Quantum Mechanics Built on Weird Observation

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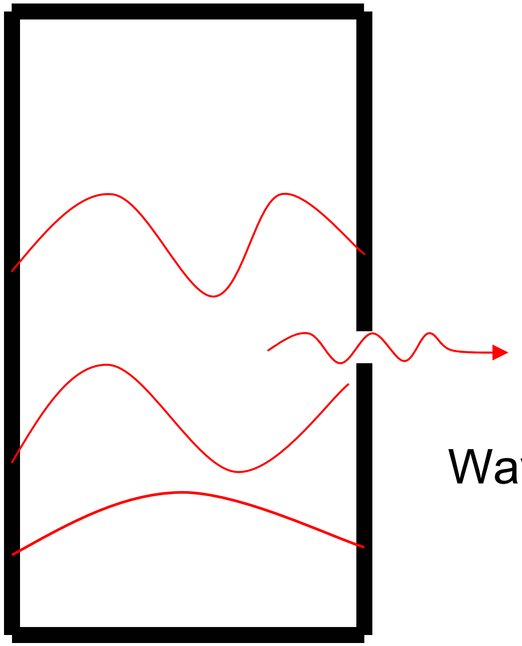
1. *Blackbody Radiation.*
2. *Diffraction by a double slit*
3. *A Particle in a box*

Blackbody Radiation: perfect absorber and radiator



A cubical solid at a high temperature emits photons reflecting several times before emerging through a narrow hole. The reflections ensure that the radiation is in thermal equilibrium.

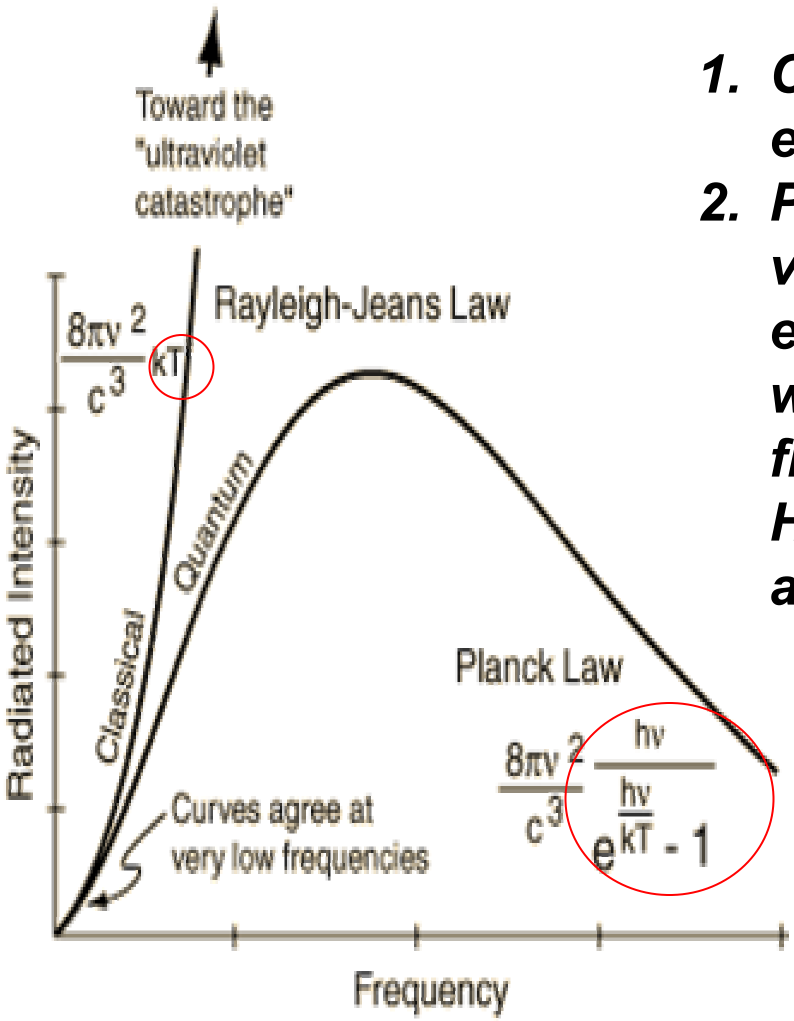
Waves of photons

We can predict what frequencies of light are radiated and their relative magnitudes:

