t_2 - t_1} = \frac{\Delta \upsilon}{\Delta t} \tag{1}$$

To designate it fully the direction should be given, as well as the magnitude. *See also:* **Velocity (/content/velocity/729500)**

Instantaneous acceleration is defined as the limit of the ratio of the velocity change to the elapsed time as the time interval approaches zero. When the acceleration is constant, the average acceleration and the instantaneous acceleration are equal.

If a body, moving along a straight line, is accelerated from a speed of 10 to 90 ft/s (3 to 27 m/s) in 4 s, then the average change in speed per second is $(90-10)/4$ = 20 ft/s or $(27-3)/4$ = 6 m/s in each second. This is written 20 ft per second per second or 20 ft/s^2, or 6 m per second per second or 6 m/s^2. Accelerations are commonly expressed in feet per second per second, meters per second per second, or in any similar units.

Whenever a body is acted upon by an unbalanced force, it will undergo acceleration. If it is moving in a constant direction, the acting force will produce a continuous change in speed. If it is moving with a constant speed, the acting force will produce an acceleration consisting of a continuous change of direction. In the general case, the acting force may produce both a change of speed and a change of direction.

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Angular acceleration

This is a vector quantity representing the rate of change of angular velocity of a body experiencing rotational motion. If, for example, at an instant t_1, a rigid body is rotating about an axis with an angular velocity ω_1, and at a later time t_2, it has an angular velocity ω_2, the average angular acceleration $\overline{\alpha}$ is given by Eq. (**2**),

$$\overline{\alpha} = \frac{\omega_2 - \omega_1}{t_2 - t_1} = \frac{\Delta\omega}{\Delta t} \quad (2)$$

expressed in radians per second per second. The instantaneous angular acceleration is given by α = $^{d\omega}/_{\mathrm{dt}}$.

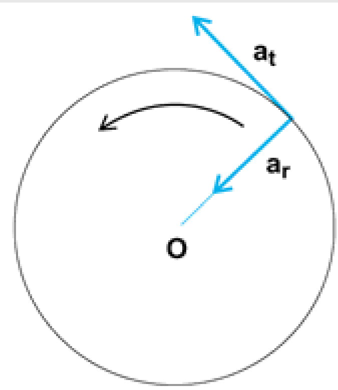
Consequently, if a rigid body is rotating about a fixed axis with an angular acceleration of magnitude α and an angular speed of ω_0 at a given time, then at a later time *t* the angular speed is given by Eq. (**3**).

$$\omega = \omega_0 + \alpha t \quad (3)$$

A simple calculation shows that the angular distance θ traversed in this time is expressed by Eq. (**4**).

$$\begin{aligned} \theta = \overline{\omega} t &= \left[\frac{\omega_0 + (\omega_0 + \alpha t)}{2}\right] t \\ &= \omega_0 t + {}^1/_2 \alpha t^2 \end{aligned} \quad (4)$$

In the **illustration** a particle is shown moving in a circular path of radius *R* about a fixed axis through *O* with an angular velocity of ω radians/s and an angular acceleration of α radians/s^2. This particle is subject to a linear acceleration which, at any instant, may be considered to be composed of two components: a radial component $\mathbf{a}_r$ and a tangential component $\mathbf{a}_t$.



Radial and tangential accelerations in circular motion.

Radial acceleration

When a body moves in a circular path with constant linear speed at each point in its path, it is also being constantly accelerated toward the center of the circle under the action of the force required to constrain it to move in its circular path. This acceleration toward the center of path is called radial acceleration. In the illustration the radial acceleration, sometimes called centripetal acceleration, is shown by the vector $\mathbf{a}_r$. The magnitude of its value is $^{\upsilon^2}/_R$, or $^{\omega^2}/_R$, where υ is the instantaneous linear velocity. This centrally directed acceleration is necessary to keep the particle moving in a circular path.

Tangential acceleration

The component of linear acceleration tangent to the path of a particle subject to an angular acceleration about the axis of rotation is called tangential acceleration. In the illustration, the tangential acceleration is shown by the vector $\mathbf{a}_t$. The magnitude of its value is α*R*. *See also:* **Acceleration measurement (/content/acceleration-measurement/002700)**; **Rotational motion (/content/rotational-motion/594400)**

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Additional Readings

H. A. Radi and J. O. Rasmussen, *Principles of Physics: For Scientists and Engineers*, Springer, New York, 2013