PHYSICS 252: TEST 4   12/9/15   Dr. Varriano   NAME:_________________

Do all 8 problems. The point value for each problem is indicated next to the problem number. Show all of your work in the space provided to receive partial credit. You may use additional sheets of paper if necessary. Be sure to turn in the additional sheets with your name written on each sheet. Put your final answer to each question on the line provided unless instructed otherwise.

A copy of relevant portions of the isotope table is attached the last page of the test for your use.

1.[10 pts]

(a) Can the rest mass of an object ever be greater than its relativistic mass? If so, when? (Answer in the space below.)

No

(b) What is the rest mass of a photon? (Answer in the space below.)

Zero

(c) Does a photon have momentum? (Answer in the space below.)

Yes

2. [16 pts]

An electron is given a kinetic energy of 2.0 MeV in an accelerator. After obtaining this energy, the electron travels from point *A* to point *B* in a portion of the accelerator tube. The length of this portion is 1.2 km as measured by a physicist in the lab. This physicist measures 4085.5 ns for the electron to travel from *A* to *B*.

(a) How fast is the electron moving? (Express the speed as a fraction times *c*.)

0.979*c*

(b) How long is the portion between points *A* and *B* as measured by the electron?

244 m

(c) Is this length in (b) a *proper* or *nonproper* length?

nonproper

(d) How much time does it take to travel from *A* to *B* if you ask the electron?

831 ns

(e) Is this time interval in (d) a *proper* or *nonproper* time interval?

proper

3. [14 pts]
(a) How much energy is required to accelerate a proton from rest to $0.8c$? (Rest mass = 938.27 MeV/c^2)

626 MeV

(b) What is the momentum of the proton once it reaches this speed? (Express your answer in units of MeV/c.)

1251 MeV/c

(c) Would more, less, or the same amount of energy be required to accelerate an electron from rest to this speed?

less

(d) How much energy is required to accelerate this proton to the speed of light?

infinite amount

4. [8 pts]
You are on board a space station. Two radioactive nuclei are traveling towards the station from the same direction at $0.7c$. They both decay. One nucleus emits a beta particle in your direction at $0.78c$ relative to the nucleus. The other nucleus emits a gamma ray in your direction.

(a) How fast do you see the beta particle approach?

$0.957c$

(b) How fast do you see the gamma ray approach?

c

PROBLEMS 5-7
Plutonium-239 (^{239}Pu) is a by-product of nuclear power plants. It decays via alpha and gamma decay. The half-life for the decay is 24100 years.

5. [14 pts]
(a) It takes about 1807 MeV of energy to break up a Pu-239 nucleus into individual protons and neutrons. These free nucleons have more mass than when they are bound together in the nucleus. How much more mass? Express your answer in unified mass units (u).

1.94 u

(b) What force holds this nucleus together? Strong nuclear

(c) Write down both decay equations for Pu-239 below.

Alpha decay :

Gamma decay :

(d) Is the daughter nucleus stable or unstable? unstable

6.[14 pts]
(a) What is the decay constant for Pu-239 expressed in inverse seconds?

9.11×10^{-13} /s

(b) If a sample of Pu-239 is measured to have an activity of 75 nanoBecquerels today, how many years would it take for the sample to reduce to an activity of 5 nanoBecquerels?

94177 yrs

(c) How many Pu-239 nuclei are in the sample measured today?

82327

7. [8 pts]
Because Pu-239 has a relatively long half-life, it must be stored. If a container of Pu-239 develops a leak and a person in the same room is accidentally exposed to a large amount of Pu-239, it can be dangerous.

(a) Which quantity would best determine the potential health risk that the worker faces? (Circle the correct choice.)

Exposure / Dose Equivalent / Absorbed Dose

(b) Which has a larger RBE factor? (Circle correct choice.)

alpha particles / beta particles / gamma rays

(c) Explain below why the most danger comes from the emitted gamma rays of the Pu-239 decay and not from the emitted alpha particles.

