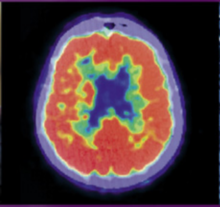
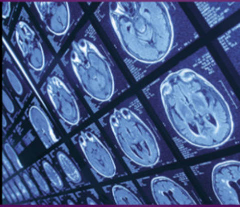
Get Through

First FRCR: MCQs for the Physics Module

Grant Mair • Andrew Baird • Andrew Nisbet

Consulting Editor: Jerry Williams

The Royal Society of Medicine Press Limited

Get Through

First FRCR: MCQs for the Physics Module

Grant Mair BSc (Hons) MB ChB MRCS
Andrew Baird MB ChB MRCS
Andrew Nisbet MB BCh
All Specialty Trainees in Radiology, South East Scotland Programme, The Royal Infirmary of Edinburgh, UK

Consulting Editor

Jerry Williams BA MSc FIPEM
Consultant Medical Physicist, RPA and Head of Radiology Physics Training Programme for South East Scotland, The Royal Infirmary of Edinburgh, UK

The ROYAL
SOCIETY of
MEDICINE
PRESS Limited

Published by the Royal Society of Medicine Press Ltd
1 Wimpole Street, London W1G 0AE, UK
Tel: +44 (0)20 7290 2921
Fax: +44 (0)20 7290 2929
Email: publishing@rsm.ac.uk
Website: www.rsmpress.co.uk

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN 978-1-85315-951-0

Distribution in Europe and Rest of World:
Marston Book Services Ltd
PO Box 269
Abingdon
Oxon OX14 4YN, UK
Tel: +44 (0)1235 465500
Fax: +44 (0)1235 465555
Email: direct.order@marston.co.uk

Distribution in the USA and Canada:
Royal Society of Medicine Press Ltd
c/o BookMasters Inc
30 Amberwood Parkway
Ashland, OH 44805, USA
Tel: +1 800 247 6553/+1 800 266 5564
Fax: +1 419 281 6883
Email: order@bookmasters.com

Distribution in Australia and New Zealand:
Elsevier Australia
30–52 Smidmore Street
Marrickville, NSW 2204, Australia
Tel: +61 2 9517 8999
Fax: +61 2 9517 2249
Email: service@elsevier.com.au

Typeset by Techset Composition Limited, Salisbury, UK
Printed and bound in Great Britain by Bell & Bain, Glasgow

Contents

Preface v
Recommended Reading vii
Abbreviations ix

1. Basic Physics: Questions 1
   Answers 4
2. Radiation Hazards and Protection: Questions 9
   Answers 16
3. Imaging with X-rays: Questions 27
   Answers 33
4. Digital Radiography: Questions 43
   Answers 45
5. Fluoroscopy: Questions 49
   Answers 52
6. Computed Tomography: Questions 57
   Answers 62
7. Radionuclide Imaging: Questions 71
   Answers 78
8. Ultrasound: Questions 90
   Answers 97
9. Magnetic Resonance Imaging: Questions 110
   Answers 118
10. Mock Examination: Questions 133
   Answers 142

To our families

Preface

To keep pace with technological advances in the workplace and evolving legislation, and as a means of examining all radiological basic science in one sitting, the Royal College of Radiologists (RCR) recently expanded and updated the syllabus for the Part 1 FRCR Physics exam. From March 2009, Part 1 candidates are now examined in all areas of medical physics relevant to radiology. Most notably, the syllabus once again includes ultrasound and magnetic resonance imaging (MRI). In addition, the new exam reflects the continued uptake of digital imaging systems in many departments around the world. From March 2010, a second module in Radiological Anatomy will also be examined in parallel to the Physics module. This book deals only with the Physics module.

All information relating to the exam can be found on the RCR website. The current format is of 40 stems each with 5 subheadings, giving a total of 200 questions. Answers are either 'True' or 'False'; there is no penalty for an incorrect answer so all questions should be attempted. As a candidate you have 2 hours in which to complete the exam. Postgraduate exams can be daunting and while structuring your individual study preparation is a personal choice there is no doubt that answering practice MCQs in parallel with traditional revision techniques will enhance your likelihood of success.

