Diagnostic Parts 2/3

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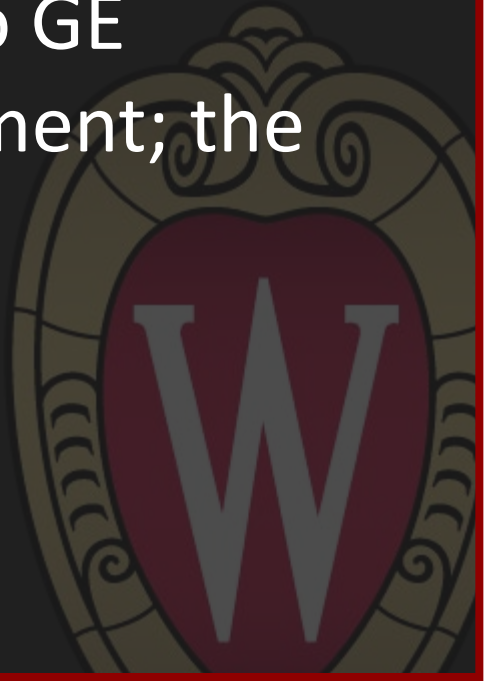
Disclosures

- TPS Equipment Grant and Consultant GE HealthCare; supplies CT protocols to GE HealthCare under a licensing agreement; the founder of protocolshare.org

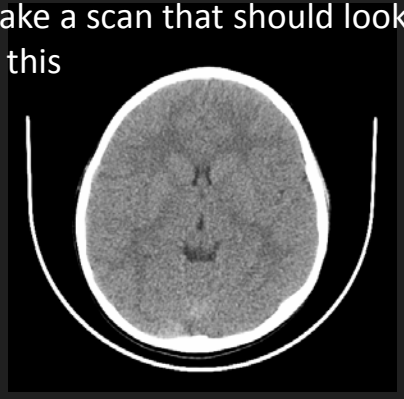


Reality Check

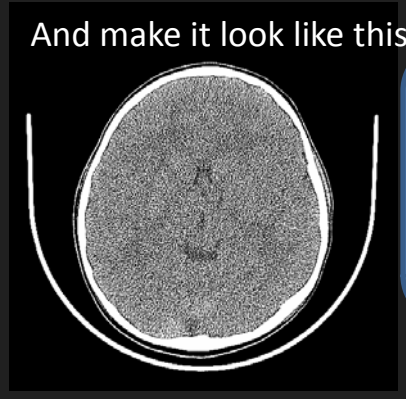
This talk is not just about passing a test, it is about the best way I know to become proficient in a field where we assist physicians in life altering decisions

- So you want a job as a medical physicist?
  - You are going to have to answer questions like
    - "We found out after this patient's CT exam the were pregnant, the patient is now frightened for their fetus and considering an abortion, can you calculate the dose the fetus received?"
    - "The peds scanner is down, we need a non con head CT protocol for a 5 y.o. boy scheduled at 2 pm on our main scanner, can you take the ped protocol and put it on the main scanner in time?"

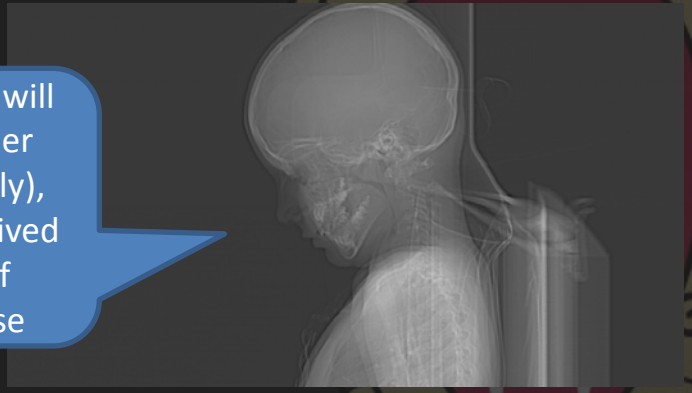
You don't want a math error to take a scan that should look like this



And make it look like this



Now this kid will need another scan (possibly), and just received a bunch of wasted dose



Eligibility

- Part 3
  - You have 6 years after "completion of training" to pass part 3, after that you are no longer consider "board eligible"
    - "completion of training" is the earlier date of either 1. graduating from a residency or obtaining part 2 approval
  - The only requirement other than the time window above for part 3 is that you have taken and passed all of part 2

Missing a deadline is serious and will delay your career, please read about this for yourself and contact the ABR if needed https://www.theabr.org/ic-rp-req

- Part 2
  - You must have passed the Medical Physics Part 1 examination (General and Clinical).
  - Experience requirement
    - If you applied for certification post July 1st 2013 You must have completed a CAMPEP-accredited residency by August 31 of the year in which the Part 2 exam is to be taken. (only if you applied for certification post July 1st 2013)
    - If you applied for certification prior to July 1st 2013, then you don't have to have a CAMPEP approved residency to take part 2, see https://www.theabr.org/ic-rp-req
  - Effective January 1, 2015, candidates who have passed the Part 1 examination will be allowed 10 years from the date they passed Part 1 to become board eligible a.k.a. reach "completion of training" status.

