Name_____ PHY106 EXAM #3
Section _____ Apr. 26, 2004

Directions: Show all work. Explain your arguments clearly. If it's not legible, it's a zero. All questions are worth 6 points. Where there is more than 1 part, the points are indicated. There are 14 questions. Do **12 of the 14**, and **clearly XXXX out the two you don't want to count.**. Formulas, Tables and Graphs you may need are on the last page.

1. Which of the following is true about the photoelectric effect:
   a. The wave picture of light could not account for the results.
   b. It showed that light is composed of particles, called photons, and each photon's energy depends on its wavelength.
   c. It showed that the energy per photon depends on the square of the amplitude of the associated light wave.
   d. All of the above.
   e. Both a & b
   f. Both b & c
   ANS: E

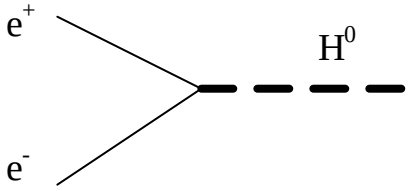
2. Briefly explain what observations by Rutherford lead to his understanding of the atom. Diagrams to aid in your discussion are encouraged.

   Rutherford scattered alpha particles off of gold foils and found that some of the alpha particles were deflected by very large angles, and some even came back in the direction in which they came. Based on the "plum-pudding model", this should almost never happen, yet it happened at a fairly large rate (~1/7000). To account for these results, he surmised that the atom must contain a hard dense core of positive charge.

3. The Higgs particle (H^0) is the last remaining particle in the Standard Model of Particle Physics, and it has yet to be discovered. Suppose the Higgs' mass is 300 [GeV/c^2] and can be produced by annihilating an electron and positron as shown below.

   a. What is the minimum amount of energy the electron and positron much **each have** in order to produce this elusive Higgs particle. **Explain** (3 pts)

      They must each have 150 GeV of energy since the total energy needed is 300 GeV to create the Higgs.



   b. Can this Higgs particle decay (disintegrate) into a top and antitop quark? **Explain why or why it cannot do this**. (3 pts)

      No, the top quark has a rest mass energy of 175 GeV, and therefore, to create a pair of them it would require 350 GeV. Since we only have 300 GeV of total energy, the top and antitop cannot be created

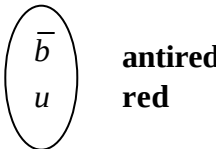
4. Consider the protons and neutrons in a nucleus. Of the three fundamental forces we discussed in class (neglect Weak force), explain which ones act between protons and neutrons, protons and protons and neutrons and neutrons, and tell whether they are attractive, repulsive, or neither. Only fill in the forces which apply (you don't have to fill in all 3 slots, necessarily).
(4 pts)

Pair	Which forces act between them	Attractive, Repulsive, or Neither
Proton – Proton	**1. Strong**	**Attractive**
	2. EM	**Repulsive**
	3. Gravity	**Attractive**
Proton – Neutron	**1. Strong**	**Attractive**
	2. Gravity	**Attractive**
	3.	
Neutron - Neutron	**1. Strong**	**Attractive**
	2. gravity	**Attractive**
	3.	

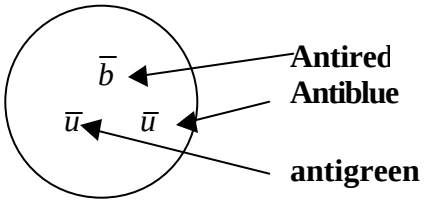
With regard to your answers above, explain why the nucleus stays together. (2 pts)

The protons & protons, protons & neutrons and neutrons & neutrons all interact through a residual of the strong force, which is attractive and very strong. It is stronger than all other forces and thus dominates in the nucleus.

5. Draw a diagram of a **meson** and an **anti-baryon**, each containing **at least one anti-bottom quark**. Label all quarks and anti-quarks, assign colors to each one, and indicate the total charge of the meson and anti-baryon.



