Classical Physics:

1. In the "beginning" there were particles and there were waves
   a. Particles are characterized by an:
      i. Energy (E)
         1. E=K+V (kinetic + potential energy)
            a. $K = \frac{1}{2}mv^2$
      ii. Momentum Vector ($\vec{p}$)
         1. $|\vec{p}| = mv$
         2. direction $\vec{p}$ points in direction of travel.

   b. Wave are characterize by an:
      i. Amplitude (A)
      ii. Wave Vector ($\vec{k}$)
         1. $|\vec{k}| = 2\pi/\lambda$ (λ is the wave length
         2. direction $\vec{k}$ points in direction of travel

   c. Wave and Particles <u>Did Not Mix</u>

2. <u>But</u> there were four observations/experiments that showed that sometimes particles behave like waves and waves behave like particles:

   a. Black Body Radiation
      i. A black body is an object that absorbs all light that falls on it, and emits light in a wavelength spectrum determined solely by its temperature.
      ii. The idea of quantized energy emerges.

b. Photoelectric Effect & Compton Effect

i. Electrons are emitted from matter (metals and non-metallic solids, liquids or gases) as a consequence of their absorption of energy from electromagnetic radiation of very short wavelength, such as visible or ultraviolet light.

ii. In 1902, Philipp Eduard Anton von Lenard observed that the energy of individual emitted electrons increased with the frequency (which is related to the color) of the light. This appeared to be at odds with James Clerk Maxwell's wave theory of light, which was thought to predict that the electron energy would be proportional to the intensity of the radiation.

iii. In 1905, Albert Einstein solved this apparent paradox by describing light as composed of discrete quanta, now called photons, rather than continuous waves.

iv. Light Behaves like Particles (i.e. photons)

c. Pair Production

i. Pair production refers to the creation of an elementary particle and its antiparticle, usually from a photon

ii. Light is converted into 2 particles, an electron and a positron

d. de Broglie Effect

i. Electrons Behave like Waves

3. In quantum mechanics, information about a **particle** is described by a <u>**wave**</u> **function** $\Psi(\mathrm{x,t})$

a. **Shroedinger Equation**: Describes the behavior of a particle with mass m subject to a to a potential energy $V(x,t)$:

$$i\hbar\frac{\partial\Psi(\mathrm{x,t})}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2\Psi(\mathrm{x,t})}{\partial x^2} + V(x)\Psi(\mathrm{x,t})$$

i. 2nd order partial differential equation

ii. Dependent Variable: Ψ

iii. Independent Variables: x, t

b. Since we can't solve this yet we will look at the time indedendent form of the Schroedinger Equation:

$$-\frac{\hbar^2}{2m}\frac{d^2\psi\,(\mathrm{x})}{dx^2} + V(x)\psi(\mathrm{x}) = E\psi(\mathrm{x})$$

i. 2nd order differential equation

ii. Dependent Variable: ψ

iii. Independent Variable: x

Summary of Variables and Constants	
h	Plank's constant (describes size of quanta in quantum mechanics = $6.26068 \times 10^{-34}\,\frac{\mathrm{m^2 kg}}{\mathrm{s}}$)
$\hbar$	$h/2\pi$ (reduced Plank's constant)
m	mass of particle
$\Psi(x,t)$	time dependent wave function (replaces the concept of trajectory in classical mechanics)
$\psi(x)$	time independent wave function
$\lvert\psi(x)\rvert^2$	probability density that contains information about where the particle is located
$V(x)$	potential energy of particle
E	total energy of particle (these are our eigenvalues in quantum mechanics)

Homework:

1. Using separation of variables and the time dependent Schrödinger equation derive the time independent form of the Schrödinger equation (**note do not attempt to solve this!!!!**).
   a. Hint:
      (a) Let $\Psi(x,t) = T(t)\psi(x)$
      (b) When you have separated the variables set the equations equal to E vice $-\lambda$.)

2. **Solve for $T(t)$**.