

The Maxwell-Boltzmann distribution is a normal distribution with zero mean. This is the Maxwell-Boltzmann joint probability density function for velocity.

$$f(v_x, v_y, v_z) = \left( \frac{m}{2\pi kT} \right)^{3/2} \exp \left( -\frac{m(v_x^2 + v_y^2 + v_z^2)}{2kT} \right)$$

In spherical coordinates with  $v^2 = v_x^2 + v_y^2 + v_z^2$  we have

$$f(v, \theta, \phi) = \left( \frac{m}{2\pi kT} \right)^{3/2} \exp \left( -\frac{mv^2}{2kT} \right)$$

Integrate over  $\theta$  and  $\phi$  to obtain the following probability density function which is Maxwell's speed distribution.

$$f(v) = 4\pi \left( \frac{m}{2\pi kT} \right)^{3/2} v^2 \exp \left( -\frac{mv^2}{2kT} \right)$$

Recall that

$$dv_x dv_y dv_z = v^2 \sin \theta dv d\theta d\phi$$

and

$$\int_0^\pi \sin \theta d\theta = \cos(0) - \cos(\pi) = 2$$

Hence the integral can be done by inspection.

$$f(v) = \int_0^{2\pi} \int_0^\pi f(v, \theta, \phi) v^2 \sin \theta d\theta d\phi = 4\pi v^2 f(v, \theta, \phi)$$

Historically, Maxwell's speed distribution  $f(v)$  came first. Maxwell derived it in 1860. Boltzmann extended Maxwell's work in 1868.<sup>1</sup>

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<sup>1</sup><https://mathshistory.st-andrews.ac.uk/Projects/Johnson/chapter-6/>