

Name: _____

Please answer 6 of the 7 Questions

- Describe one example where the quantization of the energy of light was used to give a more accurate or complete mathematical description of a physical process. Be specific about the reasons why the quantization plays an important role and why classical models failed. (15 points)
- Write down a mathematical expression for the linear momentum operator (\hat{p}_x) and define the meaning of "eigenfunction" and "eigenvalue" in words and symbols. Give an example of a wavefunction which is an eigenfunction of \hat{p}_x and one which is not. (15 points)
- For a particle in a box, a general wavefunction is given by $\Psi_n = (2/L)^{1/2} \sin(n\pi x/L)$ for a box with infinite height barriers at $x=0$ and $x=L$. What is the probability of finding a particle in a box of size 0.1 pm in the $n=5$ wavefunction between the position $x=0.01$ pm and $x=0.02$ pm. (15 points)
Helpful trigonometric identity — $[\sin^2 \theta = (1/2)(1 - \cos 2\theta)]$
- Describe in your own words why the harmonic oscillator energy levels are equally spaced as $[E_v = \hbar \omega (v+1/2)]$ while the 1D particle in a box levels are spaced quadratically $[E_n = h^2 n^2 / 8 m L^2]$. Specifically, relate how energy level spacing changes with the size of a box to the harmonic oscillator potential which is effectively a continually enlarging box. Compare this effect then with the spacing of the hydrogen atom energy levels $[E_n = -hcR_H/n^2]$. (15 points)
- Write down all the possible term symbols for a calcium atom with the excited state electron configuration $[\text{Ne}]3s^1 4d^1$ and for boron atom with the excited state electron configuration $[\text{He}]2p^2 3d^1$. Indicate the total number of states (m_j) each of the term symbols represents. For calcium, indicate which of these excited states could emit a photon of light in a decay to the 1S_0 ground state $[\text{Ne}]3s^2$ and why. (15 points)
- State the Pauli principle and discuss why the following electron configuration wavefunctions would be valid or invalid for a lithium atom (the numbers indicate electron labels). (15 points)

$$1 = 1s(1) 1s(2) 2s(3) \alpha(1) \beta(2) \alpha(3)$$

$$2 = 1s(1) 1s(2) 2s(3) (\alpha(1) \beta(2) \alpha(3) - \alpha(2) \beta(1) \alpha(3))$$

$$3 = 1s(1) \alpha(1) (1s(2) 2s(3) \beta(2) \alpha(3) - 1s(3) 2s(2) \beta(3) \alpha(2)) + \\ 1s(2) \alpha(2) (1s(3) 2s(1) \beta(3) \alpha(1) - 1s(1) 2s(3) \beta(1) \alpha(3)) + \\ 1s(3) \alpha(3) (1s(1) 2s(2) \beta(1) \alpha(2) - 1s(2) 2s(1) \beta(2) \alpha(1))$$