Q=+1



Q = -1

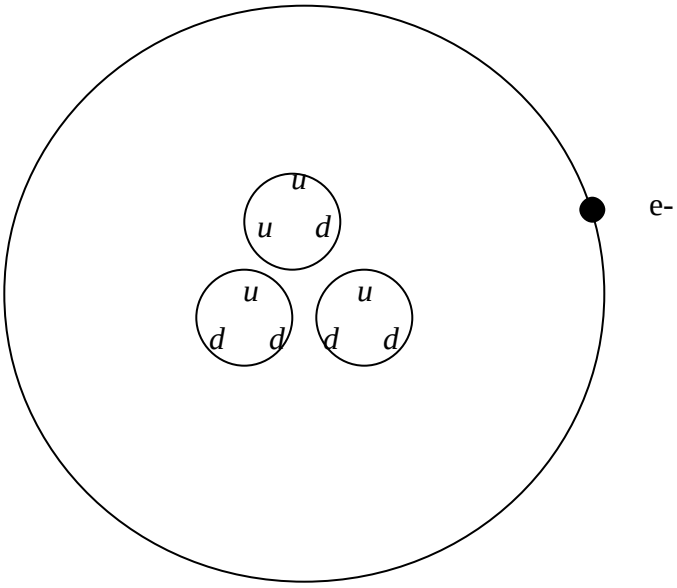
6. You perform an experiment where you collide an electron with energy of 2 GeV into a positron with the same energy and **they annihilate through the electromagnetic interaction**.
    a. **Which of the 6 <u>leptons</u>** can emerge from this collision? (2 pts)
    e, m, t, but not their neutrinos

    b. What is the kinetic energy of the most massive lepton from part (a)? You must show/explain how you arrive at your answer. (4 pts)

    The most massive os the tau, which hasa rest mass energy of 1.8 GeV. Since you produce a t+ and t-, this consumes 3.6 GeV of the total 4 GeV which you have. This leaves 0.4 GeV left over to split between the two, so they each have 0.2 GeV of kinetic energy.

7. Which of the following is true about mesons?
    a. The quark and antiquark bind because quarks and antiquarks have opposite electric charge.
    b. A top quark when combined with an anti-up quark will form a meson with zero electric charge.
    c. Because there are 3 colors, and 3 anticolors, there are 9 ways to form any meson.
    d. Their total electric charge must be –1, 0 or +1.
    e. None of the above.
    ANS: D

8. Tritium is an isotope of hydrogen that contains 1 proton, 2 neutrons and 1 electron.
    a. Draw a simple diagram of this **atom**, indicating the proper quark content of the proton and neutron. Also indicate possible colors for each of the quarks. (5 pts)



Quarks in proton
1 red, 1 green 1 blue

Quarks in each neutron
1 red, 1 green 1 blue

b. What mediator is responsible for keeping the electron orbiting around the nucleus? (1 pt)

The photon

9. Which of the following is true about force carriers?
   a. Gluons do not interact with particles which have electric charge.
   b. A photon can mediate the interaction between a quark and a neutrino.
   c. Gluons can interact with each other whereas photons cannot.
   d. The fundamental forces are believed to result from the exchange of a particular force carrier.
   e. Both a & d.
   f. Both c & d.
   ANS: F

10. Fill in the blanks with the best answer (**use units where necessary**).
    In an experiment, we collide an electron of energy 5 GeV into a positron of equal energy. The interaction is mediated by a _____photon_____ (2 pts) . This resulting mediator has how much energy after the annihilation?____10 GeV_____ (2 pts) . If the mediator then forms a bottom and antibottom quark, how much kinetic energy does the emerging bottom quark have? ___0.5 GeV_____(2 pts)

11. We learned that matter particles can exhibit wavelike properties and thus can be used to "see" small objects. Which of the following objects can "see" finer details of matter, a 500 [nm] visible photon or an electron with a speed of 1000 [m/s]. You must show how you arrived at your conclusion.

    Wavelength of electron: $\lambda = h/mv = 6.6\times10^{-34} / (9.1\times10^{-31})(1000) = 7.25\times10^{-7}$ **[m] = 725 [nm]**

    A 500 [nm] visible photon has smaller wavelength and therefore can "see" finer details.

12. A solar cell absorbs visible light (assume 500 [nm]) and converts it to usable energy. To run a 100 [W] light bulb for an hour requires 3.6×10^{5} [J] of energy.

    a. What is the energy of each absorbed photon in [J] ?

