PHYS 200 Midterm 2 Cheat Sheet

Relativistic Dynamics

$$E = \gamma mc^2, |\vec{p}| = \gamma mv \to E^2 = m^2c^4 + p^2c^2$$

$$\vec{F} = \frac{d\vec{p}}{dt}$$

LMatrix :

$$\begin{bmatrix} \gamma & -\beta\gamma & 0 & 0 \\ -\beta\gamma & \gamma & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Photons

1. massless
2. no rest frame
3. always move at c (in all frames)
4. $E = pc = hc/\lambda$, definite energy and momentum, related to **wavelength**

Mass

1. Energy, momentum is always conserved $\to$ mass doens't have to be, can convert mass into KE
2. Fusion: 2 light things $\to$ heavy thing + E
3. Fission: 1 heavy thign $\to$ 2 (or more) lighter things + E
4. Since stable is less energy state, we exert energy to go to stable state
5. In hydrogen atom $m_H = m_e + m_p - BE \to m_H < m_e + m_p$

Particle decay, how to solve for diff frames

1. Move to center of mass frame (where stationary object decays).
2. Compute momentum & energy, using LT revert back to original frame (be careful of sign).

Compton Scattering

$$\lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

1. m is dependent on the object we are striking the photon to.
2. Don't forget unit conversions.

Classical view

$$\vec{E_0} \cos kx - \omega t + \psi \qquad (k = 2\pi/\lambda, \omega = 2\pi f)$$

Classical view continued

1. $c = hf$
2. Energy is proportional to E_0^2, B_0^2
3. Intensity $\propto (E_0)^2$ a.k.a Probability $\propto (E_0)^2$ and I
4. Intensity = energy / (area * time), not dependent on frequency of light
5. If intensity increase, it is related to the number of photons

Photo Electric Effect

1. $E_\gamma = hf$
2. $KE_{\text{max}} = hf - W$
3. W is same unless metal changes
4. $eV_{\text{stop}} = KE_{\text{max}} = hf - W$
5. If retarding potential applied, it is not that electrons are not ejected, it is because some ejected electrons can't make through

QM effect of light

1. Compton Scattering
2. Photoelectric: not existence of effect, rather it is effect of retarding potential, nature that it's a hit or a miss and photon disappers after hitting
3. Blackbody radiation: When wavelength is low, radiation is not infinite. (related to cost of ejecting a high energy particle)

Diffraction pattern

1. Photon / electron has a probability of hitting part of screen
2. Somehow each particle knows diffraction pattern. Somehow each particle passes through both slits at the same time
3. We don't know till measure
4. hit screen at certain point (particle behav.), interference (with itself) pattern (wave behaviour)
5. After measurement (position checked), position collapses and has definite position. 6. Before measurement, no position is known (only a probability distribution is known)

Probability

1. Intensity $\propto$ E-field squared, thus probability $\propto$ wave amplitude squared
2. $P(x) = |\psi(x)|^2 = \psi(x)\bar{\psi(x)}$

Terminlogies

1. Measurement : process through which observales is determined / recorded (position, momentum recorded)
2. Eigenstate : A quantum state with 100 percent certainty
3. Quamtum superposition : Combination of different eigenstates with complex coefficients
4. State : complete description of properties at some moment in time

QM / Measurements

1. $\sum_{\forall x} c(x)\,|x\rangle \equiv \int_{-\infty}^{\infty} c(x)\,|x\rangle\,dx$
2. $|\psi(x)\rangle = \int_{\infty}^{\infty} \psi(x)\,|x\rangle\,dx$
3. After measurement, state changes to appropriate eigen state
4. If repeated measurement right after, get same result (system still in that eigenstate)
5. If asked about diff measurement, we have to change basis i.e. new eigenstate
6. Given $a_1\,|x_1\rangle + a_2\,|x_2\rangle$, a particle DOES NOT have a definite state.

