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NATIONAL UNIVERSITY OF IRELAND
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SUMMER EXAMINATIONS 1999

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B.Sc. (Honours) in Applied Physics & Electronics: Paper 3

EP416: Radiation, Environment & Medical

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Time Allowed: TWO hours	Answer THREE questions

Q.1 Answer 3 of the following parts:

(a) Describe, using diagrams, limited angle and transaxial SPECT (Single photon emission computerised tomography) as used in nuclear medicine.

(b) Write a short essay on our radiation (ionising) environment.

(c) Describe a gamma-ray sterilization plant.

(d) Calculate the dose rate at a distance of 4 m from a small 5 Ci (1.85×10^5 MBq) unshielded source of Cobalt-60. If a member of the public occupies this location for a full working year calculate the thickness of shielding (Pb) required.
(For ^{60}Co: $\Gamma = 34 \times 10^{-8}$ Sv m^2/ MBq hr, Half value layer in Pb = 11 mm, Tenth value layer in Pb = 40 mm).

Q.2 Answer (a) and (b)

(a) Derive the equation for the instantaneous dose rate [Gys^{-1}] to an organ, containing a gamma ray emitting radioactive substance, in terms of the relevant parameters. From this derive the equation for the accumulated dose [Gy] received after a time t from a radiosotope which is being removed exponentially with an effective half-life of T_e and an initial activity of q_0. Also derive the equation for the total dose received when the time goes to infinity.

(b) Define the following terms in respect to gaseous and particulate substances: threshold limit value, isokinetic sampling, respirable fraction, class 100 clean room, PM_{10}.

Air is sampled for 5 minutes at a flow rate of 10 *l*/minute, using a 47 mm diameter filter (of active diameter = 41 mm).

A total of 441 particles are counted using 5 optical microscope fields of view, each 0.3 mm in diameter. What is the aerosol particle number concentration ?

Q.3 This question relates to angiography, the radiographic imaging of the vascular anatomy. Angiography is to take place of the human thigh. The leg is 30 cm in diameter and contains within it a femoral bone with a diameter of 5 cm. Immediately behind the femur is located the femoral artery, which can be presumed to have a diameter of 1 cm. (See figure 2).

(a) Calculate the contrast of the blood vessel with its surroundings. Assume that the X-ray tube uses a tungsten anode and is operated at a peak Kilovoltage (kVp) of 80. You may assume that the attenuation of blood is 5% larger than that of muscle tissue. Do you think that the blood vessel is visible ?

(b) The radiologist now decides to use a contrast medium containing iodine. Assume that the blood vessel is filled with a concentration of iodine and blood in the ratio 1 : 100, calculate the contrast of the blood vessel now. Do you think that the vessel will be visible now ?

(c) Using a Digital Subtraction computer, the radiologist now subtracts the image obtained in 1(a) from the image obtained in 1(b). What is the theoretical contrast now ? To illustrate your answers, sketch a profile of intensity values in the image receptor plane in 2(a), 2(b), and 2(c).

(d) What would, in clinical practice, be the limitations on the contrast that is achievable by a blood vessel in Digital Subtraction Angiography.

In order to answer these questions you will need to make some reasonable assumptions about the values of the relevant parameters. For example, the linear attenuation coefficients of bone, soft tissue and iodine can be found from Figure 1. Clearly state any other assumptions you make in your answers.

Q.4 Explain what are meant by the following: aerosol particle, terminal fall velocity, slip correction factor, aerodynamic particle diameter and geometric standard deviation.

Measurements of aerosol particle size are given in Table 1 below. Determine the geometric mean radius, r_g, the geometric standard deviation σ_g and the total particle number concentration, N, from the data.

(Handouts: - logarithmic probability paper
2 x 2 cycle logarithmic graph paper)

Table 1

Particle Radius Interval (μm)	dN (cm^{-3})
0.1 - 0.13	10.5
0.13 - 0.16	16.6
0.16 - 0.2	30.5
0.2 - 0.25	47
0.25 - 0.35	101
0.35 - 0.50	137
0.5 - 0.7	130
0.7 - 1.0	107
1 - 1.5	75
1.5 - 2.0	23
2.0 - 2.4	7.3

Q.5 Explain the following terms: mechanical mobility, relaxation time, step distance, Stokes number, collision efficiency. Convert 1 ppb of SO_2, at 20 °C and 750 mm Hg, to $\mu g\ m^{-3}$. (molecular mass of SO_2 = 64 g/mole).

Convert 56 $\mu g\ m^{-3}$ of 0_3 to ppb at standard temperature and pressure. (molecular mass of 0_3 = 48 g/mole)

$R = 8.314\ J\ mole^{-1}\ K^{-1}$
Standard atmospheric pressure = $1.0125 \times 10^5\ Nm^{-2}$.