RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (General) Degree in Applied Sciences
Third Year - Semester I Examination – November/December 2016

PHY 3211 – MEDICAL PHYSICS

Time: Two (2) hours

Instructions:

1. Answer **all** the questions
2. Only the calculators provided by the university are allowed to be used.

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \mathrm{ms^{-1}}$
electron charge	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Plank constant	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
mass of electron	$\mathrm{m}_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
mass of proton	$\mathrm{m}_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
acceleration of free fall on the Earth's surface	$g = 9.81\ \mathrm{m\,s^{-1}}$
electron volt	$1\ \mathrm{eV} = 1.60 \times 10^{-19}\ \mathrm{J}$
Rydberg constant	$R_H = 1.097 \times 10^{7}\ \mathrm{m^{-1}}$
Atomic mass unit	$1\ \mathrm{u} = 931.6\ \mathrm{MeV}$
Angstrom	$1\text{Å} = 1 \times 10^{-10}\ \mathrm{m}$

1. On 1st of November 2006, the former Russian spy Alexander Litvinenko fell ill. Twenty one days later he died from the radiation effects of polonium- 210. Experts suggest that as little as 0.89 μg of polonium-210 would be enough to kill, although Mr Litvinenko's death was linked to a much larger dose of the radioactive isotope. Traces of the isotope were later found in washrooms at five

locations around London visited by the Russian.

Polonium-210 has a half-life of 138 days.

(a) (i) In a 0.89 μg sample of polonium-210 there are 2.54×10^{15} atoms of polonium. Show that the decay constant for polonium-210 is about $6 \times 10^{-8}\ s^{-1}$, and hence calculate the activity of a sample of this size. **(4 marks)**

(ii) Calculate the fraction of polonium-210 nuclei that have decayed after 21 days. **(3 marks)**

(b) Polonium-210 emits alpha particles. Explain why polonium-210 is virtually harmless unless it is taken into the body. **(2 marks)**

(c) (i) Complete the equation below for the decay of polonium. **(2 marks)**

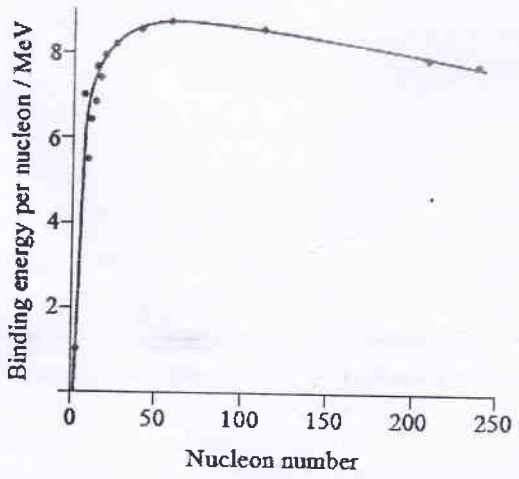
$$^{210}_{84}\text{Po} \rightarrow \text{.....Pb} + \text{.....}\alpha$$

(ii) State why the Pb nuclei would recoil from the alpha particles emitted during the decay. **(2 marks)**

(d) Radioactive decay is said to occur *spontaneously* and *randomly*. Explain what is meant by spontaneous and random in this context. **(2 marks)**

(e) Suggest why traces of the isotope were found in locations visited by the Russian. **(2 marks)**

2. (I) The graph shows how the binding energy per nucleon varies with nucleon number for a range of nuclides.



(a) State what is meant by **binding energy** of a nucleus. **(2 marks)**

(b) Explain why nuclear fusion is only viable as an energy source if light

nuclei are used. (2 marks)

(II) Ionization smoke detectors contain a small amount of the radioactive isotope americium (Am). ^{241}Am is an α-emitter. It has a half-life of 432 years, and the activity from the source in a new smoke detector is about 3.5×10^4 Bq.