Polarisation

1. $|\theta\rangle = \cos\theta\,|0\rangle + \sin\theta\,|90\rangle$
2. probability transmission : $\cos^2\theta$
3. probability absorbed : $\sin^2\theta$
4. In case of $|\phi\rangle = a\,|x\rangle + b\,|y\rangle$, when getting probability need to normalize $|a|^2 + |b|^2 = 1$

De bregolie wave length

1. For any particle, $pc = hc/\lambda \implies p = h/\lambda$.
2. Use $e^{i2\pi px/h}$
3. $\psi(x) = \frac{1}{\sqrt{\hbar}}\int \tilde{\psi}(p)e^{ipx/\hbar}dp$
4. $\tilde{\psi(p)} = \frac{1}{\sqrt{\hbar}}\int \psi(x)e^{-ipx/\hbar}dx$
5. For post-measurement, $\psi(x) = e^{ip_0x/\hbar}, \tilde{\psi}(p) = e^{-ipx_0/\hbar}$, cannot be properly normalized
6. $\psi(R,t) = e^{2\pi i(R/\lambda - ft)}, \quad R \approx D + \frac{Y^2}{2D}$
7. $\langle x\rangle = \int_{-\infty}^{\infty} xP(x)dx = \int_{-\infty}^{\infty} x|\Psi(x)|^2dx$
8. $\hbar = \frac{h}{2\pi}$, heisenberg uncertainty: $\Delta x\Delta p \geq \hbar/2$

Wave Packets

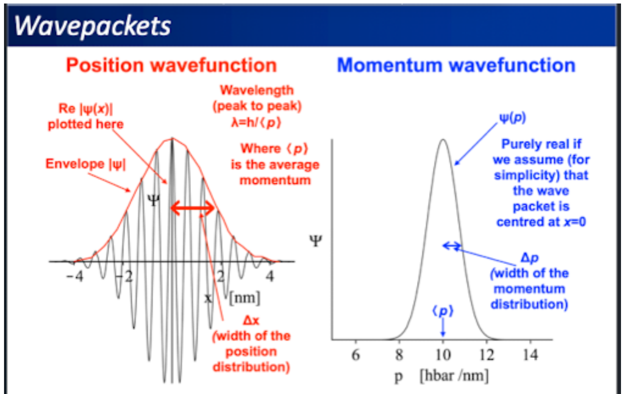

Figure 1: The real part of the position wavefunction for a wavepacket with $\langle p\rangle$=10 $\hbar$/nm and width Δx = 1nm [left]; the momentum wavefunction of the same wavepacket [right].

1. Wavepackets are needed to localize real wavefunctions (which are not as shown above)
2. The narrower the wavepacket in position, wider range of frequencies, wider momentum wavefunction
3. The narrower the wavepacket in momentum, the wider position wavefunction.
4. $\langle p\rangle = \int_{-\infty}^{\infty} p|\tilde{\Psi}(p)|^2 dp$
5. $(\Delta p)^2 = \int_{-\infty}^{\infty} (p-\langle p\rangle)^2 |\tilde{\Psi}(x)|^2 dp$

Constants, Formulae and others

$$c = 3.00\times 10^8 \mathrm{ms}^{-1}, \qquad e = 1.60\times 10^{-19} C$$
$$h = 6.626\times 10^{-34}\mathrm{Js}$$
$$m_e = 9.11\times 10^{-31}\mathrm{kg}, \qquad m_p = 1.67\times 10^{-27}\mathrm{kg}$$
$$m_{\pi_0} = 2.406\times 10^{-28}\mathrm{kg}\ , u'_x = \frac{u_x - v}{1-u_x v/c^2}$$
$$\mathbf{P} = (\gamma(u)mc, \gamma(u)m\vec{u}) = (E/c, \vec{p})$$
$$1J = 6.242\times 10^{18} eV$$

1. Bound system has binding energy. Stable so low E.
2. Bound system's mass is less than the sum of the masses of the components.
3. Unstable bound system has sum of masses heavier than its components.
4. Having half vertical and half horizontal polarized light is different from $\frac{1}{\sqrt{2}}|0\rangle + \frac{1}{\sqrt{2}}|90\rangle$
5. Bright fringes : $\frac{dY}{D} = m\lambda$, d : slit size, D : Distance to screen, Y : Height

Time evolution

1. A wavefunction of a moving free particle with a well defined momentum is simply a travelling wave

$$e^{(i/\hbar)(px-Et)}$$

2. $E = 1/2mv^2 = p^2/2m$ (non-relativistic)
3. Time evolution for each component in a quamtum superposition happens independently