PHYS 250 MT1 Formula 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.

Photoelectric Effect

- Current is linearly proportional to intensity.
- Current appears without delay.
- Photoelectrons are only emitted if the light frequency f exceeds a threshold frequency f_0
- The value of f_0 depends on cathode material.
- Current becomes independent of V for large V.
- If the voltage is made negative, then the current decreases until some stopping potential.
- V_{stop} is independent of light intensity.
- Electron immediately has enough energy to escape.
- Number of electrons $\propto$ Intensity
- Maximum $E_k \propto$ Frequency

Classical Interpretation:

- Metal is heated to high temperature to allow Thermal Emission
- Can possibly raise electron temperature to significantly higher than the metal, so that the electron can emit without the metal melting.
- Nothing to suggest threshold frequency
- Does not explain instantaneous current
- Does not explain why V_{stop} is constant.

Stopping Potential:

$V_{stop} = \frac{hf - E_0}{\text{e}}$

The Photon Rate:

$P = \frac{\mathrm{d}N}{\mathrm{d}t} hf$

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... & $n > m$

Wave Function

We want to relate the probability functions with electrons, but there are no waves for electrons. We assume there is some continuous, wave-like function for matter that is analogous for light.

Probability Density:

$P(x) = |\psi(x)|^2$

Normalization:

$\int_{-\infty}^{\infty} |\psi(x)|^2 dx = 1$

Quantum Models

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

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

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

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:

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

Penetration distance:

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

- Quantum tunneling requires no energy
- Tunneling requires oscillatory solutions on the other side

Tunneling Probability:

$P_{tunnel} = e^{-2w/\eta}$ for some edge $x = w$

Updated September 21, 2018
https://github.com/DonneyF/formula-sheets