1. Indicate whether the following statements are true (T) or false (F). [20 points]

( ) The atomic number of the isotope $^{16}$O is 16.

( ) The number of atoms in a gram of matter is equal to Avogadro’s number.

( ) The L-shell of a neutral $^{14}$N atom contains 5 electrons.

( ) The deBroglie wavelength of an electron decreases as the speed of the electron increases.

( ) We can predict when a given radioactive atom will disintegrate if we know the half-life of the radionuclide species.

( ) Matter appears to be continuous, rather than discrete, because the nucleus of each atom is over 50% the size of the atom itself.

( ) The Q-value of a reaction can be defined in terms of either the rest masses or the kinetic energies of the constituents (reactants and products).

( ) A beta particle is heavier than a neutron.

( ) The lifetime of a star is directly proportional to its size.

( ) Fusion is the process whereby an electron and a positron annihilate.

( ) $^{14}$C is produced in the earth’s atmosphere via the reaction $^{14}$N$(n,p)^{14}$C.

( ) Alpha particles are the preferred radiation to measure sheet metal thickness.

( ) The half-life of $^{60}$Co is greater than 5 y.

( ) The natural abundance of $^2$H on earth is 1.5%.

( ) Delayed neutrons from fission products are useful in helping us control nuclear fission reactors.

( ) Inelastic scattering is an endoergic reaction.

( ) Fission has been used for power production rather than fusion because fission reactions yield more energy per nucleon than do fusion reactions.

( ) On average, we receive more than 2 rem/y from natural background radiation.

( ) PET is an acronym for practical electron tomography.

( ) Radioactive tracers can be used to measure the volumetric flow rate of a river or open stream.
2. Consider the binary reaction $^6\text{Li}(n,p)^6\text{He}$.
   (a) What is the Q-value for this reaction? [5 points]
   (b) What is the kinematic threshold for this reaction? [5 points]
   (c) What is the Coulombic threshold for this reaction? [5 points]
   (d) What is the minimum kinetic energy that the products can have? [5 points]

3. A small $^{99m}\text{Tc}$ radioisotope source is located inside a collimator that directs a nearly parallel beam of photons onto a sample of water. Initially, the intensity of all the $^{99m}\text{Tc}$ photons is $2 \times 10^6 \text{ cm}^{-2} \text{ s}^{-1}$.
   (a) What is the intensity of all the photons 24 hours later? [5 points]
   (b) What is the energy of the dominant (highest frequency of emission) photon emitted by $^{99m}\text{Tc}$? [5 points]
   (c) What is the average distance these photons travel in water before an interaction? [5 points]
   (d) What is the initial rate, per unit volume, of photoelectric interactions at this energy in the water? [5 points]

4. Consider a sample of natural lithium.
   (a) What is the thermal-neutron macroscopic scattering cross section (also called the linear scattering interaction coefficient) of this sample? [5 points]
   (b) What is the macroscopic capture cross section for thermal neutrons of this sample? [5 points]

5. A 25-year old female dental hygienist receives a whole body X-ray dose of 4.0 rad in one exposure because of lax practices in the office.
   (a) Express this dose in grays (Gy). [5 points]
   (b) Estimate the probability she will die of radiogenic cancer sometime in the future as a result of this exposure. [5 points]
   (c) Estimate the probability that her child born when she is 30 years old will have some type of genetic disorder (use UNSCEAR data). [5 points]

6. Consider a homogeneous mixture of graphite and uranium with a carbon-to-uranium atom ratio of 1,500:1. The uranium is enriched to 1.0 atom-% in $^{235}\text{U}$. The remainder of the uranium is the isotope $^{238}\text{U}$.
   (a) Calculate the thermal fission factor $\eta$ for this material. [5 points]
   (b) Calculate the thermal fission factor $f$ for this material. [5 points]
   (c) Can a critical assembly be made using this material? Explain. [5 points]