8.[16 pts]
Fill in the blanks in the following decay equations. Refer to the attached isotope chart for pertinent information.

(a) (β^-, γ decay) $^{211}_{82}\mathrm{Pb} \rightarrow$ _______ + _______ + _______ then _______ $\rightarrow$ _______ + γ

(b) (α, γ decay) _______ $\rightarrow$ $^{210}_{82}\mathrm{Pb}^{*}$ + _______ then _______ $\rightarrow$ _______ + γ

(c) Find the amount of energy released in the beta decay of Lead-211.

1.379 MeV

(d) Suppose that a gamma ray emitted in the decay of a Lead-211 nucleus has a wavelength of 0.003 nm. What would be the maximum kinetic energy of the electron emitted in this decay?

0.965 MeV

TABLE A.3 Table of Selected Atomic Masses*

Atomic Number Z	Element	Symbol	Mass Number A	Atomic Mass†	Percent Abundance, or Decay Mode (if radioactive)‡	Half-Life (if radioactive)
0	(Neutron)	n	1	1.008665	β^-	10.6 min
1	Hydrogen	H	1	1.007825	99.985	
	Deuterium	D	2	2.014102	0.015	
	Tritium	T	3	3.016049	β^-	12.33 y
2	Helium	He	3	3.016029	0.00014	
			4	4.002603	≈100	
3	Lithium	Li	6	6.015123	7.5	
			7	7.016005	92.5	
4	Beryllium	Be	7	7.016930	EC, γ	53.3 days
			8	8.005305	2α	6.7×10^{-17} s
			9	9.012183	100	

TABLE A.3 *Continued*

Atomic Number Z	Element	Symbol	Mass Number A	Atomic Mass†	Percent Abundance, or Decay Mode (if radioactive)‡	Half-Life (if radioactive)
81	Thallium	Tl	205	204.97441	70.5	
			208	207.981988	β^-, γ	3.053 min
82	Lead	Pb	204	203.973044	β^-, 1.48	1.4×10^{17} y
			206	205.97446	24.1	
			207	206.97589	22.1	
			208	207.97664	52.3	
			210	209.98418	α, β^-, γ	22.3 y
			211	210.98874	β^-, γ	36.1 min
			212	211.99188	β^-, γ	10.64 h
			214	213.99980	β^-, γ	26.8 min
83	Bismuth	Bi	209	208.98039	100	
			211	210.98726	α, β^-, γ	2.15 min
84	Polonium	Po	210	209.98286	α, γ	138.38 days
			214	213.99519	α, γ	164 μs
85	Astatine	At	218	218.00870	α, β^-	≈2 s
86	Radon	Rn	222	222.017574	α, γ	3.8235 days
87	Francium	Fr	223	223.019734	α, β^-, γ	21.8 min
88	Radium	Ra	226	226.025406	α, γ	1.60×10^3 y
			228	228.031069	β^-	5.76 y
89	Actinium	Ac	227	227.027751	α, β^-, γ	21.773 y
90	Thorium	Th	228	228.02873	α, γ	1.9131 y
			232	232.038054	100, α, γ	1.41×10^{10} y
91	Protactinium	Pa	231	231.035881	α, γ	3.28×10^4 y
92	Uranium	U	232	232.03714	α, γ	72 y
			233	233.039629	α, γ	1.592×10^5 y
			235	235.043925	0.72; α, γ	7.038×10^8 y
			236	236.045563	α, γ	2.342×10^7 y
			238	238.050786	99.275; α, γ	4.468×10^9 y
			239	239.054291	β^-, γ	23.5 min
93	Neptunium	Np	239	239.052932	β^-, γ	2.35 days
94	Plutonium	Pu	239	239.052158	α, γ	2.41×10^4 y
95	Americium	Am	243	243.061374	α, γ	7.37×10^3 y