SEMESTER 2 EXAMINATION 2013-2014

MEDICAL PHYSICS

Duration: 120 MINS (2 hours)

This paper contains 10 questions.

Answer **all** questions in **Section A** and **only two** questions in **Section B**.

Section A carries 1/3 of the total marks for the exam paper and you should aim to spend about 40 mins on it.

Section B carries 2/3 of the total marks for the exam paper and you should aim to spend about 80 mins on it.

An outline marking scheme is shown in brackets to the right of each question.

A Sheet of Physical Constants is provided with this examination paper.

Only university approved calculators may be used.

A foreign language translation dictionary (paper version) is permitted provided it contains no notes, additions or annotations.

Section A

A1. What are the main contributions to spatial resolution in a Positron Emission Tomography system? [3]

A2. Describe the three phases of cell damage which take place during irradiation. List three effects that enhance the radiation damage. [3]

A3. When protons are placed in a magnetic field, they precess. Explain why this occurs, and describe the resulting spin states of the protons and the significance of this in MRI. [3]

A4. Describe and quantify the main contributions to the average background radiation dose for the public in the UK. [3]

A5. Briefly explain how a linear array transducer is used to produce an ultrasonic B-scan image. [4]

A6. Give a brief outline of SPECT and its applications. [4]

Section B

B1. This question relates to spatial localisation methods in magnetic resonance imaging (MRI).

(a) Describe the three methods of spatial localisation in MRI. [7]

(b) Describe a basic gradient echo pulse sequence (include a pulse sequence diagram). [6]

(c) Describe the T2 relaxation mechanism (include equations and a graph) and explain why a gradient echo sequence is T2* weighted as opposed to T2 weighted. Describe the typical gradient echo pulse sequence parameters required to achieve this weighting. [7]

TURN OVER

B2. This question relates to assessment of image quality in medical physics

(a) Define the terms *image resolution*, *point spread function* and *spatial frequency content* in relation to a medical physics image. Explain how they are related to each other. [6]

(b) Explain the meaning of *contrast* in an image. Write down two expressions that may be useful to describe the contrast in an image, and explain the circumstances in which each may be more relevant. [6]

(c) Sketch labelled plots showing the linearity and dynamic range for:

(i) an ideal imaging system; [1]

(ii) a realistic digital imaging system; [2]

(iii) a realistic film-based imaging system. [2]

(d) Describe three important contributions to the noise in a medical physics image. [3]

B3. This question relates to the *Anger* camera, its design and operation.

(a) Describe the design and principles of operation of the Anger gamma camera used in nuclear medicine. You should include a detailed, labelled, schematic diagram of the camera. [6]

(b) Describe the reconstruction of photon arrival position and energy in analog and digital Anger cameras. [4]

(c) Explain the use of a linearity map for improving the image from an Anger camera. [2]

(d) What are the technical and clinical advantages of gamma cameras based on CZT technology compared to the more traditional Anger design? [4]

(e) Derive an expression, defining all terms, for the final image resolution for a gamma camera image of an object placed a distance z away from the camera collimator. [4]

TURN OVER

B4. This question relates to the use of high energy radiations for radiotherapy use:

(a) Explain how high energy photons interact with tissue, up to and including the processes that finally deposit energy into the tissue. [5]

(b) Plot curves showing how the dose changes as a function of depth for 100keV and 20 MeV X-ray beams incident on the skin. Explain the features, and use this to define the terms *build-up effect*, *kerma* and *electronic equilibrium*. [7]

(c) If the range of a 15MeV electron is such that a thickness of 3.0 g.cm^{-2} of tissue is needed to establish electronic equilibrium, estimate the peak dose depth for a 15MeV X-ray radiotherapy treatment. [2]

(d) Explain how a proton beam can be used to deliver dose to tissue at a specific depth. Include in your answer a discussion of how the energy loss of a proton changes with distance travelled. Describe some clinical benefits and appropriate uses of proton therapy. [6]

END OF PAPER