PHYS 250 MT2 Cheat Sheet

Energy & Waves

$E_{max}^2 \approx (\text{amplitude})^2$

• Does not depend on frequency or matter.

Energy of a photon:

$E = hf = \frac{hc}{\lambda}$

• Interference is evidence that light is a wave.

Emission and Absorption

- Atom jumps from lower energy to higher energy state by absorbing a photon. It can emit a photon of the same frequency as it jumps back. (Spontaneous Transmission)
- Stimulated Emission: Production of two identical photons by one photon interacting with an excited atom. Only occurs if the first photon's frequency matches the energy difference.
- A laser uses a chain reaction of stimulated emission in many excited atoms. The number of excited atoms must out number the non-excited atoms to be stable.
- Population Inversion: Having an amount of atoms N such that the number of excited atoms is proportionally larger than the number of non-excited atoms.

Balmer's Formula (λ in hydrogen spectrum):

$\frac{91.18\text{nm}}{\frac{1}{m^2} - \frac{1}{n^2}}$ for m = 1,2,3... & $n > m$

Bohr Model

- Electrons can exist only in certain orbits. A particular arrangement of electrons is a stationary state.
- Each stationary state has a discrete energy.

Hydrogen radius:

$r_n = n^2 a_B$

Hydrogen Energy:

$E_n = -13.60\text{ eV}/n^2$

Bohr Model can't explain

- Why angular momentum is quantized
- Why electrons don't radiate energy when in orbits
- How does electron know what orbit to jump to?
- Can't be generalized
- Shapes of molecular orbits
- Molecular bonds
- Very closely spaced spectral lines

Schroedinger Equation

$$\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2}[E - U(x)]\psi(x) = 0$$

$$\hbar = h/2\pi$$

de Broglie wavelength:

$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE_k}}$

Restrictions

- $\psi(x)$ is continuous
- $\psi(x) = 0$ if x is in a region where te particle is impossible to be in
- $\psi(x) \to 0$ as $x \to \infty$
- $\psi(x)$ is a normalized function

Potential Wells

- A particle with energy $E > U_0$ an escape into the classically forbidden region.
- Particle's energy is quantized
- There area finite number of bound states
- $\psi(x)$ extends into the classically forbidden region
- Node spacing is smaller when kinetic energy is larger
- Classical particle is more likely to be found where it is moving slowly
- Wave function amplitude is larger where the kinetic energy is smaller

Wave Function in the classically forbidden region:

$\psi(x) = \psi_{\text{edge}} e^{-(x-L)/\eta}$

Penetration distance:

$\eta = \frac{\hbar}{\sqrt{2m(U_0 - E)}}$

- Quantum tunneling requires no energy
- Tunneling requires oscillatory solutions on the other side
- $U_0 - E$ can be the metal's work function

Infinite well energy:

$E_n = \frac{n^2\pi^2\hbar^2}{2mL^2}$

Tunneling Probability:

$P_{\text{tunnel}} = e^{-2w/\eta}$ for potential well width of w

Wave Packets

- A localized particle
- Travels with constant speed
- For any wave packet $\Delta f \Delta t \geq 1$

Uncertainty:

$\Delta x = v_x \Delta t = \frac{p_x}{m}\Delta t$

Uncertainty Principle:

$\Delta x \, \Delta p_x \geq h/2$

Measurement

- Measuring changes the system
- Measuring collapses wavefunciton to a specific eigenstate
- Cannot know both position and energy.
- Measuring position → Probability density changes with time
- Measuring energy → Probability density does not change

Hydrogen Atom

Bohr Radius:

$a_B = \frac{4\pi\varepsilon_0\hbar^2}{me^2}$

Energy:

$E_n = -13.60\text{ eV}/n^2,\ n = 1, 2, 3\ldots$

Momentum:

$L = \sqrt{l(l+1)}\,\hbar,\ l = 0, 1, 2\ldots n-1$

$L_z = m\hbar,\ m = -l, -l+1, \ldots 0, \ldots l-1, l$

Symbols for l:

$0 \to s,\ 1 \to p,\ 2 \to d,\ 3 \to f$

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https://github.com/DonneyF/formula-sheets