Ph.D. Qualifying Examination
Applied Health Physics

1. (10 min.) Radioactive material released into the atmosphere is transported downwind and diffuses through the atmosphere.

(a.) What mathematical formulations are used typically to describe the dispersion of radioactive material in the atmosphere?

(b.) This material comes under the influence of a number of processes as it is transported downwind and diffuses through the atmosphere including “rainout”, “washout”, and “dry deposition”. Explain each of these processes and include in your discussion all components of these general processes.

2. (10 min.) Recently, the NCRP has been holding discussions regarding the appropriate limits for deterministic (i.e., nonstochastic) effects of radiation. There is some sentiment to have the same limits for these effects for occupationally-exposed workers and for the general public. Current limits are more than a factor of ten lower for the general population. The rationale is that, if the limits truly are designed to prevent deterministic effects, there is no need for different limits for these two populations. Choose one side of this argument and provide a discussion that could be used to support it.

3. (15 min.) An ion chamber is needed to measure low dose rates. Because of the limitations of the electrometer to be used, the chamber current must be $> 10^{-12}$ amps for a dose rate of $10^{-2}$ Gy/hr.

Assume that the gas filling has density of $10^{-3}$ g cm$^{-3}$ and a mean energy per ion pair of 32 eV, and the chamber is to be used in a radiation field which results in secondary electrons with a minimum range of $10^{-2}$ g cm$^{-2}$.

(a.) For a spherical detector, calculate the minimum diameter of the detector.

(b.) Can the Bragg Gray cavity theory be used in order to calculate the dose in the wall of the detector? Explain.

4. (10 min.) NCRP provides recommended methods for calculating the minimum shielding required for medical diagnostic radiation-generating machine installations.

(a.) Is this approach consistent with ALARA? Give a brief justification for your answer, and also for the opposite view.

(b.) If a facility has been designed with sufficient shielding to maintain dose below the regulatory limit in the adjacent room, assuming an occupancy factor of 1, what could be done during building design or remodeling to improve ALARA compliance, without adding shielding material?
5. (10 min.) A member of the public is exposed to an unknown dose of gamma-radiation from an improperly decommissioned medical source. What are some biological indicators that could be used alone or in combination to estimate the dose that the person received?

6. (10 min.) You are the staff health physicist at a facility that will be producing neutrons with energies of about 100 keV. Since the recommended radiation-weighting factor for neutrons of energies between 10 and 100 keV is 10 and it is 20 for neutrons of energies between 100 keV and 2 MeV, how would you assess the doses to scientists working with the beam? Justify your answer. Describe a method to determine the radiation-weighting factor for the neutrons in question. What other radiological hazards would be associated with the operation of this facility?

7. (15 min.) In processing radioactive material, some of it routinely becomes airborne within the workplace room. To determine inhalation hazard, you make routine cascade impactor measurements where the impactor at your disposal samples 25 Lpm, has 50% collection efficiencies at 10 μm, 2μm, and 0.8 μm diameters, and collects the remaining airborne material on an afterfilter. Assume you have an ideal impactor and radionuclide half-lives are long compared with sampling and analysis times and suppose the following data are measured based upon a 1-hour sampling time:

<table>
<thead>
<tr>
<th>Stage 1 (10μm)</th>
<th>Stage 2 (2μm)</th>
<th>Stage 3 (0.8μm)</th>
<th>Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 pCi</td>
<td>500 pCi</td>
<td>200 pCi</td>
<td>50 pCi</td>
</tr>
</tbody>
</table>

(a.) (60%) Draw a histogram for the concentration of the radioactivity giving a representation of the particle size distribution of the airborne radioactivity indicated by these measurements. Include units on your graph.

(b.) (30%) If all processing ceases, the room is sealed for a few weeks, and then another cascade impactor sample is taken, sketch the histogram you would expect. Very briefly (i.e., 1 or 2 words each), what are the mechanisms leading to each value you indicate relative to the original values given.

(c.) (10%) Now, assume the radiation hazard is not from the processing of solids or liquids but originates from rare gas actinides with active decay products. If no aerosol besides that formed in association with the air chemistry of actinide decays is present in the room, give a histogrammatic representation of what the activity data collected by this same impactor set-up might look like.
8. (20 min.) The scenario: Unknown to the reactor supervisor of the TAMU Department of Nuclear Engineering, the AGN-201 reactor core shield tank has completely drained because of a valve knocked out of position during the precriticality check-off. During an ensuing maintenance procedure, the supervisor brings the reactor critical and then raises reactor power to a steady-state level of five watts. After ten minutes at this operating power, the supervisor notices excessive counts registering on the skirt monitor and subsequently scrams the reactor.

The problem: You have been appointed by the Office of Radiological Safety (ORS) to assess the neutron and gamma dose equivalents for the reactor supervisor during the time the reactor was operated without proper shielding (an investigation revealed that the antiquated relay for the skirt monitor high level protective trip was stuck in the closed position).

Find:
(a.) (50%) The neutron dose equivalent, in rem, received by the supervisor during the reactor operation.
(b.) (50%) The gamma-ray dose equivalent, in rem, received by the supervisor during the reactor operation.

Given:
i) It has been determined that $3 \times 10^{10}$ fissions occurred during the whole of the period under investigation (it took an additional ten minutes of reactor operations to reach the five watt level from the source range level).
ii) Each fission produces three neutrons and eight gamma-rays.
iii) The mean neutron and gamma-ray energies are 2.5-MeV and 1-MeV, respectively.
iv) The neutron spectrum for the criticality is represented by an absorbed dose rate conversion factor of 2.5-mrad h$^{-1}$ per 20 neutrons cm$^{-2}$ s$^{-1}$.
v) The gamma-ray spectrum for the criticality is represented by an exposure rate conversion factor of 1 R h$^{-1}$ per 5.5x10$^2$ gamma-rays cm$^{-2}$ s$^{-1}$.
vi) The supervisor was standing twenty feet from the core centerline, behind a twelve-inch concrete shield.
vii) The neutron dose attenuation factor for 2.5-MeV neutrons through twelve inches of concrete is 0.005.
viii) The fission gamma-ray spectrum mass attenuation coefficient is 0.0727 cm$^2$ g$^{-1}$ for concrete.
ix) Density of concrete is 2.3 g cm$^{-3}$. 
9. (10 min.)

(a.) (10%) Which organ has the highest probability of radiation-induced cancer as the result of exposure to airborne radon progeny?

(b.) (10%) Approximately what percentage of the total effective dose equivalent, from exposure to "background" radiation in the United States, can be attributed to radon, per annum?

(c.) (40%) Calculate the potential alpha energy released in the lungs from the deposition of the short-lived decay products in equilibrium with 100 pCi of $^{222}\text{Rn}$ (in one liter of air at STP).

(d.) (40%) Calculate the average dose to the lungs for a one-year exposure to the short-lived decay products in equilibrium with 100 pCi/m$^3$ of $^{222}\text{Rn}$. You may assume an average deposition and retention of twenty-five percent.

10. (10 min.) Discuss the relative advantages and disadvantages of the following dosimeter types for use in neutron dosimetry for radiation workers:

(a.) TLD albedo

(b.) Track etch

(c.) Bubble dosimeters