PHYSICS 215 - Midterm Exam 2 Name: ______________________________

Please open the exam when I give the word.
There are 100 points total, with 10 EC (Extra Credit) points.

Be sure to write out your algebra!

If you're stuck, still write out what you *can* show.
Then go on to other parts.

If you are missing a previous answer for a further step, define a symbol for that answer, and calculate the next step *symbolically* in terms of the previous result.

Use the back sides of sheets for scratch paper

Useful Constants:

a_o = 5.2918 E-11 m
$\alpha = e^2/4\pi\varepsilon_0 \hbar c$ = .0072874 ~ 1/137
c = 2.9979 E8 m/s
e = 1.6022 E-19 C
$1/4\pi\varepsilon_0$ = 8.9876 E9 Nm^2/C^2
$e^2/4\pi\varepsilon_0$ = 1.4400 E-9 eV•m
E_o = -13.606 eV
h = 6.6261 E-34 J.s = 4.1357 E-15 eV•s
$\hbar = h/2\pi$ = 1.0546 E-34 J.s = 6.5821 E-16 eV•s
hc = 1239.8 eV•nm
$\lambda_c = h/m_e c$ = 2.4263 E-12 m
m_e = 9.1094 E-31 kg = 511.00 keV/c^2
m_p = 1.6726 E-27 kg = 938.27 MeV/c^2
N_A = 6.0221 E23 mol^{-1}
R_∞ = 1.09737 E7 m^{-1}

Problem #1 _____

Problem #2 _____

Problem #3 _____

Problem #4 _____

Total _____

1. Two spaceships (A and B) approach Earth from opposite directions. As seen from Earth, each has a speed of 0.95c. Now ship A fires a laser beam towards Earth (and ship B).
   a) [5] At what speed does the laser light travel in Earth's frame? Explain why.

   b) [8] Demonstrate the correctness of your answer by explicit calculation.

   c) [5] At what speed does the laser light travel as measured in B's frame? Explain why.

   d) [7] Suppose spaceship A measures a time interval of $T_A = 100$ seconds between the events CA, when it passes asteroid C, and DA, when it passes asteroid D. How long would the time interval be as measured on Earth?

   e) [10 Extra Credit] How long is the time between events CA and DA, as measured on spaceship B?

2. a) [8] Find the kinetic energy K of an electron, at which its de Broglie wavelength is equal to the Compton wavelength $\lambda_c = h/m_e c$ (algebraically, in terms of the electron rest energy).

b) [5] Through how many Volts would the electron have to be accelerated to achieve this kinetic energy? (Give a numerical answer if possible.)

c) [7] Solve algebraically and then numerically for the velocity (as a fraction of the speed of light) at which this occurs.

d) [5] If the velocity were increased, would the de Broglie wavelength now be larger, smaller, or the same as the Compton wavelength? Explain why.

3. A prism is used to separate white light into a spectrum of colors projected onto a metal with a work function of 2.4 eV.

a) [5] Find the wavelength λ_o of light which will just barely cause electrons to leave the metal.

b) [5] Suppose you wish to produce electrons with up to 0.6 eV of kinetic energy from the metal. Will the wavelength required be shorter or longer than λ_o? Explain why.

c) [5] Find the wavelength which would just barely produce such electrons.

d) [5] Would special relativity be required to calculate the momentum of the electrons? Or would nonrelativistic kinematics suffice? Explain why.

e) [5] Suppose the intensity of the light source is doubled. What aspects of the experiment change, and which remain the same? Explain how the results that remain the same are consistent with quantum mechanics, but not with classical physics.

4. MSU's SOAR telescope in Chile measures wavelengths of light emitted by distant galaxies. Distant galaxies typically are receding from earth at high velocity. The measurements are characterized by the *redshift* z, defined as $\mathbf{z = (\lambda_{measured} / \lambda_{emitted}) - 1}$
For the rest of the problem we consider the situation where we measure z = 0.3 for a galaxy.
   a) [7] Calculate $\boldsymbol{\lambda_{emitted}}$ for light corresponding to a Hydrogen transition from n=4 to n=2.

   b) [5] Calculate the wavelength observed on earth for this emitted light.

   c) [8] Calculate the galaxy's speed of recession as a fraction of the speed of light (numerically if possible).

   d) [5] Why is the condition z > 0 called a redshift?