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| **Topic** | Quantum physics research |
| **Subtopic** | DeBoglie wavelength |
| **Concept Name** | The debroglie wavelength and its equation |
| **Description** | De Broglie postulated that in analogy to light, matter could also have particle and wave characteristics. |
| **Formula** | * + Where E represents relative energy equation by Albert Einstein which implies that the energy of a body is its mass multiplied by the speed of light   + De Broglie hypothesized that this energy was also equal to KE standing for kinetic energy and m0c2 being the resting mass energy   + standing for electon momentum   + standing for wavelength   + standing for energy   + standing for Planck’s constant     - Planck’s constant relates to the energy in one quantum also known as photon of electromagnetic radiation to the frequency of that radiation   + standing for frequency * E=mc^2=KE+m\_0c^2 |
| **Drawing/Animation** | http://wikipremed.com/01physicscards600/472a.gif |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| **Topic** | Quantum physics research |
| **Subtopic** | DeBroglie wavelength |
| **Concept Name** | Quantizized angular momentum and the bohr atom |
| **Description** | De Broglie’s matter wave provided an explanation of the quantization of angular momentum in the Bohr atom. Waves travelling in opposite directions in a confined space can set up a standing wave due to constructive interference. A standing wave in a circle is formed when an integer number of wavelengths fits around the circumference: |
| **Formula** | * + standing for wavelength   + standing for Planck’s constant   + m standing for mass   + v standing for velocity   + r standing for radius   + n standing for orbit   + standing for wavelength   + L is only conserved   λ=h/mv  2πr=nλ\_n  L=mvr=(hr)/λ=(hr)/[(2πr)/n] =(nh)/(2π) |
| **Drawing/Animation** | https://myweb.rollins.edu/jsiry/Bohr_atom_mode.svg.png |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| **Topic** | Quantum physics research |
| **Subtopic** | DeBoglie wavelength |
| **Concept Name** | Davisson-Germer Experiment |
| **Description** | Davisson and Germer showed that electrons do behave like matter waves and can be diffracted. Electrons are reflected from the surface of a nickel target. The surface layer of atoms in nickel acts as a diffraction grating. |
| **Formula** | 2mv^2 = eV → v = √((2Ve)/m) |
| **Drawing/Animation** | http://dev.physicslab.org/img/7230f851-fb87-46d6-ae06-41a587f774c2.gif https://i.gyazo.com/ca7ed10c220e182b532da6f8c4fa3404.png |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| **Topic** | Quantum physics research |
| **Subtopic** | Matter Waves |
| **Concept Name** | Matter waves |
| **Description** | * Electron diffraction was demonstrated by Davisson and Germer and G. P. Thomson (son of J. J. Thomson). * Subsequently, diffraction for other matter waves such as atoms, neutrons and even molecules has been demonstrated. * Atom interferometers can be constructed using standing waves of light as atomic mirrors and beam splitters * All matter can have wavelike properties. * The electron microscope is based on the wave properties of electrons.] |
| **Formula** | http://www.grandinetti.org/resources/Teaching/Chem121/Lectures/QuantumTheoryofMatter/DeBroglieCalc.gif |
| **Drawing/Animation** | http://www.mysearch.org.uk/website1/images/pictures/526.1.jpg https://i.gyazo.com/d2f673442ee78d1b3d0b162b737069a0.png |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| **Topic** | Quantum physics research |
| **Subtopic** | Heisenberg uncertainty principle |
| **Concept Name** | Minimum uncertainty |
| **Description** | * Our knowledge of conjugate quantities is inherently uncertain. * No matter how good our measuring instruments are we cannot simultaneously know x and p or E and t with complete precision. |
| **Formula** | * Heisenberg uncertainty principle * For Gaussian functions * Heisenberg uncertainty principle * For Gaussian functions |
| **Drawing/Animation** | http://www.electrical4u.com/addpost/images/precisely%20determined%20momentum-2.jpg |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| **Topic** | Quantum physics research |
| **Subtopic** | Schrödinger's Equation |
