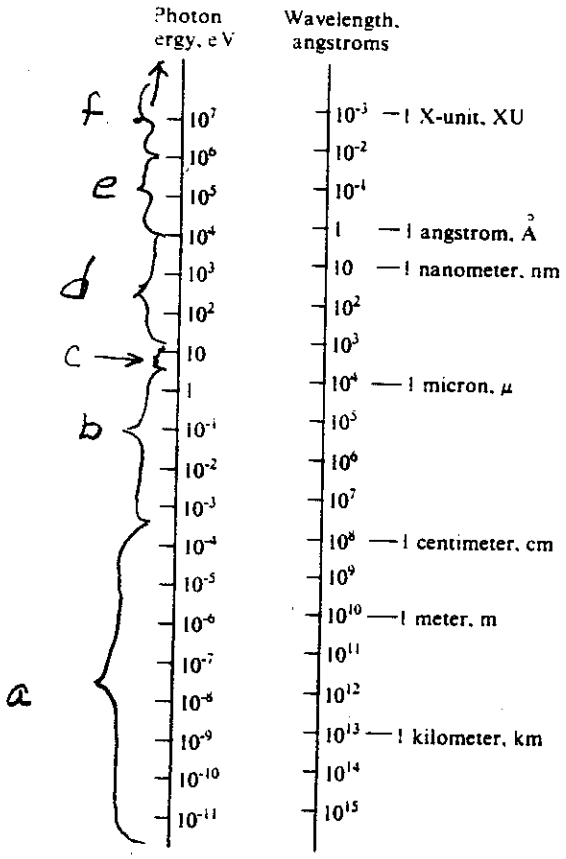
October 1991

## Ph.D. Qualifying Examination
## Interactions, Measurements, Theory of Radiation

1. (10 min.) Electromagnetic radiation spans the energy scale from almost 0 upward. Below is a scale in terms of both wavelength and energy, with certain ranges are bracketed. Please name or otherwise describe the atomic, molecular, or nuclear processes that produce the electromagnetic radiation associated with each of the indicated ranges. Also, what is a (or the) name commonly applied to radiation in these wavelength regimes?



2. (15 min.) Suppose a certain nucleus is known to have a half-life of 1 second. If an observer detects a large number of these nuclei at the origin of his coordinate system and they are moving with velocity $2.7 \times 10^8$ m/s at time t=0, how far from that point will the observer find that those nuclei have travelled when only half of the originally observed group remain?

3. (20 min.) Natural boron has a density of 2.45 gm/cm$^3$ and an atomic weight of 10.82. Boron consists of two isotopes, $^{10}$B (19.9%) and $^{11}$B (80.1%), with microscopic absorption cross sections of 3838 barns and 5 barns, respectively for 0.025 eV neutrons. The microscopic scattering cross section is 4 barns for each isotope.

(50%) a. Calculate the macroscopic cross sections at 0.025 eV for absorption, scattering and total interaction.

(20%) b. What fractional attenuation will a 0.025 eV neutron beam experience when penetrating 1 mm of boron and 1 cm of boron?

(30%) c. Assuming the absorption cross section is "one-over-v", calculate the macroscopic cross sections for boron for 0.0025 - eV and 100 - eV neutrons.

4. (15 min.) Before testing of nuclear weapons in the atmosphere and before massive burning of fossil fuel diluted the atmospheric $^{14}$C, the specific activity of atmospheric carbon was 15.3 disintegrations/g/min. In a recent development, ultrasensitive mass spectrometers are being used to extend the range of carbon-14 dating back to 100,000 years before the present. The half-life of $^{14}$C is 5740 years. For this problem ignore carbon-13.

a) How well must the mass spectrometer select against spurious signals from the $^{12}$C, ie., what is the ratio of $^{12}$C to $^{14}$C for a 100,000 year old sample?

b) If the number of $^{14}$C atoms counted by the spectrometer is in error by 10%, for example, 90 atoms instead of 100 atoms, how much would that affect the assigned age of the carbon sample?

5. (20 min.) An infinite slab of thickness t contains uniformly distributed, isotropic, and monoenergetic gamma sources of strength S photons/cm$^3$-sec. The linear attenuation coefficient is $\mu$ cm$^{-1}$. Using the integral method, find the uncollided scalar flux density at one face of the slab. Express your result in terms of exponential integrals,

$$E_n(x) = \int_0^1 w^{n-2} e^{-x/w}\, dw.$$

6. (20 min.) A radioisotope generator contains 500 mCi of $^{131}Ba$ ($t_{1/2}$ = 11.6 d) producing the daughter $^{131}Cs$ ($t_{1/2}$ = 9.7 d). At time t=0 the daughter is completely removed.

(50%) a. Derive a general expression which predicts the activity of $^{131}Cs$ as a function of time.

(35%) b. When will the $^{131}Cs$ activity reach its maximum value?

(15%) c. How many becquerels of $^{131}Cs$ can be removed at the time of its maximum value assuming a 100% removal efficiency?

7. (20 min.) Describe the types of ionizing radiation emitted from fission in a nuclear reactor. Also describe the types of radiations that these initial radiations can induce. Include a description including any differences for the fuel, moderator, and reflector.