(a) Explain why the radiation produced by a smoke detector does not pose a health hazard. **(2 marks)**

(b) (i) Complete the nuclear equation of the decay of americium. **(2 marks)**

$$^{241}Am \rightarrow {}^{\cdots}_{93}Np + {}^{\cdots}_{\cdots}\alpha$$

(ii) Using data from the table, calculate the energy of α-particles released when a nucleus of americium-241 undergoes alpha decay. **(4 marks)**

Nuclide	Mass / u
Am	241.056822
Np	237.048166
α-particle	4.002603

(c) An ionization smoke detector is sold with the guarantee that it 'lasts a lifetime'. Comment on the appropriateness of this guarantee, based on its use of americium-241. **(2 marks)**

3. A diagnostic X-ray tube produces a beam of X-rays. The beam passes through a diaphragm consisting of two pairs of lead sheets which can be moved at right angles to each other, and then through an aluminum filter.

(a) Using appropriate diagrams state the principle of production of X-rays. **(4 marks)**

(b) (i) State the use of the lead sheets **(2 marks)**

(ii) State the use of aluminum filter **(2 marks)**

(c) When a monochromatic beam of X-ray photons is passed through aluminum sheet of thickness 2.7 mm, its intensity is reduced by 8.3%.

(i) State what is meant by the linear attenuation coefficient. **(2 marks)**

(ii) Define half-value thickness. **(2 marks)**

(iii) Calculate the mass attenuation coefficient of aluminum for these X-rays. Density of aluminum is 2700 kg m^{-3}. **(5 marks)**

(d) A tumor could be destroyed by absorbing X-rays using the Compton scattering absorption mechanism. Explain. **(3 marks)**

4. A patient with a history of thyroid cancer has suspected bone marrow metastases in the cervical spine. It is recommended to perform a bone scan using the gamma camera.

(a) Give another name for the gamma camera. **(1 mark)**

(b) (i) State the function of the gamma camera **(3 marks)**

(ii) What is the most commonly used radioisotope for this purpose? Give reasons for using this particular isotope? **(3 marks)**

(b) The following diagram shows a cross section of a gamma camera.

(i) For each of the labeled parts, state what it is and explain its purpose **(6 marks)**

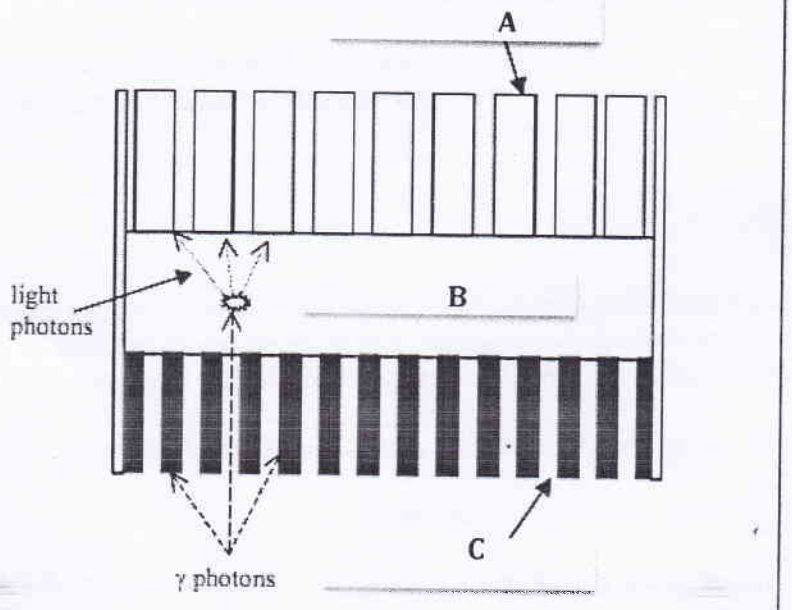


Diagram showing the internal construction of a Gamma camera

(ii) What is the fundamental difference between gamma camera and X-ray images? **(2 marks)**

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