| **Concept Name** | Time-Dependent Equation |
| **Description** | * The wave function   + The state of a physical system is represented by a wave function which contains all the information that can be known about the system.   + The wave function is in general complex (it has real and imaginary parts) * The wave function of a particle undergoing a force F(x) is the solution to the Schrödinger equation: |
| **Formula** | https://i.gyazo.com/5f7b78b0a6528bbc0c5baa6d0aaf6b80.png  U(x) is the potential energy associated with the force:  psi(x,t)=phi(x)chi(t)  (iℏ)/(chi(t))(del)/(delt)chi(t) = -1/(phi(x))ℏ^2/(2m)del^2/(delx^2) phi(x) + U(x)  (iℏ)/(chi(t))d/(dt)chi(t) =E    -1/(phi(x))ℏ^2/(2m)d^2/(dx^2)phi(x) +U(x) = E  F= (delU)/(delx) |
| **Drawing/Animation** |  |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| **Topic** | Quantum physics research |
| **Subtopic** | Schrödinger's Equation |
| **Concept Name** | Separation of variables |
| **Description** | Since U(x)does not depend on time, solutions can be written in separable form as a part that is only position dependent and a part that is only time dependent: |
| **Formula** | * Ψ(x,t)=ϕ(x)χ(t)   Left hand side (LHS) is a function of t alone. Right hand side (RHS) is a function of xx alone.  LHS=RHS only if LHS = E and RHS = EE (EE is a constant).  Solutions for the time-dependent equation:  Check:  Psi(x,t)=phi(x)chi(t)  (ihphi(x)del)/(deltchi(t))=-((chi(t)h^2)/(2m)del^2)/(delx^(2phi(x)))+U(x)phi(x)chi(t)  (ih)/(chi(t))(del)/(delt)chi(t)=-(1)/(phi(x))(h^2)/(2m)(del^2)/(delx^2)phi(x)+U(x)  (ih)/(chi(t))(d)/(dt)chi(t)=E  -(1)/(phi(x))(h^2)/(2m)(d^2)/(dx^2)phi(x)+U(x)=E |
| **Drawing/Animation** |  |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| **Topic** | Quantum physics research |
| **Subtopic** | Schrödinger's Equation |
| **Concept Name** | Time-independant Equation |
| **Description** | This equation is not always easy to solve analytically, but can be solved numerically on a computer. However we can analytically solve some special cases…. |
| **Formula** | Physically acceptable solutions ϕ(x)ϕ(x) (stationary states) must satisfy certain conditions:   1. ϕ(x) must be normalized 2. ϕ(x) must be continuous 3. ϕ(x) must be single valued 4. U(x)=0 in regions where it is physically impossible to find the system 5. ϕ(x)=>0ϕ(x)\ri0 as x=>±∞   -(h^2)/(2m)(d^2)/(dx^2) psi(x) + U(x)psi(x) =Epsi(x) |
| **Drawing/Animation** |  |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| **Topic** | Quantum physics research |
| **Subtopic** | The Quantum Mechanic Wave Function |
| **Concept Name** | The Quantum Mechanic Wave Function |
| **Description** | * In quantum mechanics, the state of a physical system is represented by a wave function which contains all the information that can be known about the system. * The wave function is in general complex (it has real and imaginary parts). |
| **Formula** | In configuration (coordinate) space the wave function of a particle is a function of the position of the particle at a given time:  Ψ(x,y,z,t)  For NN particles, this can be generalized to  Ψ(x1,x2,...xN,y1,y2,...yN,z1,z2,...zN,t)  Psi(x,y,z,t)  Psi(x1,x2,...xN,y1,y2,...yN,z1,z2,...zN,t) |
| **Drawing/Animation** |  |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| --- | --- |
| **Topic** | Quantum physics research |
| **Subtopic** | The Quantum Mechanic Wave Function |
| **Concept Name** | Normalization |
| **Description** | * The wave functions Ψ and cΨ represent the same state, where cc is a complex number. * We can always multiply the wave function by an arbitrary complex number without changing it. * Multiple of a Ψ function by a complex number does not change any observable quantity that can be measured about the particle. |
| **Formula** | Consider the normalization integral  If I is a finite number, then the wave function is square integrable. If we multiply the wave function by a constant.  then the wave function is said to be normalized (to unity):  I=int|Psi(x,t)|^2 dx=intPsi(x,t)dx  1/sqrt(I)  int|Psi(x,t)|^2 dx=1 |
| **Drawing/Animation** |  |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| --- | --- |
| **Topic** | Quantum physics research |
| **Subtopic** | The Quantum Mechanic Wave Function |
