PHYS 250 Final Formula Sheet

Energy & Waves

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

• Does not depend on frequency or matter.

Energy of a photon:

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

• Interference is evidence that light is a wave.

Photoelectric Effect

- The value of f_0 depends on cathode material.
- V_{stop} is independent of light intensity.
- Number of electrons $\propto$ Intensity
- Maximum $E_k \propto$ Frequency

Stopping Potential: $V_{\text{stop}} = \dfrac{hf - E_0}{e}$

The Photon Rate: $P = \dfrac{\mathrm{d}N}{\mathrm{d}t} hf$

Emission and Absorption

- Atom transitions to higher energy state by absorbing a photon. Emits a photon of the same frequency if it jumps back.
- 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.
- Population Inversion: Having proportionally larger excited atoms than the number of non-excited atoms.

Balmer's Formula (λ in hydrogen spectrum):

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

Bohr Model

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

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:

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

Potential Wells

- A particle with energy $E > U_0$ an escape into the classically forbidden region.
- Node spacing is smaller when E_K is larger
- Classical particle is more likely to be found where it is moving slowly
- $\psi(x)$ amplitude is larger where E_K is smaller

Wave Function in the classically forbidden region:

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

Penetration distance:

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

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

Infinite well energy:

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

Tunneling Probability:

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

Measurement

- Measuring collapses wave function to a specific eigenstate
- Cannot know both position and energy.
- Measuring position $\longrightarrow |\psi(x)|^2$ changes in time
- Measuring energy $\longrightarrow |\psi(x)|^2$ no change in time

Wave Packets

- A localized particle 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: $\Delta x \Delta p_x \geq h/2$

Hydrogen Atom

Bohr Radius: $a_B = \dfrac{4\pi\varepsilon_0\hbar^2}{me^2}$

Energy:

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

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:

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

Radial probability: $P_r(r) = 4\pi r^2 |R_{nl}(r)|$

Spin: $S_z = m_s\hbar$, $m_s = \pm 1/2$

Spin Angular Momentum: $S = \sqrt{3}/2\hbar$

Pauli Exclusion Principle: No two electrons can have the same set of quantum numbers. If one electron is present in a state, it excludes all others.

High l $\rightarrow$ circular orbit

Special Relativity

- Laws of physics are the same in all inertial frames
- Any two events occurring simultaneously in one reference frame are not simultaneous in any reference frame moving relative to the original.
- Proper time: The time interval between two events occurring in the same position.

$\gamma = \dfrac{1}{\sqrt{1 - (\frac{v}{c})^2}}$ $\quad \gamma_p = \dfrac{1}{\sqrt{1 - (\frac{u}{c})^2}}$

Time Dilation: $\Delta t = \gamma \Delta \tau$

Length Contraction: $L' = \frac{L}{\gamma}$

Spacetime Interval: $s^2 = c^2(\Delta t)^2 - (\Delta x)^2$

Relativistic Momentum: $p = \gamma_p mu$

Relativistic Energy:

$E = \gamma_p mc^2 = E_0 + K = mc^2 + (\gamma_p - 1)mc^2$

$pc = \frac{u}{c} E$

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