

Nuclear diagnostics and Magnetic Resonance Imaging

Aims, objectives, recommended books, and course structure

Aims

With the course I aim to:

- Provide students with a general overview of the physical principles that underlie nuclear diagnostics (ND) and magnetic resonance imaging (MRI);
- Allow students to appreciate the factors that influence the development of contrast in ND and MRI; and
- Give students the means to estimate the resolution, speed, and sensitivity of ND and MRI imaging modalities.

Objectives

At the end of the course students will be able to:

- Explain the principal methods used for the production of radionuclides;
- Explain and apply the definitions of activity, half-life and decay constant;
- Calculate the energies of the particles involved in radioactive decay in a given situation;
- Explain the principal radioactive decay pathways and the application of the radiation produced to medical imaging;
- Explain how a gamma camera operates and discuss the main parameters that affect its performance;
- Calculate the resolution and efficiency of a gamma camera in a particular situation; and
- Explain the different types of event that can be recorded by using a gamma camera and discuss how these affect the image.

Objectives 2: SPECT and PET

At the end of the course students will be able to:

- Explain how Single Photon Emission Computed Tomography (SPECT) is performed;
- Explain the methods typically used in the reconstruction of a SPECT images;
- Explain how a Positron Emission Tomography (PET) image is produced and discuss the principal limitations of PET;
- Discuss the different types of detection events recorded by a PET system and how they affect the image;
- Calculate the resolution, detection efficiency, detection rate, and coincidence rate for a particular PET scanner;
- Explain how to compensate for attenuation and unwanted random and scatter events in PET; and
- Describe and discuss the main differences between 2D and 3D PET image acquisition.

Objectives 3: Magnetic resonance imaging

At the end of the course students will be able to:

- Describe the principles of nuclear magnetic resonance (NMR);
 - Discuss how relaxation mechanisms contribute to the generation of contrast in magnetic resonance imaging (MRI);
 - Describe techniques for spatial localisation of the NMR signals in MRI;
 - Distinguish between phase and frequency encoding is used in MRI to enable the spatial localisation of the NMR signal;
 - Use the Fourier-transform technique to exploit ‘k-space’ to describe MRI images in this space;
 - Connect the receiver bandwidth, acquisition time, and sampling frequency to the field of view and resolution;
 - Identify the causes of the most common image artefacts;
 - Show how the signal-to-noise ratio (SNR) is affected by the choice of data acquisition parameters;
 - Recall the major hardware components necessary for MRI;
 - Recall, devise, and interpret typical MRI pulse sequences and discuss the changes in image contrast induced by changes in the pulse sequences; and
 - Calculate the optimal ‘TR’ and ‘TE’ to maximise image contrast for ‘proton density’, ‘T1’, and ‘T2’ weighted imaging.
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Recommended books

Physics in Nuclear Medicine

S. Cherry, J.A. Sorenson, M.E. Phelps

Central Library: 616.075 CHE

The Essential Physics of Medical Imaging

J. Bushberg, J. Seibert, E. Leidholdt, J. Boone

Central Library: 616.075 BUS

MRI: the basics

R. Hasegami, W. Bradley, C. Lisanti

Central Library: 616.075 HAS

Structure

Taught material and discussion

The course material is broken down into:

- “Weeks”; each week will contain roughly 2 “blocks”
- “Blocks”; each block is broken down into a number of “segments”. The material presented in a “block” will correspond to that contained in a single 50-minute lecture.
- “Segments”; each segment will usually contain the material related to a particular (sub-)topic
 - Each segment will be presented as a set of slides and a Panopto presentation. Active-learning exercises will be interspersed with the segments.

Overview of schedule in weeks and blocks

Week	Block	Topic
1	1	Introduction, radiopharmaceuticals, & revision of theory of nuclear decay
	2	Radionuclides for nuclear medicine
2	1	The gamma camera
	2	Single photon emission computed tomography; SPECT
3	1	Positron-emission tomography 1
	2	Positron-emission tomography 2
		Problem sheet 1
4	1	Magnetic Resonance Imaging (MRI): introduction
	2	MRI: manipulation of magnetisation
5	1	MRI: determination of T_1 and T_2
	2	MRI: spatial localisation
6	1	MRI: contrast
	2	MRI: artefacts 1
		Problem sheet 2
7	1	MRI: artefacts 2