$$\rho(\nu,T)d\nu = \frac{8\pi\nu^2}{c^3} E_{avg}\, d\nu$$

Averaged energy per mode

Density of modes



1. ***Classical theory can not fit experimental curve well.***
2. ***Planck's quantum theory fits very well if he assumed that the energy radiated by the dipoles was proportional to the frequency and it was quantized. He obtained the different averaged energy per mode.***

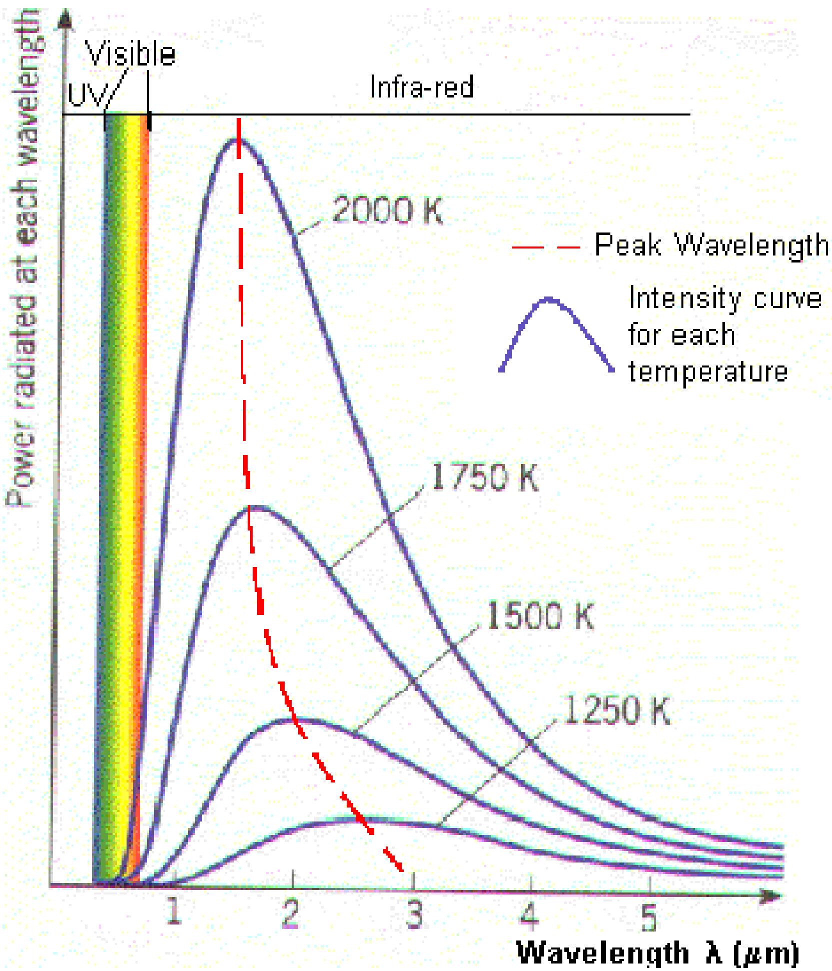


Fig 2: Black body radiation curves showing peak wavelengths at various temperatures

