First Exam
October 14, 1997

Name:______________________________

Social Security #:______________________________

1. Write your name and social security number on this page.

2. The point values for each problem are indicated on the exam. The total is 100 points.

3. The exam will be hand-graded for partial credit, so show all your work.

4. During the exam you can use a calculator and a sheet (8.5x11 inches) with any information you want written on both sides.

5. You will have 75 minutes to work on the exam.

6. By writing your name on this exam, you pledge that you have upheld the Honor Code and have arrived at each answer solely by your own work.

Some potentially useful information:
\[
\begin{align*}
    hc &= 1240 \text{ eV nm} = 1240 \text{ MeV fm} \\
    c &= 2.998 \times 10^8 \text{ m/s} \\
    k &= 8.617 \times 10^{-5} \text{ eV/K} \\
    h &= 4.136 \times 10^{-15} \text{ eV s} \\
    \text{rest energy of electron} &= 0.511 \text{ MeV} \\
    \text{rest energy of proton} &= 938.3 \text{ MeV} \\
    \text{rest energy of neutron} &= 939.6 \text{ MeV} \\
    \text{rest energy of muon} &= 105.6 \text{ MeV} \\
    \text{rest energy of pion} &= 139.6 \text{ MeV} \\
    \text{rest energy of deuterium atom} &= 1876.1 \text{ MeV} \\
    \text{rest energy of helium atom} &= 3728.4 \text{ MeV} \\
    1 \text{ femto} &= 1 \text{ f} = 10^{-15} \\
    1 \text{ pico} &= 1 \text{ p} = 10^{-12} \\
    1 \text{ nano} &= 1 \text{ n} = 10^{-9} \\
    1 \text{ micro} &= 1 \mu = 10^{-6}
\end{align*}
\]
1. (8 points) An electron is trapped in an infinite one-dimensional well. To excite the electron from the second excited state to the fourth excited state requires 5.0 eV of energy. What is the width of the well?

2. (8 points) A photon of energy 300 keV collides with an electron at rest and is scattered at an angle of 45° with respect to its initial direction. What is the energy of the scattered photon and the kinetic energy of the scattered electron (in units of eV)?
3. (8 points) Suppose that you observe light emitted from a distant star to be at a wavelength of 525 nm. The wavelength of the light to an observer on the distant star is 950 nm. What is the velocity of the star relative to you (in units of the speed of light $c$), and is it moving towards or away from you?

4. (10 points) A particle moving with kinetic energy equal to its rest energy has a de Broglie wavelength of 0.1920 fm. What kind of particle is it?
5. (10 points) Galaxy A is reported to be moving away from the Earth with a speed of 0.35c. Galaxy B is found to be moving away from the Earth at the same speed of 0.35c in the opposite direction. What velocity (magnitude and direction) does an observer on Galaxy A find for Galaxy B? Express the answer in units of the speed of light c.

6. (8 points) The elementary particle called the $\phi$ has a measured rest energy of 1019 MeV, with an experimental spread of 4 MeV. What is the approximate minimum value of the lifetime for this unstable particle?
7. (20 points) Observer $O$ notes that two colored flashes of light, spatially separated by 2400 m, occur along the positive $x$-axis of his reference frame. A blue flash occurs first, followed after 5.0 $\mu$s by a red flash, the latter being the most distant from the origin of his reference frame. A second observer $O'$ obtains exactly the same numerical values for both the time difference and the absolute spatial separation between the two events but declares that the red flash occurs first. (Note: the exact colors of the two flashes are not important for this problem; the colors merely serve to uniquely identify the two flashes.)

(a) What is the relative speed of $O'$ with respect to $O$ (in units of the speed of light $c$)?

(b) Which flash will $O'$ find to be the more distant from the origin of her reference frame?
8. (10 points) The stopping potential for photoelectrons emitted from a surface illuminated by light of wavelength 491 nm is 0.71 V. When the incident wavelength is changed to a new value, the stopping potential is found to be 1.43 V.

(a) What is the work function for the surface?

(b) What is the new wavelength?

9. (8 points) The length of a spaceship is measured to be exactly half its rest length.

(a) What is the speed (in units of the speed of light $c$) of the spaceship relative to the observer’s frame?

(b) Do the spaceship’s clocks run fast or slow (and by what factor) compared to clocks in the observer’s frame?
10. (10 points) Sketched below is the wavefunction that solves the time-independent Schrödinger equation in a particular potential $U(x)$. The energy eigenvalue is $E$. The wavefunction is zero outside the region shown. The three regions have equal width. On the second drawing below, draw in a potential $U(x)$ that will generate such a wavefunction. The level of the energy eigenvalue $E$ is already specified on the plot. You can assume that the potential is constant within a given region.