Exam 4.00
23 April 2004
General Physics II (PHSX 2020)
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NAME: W.B. YEATS SEAT: O

SCORE: 100 / 100

Multiple choice: Each question is worth 5 points.

1. A ^{4}He nucleus is very stable (i.e., it does not decay spontaneously) compared to most other nuclei. This tells us that the value of BE/A must be _____ compared to other nuclei.

A. high	**B.** low	**C.** There's no way to answer this with the information given.

2. In a fusion reaction, the total mass of the products must be

A. the same as the original materials.	**B.** greater than the original materials.	**C.** less than the original materials.	**E.** There is no way to predict this.	**D.** none of these

3. In a fission reaction, the total mass of the products must be

A. the same as the original materials.	**B.** greater than the original materials.	**C.** less than the original materials.	**E.** There is no way to predict this.	**D.** none of these

4. A sample of nuclei are described in terms of a "half life." What is this?

A. The time it takes for all nuclei to decay.	**B.** The time it takes for half the nuclei to decay.	**C.** Half the time it takes for all the nuclei to decay.	**D.** Half the time it takes for half the nuclei to decay.	**E.** 42

5. In particle physics, particles are responsible for forces. Forces that reach out infinite distances must be attributed to particles with

A. infinite mass.	**B.** zero mass.	**C.** infinite wavelength.	**D.** zero wavelength.	**E.** Two answers are correct.

6. On its way from Sun to Earth, a neutrino changes. Therefore, it must experience some amount of time from its own reference frame. Therefore, it must

A. have a finite mass.	**B.** have an infinite mass.	**C.** have zero mass.	**D.** 42	**E.** 42

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SITUATION I: Falling to pieces

A. [10 points] In the sun, the first step in the proton-proton cycle is to fuse two hydrogen nuclei together into a more massive isotope of hydrogen. Write out this specific reaction, including all of the appropriate products.

Z = 1

$${}_1^1H + {}_1^1H \rightarrow {}_1^2H + \beta^+ + \nu_e \ (+\gamma's)$$

Z = 2, A = 2

Z = 1, A = 2 ; Z = 1, A = 0

Z = 2, A = 2

"balances" β^+

B. [10 points] Calculate the energy released in the process in the following reaction: $n + {}^{238}U \rightarrow {}^{96}Sr + {}^{140}Xe + 3n$ The mass of ^{238}U is 238.050 784 u, the mass of ^{96}Sr is 95.921 750 u, and the mass of ^{140}Xe is 139.921 610 u.

$$\left[m_n + m(^{238}U)\right] - \left[m(^{96}Sr) + m(^{140}Xe) + 3m_n\right] =$$

$$= \left[1.008665u + 238.050784u\right] - \left[95.921750u + 139.921610u + 3(1.008665u)\right]$$

$$= .190094u$$

$$E = \Delta mc^2 = (.190094u)\left(931.5 \frac{MeV}{c^2/u}\right)c^2 = \boxed{177\ MeV}$$

C. [15 points] Calculate the binding energy of ^{12}C (Z=6) nucleus whose mass is 12.000 000 u. The mass of ^{1}H is 1.007 825, and other masses and conversions are shown on your cover sheet. (Show your work clearly.)

A = 12, Z = 6

N = A − Z = 6

$$\Delta M = (6m_n + 6m(^1H) - m(^{12}C) =$$

$$6(1.008665u + 1.007825u) - 12.000000u =$$

$$= .09894u$$

$$E = \Delta mc^2 = (.09894u)\left(931.5 \frac{MeV/c^2}{u}\right)c^2 = \boxed{92.2\ MeV}$$

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SITUATION II: A matter of time and energy

1. [10 points] Imagine that you're in the lab, playing with a nuclear isotope whose half life is 32.0 minutes. How long will you need to wait until the count rate that measure for a sample of this isotope changes so that it is 2.00% of its original value?

$N = N_0 e^{-\lambda t}$

$\frac{N}{N_0} = e^{-\lambda t}$

$C = .02 = \frac{N}{N_0}$

$\ln\left(\frac{N}{N_0}\right) = -\lambda t = -\frac{.693}{t_{1/2}} t$

$t = \frac{-t_{1/2}}{.693} \ln\left(\frac{N}{N_0}\right) = -\frac{32.0\,\text{min}}{.693} \ln(.02) = \boxed{181\,\text{min}}$

2. [15 points]. You are a particle physicist, looking for a particle responsible for the force that could have a range of 10^{-18} m. Approximate the mass of this particle, presuming that it could approach the speed of light. (Show all of your work clearly.)

$d \sim$

$d = vt = c\,\Delta t$ (t_{max} ← uncertainty ...)

$\Delta t = \frac{d}{c}$

$(E = mc^2) \rightarrow \Delta E\,\Delta t \geq \frac{h}{4\pi}$

$\Delta mc^2\,\Delta t \geq \frac{h}{4\pi}$

$\Delta m \simeq \frac{h}{4\pi c^2} \frac{1}{\Delta t}$

$\Delta m \simeq \frac{h}{4\pi c^2} \frac{c}{d} = \boxed{1.76\times10^{-25}\,\text{kg}}$

Could also be:
106u
or 9.86×10^4 MeV
(Depending on units used.)

3. [10 points] A particular particle has a rest mass of 135 MeV/c^2. It spontaneously decays into two identical photons. ~~Calculate the~~ wavelength of these photons.

$E_m = 2E_\gamma$

$mc^2 = 2\frac{hc}{\lambda}$

$\lambda = \frac{2hc}{mc^2} = \frac{2(1240\,\text{eV nm})}{135\times10^6\,\text{eV}/c^2\,c^2}$

$= \boxed{1.84\times10^{-5}\,\text{nm} = 1.84\times10^{-14}\,\text{m}}$