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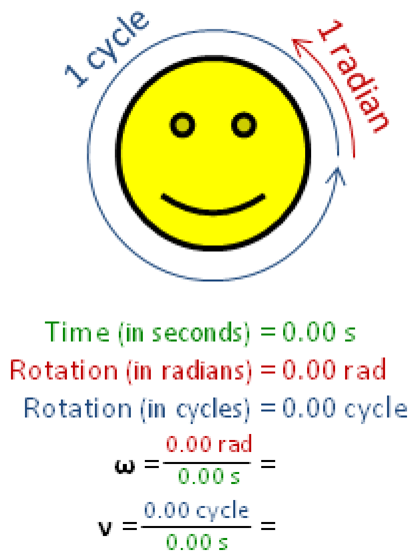
Angular frequency

In physics, **angular frequency** $\boldsymbol{\omega}$ (also referred to by the terms **angular speed**, **radial frequency**, **circular frequency**, **orbital frequency**, **radian frequency**, and **pulsatance**) is a scalar measure of rotation rate. It refers to the angular displacement per unit time (for example, in rotation) or the rate of change of the phase of a sinusoidal waveform (for example, in oscillations and waves), or as the rate of change of the argument of the sine function. Angular frequency (or angular speed) is the magnitude of the vector quantity angular velocity.[1]



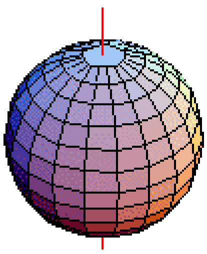
Angular frequency ω (in radians per second), is larger than frequency ν (in cycles per second, also called Hz), by a factor of 2π. This figure uses the symbol ν, rather than f to denote frequency.

One revolution is equal to 2π radians, hence[1][2]

$$\omega = \frac{2\pi}{T} = 2\pi f,$$

where:

ω is the angular frequency or angular speed (measured in radians per second),
T is the period (measured in seconds),
f is the ordinary frequency (measured in hertz) (sometimes symbolised with ν).



A sphere rotating around an axis. Points farther from the axis move faster, satisfying $\omega = v/r$.

Contents

Units

In SI units, angular frequency is normally presented in radians per second, even when it does not express a rotational value. From the perspective of dimensional analysis, the unit Hertz (Hz) is also correct, but in practice it is only used for ordinary frequency f, and almost never for ω. This convention is used to help avoid the confusion[3] that arises when dealing with frequency or the Planck constant because the units of angular measure (cycle or radian) are omitted in SI.[4][5][6][7][8]

In digital signal processing, the angular frequency may be normalized by the sampling rate, yielding the normalized frequency.

Examples

Circular motion

In a rotating or orbiting object, there is a relation between distance from the axis, r, tangential speed,v, and the angular frequency of the rotation. During one period, T, a body in circular motion travels a distance vT. This distance is also equal to the circumference of the path traced out by the body, $2\pi r$. Setting these two quantities equal, and recalling the link between period and angular frequency we obtain: $\omega = v/r.$

Oscillations of a spring

An object attached to a spring can oscillate. If the spring is assumed to be ideal and massless with no damping, then the motion is simple and harmonic with an angular frequency given by[9]

$$\omega = \sqrt{\frac{k}{m}},$$

where

> *k* is the spring constant,
> *m* is the mass of the object.

ω is referred to as the natural frequency (which can sometimes be denoted as ω_0).

As the object oscillates, its acceleration can be calculated by

$$a = -\omega^2 x,$$

where *x* is displacement from an equilibrium position.

Using "ordinary" revolutions-per-second frequency, this equation would be

$$a = -4\pi^2 f^2 x.$$

LC circuits

The resonant angular frequency in a series LC circuit equals the square root of the reciprocal of the product of the capacitance (*C* measured in farads) and the inductance of the circuit (*L*, with SI unit henry):[10]

$$\omega = \sqrt{\frac{1}{LC}}.$$

Adding series resistance (for example, due to the resistance of the wire in a coil) does not change the resonant frequency of the series LC circuit. For a parallel tuned circuit, the above equation is often a useful approximation, but the resonant frequency does depend on the losses of parallel elements.

Terminology

Angular frequency is often loosely referred to as frequency, although in a strict sense these two quantities differ by a factor of 2π.

See also

- Cycle per second
- Radian per second
- Degree (angle)
- Mean motion
- Orders of magnitude (angular velocity)
- Simple harmonic motion

References and notes

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Related Reading:

- Olenick, Richard P.; Apostol, Tom M.; Goodstein, David L. (2007). *The Mechanical Universe* (https://books.google.com/books?id=xMWwTpn53KsC&q=angular+frequency&pg=RA1-PA383). New York City: Cambridge University Press. pp. 383–385, 391–395. ISBN 978-0-521-71592-8.

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