The University Of Sheffield.

Data Provided:

DEPARTMENT OF PHYSICS & ASTRONOMY

Spring Semester 2005-2006

IMAGE FORMATION **2 hours**

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

The student should answers ALL QUESTIONS in Section A.

The student should answer TWO questions from Section B.

SECTION A (answer all questions in this section: 2 marks each)

A1 Write out the two dimensional convolution equations as applied to an imaging system with definitions of the usual meaning of the functions involved.

A2 The Fourier transform of a function $f(x,y)$ is normally given as a complex transform. Give the expansion of the real valued function $f(x,y)$ in terms of real valued functions.

A3 If $g(x,y)$ is the result of the convolution of $f(x,y)$ and $h(x,y)$, give the relationship between their Fourier transforms. Derive two separate expressions for the real and imaginary parts of the Fourier transform of $g(x,y)$ in terms of the Fourier transforms of the other functions.

A4 Write down the Fourier transform of the Gaussian function $\frac{1}{2\pi d^2}\exp\left(-\frac{x^2+y^2}{2d^2}\right)$.

A5 An object $f(x,y)$ is related to its projections $p(s,\theta)$ through the Radon transform. Write out this transform and explain its physical meaning.

A6 What is the Central Slice Theorem?

A7 Show graphically how the linear attenuation coefficient for gamma and X-rays varies with energy?

A8 An imaging system has a resolution (FWHM) of 2 mm and an image size of 400 mm $\times$ 400 mm. If the image is to be digitised, approximately how many pixels in total would be needed to avoid significant loss of information due to sampling?

A9 Give a formula for the energy of the scattered gamma ray in a Compton scattering event as a function of the energy of the incident gamma ray and the angle of scatter.

A10 State two properties of an ideal radioisotope for medical imaging.

A11 What is the most commonly used scintillator material for single photon radionuclide imaging? What fraction of 140 keV gamma rays entering a 1 cm thick crystal of this material will be absorbed?

A12 Give two reasons why ^{14}C is unsuitable for radionuclide imaging.

A13 Give two significant ways in which Positron Emission Tomography differs from Single Photon Emission Tomography.

A14 What is a random coincidence in Positron Emission Tomography? How may the random coincidence rate be estimated independently of the true coincidence rate?

A15 What is the cause of 'dead time' in a gamma camera? Give the formula relating the dead time parameter τ to the true count rate C_T and the observed count rate C_O.

A16 Define the gyromagnetic ratio.

A17 What field strength is currently commonly used in Magnetic Resonance Imaging and what is the resonant frequency for protons associated with this field strength?

A18 What material is commonly used to make the main field magnetic-coil windings on a magnetic-resonance imaging system?

A19 Would you expect the T_1 value of fat to be higher or lower than that of water?

A20 A slice for magnetic-resonance imaging is selected using a magnetic-field gradient. How is the slice thickness related to this field gradient?

SECTION B (Answer two questions from this section: 30 marks each)

B1 (a) An X-ray Computed Tomography system uses a translate-rotate data collection strategy. Describe how an image of the distribution of the linear attenuation coefficient within a slice can be derived from projections of X-ray attenuation through the slice. A formal mathematical proof of the reconstruction method used is not required, but a clear description is. [25]

(b) A CT scanner has to be able to form an image within a 50 cm diameter image area. The spatial sampling along each profile is 0.5 mm. What angular resolution (the angle between projections) is required to match this sampling distance at the boundary of the image area? [5]

B2 (a) Describe how a gamma camera forms an image of the distribution of a radiotracer within a patient. [20]

(b) A parallel hole collimator has holes of circular cross section. Derive a formula for the plane sensitivity of the collimator per unit area in terms of the dimensions of the holes. Assume the septa are of negligible thickness and the holes are packed in an hexagonal array. [10]

B3 (a) A sample of material containing protons is placed in a uniform magnetic field. Describe the processes by which a free induction decay (FID) signal can be obtained from this sample. [15]

(b) The magnitude of the FID from a sample as a function of time (the decay of the signal) is controlled by two decay constants, T_1 and T_2. Describe what these decay constants represent and the processes by which they arise. [10]

(c) T_2 cannot normally be measured directly. Why is this and what method can be used to measure it? [5]

END OF QUESTION PAPER