Formula for success Part 2

- Read “The Essential Physics of Medical Imaging” by Bushberg, Seibert, Leidholdt, and Boone
  - Memorize and understand EVERY equation shown in this book (you can skip the Nuc. Med. Chapters in memorization, but we need to understand that material to be competent professionals)
  - Understand every plot shown in this book (650 total images in the 3rd edition) (you can skip the Nuc. Med. Chapters in memorization, but we need to understand that material to be competent professionals)
  - Scan the text for definitions and memorize them (for example, the relationship between Mechanical index/peak rarefactional pressure/frequency is given in words, not a formula…but you should memorize it)

If you do this, I can guarantee you will pass*

*Not Really

Formula for success Part 3

- Get as much clinical experience in as many different settings with as many different people as you can
  - You need to see/use different equipment. While the questions are pretty vendor neutral, looking over a DICOM header or reviewing an image presentation you have seen before will make you much more comfortable. Or even just knowing how the cover styles on different scanners vendor/models look can be important for identifying a modality or making you feel comfortable.
  - You need to use different types of testing equipment. If you only use solid state detectors, you may not get what the examiner is talking about when they are discussing the “old school” method for HVL…
  - There may be procedures/indications/protocols a site simply never does, like stereotactic breast biopsy. Working in different settings is going to expose you to more.
- Read as many testing document instruction manuals as you can find.
  - You can BS your way for a bit if you have memorized the steps and understand why you need to do the tests you do on a specific modality… Reading these manuals and performing the tests is taking the step from part 2 to 3.

Best way to accomplish the above is to go to a residency

Part 3 Hands on must do's

- Conduct ACR tests for CT, MR, and Mammography
- Do a shielding report calculation for CT, a rad room, and a fluoro room
- Go over badge data and procedure dose data (CTDIvol, effective dose, skin dose, fetal dose, etc.) with an RSO or other QMP and discuss what the numbers mean and what relevant limits apply to radiation workers and the general public and when different negative effects kick in
- Familiarize your self with testing equipment (read product manuals and know what it looks like if shown a picture) for all phantoms/test objects/chambers
- At least get hands on experience with the items in the ABR's "ABR Standards of Clinical Training" https://www.theabr.org/sites/all/themes/abr-media/pdf/MP_Standards_of_Clinical_Training_for_Pt2.pdf

Diagnostic Medical Physics

Completion of:

- Mammography annual system evaluations
- Stereotactic breast biopsy system performance evaluation
- CT system performance evaluation
- MRI system performance evaluation
- General purpose radiography system performance evaluation
- Fluoroscopy system performance evaluation
- Interventional x-ray system performance evaluation
- Storage phosphor (e.g., computed radiography) or digital detector performance evaluation
- Ultrasound (US) system performance evaluation
- Shielding design for an interventional imaging system or CT scanner
- MR safety evaluation
- Evaluation of a diagnostic workstation
- Bone mineral analyzer evaluation

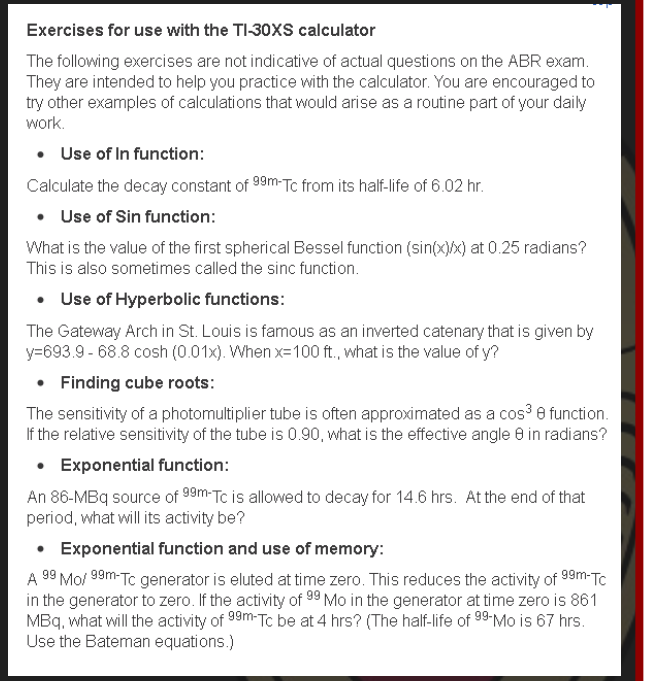
Example of why you need real world experience in many settings

The ABR has “point and click” questions now, in this example from their website you need to know the x-ray tube is inside the yellow box…if you are an “MR physicist” coming out of grad school this may be difficult ☺

Test Format Part 2

- Test administered at Pearson Vue Test Centers
  - (same place you took part 1)
- All done via computer interface
- 80 questions total (not sure if this is official ABR information, but the breakdown between simple/complex questions is 53/27)
- 5 hours given
- Expect a 30 minute “check in time”
  - Pearson will tell you how early to arrive
- A list of constants will be provided! So don’t study them… http://www.theabr.org/ic-rp-calc

Practice using the calculator so you don’t have to worry about it



Exercises for use with the TI-30XS calculator

The following exercises are not indicative of actual questions on the ABR exam. They are intended to help you practice with the calculator. You are encouraged to try other examples of calculations that would arise as a routine part of your daily work.