       $E=hc/\lambda = 6.6\times10^{-34} * 3\times10^{8} / 500\times10^{-9} = 4\times10^{-19}$ [J/photon]

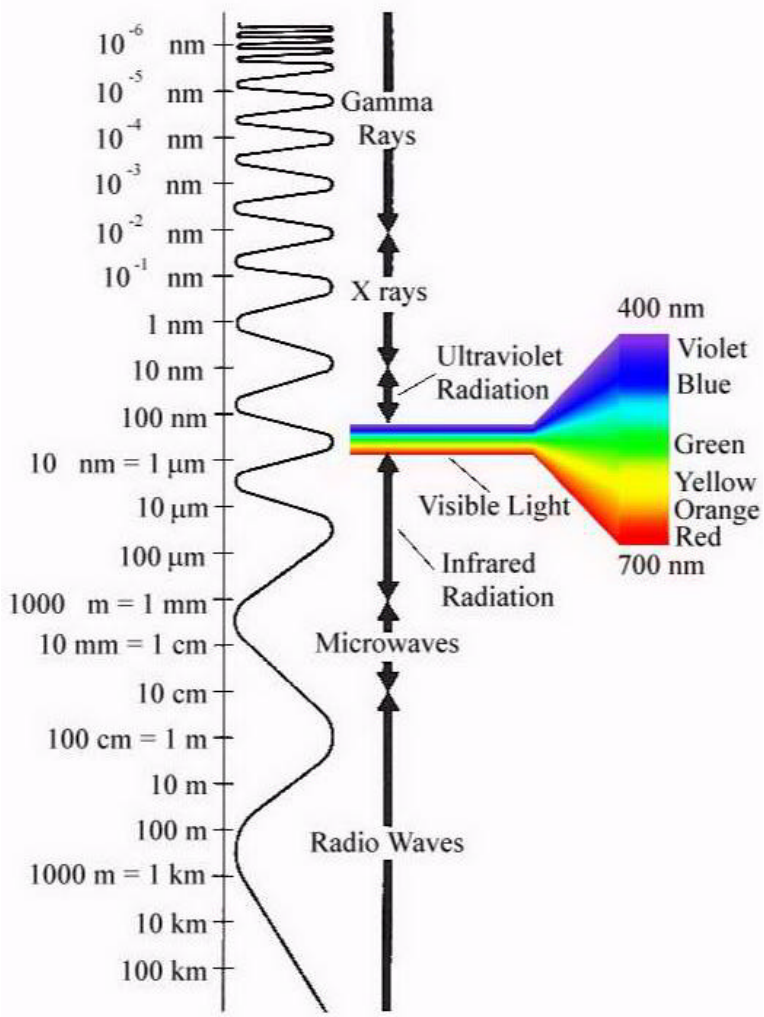
    b. How many photons are required to run this bulb for an hour?

       #photons = 3.6×10^{5} [J] / 4×10^{-19} [J/photon] = 9×10^{23} photons

13. Which of the following is true?
    a. In years of experimentation, we have learned that quarks are fundamental; that is, they are not composed of smaller objects.
    b. The attraction between an up and down quark is primarily because of their opposite electric charge.
    c. Hydrogen, and in fact all elements, are composed entirely of up and down quarks.
    d. A top quark can combine with a light quark to form a meson as long as the combination is colorless.
    e. None of the above.
    ANS: E

14. Answer true (T) or false (F) for each of the following.
    a. Both the photon and the gluon have zero mass and zero electric charge. T F
    ANS: T
    b. Both the photon and the gluon can interact with charged leptons. . T F
    ANS: F
    c. Neither (the photon or gluon) can interact with neutrinos. . T F
    ANS:T

Quark type	Electric Charge	Mass (GeV/c^2)	Lepton Type	Electric Charge	Mass (GeV/c^2)
d	-1/3	~ 0.010	e^-	-1	~ 0.0005
u	+2/3	~ 0.005	ν_e	0	~ 0
s	-1/3	~ 0.100	μ^-	-1	~ 0.106
c	+2/3	~ 1.5	ν_μ	0	~ 0
b	-1/3	~ 4.5	τ^-	-1	~ 1.8
t	+2/3	~ 175	ν_τ	0	~ 0



Formulas	Constants/Conversions
$E = h\nu = hc/\lambda$	$h = 6.6\times10^{-34}$ [J s]
$E=mc^2$	$c = 3\times10^{8}$ [m/s]
$KE = \frac{1}{2} mv^2$	1 [eV] = 1.6×10^{-19} [J]
$\lambda = h/mv$	Mega = 10^6, Giga = 10^9, nano = 10^{-9}
	Electron mass = 9.1×10^{-31} [kg]