PHYSICS 215 - Thermodynamics and Modern Physics

Practice Midterm Exam 3

Name: ______________________________

PID: ______________________________

Problem #1 _____

Problem #2 _____

Problem #3 _____

Problem #4 _____

Extra Credit _____

Total _____/24

I will attempt to avoid multiple jeopardy. Please help me by giving an algebraic symbol for the answer to each part if you use it in subsequent parts.

Useful Constants:

Avogadro's number, $N_A = 6.02E23\ mol^{-1}$
Speed of light, c = 3.00E8 m/s
Charge of an electron, -e = -1.6E-19 C
Mass of the electron, $m_e = 9.1E\text{-}31\ kg = 511\ keV/c^2 = 5.49E\text{-}4\ u$
Mass of the proton, $m_p = 1.67E\text{-}27\ kg = 938\ MeV/c^2 = 1.00728\ u$
Mass of the α particle, $m_\alpha = 3727.4\ MeV/c^2 = 4.00151\ u$
Planck's constant, h = 6.63E-34 J.s = 4.14E-15 eV.s
Planck's reduced constant, $\hbar = h/2\pi = 1.05E\text{-}34$ J.s = 6.58E-16 eV.s
Compton Wavelength of the electron, $\lambda_c = h/m_e c = 2.4263E\text{-}12$ m
The Bohr Magneton, $\mu_B = 5.79E\text{-}5$ eV/T
Atomic mass unit, $u = 1.66E\text{-}27\ kg = 931.5\ MeV/c^2$

Useful Formulae:

de Broglie wavelength: $\lambda = h/p$

Heisenberg Uncertainty Principle: $\Delta p_x \Delta x \geq \hbar/2$ $\Delta E \Delta t \geq \hbar/2$

Probability = ψ^2 Normalization condition: $\int \psi^2 dx = 1$

Infinite Square Well Potential in 1-dim: $\psi = \sqrt{2/L}\sin(n\pi x/L)$ $E_n = n^2\pi^2\hbar^2/2mL^2$

Infinite Square Well Potential in 3-dims: $E = \frac{\pi^2\hbar^2}{2m}(n_1^2/L_1^2 + n_2^2/L_2^2 + n_3^2/L_3^2)$

Simple Harmonic Oscillator: $V = \frac{1}{2}kx^2$ $\omega^2 = k/m$ $E_n = (n+\frac{1}{2})\hbar\omega$

Quantum number relations: $n>0$ $l<n$ $\mathbf{L} = \sqrt{l(l+1)}\,\hbar$ $|m_l| \leq l$ $L_z = m_l\hbar$

$s=\pm\frac{1}{2}$ $\mathbf{S} = \sqrt{s(s+1)}\,\hbar$

	S	P	D	F	G
L =	0	1	2	3	4

$\mathbf{J} = \mathbf{L} + \mathbf{S}$ $j = l \pm s$

Spectroscopic Notation: $n^{2s+1}L_j$

Zeeman Effect: $V_B = -\boldsymbol{\mu}.\mathbf{B} = \mu_B B m_l$ or $2\mu_B B m_s$

Anomalous Zeeman Effect: $V_B = \mu_B B g m_j$ where g = Landé g-factor = $1 + \frac{J(J+1)+S(S+1)-L(L+1)}{2J(J+1)}$

A useful integral: $\int \sin^2 a\theta\, d\theta = \theta/2a - \sin 2a\theta/4a$

1. [6 points] Consider an electron trapped in a three dimensional rectangular infinite potential well with sides of length $L_1 = L$, $L_2 = L$ and $L_3 = 2L$.

(a) What is the ratio of the energy of the **first excited state** relative to the **ground state**?

(b) What is the ratio of the energy of the **second excited state** relative to the **ground state**?

(c) What is the ratio of the energy of the **third excited state** relative to the **ground state**?

(d) Which of these energy levels are degenerate?

(e) If L = 1 nm, what is the energy of the **ground state** in electron volts?

2. [5 points] For an electron in the 3d state of atomic hydrogen,

(a) What is orbital angular momentum quantum number, *l*?

(b) What is the magnitude of the orbital angular momentum vector, **L**, in units of ħ?

(c) Sketch all possible orientations of the orbital angular momentum vector, **L**.

(d) What is the minimum angle between **L** and the z axis?

3. [7 points] Consider an atom in the $3^2P_{3/2}$ state.

(a) What is the principal quantum number, n?

(b) What is the orbital angular momentum quantum number, L?

(c) What is the value of the spin quantum number, S?

(d) What is the multiplicity of the state?

If the atom is placed in a magnetic field of 0.65 T,

(e) Into how many levels will the original energy level be split?

(f) What is the energy difference between adjacent levels?

4. [6 points] Identify the particle, **x**, in the following nuclear interactions:-

(a) $\mathbf{x} + {}^{14}N_7 \rightarrow {}^{17}O_8 + p$

(b) $\alpha + {}^{9}Be_4 \rightarrow {}^{12}C_6 + \mathbf{x}$

(c) $\alpha + {}^{197}Au_{79} \rightarrow {}^{200}Hg_{80} + \mathbf{x}$

(d) $\mathbf{x} + {}^{7}Li_3 \rightarrow {}^{7}Be_4 + n$

(e) $n + {}^{30}Si_{14} \rightarrow {}^{31}P_{15} + \mathbf{x}$

(f) $p + {}^{7}Li_3 \rightarrow \mathbf{x} + \mathbf{x}$