- **Use of ln function:**

Calculate the decay constant of ^{99m}Tc from its half-life of 6.02 hr.

- **Use of Sin function:**

What is the value of the first spherical Bessel function (sin(x)/x) at 0.25 radians? This is also sometimes called the sinc function.

- **Use of Hyperbolic functions:**

The Gateway Arch in St. Louis is famous as an inverted catenary that is given by y=693.9 - 68.8 cosh (0.01x). When x=100 ft., what is the value of y?

- **Finding cube roots:**

The sensitivity of a photomultiplier tube is often approximated as a $\cos^3 \theta$ function. If the relative sensitivity of the tube is 0.90, what is the effective angle θ in radians?

- **Exponential function:**

An 86-MBq source of ^{99m}Tc is allowed to decay for 14.6 hrs. At the end of that period, what will its activity be?

- **Exponential function and use of memory:**

A ^{99}Mo/ ^{99m}Tc generator is eluted at time zero. This reduces the activity of ^{99m}Tc in the generator to zero. If the activity of ^{99}Mo in the generator at time zero is 861 MBq, what will the activity of ^{99m}Tc be at 4 hrs? (The half-life of ^{99}Mo is 67 hrs. Use the Bateman equations.)

Test Format Part 3

- 5 examiners will separately and privately ask you questions, each for 30 minutes
- Each examiner will ask you 5 main questions
- Each of those main questions will be from one of the 5 categories outlined by the ABR (I list them later in the talk)
- Each question is broken down into small leading questions.
  - In general, they get more and more specific and deeper in understanding/fact recalling as they progress.
  - Not clear while taking the test what “sub question” you are really on. The examiner has a rubric we never get to see.
- You move around to different hotel rooms for the test. Each room has an examiner with a computer they use to show you images.
- You get scrap paper and a writing utensil.
- Exam is located in Louisville, Kentucky at the Crown Plaza Hotel (right next to an airport)

ABR supplied study information

- The ABR provides
  - Sample questions (simple and complex questions)
  - A list of topics for part 2
  - A detailed list of topics for part 3
    - This list is more detailed than the part 2 list and I suggest using it to study for part 2, which is really just prep for part 3
  - A MOC exam study guide
    - Includes a list of relevant AAPM TG reports, NCRP reports, ICRP reports, ACR references, Journal references, and some books

ABR supplied study information

- Simple questions (part 2)
  - Recall a fact
  - Recall a relationship
  - Perform a 1 step calculation
  - There are 5 new types of simple question now (this is new)

PART 2: Diagnostic Medical Physics

SIMPLE QUESTIONS

1. For a phototimed radiograph, an increase in which of the following factors will increase patient skin dose?

A. Milliampere
B. Kilovolt
C. Patient thickness
D. Focal spot size
E. Source-to-image distance

2. A region of interest (ROI) in a CT image has an intensity of -30 HU. What is the ratio of the linear attenuation coefficient for the ROI to that of water?

A. 0.70
B. 0.97
C. 1.00
D. 1.03
E. 1.30

3. As a potential contrast agent for ultrasound, which of the following materials is expected to be the strongest reflector for a fixed concentration of small (<5 nm) particles?

A. Encapsulated polymer
B. Encapsulated lipid
C. Encapsulated gas

4. In a spinecho MRI pulse sequence with TR = 2000 ms and TE = 100 ms, which anatomy feature has the highest signal intensity in a brain image?

A. Gray matter
B. White matter
C. Lens of the eye
D. Cerebrospinal fluid

ABR supplied study information

- Complex question (part 2)
  - Perform a >1 step calculation
  - Perform a calculation and apply some kind of fact
  - Some of these may involve many steps (there are shielding questions)

COMPLEX QUESTIONS

1. For the series of repeat measurements of the output of an x-ray tube and generator for an 80-kV beam, 10 mAs at 1 m, what is the coefficient of variation?

Measurement#	Output (mR)
1	71.3
2	70.9
3	72.2
4	71.8
5	71.5

A. 70
B. 7.0
C. 0.7
D. 0.07
E. 0.007

2. A 5-MHz ultrasound beam is incident on a blood vessel at an angle of 45 degrees. If the blood is moving toward the transducer, and the mean velocity is 30 cm/s, what is the mean frequency shift of the reflected beam?

A. 0.7 kHz
B. 1.4 kHz
C. 2.8 kHz
D. 5.6 kHz
E. 11.2 kHz

New question types

SAMPLE QUESTIONS

Simple Questions (includes new item types)

1. For a phototimed radiograph, an increase in which of the following factors will increase patient skin dose?

   A. Milliampere
   B. Kilovolt
   C. Patient thickness
   D. Focal spot size
   E. Source-to-image distance

2. A region of interest (ROI) in a CT … What is the ratio of the linear attenuation c… ?

   A. 0.70
   B. 0.97

Point-and-Click

1. Point and click on the x-ray tube.

Multiple Correct Options

The candidate must select all of the correct options for each item:

1. An electrophysiology procedure is being performed on an interventional fluoroscopy system with a digital receptor and automatic exposure rate control. Which two steps can be used to reduce the probability of a radiation-induced skin burn? (Please select two options.)