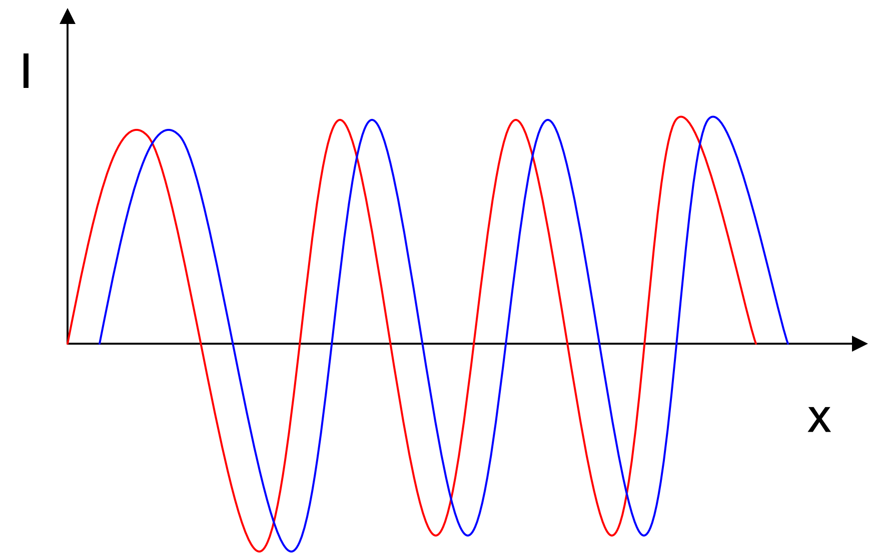
Planck's theory can predict spectral radiation of a blackbody at any temperature!

Let us see the simulation of a blackbody *radiationhttp://wps.aw.com/bc_engel_physchem_1/1,10357,1941509,.html*

Classic Waves:

$$\Psi_1 = A\sin(kx - \omega t + \varphi)$$

$$\Psi_2 = A\sin(kx + \omega t)$$



ϕ Is the phase angle of a wave, k and ω are the wave vector and angular frequency of the wave, and x is the position of the wave.

Interference of two traveling waves:

$$\Psi = \Psi_1 + \Psi_2$$

$$\Psi = A\sin(kx - \omega t + \varphi) + A\sin(kx + \omega t)$$

If ϕ=0

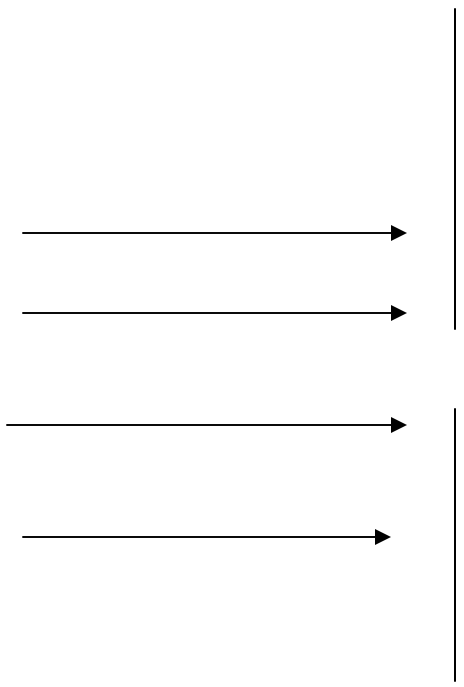
$$\Psi = 2A\sin(kx)\cos(\omega t)$$

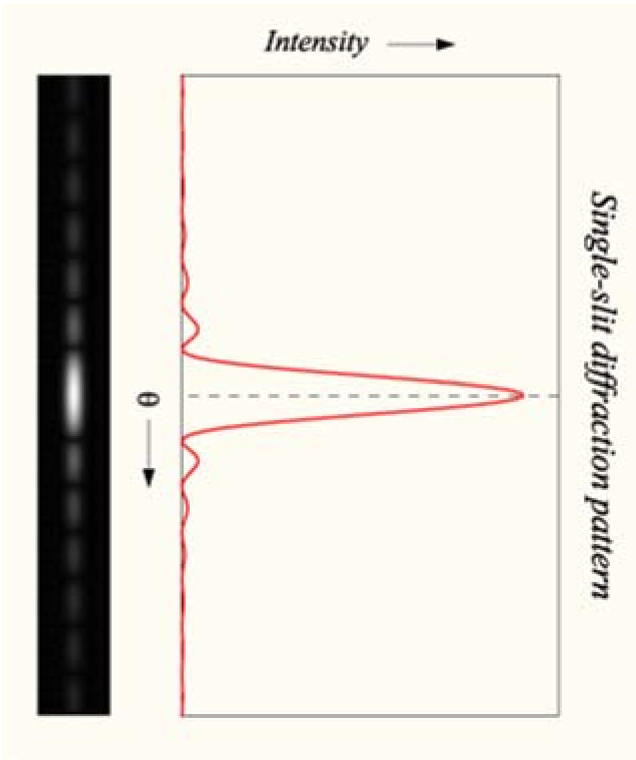
The wave function depends on x and t.