| **Concept Name** | The Born Interpretation: Probabilities |
| **Description** | P(x,t)P(x,t)  is called the probability density function. It yields the probability of the particle being in the region dxdx around position xx at time tt  Hence the normalization requirement is a statement that the probability of finding the particle somewhere is 1. |
| **Formula** | * The absolute square of the normalized wave function ΨΨ :   The probability of finding a particle in a region a  P(x,t)dx=|Psi(x,t)|^2 dx  int|Psi(x,t)|^2 dx=intP(x,t)dx=1  int\_a^b|Psi(x,t)|^2dx |
| **Drawing/Animation** |  |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| **Topic** | Quantum physics research |
| **Subtopic** | The Quantum Mechanic Wave Function |
| **Concept Name** | Superposition principle |
| **Description** | If the wave functions  Ψ1 and Ψ2  represent two possible states of the system, then any linear combination  Ψ=c1Ψ1+c2Ψ2  also represents a possible state of the system. This is the superposition principle.  This allows for superpositions of a particle wave function in two different locations (Recall double slit experiment).  Note the last two terms from the double slit experiment with electrons.  Psi\_1 and Psi\_2 Psi=c\_1Psi\_1+c\_2Psi\_2 |
| **Formula** | |Psi|^2 = |c\_1Psi\_1 +c\_2Psi\_2|^2 =(c\_1Psi\_1 +c\_2Psi\_2)(c\_1Psi\_1+c\_2Psi\_2) =|c\_1|^2|Psi\_1|^2 + |c\_2|^2|Psi\_2|^2 |
| **Drawing/Animation** |  |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| **Topic** | Quantum physics research |
| **Subtopic** | Particle Nature of Light |
| **Concept Name** | Spectroscopy and Atomic Structure |
| **Description** | A spectrometer is an instrument for measuring the wavelengths of light. The pattern of wavelengths recorded is the called a spectrum. Spectral analysis provided a powerful tool to study the structure of atoms.  We have seen that heated objects emit a continuous spectrum radiation. Gases in a discharge tube absorb and emit discrete wavelengths (discrete spectral lines). Every gas emits and absorbs a unique discrete spectrum. The absorption and emission spectra differ: Every absorbed wavelength is emitted but not every emitted wavelength is absorbed (???) |
| **Formula** |  |
| **Drawing/Animation** | https://i.gyazo.com/27d170223c6aa7cd1e9995a715eff05e.png |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| **Topic** | Quantum physics research |
| **Subtopic** | Particle Nature of Light |
| **Concept Name** | Spectral Lines of Hydrogen |
| **Description** | Balmer Series: Balmer looked at the visible spectral lines for hydrogen and empirically deduced a formula  Classical model:   * Rutherford had demonstrated that atoms have a small, positively charges nucleus. * Negatively charge electrons orbit the nucleus. * According to Maxwell’s equations, an oscillating charge emits radiation. The orbiting electron should emit a continuous spectrum. * As the electrons radiate, they lose energy, and their orbits decay until they fall into the nucleus!   https://i.gyazo.com/3fcfdfb2f1c6e70cd535055685e3bcf6.png |
| **Formula** | https://i.gyazo.com/cda803c9c5f30d14d0b368fa04af19d5.png  lambda=C\_2(n^2/(n^2-m^2 )), m=2, n=3,4,5… oo  lambda =(n=oo)=C\_2=364.56nm |
| **Drawing/Animation** |  |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| Quantum physics research |
| Particle Nature of Light |
| Bohr Model of the Atom |
| Bohr’s postulates:   * Electrons orbit the nucleus and feel the Coulomb force (as in the Rutherford model). * Only certain orbits are stable. An electron in these orbits does not radiate energy. It is said to be in a stationary state of energy. * An electron jumps between stationary states by absorbing or emitting a photon of energy equal to the energy difference between the two stationary states: * The angular momentum of an electron in a stable orbit (stationary state) is quantized in integer multiples of h/2πh/2π.   **Correspondence Principle**  The correspondence principle formulated by Bohr states that quantum physics should correspond to classical physics in the regime where classical theory is known to be valid. Roughly speaking the classical regime occurs when the quantum numbers of a system are very large. In general classical physics does not simply emerge from quantum mechanics in the way that Newtonian dynamics emerges from relativistic dynamics at small velocities. Connecting the classical limit to quantum theory is a tricky business and the subject of much research even today.  E\_i-E\_f=hf  L=(nh)/(2pi) =nh |
