Physics 310

Card Appendix

Quantum Concepts

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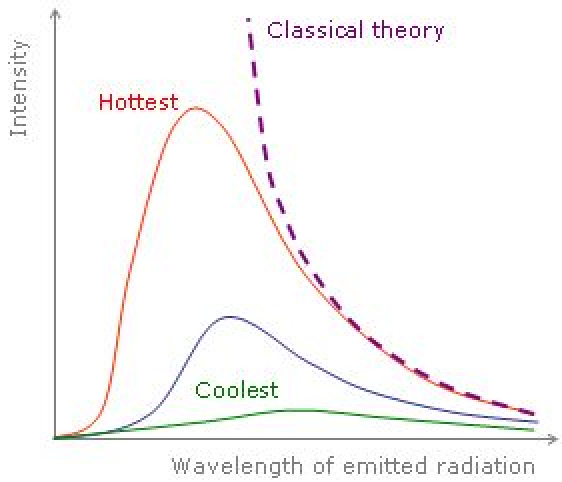


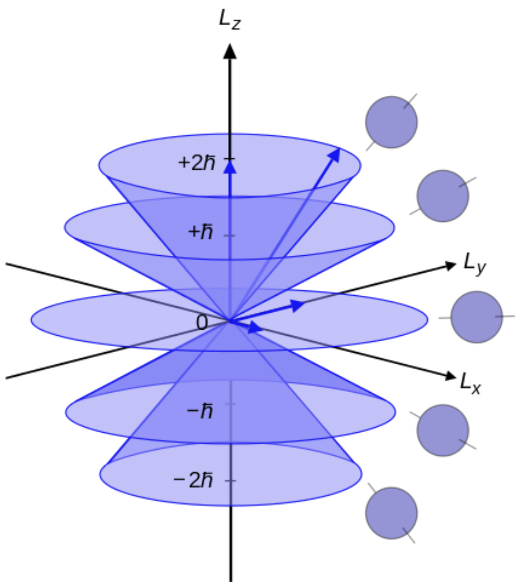
0. Blackbody Radiation:

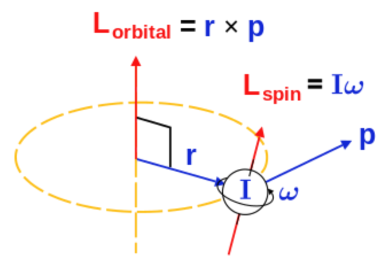
Blackbody radiation occurs when light waves hit a black body (such as a star) and releases a different type of light wave that depends on the particular black body. Classical physics expected that the intensity of radiation would increase as the wavelength of the emitted light was smaller, but in reality, the radiation followed the curves below it. Max Planck found out that energy can exist in a very small packet, and in doing so, he was able to adjust the theory so that the theoretical curves matched the actual curves

$$\int |\Psi|^2 = 1$$

3. Normalize:

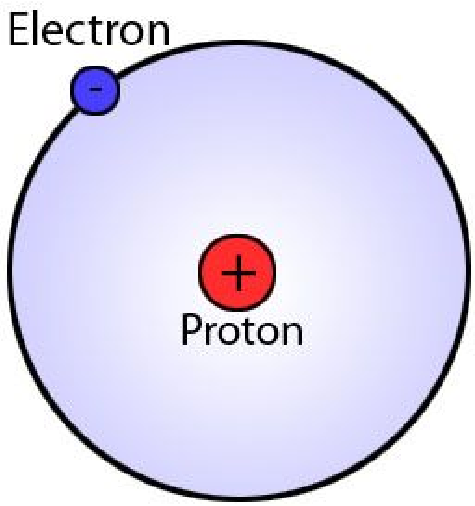
A particle must be found somewhere in space. This relationship is represented by the above equation. This equation means that the probability of finding a wavefunction is 1, just as the probability of you rolling a 1,2,3,4,5 or 6 on a 6 sided die being 1. If you normalize a wave function at some time t_0, then it will be normalized for all t.





4. Angular Momentum:

Angular momentum (L) is conversed just like classical linear momentum and it is the product of the moment of inertia and angular velocity. L = Iω Angular momentum is quantized and goes up by integers of 1. n = 1, 2, 3, … Like with other aspects of quantum mechanics, you can't know everything about angular momentum. For example, if you know the angular momentum in the z direction (L_z), you can't know the x and y components. This is shown in the figure above, where the cones represent the different possibilities of L_x and L_y.



4. Hydrogen:

The hydrogen atom is the easiest to study in quantum mechanics because it only has one valence electron. The distinct spectral lines that hydrogen emits when it is excited demonstrates how energy is quantized and only certain wavelengths excite the electron in the hydrogen atom.

