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.
   - (D) none of these
   - (E) There is no way to predict this.

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.
   - (D) none of these
   - (E) There is no way to predict this.

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
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.

\[ ^1H + ^1H \rightarrow ^2H + \beta^+ + \nu_e \quad (+8's) \]

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.

\[
\left[ M_n + M(^{238}U) \right] - \left[ M(^{96}Sr) + M(^{140}Xe) + 3M_n \right] = \\
= \left[ 1.008 665 u + 238.050 784 u \right] - \left[ 95.921 750 u + 139.921 610 u + 3(1.008 665) u \right] \\
= .190 094 u \\
E = \Delta mc^2 = \left( .190 094 \times \frac{931.5 \text{ MeV}}{c^2} \right) c^2 = \boxed{177 \text{ MeV}}
\]

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

\[
A = 12, \; Z = 6 \\
\Delta m = (6m_n + 6m(^1H)) - m(^{12}C) = \\
= \left( 1.008 665 u + 1.007 825 u \right) - 12.000 000 u = \\
= .098 94 u \\
E = \Delta mc^2 = \left( .098 94 u \right) \left( \frac{931.5 \text{ MeV}}{c^2} \right) c^2 = \boxed{92.2 \text{ MeV}}
\]
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?

\[ N = N_0 e^{-\lambda t} \]
\[ \frac{N}{N_0} = e^{-\lambda t} \]
\[ \ln \left( \frac{N}{N_0} \right) = -\lambda t = -\frac{0.693}{t_{1/2}} \]
\[ t = \frac{-\ln (0.02)}{0.693} = \frac{32.0 \text{ min}}{0.693} \ln (0.02) = 181 \text{ min} \]

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.)

\[ d = vt = \frac{c \Delta t}{c} \]
\[ \Delta t = \frac{d}{c} \]

\[ E = mc^2 \]
\[ \Delta E \approx \frac{\hbar}{4\pi} \]

\[ \Delta m = \frac{\hbar}{4\pi c^2 \Delta t} \]

Could also be:

106 u
or 9.86 \times 10^4 \text{ 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.

\[ E_m = 2E_\gamma \]
\[ mc^2 = 2 \frac{h c}{n} \]
\[ \lambda = \frac{2h c}{mc^2} = \frac{2(1240 \text{ eV } \mu m)}{135 \times 10^6 \text{ eV } \mu m} \]
\[ = 1.84 \times 10^{-5} \mu m \]
\[ = 1.84 \times 10^{-5} \text{ m} \]