

TRIANGULAR WAVE FUNCTION: PROBABILITIES

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Reference: Griffiths, David J. (2005), Introduction to Quantum Mechanics, 2nd Edition; Pearson Education - Problem 1.4.

The square modulus of the wave function which is the solution to the Schrödinger equation is interpreted as a probability density. As an example consider the wave function given by

$$(0.1) \quad \Psi(x, 0) = \begin{cases} A \frac{x}{a} & 0 \leq x \leq a \\ A \frac{b-x}{b-a} & a \leq x \leq b \\ 0 & \text{otherwise} \end{cases}$$

We can normalize Ψ by requiring

$$(0.2) \quad \int_0^b |\Psi|^2 dx = 1$$

Plugging in the formula and doing the integral gives

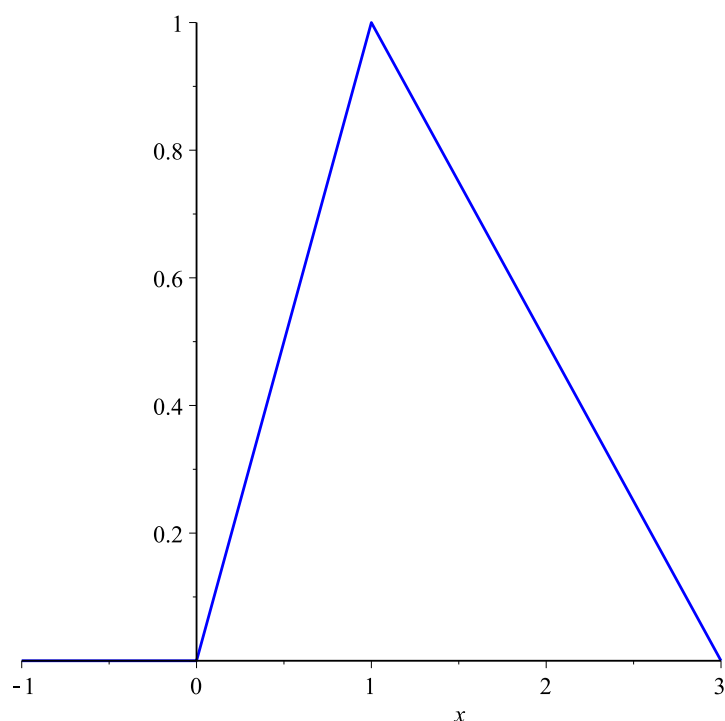
$$(0.3) \quad \int_0^b |\Psi|^2 dx = |A|^2 \left[\int_0^a \frac{x^2}{a^2} dx + \int_a^b \left(\frac{b-x}{b-a} \right)^2 dx \right]$$

$$(0.4) \quad = |A|^2 \frac{b}{3}$$

$$(0.5) \quad A = \sqrt{\frac{3}{b}}$$

where we've taken the positive real root for A . Note that A could also be multiplied by a phase factor $e^{i\delta}$ for any real δ without affecting normalization. This can be important in some applications where we need to add together wave functions.

Given this value for A , we can plot 0.1. Here, we've taken $a = 1$ and $b = 3$:



Since Ψ has its maximum at $x = a$, that is where the particle is most likely to be found. The probability of the particle being found to the left of $x = a$ is

$$(0.6) \quad P_{x < a} = \frac{3}{b} \int_0^a \frac{x^2}{a^2} dx = \frac{a}{b}$$

If $b = a$, then Ψ drops to zero at $x = a$ so $P_{x < a} = 1$. If $b = 2a$, then Ψ is an isosceles triangle symmetric about $x = a$ so $P_{x < a} = \frac{1}{2}$.

The expectation value of x is

$$(0.7) \quad \langle x \rangle = \int x |\Psi|^2 dx = \frac{a}{2} + \frac{b}{4}$$

where we used Maple to simplify the integration. If $b = 2a$, then $\langle x \rangle = a$ as expected.