The questions in this book are arranged in a similar format to the exam and we have carefully tried to cover the entire syllabus. Our questions are designed as aids to the revision process, with each question intended to supply a learning point and each chapter to highlight the areas of knowledge required. By working through each chapter we hope you will gain confidence in your knowledge of the key topics as well as identify areas that may require further study. Full answers are given to all the questions, and while they are not intended to be complete descriptions of a subject they should form the basis of further revision. Given the complexity of the subjects covered in this book we accept there will inevitably be some debate or disagreement over our answers. We hope this will stimulate discussion around the subject and may ultimately enhance understanding. To provide additional feedback, each group of questions is assigned a difficulty level, ranging from * (easiest) to ***** (most difficult).

The included mock exam should be attempted under exam conditions and is more representative of the level of difficulty likely to be encountered. Allow 2 hours for completion and score +1 for each correct answer and 0 for incorrect answers. The content of the mock exam is representative of our own experience; it should be noted, however, that the College may choose to examine candidates on any aspect of the curriculum.

The authors are all Specialty Registrars on the South East Scotland Radiology Training Scheme and have all contributed equally to the writing of this book. All were successful in passing the new FRCR Part 1 examination at their first sitting. Jerry Williams is the Head of the Radiology Physics Training Programme for South East Scotland. In addition he is the co-author of *Farr's Physics for Medical Imaging*. We are indebted to him for his guidance and help with the writing of this book. Special thanks also go to Nick Weir, a medical physicist based in Edinburgh, for his help with the MRI chapter.

Finally, we wish you the best of luck and every success in the exam!

Andrew Nisbet
Andrew Baird
Grant Mair

Reference

Allisy-Roberts PJ, Williams J. *Farr's Physics for Medical Imaging*, 2nd edn. Philadelphia: Elsevier, 2008.

Recommended Reading

Allisy-Roberts PJ, Williams J. *Farr's Physics for Medical Imaging*, 2nd edn. Philadelphia: Elsevier, 2007.

Campus Medica. *e-MRI, Magnetic Resonance Imaging physics and technique course on the web*. www.e-mri.org.

Hendee WR, Ritenour ER. *Medical Imaging Physics*, 4th edn. New York: Wiley-Liss, 2002.

Kalender W. *Computed Tomography: Fundamentals, System Technology, Image Quality, Application*, 2nd edn. Weinheim: Wiley-VCH, 2004.

McRobbie DW, Moore EA, Graves MJ, Prince MR. *MRI From Picture to Proton*, 2nd edn. Cambridge: Cambridge University Press, 2007.

Westbrook C, Roth CK, Talbot J. *MRI at a Glance*. Oxford: WileyBlackwell, 2002.

This page intentionally left blank

Abbreviations

2D	two-dimensional
3D	three-dimensional
AC	alternating current
ACOP	Approved Code of Practice
ALARP	as low as is reasonably practicable
AP	anteroposterior
ARSAC	Administration of Radioactive Substances Advisory Committee
BMUS	British Medical Ultrasound Society
Bq	becquerel
c	speed of light
Ca	calcium
CCD	charge coupled device
CR	computed radiography
CSF	cerebrospinal fluid
CsI	caesium iodide
CT	computed tomography
CTDI	Computed Tomography Dose Index
CT KUB	computed tomography kidneys, ureters and bladder
CXR	chest X-ray
DAP	dose area product
dB	decibels
DC	direct current
DDI	detector dose indicator
DICOM	Digital Imaging and COmmunications in Medicine
DLP	dose length product
DMSA	dimercaptosuccinic acid
DNA	deoxyribonucleic acid
DQE	detective quantum efficiency
DR	digital radiography
DRL	diagnostic reference level
DSA	digital subtraction angiography
E	energy
e^-	electron
ECG	electrocardiogram
eGFR	estimated glomerular filtration rate
EPI	echo-planar imaging
eV	electron volt (often prefixed with kilo, e.g. keV)
F	fluorine
f	frequency
FDG	fluorodeoxyglucose
FID	free induction decay
FLAIR	FLuid Attenuated Inversion Recovery
FOV	field of view
fps	frames per second
FRCR	Fellow of the Royal College of Radiologists
FSE	fast (turbo) spin echo
GB	gigabyte