| Bohr model of the hydrogen atom: Coulomb force on the electron:  If the electron is moving in a circular orbit, then from quantization of angular momentum,  Equating the two expressions for v we obtained quantized radii of the allowed stable orbits:  ao is the Bohr radius (orbit corresponding to n=1n=1). This radius agrees with the experimentally measured radius of the hydrogen atom!  Total energy of the electron = kinetic energy + potential energy  Inserting the quantized orbital radii,  E1: lowest energy ground state( corresponding to n=1). Energy states with quantum number n>1: excited states.  The negative sign indicates that the electron is bound to the nucleus due to Coulombs force.  The energy required for the electron in the ground state to just escape the attraction of the proton is the ionization energy:  This agrees with the measured ionization energy for hydrogen!  Frequency of light absorbed or emitted when the electron jumps between energy levels:  This formula agrees exactly with the general Balmer formula!  Energy level diagram   * When an electron jumps to the ground energy state it cannot jump down any further. It will remain in the ground state. * If an electron is in the ground state. Transitions from 1 to n are observed but transitions from 2 to n will not be observed in the absorption spectrum. However, transitions from n to 2 and n to 1 will be observed in the emission spectrum. Hence the difference between absorption and emission spectra.   Bohr’s model works for other hydrogen-like atoms in which all but one electron has been removed. For a single electron orbiting a nucleus of charge Ze,  For multi-electron atoms, the orbits are more complex, so Bohr’s simple model with circular orbits does not apply.  F=(ke^2)/r^2 =ma=(mv^2)/r  v^2=(ke^2)/(mr)  L=mvr=nℏ  V^2=(n^2 ℏ^2)/( m^2 r^2 )  rn=(n^2 ℏ^2)/(m ke^2 )=n^2 ao, ao=ℏ^2/(mke^2 )=0.0529nm  E=K+V=1/2 mv^2-(ke^2)/r=1/2 m (ke^2)/(mr) -(ke^2)/r=-(ke^2)/(2r)  r\_n=n^2 a\_o  E=-(ke^2)/(2a\_0n^2 )=-(E\_1)/n^2 , E1=(ke^2)/(2a\_o1^2 )=13.6eV  E\_(ion)=E\_∞-E\_1=13.6eV  hf=E\_m-E\_n=(-E\_1/m^2 +E\_1/n^2 ) f=E\_1/h(1/n^2 -1/m^2 )  1/lambda=f/c=E\_1/(hc) (1/n^2 -1/m^2 ),  (1/E\_1)/(hc)=91.18nm=1/R  E=-(ke^2 Z^2)/(2a\_0n^2 )=-(E\_1Z^2)/n^2 , E\_1=(ke^2)/(a\_0 1^2 )=13.6eV  r\_n=(n^2 a0)/Z |
| https://i.gyazo.com/0039aa30847f7f6f1a7620aec0dce331.png |
| Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |

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| **Topic** | Quantum physics research |
| **Subtopic** | Particle Nature of Light |
| **Concept Name** | Frank-Hertz Experiment |
| **Description** | In 1914, Franck and Hertz directly measured the energy quantization of atoms via the inelastic scattering of electrons.  https://i.gyazo.com/248ce8df55d363500e76739243996831.png  Measure current of electron beam (I) vs. accelerating grid voltage (V) inside a glass tube filled with mercury gas.  Results: A series of peaks and dips are seen in the current as a function of accelerating voltage  Explanation:   * As V is increased electron energy increases. * Electrons can reach the collector if they overcome the retarding potential of 1.5V. At this point current starts to increase. * As V is increased further, electrons gain enough energy to excite the mercury atoms to their first excited state and hence lose energy. * These electrons cannot overcome the retarding potential and the current dips.   https://i.gyazo.com/518d9bfb2c3b07d8e886d4f519b3811b.png   * As V is increased further, the electrons again reach an energy that excites the mercury atoms and hence lose energy again. * This repeated process causes the rise and dips of current. * Each dip corresponds to a transition between quantized energy levels in mercury.   The energy of the electrons at which the dips occur correspond to the first excitation energy of mercury (4.9eV) |
| **Formula** |  |
| **Drawing/Animation** |  |
| **Relevant Tags** | Hashtag all relevant topics discussed in this module (e.g. #forces #gravity #acceleration) |