The Royal Australian and New Zealand College of Radiologists®

AIT
(Applied Imaging Technology)
Paper 1

Tuesday, 11 September 2018

Please write your answers in the books provided, starting each question on a new page.

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Case 1

Section 1 (Radiation Biology and Safety)

Question 1

(a) Ionising radiation exposure may be expressed as absorbed dose, equivalent dose or effective dose.
Define each of these quantities and give the units in which they are measured.
(3 marks)

(b) Ionising radiation can cause harmful effects to persons irradiated.
Describe 2 possible effects for medical irradiation with low doses (<100 mSv) and 2 possible effects with high doses and dose rates (>2 Sv). **(4 marks)**

(c) A patient has received a considerable dose of ionising radiation over the course of many years as a result of multiple CT scans. Their GP believes that they should receive another CT scan, but is concerned about the previous dose received.
What would your advice be concerning the advisability of further CT scans?
How would this advice differ if the patient had no previous ionising radiation exposure?
(3 marks)

Question 2

(a) All people are subject to background radiation, which can be thought to consist of natural background radiation and artificial or man-made radiation components.
What are the approximate radiation levels for natural and man-made radiation in Australia or any other country you wish to identify?
Name the source of a major component for each type of background radiation. **(4 marks)**

(b) Radiation has been described as a mild carcinogen. Further, the effect of radiation on different organs of the body does not show a uniform response.
Identify the major study which has contributed most to our knowledge of the effects of radiation on cancer. Name four of the most sensitive organs to radiation. **(3 marks)**

(c) In the context of biological effects of radiation discuss:

i. Somatic versus hereditary effect (1 mark)
ii. Latency period (1 mark)
iii. Linear energy transfer. (1 mark)

Question 3

(a) Name and define with units two commonly used dose indicators for a CT examination that are also used as the basis for optimization of CT protocols. **(4 marks)**

(b) Explain the principle of optimisation in radiation safety for medical exposure and define how national DRLs can be used to achieve optimisation for CT examinations. **(4 marks)**

(c) Kerma area product (KAP also known as DAP) is a commonly used dose indicator for both x-ray examinations and fluoroscopy procedures. Define this quantity and discuss why it can be an appropriate dose indicator for optimisation purposes. **(2 marks)**

Case 2

Section 2 (Basic Physics & Technology including Mammography, Fluoroscopy & DSA)

Question 1

(a) Identify and describe the two most common atomic interactions that occur when diagnostic x-rays (assume 50 to 120kV range) pass through human tissue **(4 marks)**

(b) Identify the key factors that will influence the probability of each of these interaction processes. **(2 marks)**

(c) Briefly explain the rationale for choosing low kilovoltage (e.g. 50kV) for a hand X-ray. Your answer should consider image quality and patient radiation dose implications. **(2 marks)**

(d) Identify and briefly describe two (2) applications of the photoelectric k-edge in optimising the x-ray image production process. **(2 marks)**

Question 2

(a) Define the terms spatial resolution and image contrast and explain how they apply to clinical radiographic images. **(4 marks)**

(b) Explain why contrast-to-noise ratio is a more relevant metric than contrast alone in the context of adjusting the appearance of digital images on a PACS monitor. **(2 marks)**

(c) Identify and briefly describe the impact of 3 factors having a substantial effect on spatial resolution in projection radiographic imaging. **(4 marks)**

Question 3

A patient is undergoing an interventional Posterior Anterior (PA) investigation using a fluoroscopic system with a flat panel detector. The exam is undertaken utilising automatic brightness control, and (initially) a square image receptor field-of-view of 30 cm x 30 cm.

