Conservation of Energy and Momentum Worksheet

Recall the basic relations:

$E_i = E_f$

$P_i = P_f$

$\Delta E \Delta t \geq \frac{h}{2\pi}$

$\Delta p \Delta x \geq \frac{h}{2\pi}$

Equations:

1. $E = K + U + mc^2$ (usually $U = 0$)
2. $E = \sqrt{(pc)^2 + (mc^2)^2}$ for all particles
3. $E = hf$ (for a photon)
4. $p = mv$ (for a massive particle at low speeds)
5. $p = \frac{E}{c}$ (for a massless particle)

Constants:

$h = 6.63 \times 10^{-34}\ J \cdot s = 4.14 \times 10^{-21}\ MeV \cdot s$

$c = 3.00 \times 10^{8}\ m/s$

Mass of electron = mass of positron $= 9.1 \times 10^{-31}\ kg = .511\ MeV/c^2$

Mass of hydrogen atom $= 1.67 \times 10^{-27}\ kg$

Example 1:
A gamma ray photon has energy equal to 5 MeV. What is its:

a. momentum (in kg-m/s)?
b. momentum (in MeV/c)?
c. frequency (in s^{-1})?

Example 2:
An electron and positron are at rest in a particular frame of reference. What is their:

a. total energy (in J)?
b. total energy (in MeV)?

Example 3
A 5 MeV gamma ray turns into an electron-positron pair moving in the same direction as the gamma ray. What is:

a. the total momentum of the electron and positron (in MeV/c)?
b. the total energy of the electron and positron (in MeV) using energy conservation?
c. the total energy of the electron and positron using Equation 2 (above) (in MeV)?
d. the difference in energy between the results of (b) and (c)?

Example 4:
Using the result (d) from Example 3, and the uncertainty principle, for how much time can the electron-positron pair exist before they must annihilate (turn back into a gamma ray)?