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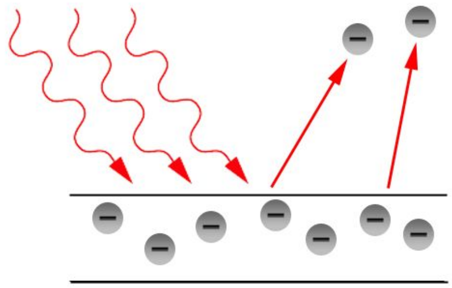
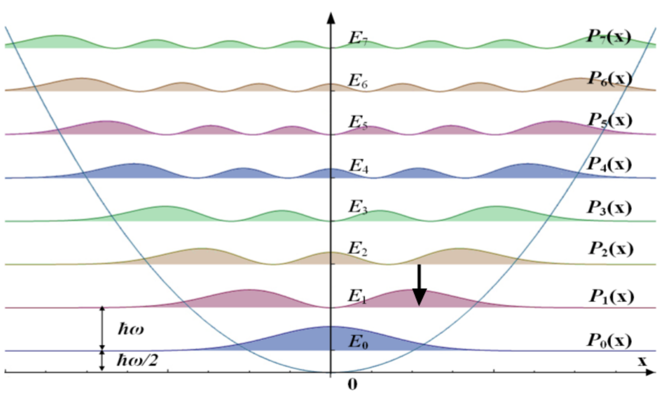
5. Wavefunction:

A wavefunction is a type of function that is used ubiquitously throughout quantum mechanics. While the wavefunction is not a physical entity, it contains information about a particle. It is used primarily to find the probability of a particle existing at a particular place and time.



6. Photoelectric Effect:

In the photoelectric experiment, light (red sine waves) is shone on a metal, and electrons are immediately emitted. Classical physics expected that shining light on metal would release electrons, but after some time for the metal to absorb the energy of the light. After this experiment was verified, electrons were then considered to have characteristics of particles as well as waves.



7. Lowering Operator:

The lowering operator is also known as a step-down operator. When you apply the lowering operator to the energy of a system, the energy 'steps-down' one lower. So if a particle in the energy state E_2 and you apply the lowering operator, the particle would then be in energy state E_1. Note: you cannot apply the lowering operator to the ground state energy, E_0 because there is no energy lower than the ground state.

8. Schrodinger's Cat:

In quantum mechanics, measurement is an active process. You can't know something unless you observe it, but once you observe it, it changes. This uncertainty is demonstrated by Schrodinger's cat. The cat is in a box with a device that could kill it at any moment. As a physicist, you can't know if the cat is dead or alive without seeing it. So you assume the cat in the box is both dead and alive at the same time. For particles, this is known as a superposition of wavefunctions.

9. Famous Physiscists

9.1 Vera Rubin

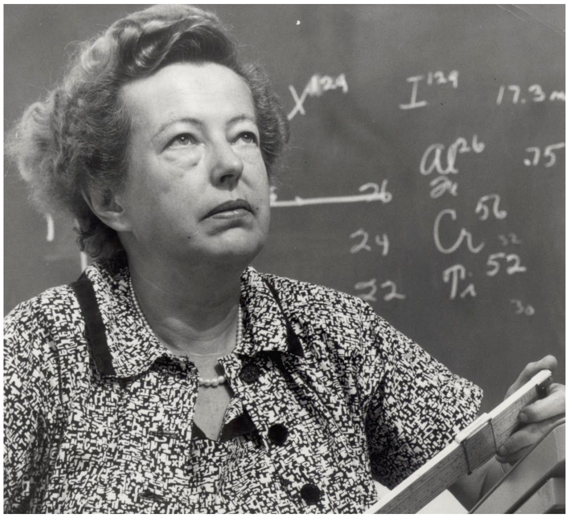
A 1948 graduate of Vassar College, Vera Rubin helped pave the way for future female astronomers. One of her life long works was looking for evidence of dark matter particles. Her research found evidence for dark matter, but no one has been able to capture it yet.

9.2 Lene Hau

In 1998, Professor Lene Hau slowed light down to about 17 m/s. This is compared to 299,792,458 m/s which is the speed of light. Then in 2001, she completely stopped light and restarted it in a separate location during her quantum network experiments. Previously, this had never been done.

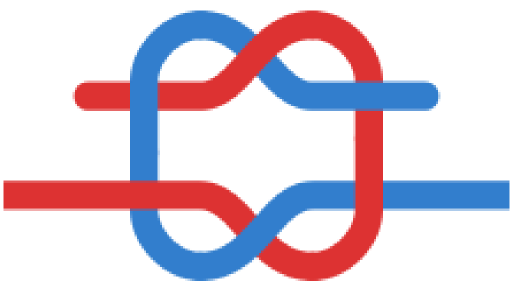
9.3 Fabiola Gianotti

Dr. Gianotti works for CERN and led the ATLAS experiment that discovered a particle with the properties of the predicted 'Higgs boson' particle. Previously, this particle had only been theoretical.