   A. Positioning the patient close to the digital detector
   B. Using a higher magnification mode
   C. Increasing the amount of added filtration
   D. Using a lateral projection versus and anteroposterior projection

Answer = A and C

Fill in the Blank

The candidate must type in the correct response:

1. According to MQSA regulations, the calculated average glandular dose to the ACR phantom for a single craniocaudal view must be less than _____ mGy.

Answer = 3

New Question Types

SAMPLE QUESTIONS

Simple Questions (includes new item types)

1. For a phototimed radiograph, an increase in which of the following increase patient skin dose?

   A. Milliampere
   B. Kilovolt
   C. Patient thickness
   D. Focal spot size
   E. Source-to-image distance

2. A region of interest (ROI) in a CT image has an intensity of -30 HU the ratio of the linear attenuation coefficient for the ROI to that of wat

   A. 0.70
   B. 0.97

R-Type

Lead-In:

The following is a list of components of an image intensifier fluoroscopy system. The system has three magnification modes: 23 cm, 15 cm, and 12 cm. Identify the component that is the best answer for each question. Each option may be used once, more than once, or not at all.

1. Which major component of an image intensifier system has the smallest physical size?

   A. Input phosphor
   B. Photo cathode
   C. Focusing electrodes
   D. Magnetic shielding
   E. Output phosphor
   F. Charge-coupled device array (2k × 2k)
   G. Flat panel monitor (1k × 1k)

2. Which component is held at the most negative electric potential?

   A. Input phosphor
   B. Photo cathode
   C. Focusing electrodes
   D. Magnetic shielding
   E. Output phosphor
   F. Charge-coupled device array (2k × 2k)\
   G. Flat panel monitor (1k × 1k)

3. Which component is used to minimize S-distortion?

   A. Input phosphor
   B. Photo cathode
   C. Focusing electrodes
   D. Magnetic shielding
   E. Output phosphor
   F. Charge-coupled device array (2k x 2k)
   G. Flat-panel monitor (1k x 1k)

Case-based Items

The candidate will not be able to return to the previous question to change his or her answer:

1. A 15-mm thick slice is imaged using a conventional spin-echo pulse sequence with a TE of 100 ms and a TR of 2500 ms. How long after the excitation pulse is the 180 degree refocusing pulse applied?

od vessel with
nstant velocity
blood flowing
through the
lumen

he next question, you will be unable to go back to

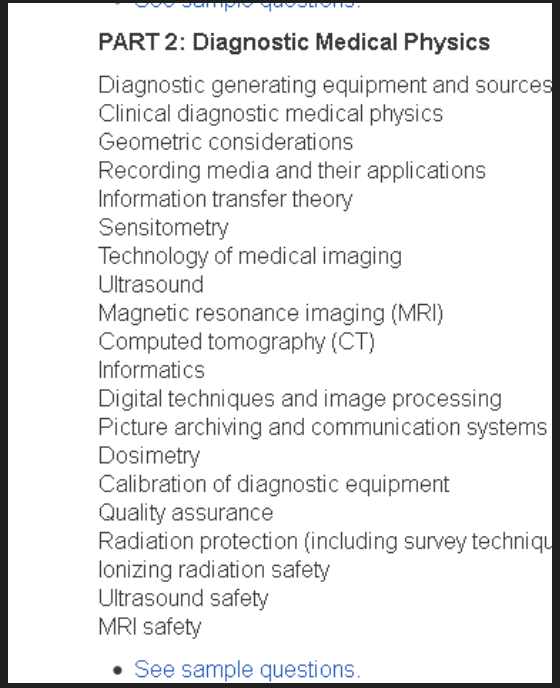
ged using a conventional spin-echo pulse
se is applied at 50 ms after the excitation pulse.
of the blood in the lumen of the vessel so that a
orresponding image?

od vessel with
nstant velocity
blood flowing
through the
lumen

ABR supplied study information

- The ABR supplies a list of topics for Part 2 (it has been updated for 2017 and is better than it was), I still recommend ignoring this list and focusing on the list for part 3 for part 2