GRE	gradient recalled echo
Gy	gray
h	Planck's constant
HSWA	Health and Safety at Work Act 1974
HVL	half-value layer
HSE	Health and Safety Executive
HU	Hounsfield unit
Hz	hertz
I	iodine
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ICRP	International Commission on Radiological Protection
IR(ME)R	Ionising Radiation (Medical Exposure) Regulations
IRR99	Ionising Radiations Regulations 1999
IVU	intravenous urography
J	joule
K_{α}	alpha characteristic radiation
K_{β}	beta characteristic radiation
keV	kiloelectron volt
kV	kilovolt
kVp	the peak kilovoltage of an X-ray tube
LET	linear energy transfer
LMP	last menstrual period
lp/mm	line pairs per millimetre
LSF	line spread function
m	mass
mA	milliamperes
MAG3	mercaptoacetyl triglycine
MARS	Medicines (Administration of Radioactive Substances) Regulations 1978
mAs	milliampere-seconds
MB	megabyte
MBq	megabecquerel
MeV	millielectron volt
MDCT	multidetector computed tomography
mGy	milligray
MHRA	Medicines and Healthcare products Regulatory Agency
MI	Mechanical Index
MIBI	2-methoxy isobutyl isonitrile
MinIP	minimum intensity projection
MIP	maximum intensity projection
Mo	molybdenum
MPR	multi-planar reconstruction
MR	magnetic resonance
MRI	magnetic resonance imaging
MTF	modulation transfer function
ms^{-1}	metres per second
mSv	millisievert
m_{xy}	magnetic vector in the x,y-axis

m_z	magnetic vector in the z-axis
N	neutron
NaI	sodium iodide
OD	optical density
OSL	optically stimulated luminescence
P	proton
PA	posteroanterior
PACS	Picture Archiving and Communications System
Pb	lead
PD	proton density
PET	positron emission tomography
PHA	pulse height analyser
PRF	pulse repetition frequency
PVDF	polyvinylidine difluoride
PZT	lead zirconate titanate
QA	quality assurance
RBE	relative biological effectiveness
RF	radiofrequency
Rh	rhodium
RPA	radiation protection advisor
RPS	radiation protection supervisor
RSA	Radioactive Substances Act 1993
SAR	specific absorption ratio
SE	spin echo
SI	Système International
SNR	signal to noise ratio
SPECT	single photon emission computed tomography
SMPTE	Society of Motion Picture and Television Engineers
STIR	short tau inversion recovery
Sv	sievert
T	tesla
Tc-99m	^{99}Technetium metastable
TE	time to echo
TGC	time gain compensation
TI	Thermal Index
TFT	thin film transistor
TLD	thermoluminescent dosimetry
TR	time to repeat
W	tungsten
Xe	xenon
Z	atomic number
z	acoustic impedance
μ	linear attenuation coefficient
β^+	positron

1. Basic Physics: Questions

1. **For atomic structure:**
   a. The atomic number is the number of protons plus electrons
   b. Electrons exist in shells of energy levels around the nucleus
   c. All electrons exist at the same energy level for a given element
   d. A nucleon is smaller than a nucleus
   e. The nucleus of an atom has a net positive charge

2. **Elements useful to radiology:**
   a. The atomic number of tungsten (W) is 82
   b. The K-edge of barium is approximately 37 keV
   c. The K-edge of calcium (Ca) is approximately 20 keV
   d. The gamma emission of ^{99}Technectium metastable (Tc-99m) is approximately 140 keV
   e. The atomic number of iodine is 53

3. **Regarding electromagnetic radiation:**
   a. Radio-waves are a form of electromagnetic radiation
   b. Radio-waves travel at $3 \times 8^{10}\ ms^{-1}$ in vacuo
   c. X-rays and gamma rays vary only in their origin
   d. Frequency and wavelength are directly proportional to one another
   e. Radio-waves travel in divergent straight lines

4. **In the production of X-rays:**
   a. Bremsstrahlung refers to the energy gained by electrons as they are accelerated towards the target
   b. Thermionic emission occurs in the target
   c. Bremsstrahlung radiation is formed at the cathode of an X-ray tube
   d. Characteristic radiation is formed at the anode of an X-ray tube
   e. Only about 50% of the energy of the bombarding electrons is emitted as useful X-ray radiation

5. **X-ray attenuation:**
   a. Is the process where photons are absorbed or scattered thus reducing the photons in the emerging beam
   b. In a monoenergetic beam, the half-value layer increases with depth due to hardening of the beam
   c. Monoenergetic beams are used in digital radiography
   d. The linear attenuation coefficient is inversely proportional to the half-value layer (HVL)
   e. The number of photons in the emerging beam reaches zero after five HVLs