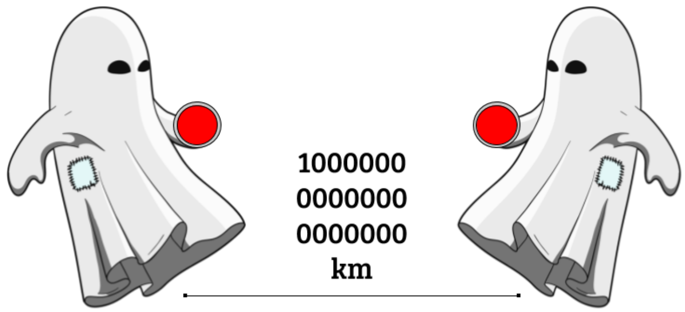
9.4 Maria Goeppert-Mayer:

Maria Goeppert-Mayer was the second woman to win the Nobel Prize for physics, after Marie Curie. She won the prize for her work in proving the shell model of the nucleus. The nuclei form shells of increasing energy in the nucleus.



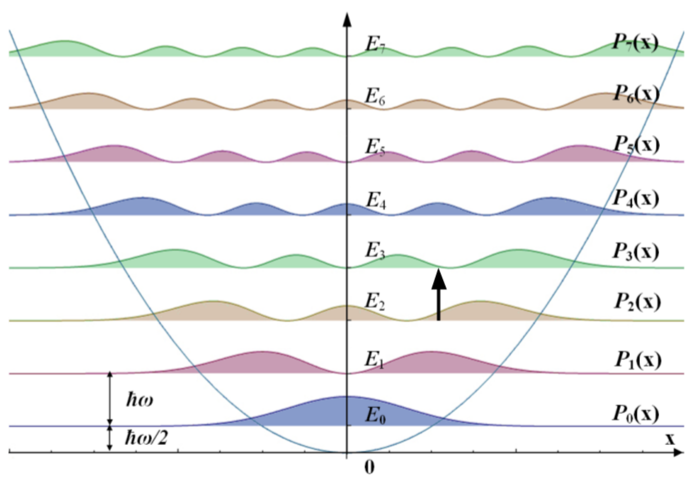
10. Entanglement:

Quantum entanglement is when two particles, separated by some distance, have quantum states that depend on each other. For example, if you measured one particle to spin up, the other would be measured to be spin down. The paradox is, once you measure one particle, it’s quantum state changes. This is also known as the wavefunction collapsing. Physicists today are still trying to find out how entanglement happens and what it means for quantum mechanics.



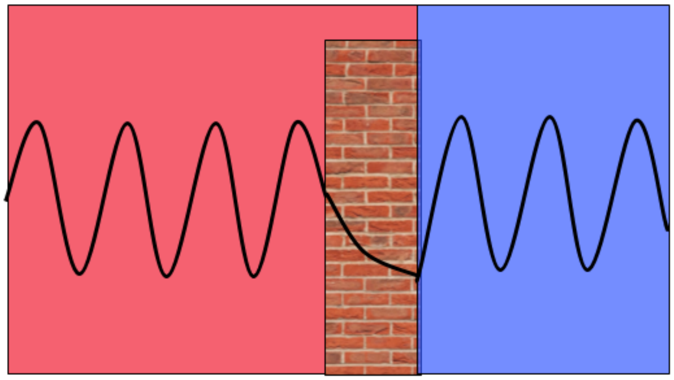
11. Spooky Action at a Distance

Classically, spooky action at a distance can be seen in forces like gravity and electromagnetism. Objects can and are affected by gravity, even though nothing is physically touching it. In quantum mechanics, spooky action at a distance is the idea that a particle can be affected by something without being physically touched. This ties directly into quantum entanglement and is much debated in the physics community.



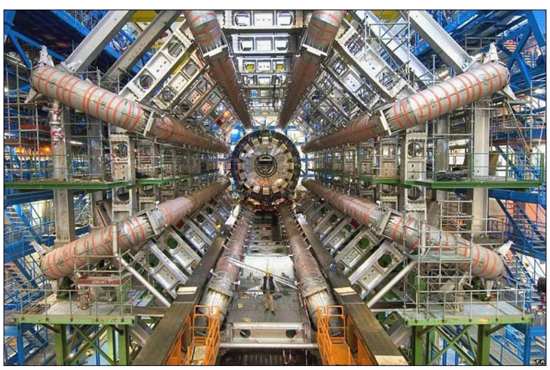
12. Raising Operator:

A raising operator is also known as a step-up operator. When you apply the raising operator to the energy of a system, the energy 'steps-up' one higher. So if a particle in the ground state energy E_0 and you apply the raising operator, the particle would then be in energy state E_1.



14. Tunneling:

A particle may be ‘trapped’ by a potential energy barrier. To ‘escape’, the particle needs to have energy greater than the potential energy. It is also possible for the particle to escape by tunneling out of the barrier. The probability of this happening is very low and you can calculate it for various particles.



25. CERN

CERN is the largest particle physics laboratory in the world. It’s based in Europe, and physicists from all over the world work there trying to discover more about our world. The lab has instruments like particle accelerators and particle detectors. This includes the Large Hadron Collider (LHC), which has a circumference of 27 kilometers (16.8 miles).