Old part 2 topic list from ABR

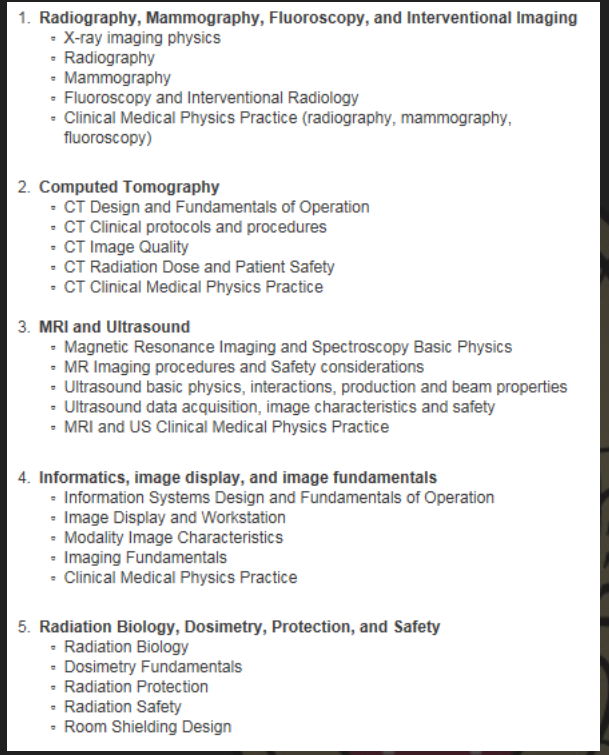


PART 2: Diagnostic Medical Physics

Diagnostic generating equipment and sources
Clinical diagnostic medical physics
Geometric considerations
Recording media and their applications
Information transfer theory
Sensitometry
Technology of medical imaging
Ultrasound
Magnetic resonance imaging (MRI)
Computed tomography (CT)
Informatics
Digital techniques and image processing
Picture archiving and communication systems
Dosimetry
Calibration of diagnostic equipment
Quality assurance
Radiation protection (including survey techniqu
Ionizing radiation safety
Ultrasound safety
MRI safety

- See sample questions.

New part 2 topic list from ABR



1. **Radiography, Mammography, Fluoroscopy, and Interventional Imaging**
   - X-ray imaging physics
   - Radiography
   - Mammography
   - Fluoroscopy and Interventional Radiology
   - Clinical Medical Physics Practice (radiography, mammography, fluoroscopy)
2. **Computed Tomography**
   - CT Design and Fundamentals of Operation
   - CT Clinical protocols and procedures
   - CT Image Quality
   - CT Radiation Dose and Patient Safety
   - CT Clinical Medical Physics Practice
3. **MRI and Ultrasound**
   - Magnetic Resonance Imaging and Spectroscopy Basic Physics
   - MR Imaging procedures and Safety considerations
   - Ultrasound basic physics, interactions, production and beam properties
   - Ultrasound data acquisition, image characteristics and safety
   - MRI and US Clinical Medical Physics Practice
4. **Informatics, image display, and image fundamentals**
   - Information Systems Design and Fundamentals of Operation
   - Image Display and Workstation
   - Modality Image Characteristics
   - Imaging Fundamentals
   - Clinical Medical Physics Practice
5. **Radiation Biology, Dosimetry, Protection, and Safety**
   - Radiation Biology
   - Dosimetry Fundamentals
   - Radiation Protection
   - Radiation Safety
   - Room Shielding Design

ABR supplied part 3study information

DMP	Category Description
Radiography, mammography, fluoroscopy, and interventional imaging	X-ray production, beam characteristics, interactions, and image-formation principles; types and characteristics of image detectors; clinical protocols for common imaging exams; fluoroscopy and interventional procedures, including acquisition parameters and dose-reduction strategies; image noise assessment and dose metrics for all projection imaging modalities; common artifacts, quality assurance, quality control, mammography accreditation, and MQSA standards
Computed tomography	CT system design and principles of operation; image- acquisition protocols, including helical acquisition and tube current modulation techniques; cone beam geometry; post-processing protocols, multi-planar and volumetric reconstruction; quantitative CT; image noise assessment, statistics, dose metrics (CTDI, DLP, SSDE), and effective dose estimation; common CT artifacts, quality assurance, and CT accreditation program
MRI and ultrasound	MR equipment, principles of magnetization, resonance, and excitation; MR pulse sequences, localization, acquisition, and processing; ultrasound (US) principles, beam properties, acquisition methods, signal processing, and image display; Doppler US and color flow imaging principles and operation; common artifacts for MRI and US, siting requirements for MRI, quality assurance, and accreditation for MRI and US
Informatics, image display, and image fundamentals	Informatics infrastructure, standards, and patient security; PACS-modality connectivity, workflow, display, and archive functions; image display requirements, characteristics, and calibration procedures; image processing techniques and qualitative data extraction; image fundamentals, sampling theory, and ROC analysis
Radiation, dosimetry, protection, and safety	Radiation biology, radiation effects, and age/gender-specific risks; radiation protection principles, guidelines, and regulations; radiation dosimetry, detectors, standards, and units; radiation shielding design factors, barrier requirements, surveys, and reports; patient safety and error-prevention issues, including dose reduction, sentinel events, and MR- and US-specific safety issues

ABR supplied MOC study information

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Maintenance of Certification
Diagnostic Medical Physics 2015 Cognitive Exam Study Guide
Updated 4/2016

The following is a general overview of the cognitive exam:

General Information
Approximately 30% of the material on the examination is core diagnostic medical physics, technology, and safety. The remaining 70% is taken from recent advances in the field.

Length and Structure
The exam is approximately 150 questions in length. All questions are multiple-choice, and most have three to five possible answers. A standard calculator is available, but no complex calculations are required.

