國立清華大學 103 學年度碩士班考試入學試題

系所班組別：生醫工程與環境科學系　丙組 (醫學物理與工程組)
考試科目（代碼）：放射物理學 (2501)

1. (10%). (a) Define the transformation constant λ. Derive it by: the initial number of atoms of a radioactive source is N_0; the number at time t is N. Correlate λ with the half-life t_h. (b) Derive the activity A of the source by: N_0, λ, and t_h.

2. (10%). (a) Plot a typical X-ray energy spectrum with x-axis of electron energy and y-axis of photon fluence. Describe the two types of X-ray: characteristic radiation and bremsstrahlung radiation. (b) An X-ray tube operated at 200 kVp with a tube current of 8 mA gives an exposure rate of 20 R/min at 50 cm. Estimate the exposure rate from the same X-ray tube if the tube current is increased to 12 mA.

3. (10%). (a) Describe the working principles of a modern CT (computed tomography) scanner and a multi-slice spiral CT. (b) Specify at least one advantage and one disadvantage of a multi-slice spiral CT. Explain your answers shortly. (c) Define the CT number. Calculate the CT number of water.

4. (10%). Define the tissue-air ratio and the backscatter factor in dose calculations. Explain your answer briefly.

5. (10%). (a) The interactions of ionizing radiation with matter give rise to different effects. Describe the pair production. (b) The pair process in lead has a cross section of 12.4 x 10^{-28} m^2/atom at 10 MeV. Use the Table to find the energy converted into kinetic energy of charged particles when a beam containing 10^4 photons passes through a block of lead of thickness 1 cm. Assume only pair interactions.

Z=82 $\rho = 11360\ kg/m^3$ $2.383\times10^{26}\ elect./kg$ $2.907\times10^{24}\ atom/kg$								A=207.20	
Photon Energy	Basic Coefficients in $(10^{-24}\frac{cm^2}{atom})$ or $(10^{-28}\frac{m^2}{atom})$				Interaction coeffi. in $(\frac{cm^2}{g})$ $[To\ get\ (\frac{m^2}{kg})\ divide\ by\ 10]$			Av. Energy transferred or absorbed	
$h\nu$ MeV	σ_{coh} coh.	σ_{inc} incoh.	τ photo	κ pair	(μ/ρ)	(μ_{tr}/ρ)	(μ_{ab}/ρ)	$\bar{E}_{tr}$	$\bar{E}_{ab}$
10	.0093	4.193	.1681	12.40	.0488	.0412	.0313	8.45	6.42
15	.0042	3.103	.1075	15.66	.0549	.0491	.0342	13.4	9.37
20	.0023	2.491	.0783	18.48	.0612	.0564	.0366	18.5	12.0
30	.0010	1.814	.0501	22.23	.0700	.0665	.0378	28.5	16.2
40	.0006	1.441	.0365	24.56	.0757	.0728	.0371	38.5	19.6
50	.0004	1.203	.0285	26.54	.0807	.0783	.0363	48.5	22.5
60	.0003	1.037	.0233	27.77	.0838	.0817	.0348	58.5	24.9
80	.0001	.8176	.0170	29.83	.0891	.0875	.0324	78.6	29.1
100	.0001	.6786	.0133	31.53	.0937	.0923	.0304	98.6	32.4

6. (10%). Discuss the effect of following factors on radiotherapy: cell cycle, oxygen, DNA repair, fractionation.

7. (10%). (a) Draw a typical cyclotron which can produce beams of protons or neutrons for clinical use. Describe its working principle. (b) A particle of charge e, moving with velocity v at right angles to a magnetic field B, experiences a force F at right angles to both B and v. The force F is given by: F = B*e*v. The centrifugal force of the charged particle is given by $m*v^2/r$, where m is the mass and r is the radius of the moving orbit of the charged particle in a cyclotron. Using data from the Table, calculate the radius of the orbit of a 20 MeV electron moving in a magnetic field of 1.5 Tesla. Hint: rest mass electron = 9.1×10^{-31} kg, charge = 1.6×10^{-19} C.

Kinetic Energy	Electrons			Protons	
	Total Energy (MeV)	Velocity Relative to Velocity of Light	Mass Relative to Rest Mass	Velocity Relative to Velocity of Light	Mass Relative to Rest Mass
5 MeV	5.511	0.9957	10.79	0.1026	1.0053
20 MeV	20.511	0.999689	40.16	0.2033	1.0213
50 MeV	50.511	0.999949	99.01	0.3141	1.0533

8. (10%). (a) Explain the effect of annihilation of a positron and describe the working principle of a PET (positron emission tomography). (b) Describe the working principle of a SPECT (single photon emission computed tomography). (c) Specify two advantages of PET over SPECT. Explain your answers shortly.

9. (10%). (a) Explain the half-life (t_h) of a radioactive source. (b) A source of Tc-99m arrives in the department at 10 AM on Monday, at which time the daughter is separated. The parent is found to have an activity of 5.0×10^9 Bq. Determine the activity of the parent after 3 days and determine the amount of daughter that may be eluted. Hint: t_h of Mo-99: 66.70 hrs; t_h of Tc-99m: 6.03 hrs.

10. (10%). (a) Plot a modern diagnostic X-ray tube. Include the parts of rotating anode and cathode in your plot. Specify the function of each part. (b) Explain "space charge" in a typical X-ray tube. Describe the impact of space charge effect while producing X-ray beams.