Let us look at the supposition of two waves:

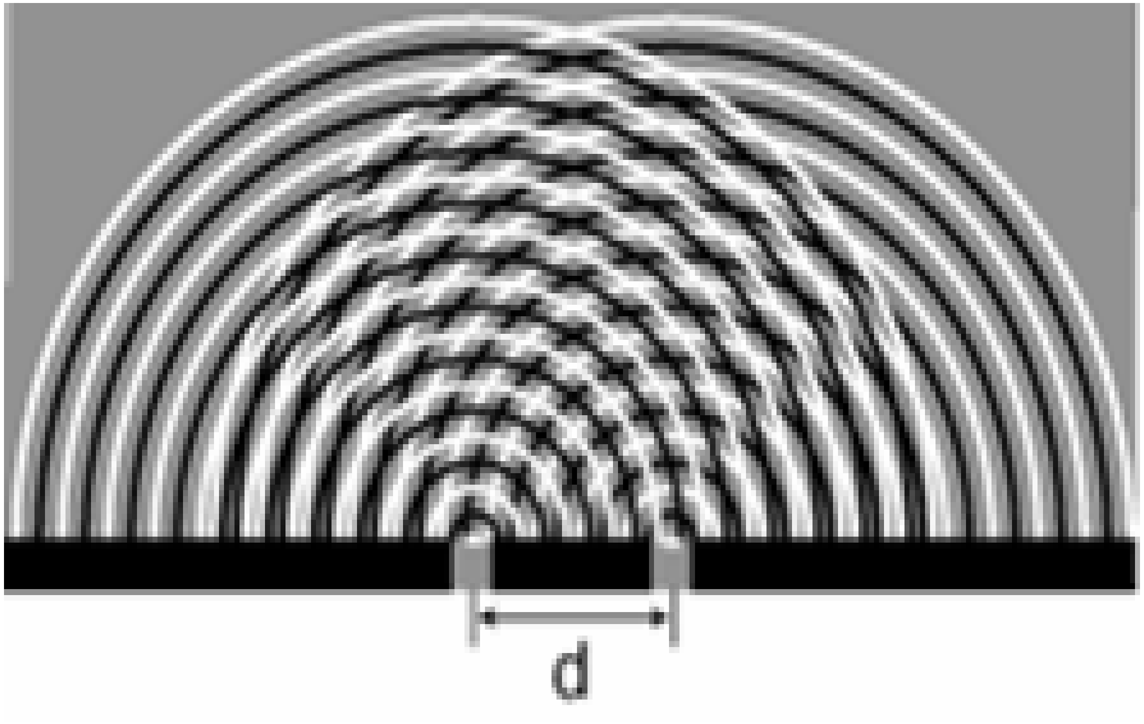
$$\omega = \frac{2\pi}{T} \qquad k = \frac{2\pi}{\lambda}$$

