The University Of Sheffield.

DEPARTMENT OF MEDICAL PHYSICS AND CLINICAL ENGINEERING

Autumn 2006-2007

PHYSICS IN MEDICINE 1 **2 HOURS**

The paper is divided into two sections: A and B.

The student should answer all questions in section A. One sentence answers are sufficient for all questions in this section.

The student should answer two questions from section B.

TURN OVER

SECTION A

(Answer all questions in this section: 2 marks each)

1. What is the approximate speed of X-rays in tissue?

2. If an atomic mass unit is 1.7×10^{-27} kg, calculate the approximate mass of ^{14}C (atomic number 6) in SI units.

3. Give an order of magnitude figure for the diameter of the Boron atom.

4. What is the approximate maximum atomic number consistent with a stable atom?

5. What magnitude of charge is associated with the neutrino?

6. Write down the equation that relates change of wavelength to scattering angle in a Compton interaction.

7. What do the letters TLD stand for in the context of ionising radiation dosimetry?

8. Which one of the following most closely represents the dose rate from a therapy LINAC?
   (a) 0.1 mGy/min,
   (b) 10 mGy/min,
   (c) 1000 mGy/min,
   (d) 100000 mGy/min.

9. What is the relationship between the linear attenuation coefficient and mass attenuation coefficient of a material?

10. What is the gamma energy most readily associated with the decay of ^{99m}Tc in nuclear medicine?

11. Write down the differential equation that relates activity of a source to time, and consequently describes radioactive decay.

12. What is the relationship between the Point Spread Function and the Modulation Transfer Function in imaging theory?

13. Consider the convolution kernel…
$$\begin{matrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{matrix}$$
Is this likely to be a blurring filter or a sharpening filter when convolved with an image?

14. A gamma camera collimator is typically a honeycomb of lead. What is the name given to the dividing walls that separate the holes?

15. Which one of the following most closely represents the tube kV of a plane film X-ray unit used for diagnostic purposes?
   (a) 20 kV,
   (b) 80 kV,
   (c) 140 kV,
   (d) 200 kV.

CONTINUED

SECTION A - continued

16. What is the name given to the intensities that populate the image matrix of a CT image?

17. Give examples of two artefacts that might be seen in a CT image.

18. What does the acronym DEXA stand for in the context of bone density measurement?

19. The clinical expert responsible for making a diagnosis from an X-ray image is called:

    (a) Radiographer,
    (b) Radiologist,
    (c) Manager,
    (d) Technologist.

20. Give an example of a parameter that is assessed when performing quality assurance checks on a diagnostic X-ray system.

SECTION B

B1.

The PET scanner relies on a positron emitter such as ^{18}F. Describe the nuclear decay and subsequent processes responsible for providing the 511 keV photons by which the PET scanner operates. [8]

What do the initials PET stand for? [2]

A scintillation counter may be used to detect gamma photons. This device uses a photomultiplier tube coupled to a crystal, and additional components are introduced to create an instrument that can characterise the activity of a source. Draw a block diagram to create such an instrument using the following components:

- Pulse Height Analyser,
- Photomultiplier tube,
- Amplifier/pulse shaper,
- Crystal,
- Counter. [5]

What is the role of the pulse height analyser? [3]

The primary use of this technology in nuclear medicine is to image patients injected with ^{99m}Tc. The primary diagnostic gamma photon emitted from this isotope is associated with internal conversion processes and the production of auger electrons. Describe the production of internal conversion and auger electrons. [10]

Which one of the following most closely describes the percentage of gamma rays that will be absorbed by the scintillation crystal found on a gamma camera?

(a) 100%,
(b) 50%,
(c) 25%,
(d) 12%. [2]

B2.

With the aid of a diagram, sketch the essential components of a high energy therapeutic linear accelerator. [6]

Describe (and justify) the spectrum that results from the X-ray generation process. [12]

Older therapeutic units used a high activity radioactive source instead of a LINAC. What is the name of the source that was typically used? [2]

Measurement of an ionising photon beam typically uses an ionisation chamber. Describe how the Geiger-Muller tube can be configured as an ionisation chamber and outline the principles by which it works. [10]

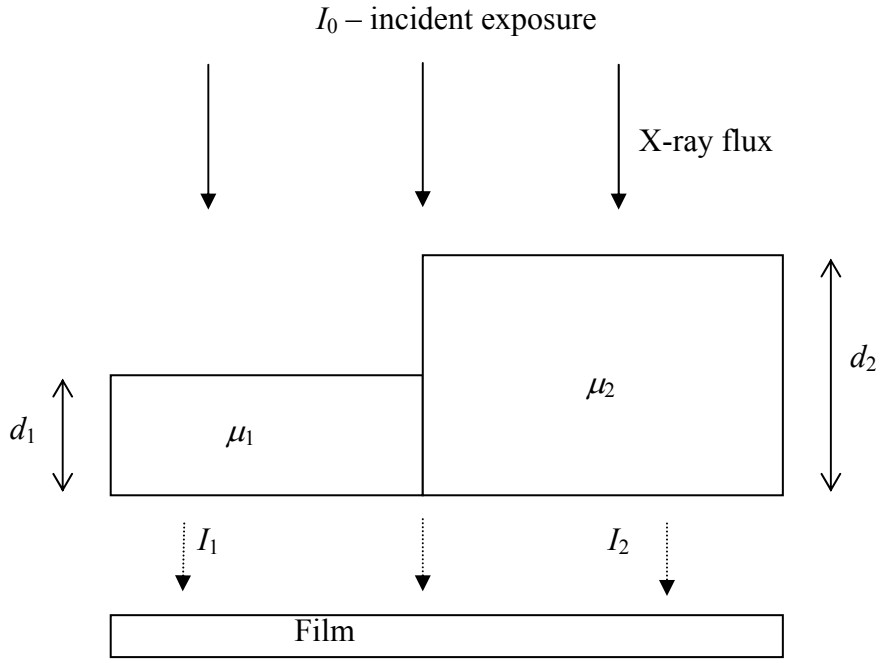
B3.

Diagnostic X-ray generation makes use of voltage transformation and rectification. With the aid of diagrams, explain one of these elements, and describe its purpose in respect of the X-ray tube. [7]

Diagnostic X-ray images are captured on a film that may be contained within a 'screened' X-ray cassette. With the aid of a diagram discuss the principles behind the screened cassette. [10]

Differential absorption in the patient is responsible for contrast on the X-ray film and can be considered to be governed by exponential photon absorption. Given that the Hurter and Driffield curve indicates that optical density is proportional to log (relative exposure), derive the relationship between contrast (C), linear attenuation coefficient (μ) and tissue thickness (d) to show that

$$C \propto \mu_2 d_2 - \mu_1 d_1$$



[13]

END OF QUESTION PAPER