1. You are a health physicist at a nuclear installation and your supervisor directs you to measure a long-lived contamination smear with a GM counter. During a 10 minute count interval a total of 1000 counts was recorded while a 1 hour background measurement yielded 2,340 counts.

   a. (5 min) What is the net sample counting rate and the standard deviation of the net counting rate?
   
   b. (5 min) What is the standard deviation and the relative probable error in the 50% confidence interval of the 10-minute sample count?
   
   c. (10 min) After your supervisor presents your results to the resident inspector, you are directed to recount the sample. What would be the optimum division of counting time between the background and the sample to minimize the resulting errors, if you are given only 2 hours to complete the counts?

2. (15 min) Maintenance work must be done on a piece of equipment located at a distance of 1.5 meters from a valve that is internally contaminated with $^{137}$Cs. Neither the piece of equipment nor the valve can be moved during the maintenance work so shielding must be employed to reduce the dose rate in the work area. A survey reveals that the exposure rate at 30 cm from the valve is 200 R/hour. The estimated time to complete the work is 3 hours. Calculate the thickness of lead shielding required to reduce the dose rate in the work area so that the maintenance workers will not exceed their assigned “dose for the job” of 100 mrem. Please state all assumptions.

DATA:

\[ Q_{\gamma} = 1 \quad Q_{\text{fast neutrons}} = 10 \quad Q_{\beta} = 1 \quad Q_{\text{thermal neutrons}} = 2.3 \]

\[ \text{HVL (lead)} = 0.8 \text{ cm} \quad \text{TVL (lead)} = 2.4 \text{ cm} \]

3. You are supposed to calculate the possible odos to a worker at a medical facility where I-131 is employed.

   a. (10 min) Given that the DAC for I-131 is $2.0 \times 10^{-8} \mu\text{Ci cm}^{-3}$ determine the equivalent dose to a worker’s thyroid from a 10 hour exposure to I-131 that has a concentration of $8 \times 10^{-9} \mu\text{Ci cm}^{-3}$. The worker did not use respiratory protection. State all assumptions.

   b. (5 min) How would you calculate the effective dose to the individual from this exposure?

4. (15 min) You are responsible for the safety of employees that work in and around a heavy ion collider. In order to assure their safety, you need to determine if the radiation weighting factor
for high energy neutrons is appropriate for neutrons with an energy of 200 MeV. Propose an experiment examining the physical characteristics of the ionization tracks that result from 200 MeV neutron beam irradiation and a second experiment using a biological system that would provide you with the data you require to verify that the radiation weighting factor is correct. Discuss the strengths and weaknesses of your proposed measurements and how they would relate to the radiation weighting factor.

5. (15 min) A number of attached mammalian cell cultures growing on mylar are exposed to a range of doses of 250 kVp X rays or a beam of 5 MeV alpha particles. On a single diagram show what a typical survival curve for each of these types of radiation would look like. Be sure to label each axis correctly in reasonable units and indicate the D₀ for each radiation. Then determine a RBE for the alpha particles based on your curves. State any assumptions.

6. (15 min) Based on the data presented below, calculate the annual limit on intake (ALI) and the derived air concentration (DAC) for the radionuclide Bi-207. Assume the material is pulmonary clearance class D.

<table>
<thead>
<tr>
<th>Committed Dose Equivalent per unit intake of activity (Sv/Bq)</th>
<th>Tissue Weighting Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>gonads 3.7 x 10⁻¹⁰</td>
<td>gonads 0.25</td>
</tr>
<tr>
<td>lungs 6.9 x 10⁻¹⁰</td>
<td>breast 0.15</td>
</tr>
<tr>
<td>ULI wall 8.3 x 10⁻¹⁰</td>
<td>lungs 0.12</td>
</tr>
<tr>
<td>LLI wall 1.6 x 10⁻⁹</td>
<td>red bone marrow 0.12</td>
</tr>
<tr>
<td>kidneys 6.9 x 10⁻⁹</td>
<td>bone surface cells 0.05</td>
</tr>
<tr>
<td>remainder 7.0 x 10⁻¹⁰</td>
<td>thyroid 0.05</td>
</tr>
<tr>
<td></td>
<td>remainder 0.3</td>
</tr>
</tbody>
</table>

Please state all assumptions.

7. (5 min) True story: You are working with an exercise planner for an emergency response exercise involving a simulated radiation dispersal device. The planner tells you his bomb will have 2 kg of Cs-137 as the radionuclide. After hearing that, what would you tell him and why? Use calculations and words to explain it.
8. Three single-stage aerosol impactors and one filter sampler are operated in parallel and at the same volumetric flow rate to collect samples of room aerosol:

![Diagram of aerosol impactors and filter sampler](image)

The steady-state activities of the samples collected on the three impaction stages are

\[ A_1^s = 600 \text{ Bq}, \quad A_2^s = 1000 \text{ Bq}, \quad A_3^s = 1200 \text{ Bq} \]

and on the filter is \[ A_f^f = 1400 \text{ Bq}. \]

(a) (10 min) First, give a crude activity-size distribution derived from these data. For a person exposed to these particles, indicate where in the respiratory system these particles will deposit.

(b) (10 min) In reality, these samples covering a broad range of particle sizes are very unlikely to contain identical radionuclides. Why? Your answer to this question must indicate how the processes radionuclides enter the gas phase and the relationship of these processes to particle size.