Particles exhibit Wave-like Behavior

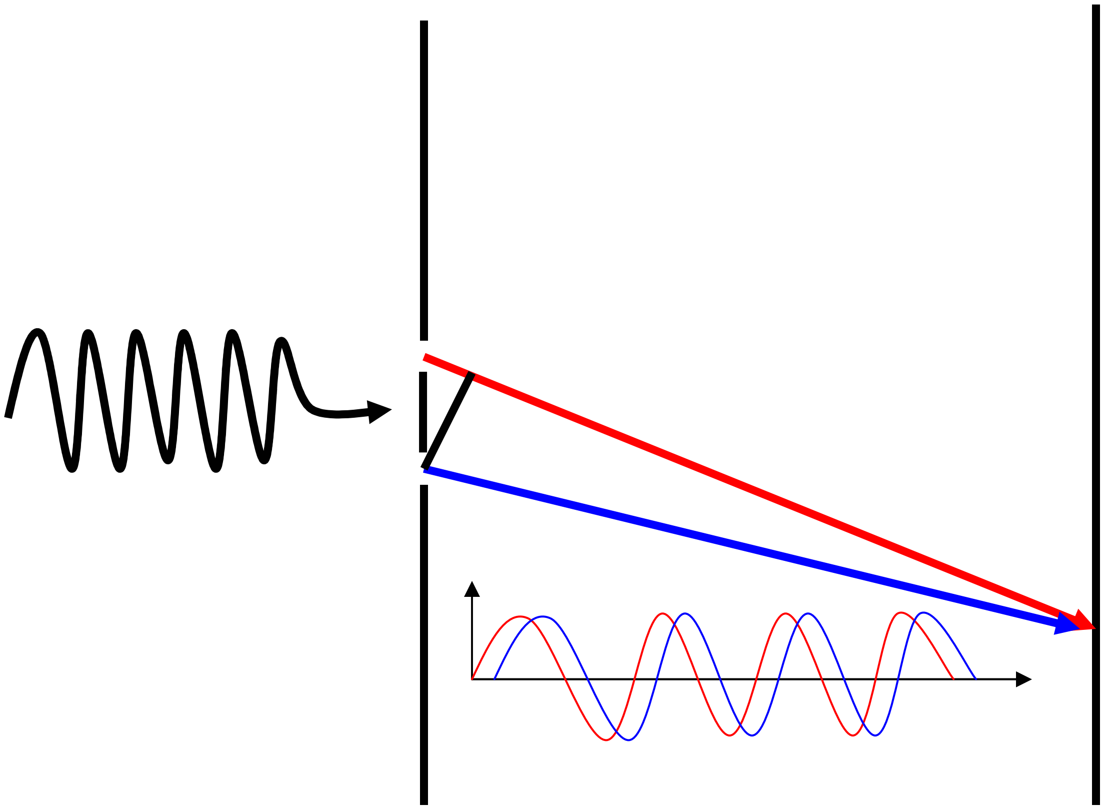


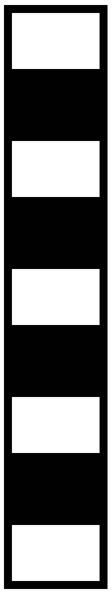


Diffraction of a wave through a single slit



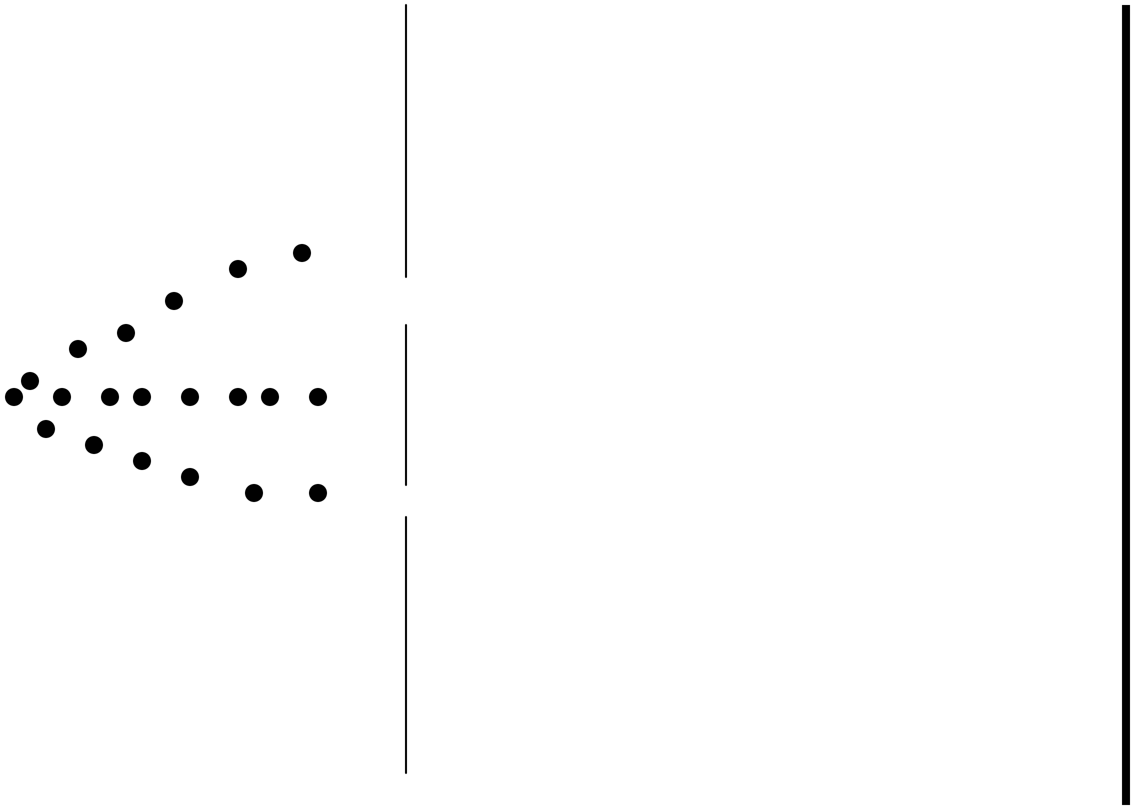
Wave interference, such as water waves





An interference pattern

Light waves of diffraction by a double slit where there is an interference pattern (white and dark)



What we see on this screen? One spot or interference pattern?

We have a bunch of particles hitting to double slits, such as electrons, atoms or molecules