ABR supplied MOC study information

Reports from the American Association of Physicists in Medicine (AAPM):

AAPM Report OR-03, Task Group #18: Assessment of Display Performance for Medical Imaging Systems (2005)

AAPM Report 93, Task Group #10: Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems (2006)

AAPM Report 96, Task Group #23: The Measurement, Reporting, and Management of Radiation Dose in CT (2008)

AAPM Report 100, Task Group #1: Acceptance Testing and Quality Assurance Procedures for Magnetic Resonance Imaging Facilities (2010)

AAPM Report 108, Task Group #108: PET and PET/CT Shielding Requirements (2006)

AAPM Report 116, Task Group #116: An exposure indicator for digital radiography (2009) (See also IEC report 62494-1)

AAPM Report 118, Task Group #118: Parallel Imaging in MRI, Technology, Applications and Quality Control

AAPM Report 125, Task Group #125: Functionality and Operation of Fluoroscopic Automatic Brightness Control/Automatic Dose Rate Control Logic in Modern Cardiovascular and Interventional Angiography Systems (2012)

Not a comprehensive list, there is more in the actual document

ABR supplied MOC study information

Journal articles:

E Kanal, et al., ACR Guidance Document on MR Safe Practices: 2013. Journal of Magnetic Resonance Imaging 2013; 37:501-530.

EL Nickoloff, AAPM/RSNA Physics Tutorial for Residents: Physics of Flat-Panel Fluoroscopy Systems. *RadioGraphics* 2011; 31:591-602

N Hangiandreou, AAPM/RSNA Physics Tutorial for Residents: Topics in US. *RadioGraphics* 2003;23(4).

JL Gennisson, Ultrasound elastography: principles and techniques. *Diagn Interv Imaging* 2013; 94(5)

V Kapoor, et al., An introduction to PET-CT imaging. *RadioGraphics* 2004;24(2):523-43.

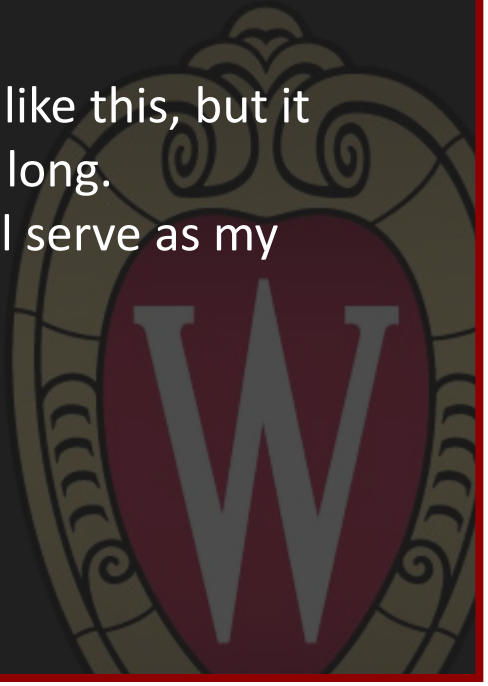
JN Morelli, et al., An Image-based Approach to Understanding the Physics of MR Artifacts. *RadioGraphics* 2011; 31:849-866.

F Mettler, et al., Effective doses in radiology and diagnostic nuclear medicine: a catalog. *Radiology* 2008;248(1):254-63.

Not a comprehensive list, there is more in the actual document

Putting all of this together for part 2

- I recommend forming your own study guide based on the Part 3 topic list (which is very detailed) and the MOC reading list (which is pretty comprehensive)
- My own personal ABR parts 2/3 study guide is formatted like this, but it includes explanations/figures/equations and is 100 pages long. Constructing that guide made studying structured and will serve as my reference for future MOC exams.

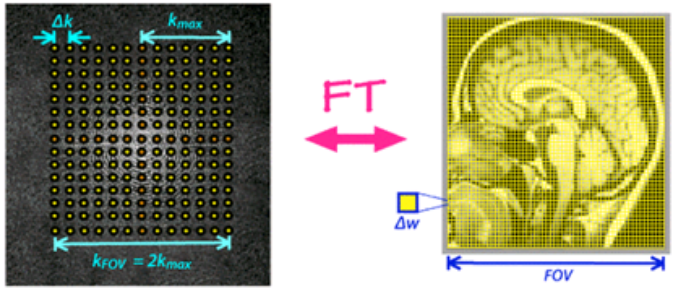


Putting all of this together for part 3

- Everything from the last slide is needed for part 3, but you also need to get out there and experience the material.
- Get your hands on the documentation a residency program must submit to get accredited. Look it over and realize that is what your hands on training should look like.
  - Ask a residency director for a copy of this. All CAMPEP approved programs have them.
  - http://www.campep.org/campeplstres.asp Has information on what programs exist.

