# Written Exam, Radiation Protection, Dosimetry, and Detectors (SH2603), October 25, 2008

**Allowed aids:** pocket calculator.
**The tables you need is handed out together with this exam**
To pass the exam, you need at least 6 points from Section A, **and** at least 4 points from Section B (also for Fx). To pass, you also need at least 11 points in total.
**Grading** is then determined by the total number of points:
A:20-22, B:18-19, C:15-17, D:13-14, E:11-12, Fx:10, F:0-9
**Motivate your answers by calculations and text. Write clearly.**
**Make your own, reasonable assumptions, when necessary. It should be clear from your text what assumptions you make.**
Good Luck!

## Section A

1. Describe the decay of the radioisotope $^{60}$Co. What kind(s) of ionising radiation is emitted from an open source of $^{60}$Co? What energies are associated with the emitted radiation? [1 p]

2. Two energy spectra from a germanium gamma-detector have been acquired. The first spectrum is used for calibration purposes and shows the energy of photons emitted from a source of $^{22}$Na (that decays by $\beta^+$). The two photo peaks are found at the channel numbers 823 and 2086. Make a linear calibration to get the relationship between energy and channel number. The second spectrum shows the gamma photons emitted from an unknown source. Using the calibration; what is the energy of the photo peak at channel number 1072 ? [1 p]

3. The International Commission for Radiation Protection (ICRP) lists three principles to follow when working with radioactive materials. One principle is that the radiation protection should be *optimised*. Another principle is that we should follow the *dose limit* recommendations. What is the *third* principle? [1 p]

4. At what approximate full body (effective) dose will a person experience acute radiation sickness? We assume that the dose is received within a short time interval. [1 p]

5. Humans are radioactive by nature. Give one example of a radioisotope that can be found in the human body. [1 p]

6. A narrow beam of 60 keV gamma photons from a $^{241}$Am source has an intensity of 100000 photons per second. Consider putting a lead sheet of 1 mm thickness in front of the beam. What will the new, reduced, intensity be? [1 p]

7. A gamma photon of high energy (2.2 MeV) is approaching a wall of concrete. What are the (principal) possible ways of interaction between the gamma photon and the material? [1 p]

8. Calculate the approximate radius of the nucleus of the uranium isotope most abundant (most common) in nature. You can assume that the radius of $^1$H is $1.2 \cdot 10^{-15}$ m. [1 p]

9. By measuring gamma radiation with for example a germanium detector, we can, in many indoor environments detect gamma photons corresponding to internal transitions in $^{214}$Bi nuclei. What gaseous radionuclide is the origin of this activity? Explain the path of decays that lead from the (same) radioisotope in gas form to $^{214}$Bi (list the decay type for each step, and list the nuclides involved). [1 p]

10. We know from the laboratory exercise that an alpha particle of around 5 MeV only travels a few centimeters in air. Now let us investigate how effective air stops energetic electrons and gamma photons. Calculate the approximate range in air for electrons of 1 MeV energy. Calculate the distance that a (narrow) beam of 1 MeV gamma photons travel in air before it has lost half of its intensity? [1 p]

## Section B

1. Ionising chambers are, by themselves, quite inefficient for detecting gamma photons in the 1 MeV range. Consider an ionising chamber detector of cylindrical shape, with a length of 10 cm. The detector is filled with argon gas at normal pressure. Assume that the photons of 1 MeV energy travel in a direction along the axis of the cylinder. Out of 1000 gamma photons passing through the gas volume of a ionising detector, how many will be detected? [1 p]

   Assume that we now put a thin layer of lead (1 mm) in front of the detector. What will happen? Will the number of detected incoming gamma photons increase or decrease? Motivate your answer well. Calculate/estimate the new number of detected gamma photons (out of 1000 photons). [2 p]

2. A source of $^{60}$Co is used at a hospital. The activity is 5 Ci. Calculate the effective dose that a nurse working in the same room would receive in one working day (8 h) if there was no radiation shielding around the source. The average distance to the source can be assumed to be 3 meters. [2 p]

   Now design a radiation protection around the source. The source does *not* have to be easy to move. Select material and thickness so that the dose to the nurse is limited to $1 \mu Sv$ per working day. [1 p]

3. In November 2006, the radioisotope polonium-210 was used to poison and kill the Russian dissident Alexander Litvinenko in London. It took the British authorities a few weeks to realise that the poison was in fact $^{210}$Po. Explain two methods that can be used, to *identify* polonium-210 (to make sure that it is really Po210, and not another radioactive material), by using detectors of ionising radiation. Assume that we have a sample (e.g. urine) from the poisoned person, and that the sample contains 1 mCi [1 p].

   It has been estimated that Litvinenko consumed around 10 micrograms of Po-210. Calculate the effective dose during 24 hours. Assume that all of the material stays in the body for the 24 hours, and that it is distributed evenly over the whole body [2 p].

4. In a lab exercise, students use a neutron source (Am-Be) to irradiate small plates made of pure silver (Ag). After about 10 minutes they remove the silver from the neutron source. The students now put the silver plate in front of a GM-counter (ionisation chamber). They discover that the radioactivity is intense at the beginning, but after 15 minutes there is almost no signal in the detector. Explain the origin of the radioactivity. what are the nuclides involved? What are the half-life (or half-lives) involved? [1 p]

   The experiment is repeated by irradiating (with the neutron source) the silver plate again for 10 minutes. The plate is then put in front of a germanium detector to see if any gamma is emitted. Should the students expect to see any gamma photons? If so, at what energy/energies? [2 p]