6. **Attenuation of X-rays:**
   a. In clinical practice, the first and second HVLs are equal
   b. The mass attenuation coefficient of a material decreases with atomic number
   c. Elastic scatter greatly affects the images produced using X-rays
   d. The photoelectric effect leads to complete absorption of X-ray photon energy
   e. The photoelectric effect predominates when diagnostic X-rays meet contrast media such as barium

7. **Regarding an X-ray beam used in clinical practice:**
   a. If the characteristic radiation was removed from a beam the intensity of that beam would increase
   b. The intensity of a beam would diminish by 16 times if you moved from 1 m to 4 m from the source
   c. The inverse square law assumes no absorption or scattering in the medium
   d. The mean energy of the beam is approximately 50% of the operating tube kV
   e. It has a constant HVL

8. **Regarding the Compton effect:**
   a. The Compton effect describes scatter of photons by the tissue
   b. A photoelectron is ejected in a collision with a photon
   c. The free electrons described in Compton scatter are often bound within the valence shell of atoms
   d. The probability of the Compton effect is proportional to the atomic number (Z) cubed
   e. The mass attenuation coefficient for the Compton effect for bone is twice that of soft tissue

9. **Photoelectric effect:**
   a. The photoelectric effect occurs at a maximum when the incident photon energy is just less than the K-edge
   b. Characteristic radiation may be emitted after the photoelectric effect
   c. Most biological damage is caused directly by the ionization of the atom by X-ray photons
   d. At higher energies the photoelectric effect becomes a more common interaction
   e. The photoelectron has energy equal to the energy of the incident photon plus the binding energy of the electron

10. X-ray interactions with matter:

a. The photoelectric effect predominates in high kV techniques such as computed tomography (CT)
b. At 30 keV or less the Compton effect predominates
c. In diagnostic high kV techniques such as CT pair production becomes a significant effect
d. In Compton scatter the electron never travels in the backward direction
e. The probability of Compton scatter occurring is related to the electron density of the material

11. Regarding luminescence:

a. The outermost filled electron band in a luminescent material is known as the conduction band
b. The process of luminescence is possible only in substances which are manufactured entirely free from impurities
c. In radiographic detectors the intensity of light emitted from a phosphor is directly proportional to the intensity of energy absorbed from the X-rays or gamma rays
d. In computed radiography (CR) image processing, the exposed detector plate is heated in order to stimulate the release of light
e. In personal dosimetry systems, optical stimulated luminescent dosimeters allow a greater sensitivity of measurement compared with thermoluminescent detectors

12. Radiation:

a. Bremsstrahlung radiation can occur at any energy from just above 0 keV to the peak voltage potential in the X-ray tube
b. K_α radiation describes the emission of a particle of two protons and two neutrons
c. Characteristic radiation results in specific energy photons being emitted relating to the electron binding energies
d. Characteristic radiation from the L-shell of tungsten is used in high kV techniques
e. Beta radiation is commonly used in nuclear diagnostic imaging.

1. Basic Physics: Answers

1a. False **

Atomic number is the number in the periodic table, defined by the number of protons. Atomic mass number is the number of protons plus the number of neutrons.

1b. True

Electrons exist at different energy levels described as shells of decreasing energy.

1c. False

It will take the same amount of energy to dislodge a K-shell electron for different atoms of the same element, but the K-shell electrons and L-shell electrons within the same atom will have different energy levels.

1d. False

Examples of nucleons are protons and neutrons. A nucleus is all the protons plus neutrons of one atom. In hydrogen the single proton is the only nucleon, and thus the nucleon and the nucleus would be the same size.

1e. True

The nucleus comprises positive protons and neutral neutrons. Negative electrons exist outside the nucleus.

2a. False *

Lead (Pb) has an atomic number of 82. Tungsten (W) has an atomic number of 74.

2b. True

The K-edge of barium is high enough that the photoelectric effect predominates in barium screening.

2c. False

The K-edge of Ca is 4 keV. Common elements in the body have a low K-edge which is why the Compton effect predominates at the higher end of the diagnostic energy range.

2d. True

This is much higher than diagnostic X-ray energies.

2e. True

With a higher atomic number than soft tissue, the K-edge of iodine is also higher. The photoelectric effect therefore predominates at diagnostic X-ray energies; this makes it suitable as a contrast agent.

3a. True *

Radio-waves are the least energetic form of electromagnetic radiation.

3b. False

They travel at $3 \times 10^8\ ms^{-1}$ in vacuo.

3c. True

X-rays arise primarily through changes in electron energy state; gamma rays arise from radioactive decay.