My study guide examples

Pixel width = 1/(2*kmax)



$\Delta k = 1 / FOV$ $\Delta w = 1 / k_{FOV}$

Chemical shift artifact 1. Lamor freq. of fat and water different by 3.5ppm (water is faster than fat, water "moves" towards higher B) 2. Lamor freq. is used to localize in space 3. So fat and water get mapped to different locations even when they are in the same voxel 4. As B goes up, CSA gets worse as freq. separation increases 5. If we increase rBW, we increase the range of freq. getting mapped to a given voxel location, so if we increase rBW higher than freq. separation between fat and water, we map fat and water to the same pixel! 6. happens in FEG direction	Diff. between fat and water is 3.5 ppm, at 1.5 T what is diff in Hz? 42.6MHz/T*1.5T*3.5/1E6 = 224Hz

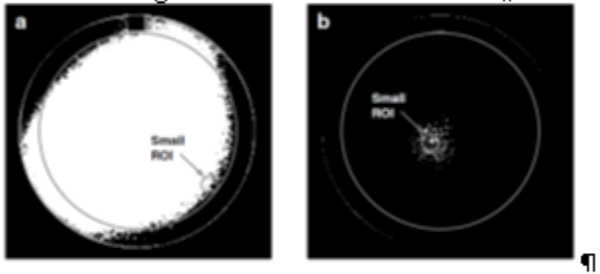
My study guide examples

MR·QA¶

¶

MRI·PIU=100*(1·−·(max-min)/(max+min))¶

Needs·to·be·greater·than·87.5%·under·3T¶



¶

Min·ROI·left,·max·ROI·right¶

¶

To·set·ww/wl·for·measurements,·set·level·to·where·water·is·"half·gone"·(a.k.a·median·signal·value),·then·set·window·to·equal·this·value.·¶

Distance·measurements·must·be·w/I·2mm¶

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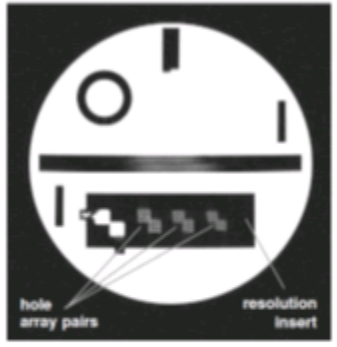


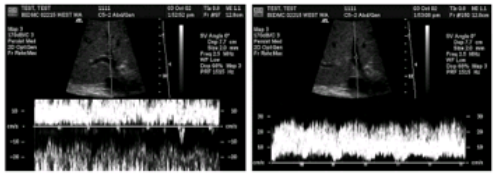
¶

The·spatial·resolution·holes·are·shown·here,·the·black·line·in·the·middle·shown·the·ramps·used·to·measure·slice·thickness,·the·rectangle·at·

ACR·quality·manual·and·ACR·other·supporting·documents¤

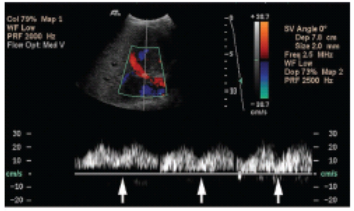
My study guide examples

6. Doppler gain → set as high as possible so long as noise is low
7. Color flow 8 cycles per scan line, spectral flow 256 cycles per scan line
8. Duplex is acquiring Doppler and b mode at the same time
9. Doppler angle should be 45-60 degrees (linear part of cosine curve)
10. Usually, flow towards transducer is red
11. Wall filter "eats" bottom of spectral waveform (filters out low freq) need to be careful not to set wall filter too high if you want to see low velocity flow
12. Changing angle of insonation can reduce aliasing (make angle less head on to flow…)
13. Color priority is kind of like ww/wl of color over b mode image, or like % transparency of color information over image

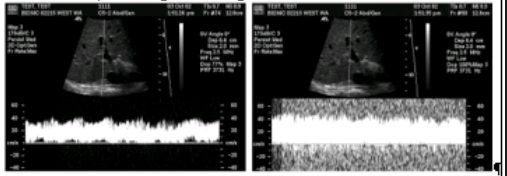


changing spectral baseline to avoid aliasing

Changing wall filter values



Too much spectral gain on right



Too little color gain above, too little below

My study guide examples

ACR for MRI and CT

1. Measure max and min luminance (measure on monitors brightness set to maximum, also do when monitor is set at darkest level) (max luminance s.b. > 90 cd/m^2, minimum < 1.2 Cd/m^2
2. Measure luminance in center and at 4 corners
3. 0-5% pattern s.b. visible
4. 95-100 pattern s.b. visible
5. Each step from 0%-100% s.b. visible
6. Borders and lines on SMPTE should be straight
7. No distortion or misalignment using the girds across the screen
8. Alphanumeric characters sharp
9. High contrast line pairs distinct w/o magnification
10. No streaking around white and black rectangles

This should be less than 30% for CRT and 15% for flat panel

$$\% \ difference = 200 \times \frac{L_{max} - L_{min}}{L_{max} + L_{min}}$$

min brightness < 1.2 cd/cm^2
Max brightness > 90 cd/cm^2
Check response curve year to year for large changes