Let us to go a movie of particle diffraction through a double slit.

Why particle move like a wave?

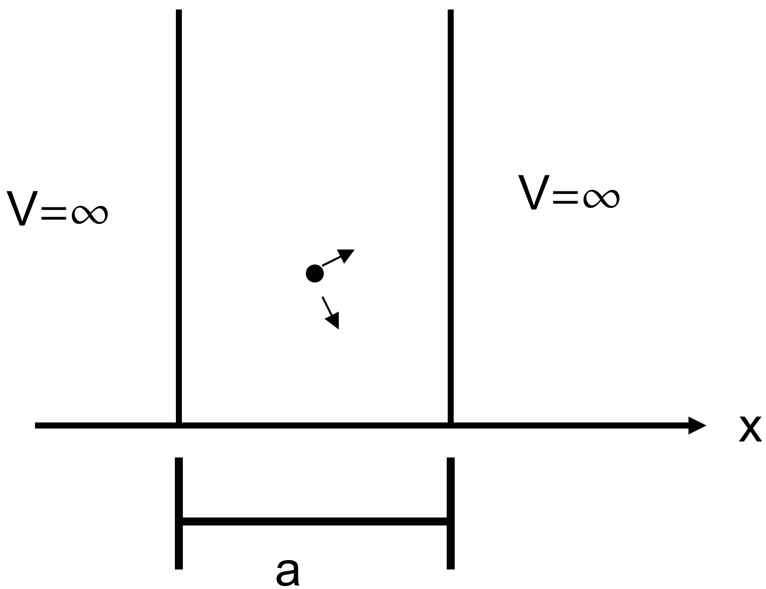
De Broglie Relation:

$$\lambda = \frac{\hbar}{p}$$

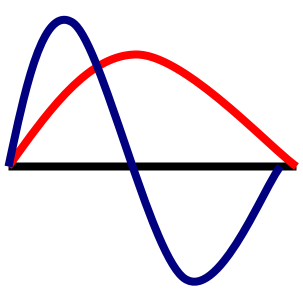
*Where h is the Planck constant and p is the particle momentum given by p=m*v in which the momentum is expressed by the particle mass and velocity.*

In the microscopic world, particles have a duality of particle and wave properties!

