Radioactivity Problems:

1. Iodine ($^{131}_{53}I$) is used to clinically diagnose the thyroid gland. Suppose the patient is given an injection of $550\mu g$ of $^{131}_{53}I$. The half-life of $^{131}_{53}I$ is 8 days.
   a. What is the patient's activity immediately after injection?
   b. What is the patient's activity after 1 hour? After 10 hours?
   c. What is the patient's activity after 6 months?
   d. Suppose that after initial injection of $550\mu g$, that of it was excreted from the body after 48 hours. What is the remining activity in the patient's body on the third day of treatment? Hint, what is the effective half-life of the $^{131}_{53}I$?

2. A photomultiplier tube (PMT) is used for the detection of gamma radiation from a patient. The light that enters the tube interacts with a scintillator that changes the gamma-ray photons into visible light. The visible light is then detected by a barium oxide (BaO) cathode in the photomultiplier tube.
   a. Barium oxide has a work function of $1.3eV$. What wavelength should the gamma-ray photons have when they are emitted from the scintillator and to be detected by the strontium vanadate cathode?
   b. Suppose that one of these photons from part a strikes the cathode and liberates an electron. How high of a potential difference must the first barium oxide dynode be if $z = 2$ secondary electrons are liberated?
   c. The PMT is made up of $N = 5$ dynodes in total. These are arranged in such a way that the same number of secondary electrons are liberated for each incident electron. How long does it take the signal to reach the anode if the separation between the dynodes is $d = 1cm$.
   d. How much current is measured at the anode if photons with a power $2 \times 10^{-8}W$ strike the cathode? When we say that we measure a current on our detector and this corresponds to a photon with a certain energy, this is how the detector electronics do the calculation.

3. In PET, a radiopharmaceutical is introduced into an organism. The annihilation of an emitted positron and an electron from the surrounding tissue produces two photons that will be detected. We say that the positron gets ejected and quickly annihilates. What happens is we form a quasi-atom of the positron and electron called positronium.
   a. Show that in the decay of such a quasi-atom, that if the speeds of the electron and positron are ignored, the two photons are emitted in opposite directions and determine the energy of a photon in eV.
   b. What effects occur if the positronium quasi-atom has a kinetic energy, and what relevance does this mean for image production?