Physics 123, Sect. 1 **Practice Exam IV**

Fri, June 11 - Mon, June 14 Identification number:_____

Instructor: Justin Peatross

No time limit

One page of notes permitted (both sides) - otherwise closed book

Calculator permitted

(The actual exam has 4 problems and three multiple-choice questions.)

$M_{{}^{14}_{6}C} = 14.003242\text{u}$, $M_{{}^{14}_{7}N} = 14.003074\text{u}$, $M_{{}^{40}_{19}K} = 39.96400\text{u}$, $M_{{}^{40}_{18}Ar} = 39.96238\text{u}$, $M_{{}^{1}_{1}H} = 1.007825\text{u}$,
$m_n = 1.00866\text{u}$, $m_e = 5.48578\times10^{-4}\,\text{u}$, $h = 6.626\times10^{-34}\,\text{J}\cdot\text{s}$, $\hbar = h/2\pi$, $1\text{eV} = 1.602\times10^{-19}\,\text{J}$,
$c = 3\times10^{8}\,\text{m/s} = 1\,\ell\text{y/yr} = \sqrt{(931.494\text{MeV})/\text{u}}$, $m_e c^2 = 0.511\text{MeV}$
$\text{Wein's Disp. Const.} = 0.2898\times10^{-2}\,\text{m}\cdot\text{K}$, $\sigma = 5.67\times10^{-8}\,\dfrac{\text{W}}{\text{m}^2\cdot\text{K}^4}$

1. Planet Zorg is drifting through space towards the Earth at 0.8c. Planet M is also approaching Earth from the opposite direction at 0.8c.
(a) At what speed do the Zorgites see Planet M approaching them?
(b) Luckily, both planets miss the Earth. However, the Zorgites are worried that Planet M will hit them. If the rest mass of planet M is $6\times10^{24}\,\text{kg}$, what is the kinetic energy of planet M from the frame of reference of the Zorgites?

2. (a) Scientists study the spectral lines absorbed by gases from a distant galaxy. If monatomic hydrogen is present, what wavelength would you expect to be absorbed for an n=2 to n=3 transition in the rest frame of the galaxy?
(b) The spectral line is Doppler shifted so that the wavelength is twice as long of the known value for hydrogen at rest. At what speed is the galaxy moving away?

3. Muons have an expected lifetime of $1/\lambda$=2.2μs before they are expected to decay in their own rest frame. Suppose that muons are created by cosmic rays 50km above the Earth. How fast must the muons travel if they are to have a 1% probability of reaching the ground before decay?

4. The brightest wavelength from a faraway star (with negligible relative velocity) is $\lambda_{max} = 500\text{nm}$.
(a) What is the temperature of the star? HINT: Stars are nearly perfect blackbody radiators.
(b) If the light from the star has intensity $10^{-9}\,\text{W/m}^2$ measured at the Earth, how many lightyears away is the star if it has a radius similar to that of our Sun, $R = 7\times10^{8}\,\text{m}$?

5. (a) The work function of tungsten is 4.58eV. What is the longest wavelength of light that can eject electrons from the surface of tungsten? (Assume that a high-power laser is not used.)
(b) The strong force, which holds the nucleus of an atom together, is mediated by particles known as pions π. The rest energy of a pion is approximately $m_\pi c^2 = 140\text{MeV}$. The exchange of pions between nucleons such as a proton and a neutron appears to violate energy conservation since at least for a brief time Δt the energy necessary to create the pion must be available. Use the uncertainty principle to estimate the range r of the strong force (which limits the size of the nucleus) since a pion can go no farther than $r = c\Delta t$ in the time Δt. Assume that most of the pion's energy is associated with its rest mass.

6. (a) A hydrogen atom is in the 4th excited state (i.e., n=5). It undergoes a transition to the 2nd excited state (i.e., n=3). A photon is emitted. What is the wavelength of this emitted light?
(b) Assuming the Bohr model, what is the ratio of the initial electron orbital radius to the final orbital radius?

7. A photon collides with an electron at rest. The photon imparts momentum to the electron, and a new photon recoils with an angle of $\theta = 30^\circ$ relative to the direction of the incoming photon.
(a) If the incoming photon has energy 1MeV, what is the kinetic energy of the recoiling electron?
(b) What will be the angle ϕ of the recoiling electron with respect to the direction of the incident photon?

8. (a) 0.01% of naturally occurring potassium is ${}^{40}_{19}\text{K}$? The lifetime is $1/\lambda = 1.28 \times 10^9\,\text{yr}$. What is the half-life?
(b) ${}^{40}_{19}\text{K}$ undergoes positron emission decay to form ${}^{40}_{18}\text{Ar}$. What are the binding energies of ${}^{40}_{19}\text{K}$ and ${}^{40}_{18}\text{Ar}$?
(c) Write down the interaction process. What is Q for this interaction?
NOTE: This decay process is important for determining the age of rocks. The ratio between the amount of ${}^{40}_{19}\text{K}$ and ${}^{40}_{18}\text{Ar}$ (trapped inside) reveals how long ago the rock was formed. Before the rock hardens, all argon presumably escapes.

9. (a) What is the binding energy of ${}^{14}_{6}\text{C}$? Give your answer in MeV.
(b) Is it possible for ${}^{14}_{6}\text{C}$ to undergo beta decay to become ${}^{14}_{7}\text{N}$? Write down the decay process and compute Q.

10. It is a good idea to review multiple-choice quiz questions since there will be three similar questions on the exam.