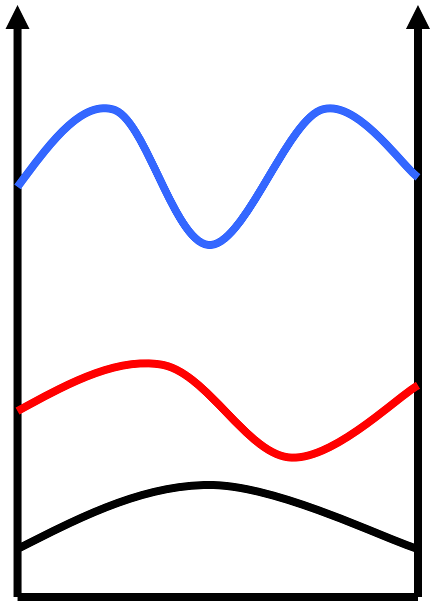
Particles in a box



Suppose a particle moves in an infinite potential well, so the particle can not escape from the well. We know that the particle move like a wave. The length of the well can be regarded a string, and it makes a wave with any wavelength. According to De Broglie relation, we know that the particle will have the different values of momentum and energy.



Let us to see a show of how particles move in a box: focusing on changes of width of the well and waveform of a particle!



Wavefunction of a particle in a box:

$$\psi_n(x) = A \sin\left(\frac{n\pi x}{a}\right)$$

$$n = 1, 2, 3 \ldots$$

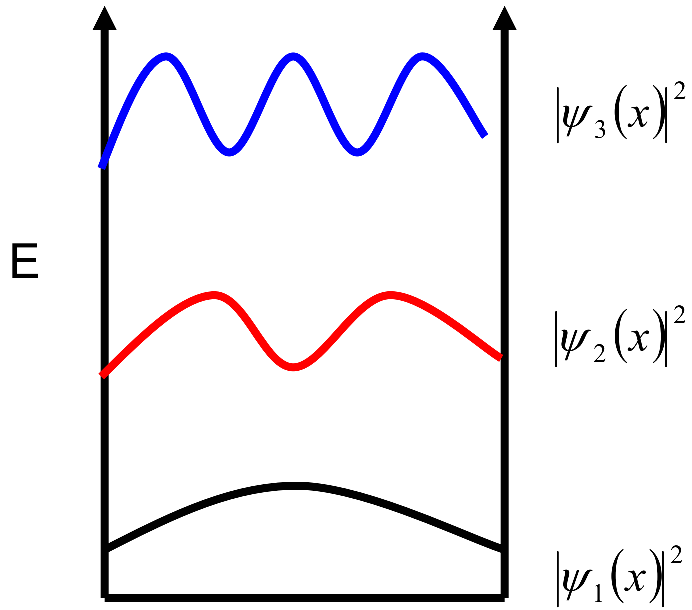
Energy of a particle in a box:

$$E = \frac{p^2}{2m} = \frac{1}{2m}\frac{h^2}{\lambda^2}$$

$$\lambda = \frac{a}{n\pi}$$

$$E = \frac{h^2}{2m}\left(\frac{n\pi}{a}\right)^2 = \frac{h^2 n^2}{8ma^2}$$

Probability of finding a particle in a box:



$$P = \psi^*(x)\psi(x)dx$$

Due to the property of the wave movement of a particle, it is hard to say the position of the particle!

Conclusions

- In the microscopic world, the particles move like a wave, rather than like linear movement of macroscopic objects.
- Energy is quantized rather than continuum, this is why we call it quantum mechanic when we study electrons and molecules.
- Quantum mechanics is a theory to study a microscopic world, such as, atoms and molecules.