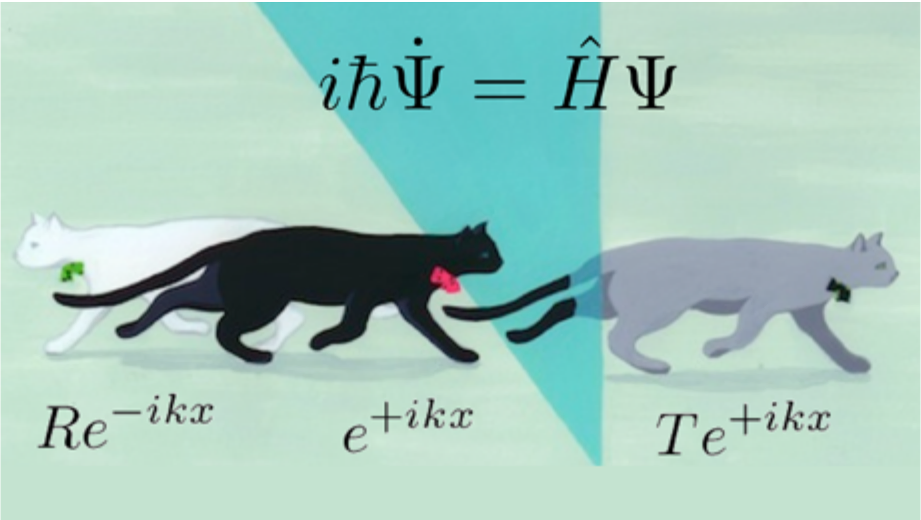
Exploring Quantum Physics

Coursera, Spring 2013 Instructors: Charles W. Clark and Victor Galitski

Quantum Theory: Old and New

Part I. The Bohr model of the atom



Quantum Theory: Old and New

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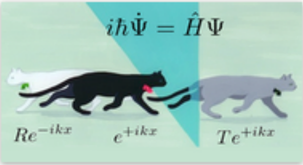
UNIVERSITY OF MARYLAND

Exploring Quantum Physics

by Dr. Charles Clark and Dr. Victor Galitski



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Additional Materials

Mathematical References

For those who may want to brush up on their mathematics before or during the courses, we present **a short crash course on the math**

Original scientific literature

Some lectures draw on material from original scientific literature, which we provide here for the convenience of students.

- Atomic clocks and quantum computers
- The Bohr model of the atom
- Bose-Einstein condensation
- The discovery of deuterium
- The discovery of deuterium - a simplified account
- The green laser pointer
- The photoelectric effect
- Does quantum mechanics provide a complete description of physical reality?
- Young's double slit experiment and diffraction

Quantum Theory: Old and New

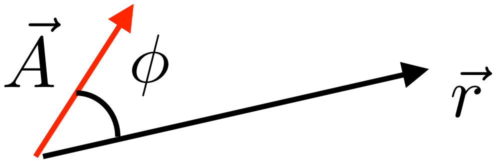
$$E = \frac{p^2}{2\mu} - \frac{Ze^2}{r}$$

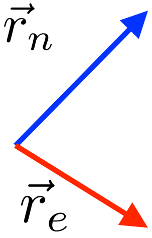
$$\vec{L} = \vec{r} \times \vec{p}$$

$$\vec{A} = \vec{p} \times \vec{L} - Ze^2\mu\hat{r}$$

$$A^2 = 2\mu E L^2 + Z^2 e^4 \mu^2$$

$$r = \frac{L^2}{Ze^2\mu + A\cos\phi}$$





$$\vec{r} = \vec{r}_n - \vec{r}_e$$

$$r = \sqrt{\vec{r} \cdot \vec{r}}$$

The hydrogen-like systems:
one electron and one nucleus

Classical mechanics provides a compact solution:

- Allows for any value of E.
- All orbits are ellipses for $E < 0$.
- All orbits are hyperbolas for $E > 0$.

Quantum Theory: Old and New

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Niels Henrik David Bohr
1885-1962
1922 Nobel Prize in Physics
"for his services in the investigation of the structure of atoms and of the radiation emanating from them".

Niels Bohr's great breakthrough

"On the Constitution of Atoms and Molecules," *Philosophical Magazine*, Series 6, Vol. 26, No. 151, pp. 1-25 (July 1913).

where

$$M_0 = \frac{h}{2\pi} = 1{\cdot}04 \times 10^{-27}.$$

If we therefore assume that the orbit of the electron in the stationary states is circular, the result of the calculation on p. 5 can be expressed by the simple condition: that the angular momentum of the electron round the nucleus in a stationary state of the system is equal to an entire multiple of a universal value, independent of the charge on the nucleus. The possible importance of the angular momentum in the discussion of atomic systems in relation to Planck's theory is emphasized by Nicholson *.

The angular momentum of the system is quantized in units of ħ.

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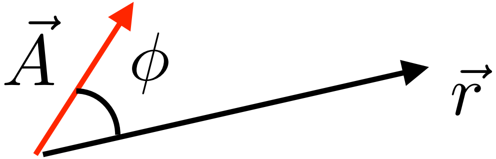

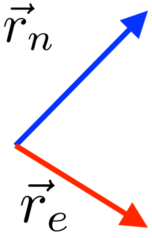

$$\vec{r} = \vec{r}_n - \vec{r}_e$$

$$r = \sqrt{\vec{r} \cdot \vec{r}}$$

Bohr: Hydrogen atom has stationary bound states for *A* = 0 and *L* = *n* ħ, with *n* = 1, 2, 3 , . . .

$$E(n) = -\frac{Z^2 e^4 \mu}{2\hbar^2 n^2} = -\frac{(Z\alpha)^2}{2n^2}\mu c^2$$

Fine-structure constant $\alpha = \frac{e^2}{\hbar c}$ ≈ 1/137.036

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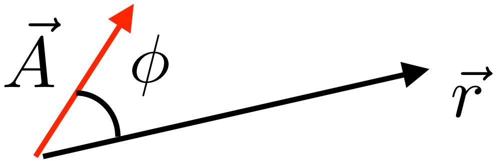


Bohr model gives important fundamental constants when Z = 1 and μ = m_e, the mass of the electron:

$$E(n) = -\frac{1}{n^2}\frac{e^4 m_e}{2\hbar^2} = -\frac{1}{n^2} R_\infty hc$$

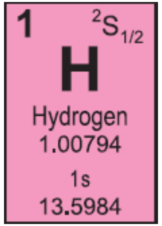
Rydberg constant R_∞ = 10 973 731 m^{-1}

R_1 hc = 13.606 eV (electron volts)

$$r(n) = n^2 \frac{\hbar^2}{m_e e^2} = n^2 a_0$$

Bohr radius = 5.292 x 10^{-11} m

Atomic Structure and Spectra



656 nm

410 nm

These lines at wavelengths given by Bohr!

λ = 650 nm R

λ = 532 nm G

λ = 405 nm V