(a) Explain with reasons, any changes to the patient skin entrance dose rate and image quality if the image is magnified by selecting an image receptor square field-of-view of 15 cm x 15 cm. Note that accurate quantification of the changes are not required. **(4 marks)**

(b) What is the impact on skin dose and image quality if collimators are manually adjusted to reduce the irradiated area while maintaining a detector field-of-view of 30 cm x 30 cm? **(2 marks)**

(c) Explain with reasons, any changes to the patient skin entrance dose rate and image quality if the gantry orientation is adjusted to an angle of 45 degrees. **(4 marks)**

Case 3

Section 3 (CT, MRI, US & Nuclear Medicine)

Question 1

(a) For a modern CT scanner, describe the impact of the following actions on the signal to noise ratio in the images and the effective dose to the patient.

You should also give brief reasons to justify your answers since half the marks for the questions will be given for correct reasons.

(Assume that the parameters modified are the only ones changed and assume any form of automatic current modulation is NOT employed.)

(i) Increasing the mAs per tube rotation. **(3 marks)**
(ii) Increasing the slice width. **(3 marks)**
(iii) Using iterative reconstruction instead of filtered back projection to reconstruct the collected data. **(3 marks)**

(b) What is the effect of decreased signal to noise ratio on contrast detectability? **(1 mark)**

Question 2

The attached diagram is a simplified version of an MRI spin-echo pulse sequence.
Questions (a) to (e) refer to this diagram.

(a) What occurs at t3 as a direct result of the 180° RF pulse? **(1 mark)**

(b) What is the purpose of the gradient field acting along the y-axis, and how does it achieve this purpose? **(3 marks)**

(c) Describe how the RF pulse at time 0 could differ for a fast sequence incorporating reduced repetition times (i.e. a reduced T_R). **(1 mark)**

(d) In terms of the echo time T_E and the repetition time T_R, what would be required to make T_1 relaxation time dominate contrast in the resultant image? **(2 marks)**

(e) In terms of the echo time T_E and the repetition time T_R, what would be required to make T_2 relaxation time dominate contrast in the resultant image? **(2 marks)**

(f) List two biohazards associated with an MRI machine (just the machine itself; do not include contrast-related effects) **(1 mark)**

Question 3

(a) Diagnostic ultrasound images are all created using a pulse-echo mode. Describe the key principles of pulse-echo mode, covering the means by which a line in an ultrasound image is formed.
Your answer should include how depth and brightness are determined. **(3 marks)**

(b) To form a real-time ultrasound image a number of assumptions about how sound travels though and interacts with tissues are required. Name FOUR of these assumptions. **(2 marks)**

(c) What can occur in the image if one or more of the assumptions made about how the sound travels and interacts in tissue are not true. **(1 mark)**

(d) Ultrasound has the potential to cause damaging biological effects via 2 primary mechanisms.

i. Name the 2 mechanisms **(1 mark)**
ii. For each briefly describe how damage can could potentially occur **(2 marks)**
iii. Modern diagnostic ultrasound equipment provides on screen feedback to the operator in the form of a numerical parameter to quantify each mechanism. Name each of these parameters. **(1 mark)**

Question 4

Suppose Nuclear Medicine perfusion lung scans at your practice are routinely acquired using SPECT imaging on a dual detector gamma camera using 99mTc-MAA as the radiopharmaceutical with an activity for an average size patient in keeping with published DRLs for this procedure.

(a) Describe how SPECT images are produced for such a study using this type of camera. The description should include any important technical aspects of the acquisition phase.

Note: DO NOT describe the operation or image formation processes of a gamma camera detector, e.g. the function of the collimator or PMT tubes in the camera head.
(5 marks)

(b) A colleague suggests doubling the activity administered to patients undergoing this scan.

(i) If the image acquisition parameters are unchanged, state how the image quality of the study would be affected and give reasons justifying your answer. **(2 marks)**
(ii) Quantify any changes, from a radiation dose perspective, in the risk to the patient. **(1 mark)**

(c) The 99mTc radioisotope used in this procedure is widely used in nuclear medicine radiopharmaceuticals. List 4 physical or chemical properties of this radioisotope that make it so useful in nuclear medicine imaging. **(2 Marks)**