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Topic	Reference
X-ray production	“Bushberg” (first few chapters and chapter 6), Handbook of Medical Physics (chapter 1 by Boone)
Beam characteristics	“Bushberg” (first few chapters and chapter 6), Handbook of Medical Physics (chapter 1 by Boone)
Interactions	“Bushberg” (first few chapters), Handbook of Medical Physics (chapter 1 by Boone)
Image formation process	“Bushberg” (chapter 7)
Types of detectors	“Bushberg” (chapter 7, 8, 9) CMOS, CCD, Flat panel TFT (how are they read out…), indirect vs. direct
Clinical protocols for common exams	NCRP 149 (for Mammo) Radiation Doses in interventional radiology procedures: The rad-IR study Journal of Vascular Interventional Radiology 2003 (good for knowing what high dose exams are and what the dose level are) Get real experience in the clinic… (know what commonly is multiphasic in CT, know what views are typical for mammo, know what we do to image scoliosis, know the workflow for MRI brain scans, etc.)
Fluoroscopy and interventional	“Bushberg” (chapter 9), AAPM TG 125, The AAPM/RSNA Physics Tutorial for Residents: Fluoroscopy: Optical Coupling and the Video System
Acquisition parameters	AAPM TG 116 Report 116 An exposure Indicator for Digital Radiography
Dose reduction	“Bushberg” (many tables throughout listing the effect of changing acquisition parameters)
Image noise assessment	“Bushberg”, Handbook of Medical Physics (read the chapters on linear systems analysis)
Dose metrics	“Bushberg” (see each modalities section, and see the section in this guide on radiation protection)
Artifacts	Computed Radiography Image Artifacts Revisited AJR:196, January 2011 Digital radiography: CR versus DR? Sometimes recognizing the distinction in technologies makes a difference by Chuck Willis Appl Radiol. January 16, 2008 Digital Mammographic Artifacts on full-field systems: what are they and how do I fix them? Radiographics 2008
QA/QC	**AAPM Report #93 Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems from TG 10** **Code of Federal Regulations Title 21 Section 1020.32 (fluoroscopic equipment)**
Mammo accreditation/MQSA	ACR Mammo Quality Control Manual AND a couple modern systems QA/QC manuals know category a/b/c, ACR Accreditation Program Requirements

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Topic	Reference
System design/operation principle	“Bushberg” (chapters 10-11) “Computed Tomography” by Jiang Hsieh or “Computed Tomography” by Willi Kalender
Image acquisition protocols	“Bushberg” (chapter 10) “Computed Tomography” by Jiang Hsieh (chapter 12) “Computed Tomography” by Willi Kalender (chapter 2)
AEC/TCM/auto kV	McCollough, Cynthia H., Michael R. Bruesewitz, and James M. Kofler Jr. "CT dose reduction and dose management tools: overview of available options 1." *Radiographics* 26.2 (2006): 503-512. Yu, Lifeng, et al. "Automatic selection of tube potential for radiation dose reduction in CT: a general strategy." *Medical physics* 37.1 (2010): 234-243. Boone, John M., et al. "Dose reduction in pediatric CT: A rational approach 1." *Radiology* 228.2 (2003): 352-360.
Cone beam	All diagnostic CT today is conebeam… dedicated CBCT is seen in Rad Onc OBI, Dental, interventional suites, …think flat panel
Post processing	“Bushberg” (chapter 5) “Computed Tomography” Jiang Hsieh
Reformats (volume render and multiplanar)	“Bushberg” (chapter 5) “Computed Tomography” Jiang Hsieh (chapter 4)
Quantitative CT	“Bushberg” (chapter 10) and “Computed Tomography” by Willi Kalendar (chapter 1 figure 1.9)
Noise	“Bushberg” (chapter 10)
Dose metrics	“Bushberg” (chapter 11)
Effective dose	“Bushberg” (chapter 11) **AAPM TG 220 and Report 204**
Artifacts	“Computed Tomography” Jiang Hsieh (chapter 7)
QA/QC	AAPM Task Group Report 66 (it is for Rad Onc, but it is the best for diagnostic right now as well) , TG 2 from 1993 also covers CT Testing
Accreditation	ACR Quality Control Manual 2012 AND FAQ manual

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MR equipment/operation	
Principles of magnetization/resonance/excitation	“Bushberg” Know the figures plotting signal intensity vs. time for T! and T2 decay for all the major pulse sequences
MR Localization/ acquisition /processing	“Bushberg” Google “pulse sequence design made easier”
MR artifacts	“Bushberg” (chapter 13) ACR MR Phantom guidelines, An image based approach to understanding the physics of MR artifacts Radiographics 2011
MR accreditation	ACR Quality Manual, ACR phantom test guidance, Site scanning instructions for use of the MR Phantom for the ACR MRI Accreditation Program
MR shielding/sitting	AAPM Report 100 Acceptance Testing and Quality Assurance Procedures for Magnetic Resonance Imaging Facilities
US principles (beam forming, processing)	“Bushberg” (chapter 14) Google US probes and know what all the different ones look like and why you would use them (convex, endocavity, linear, phased array, etc)
US image display	“Bushberg” (chapter 14 know what you are looking at on A/B/m mode, Doppler image, Doppler waveform all look like)
US Doppler/Color Flow	**Optimizing Doppler and color flow US: Application to hepatic sonography Radiographics 2004**
US accreditation	“Bushberg” (chapter 14) Confusing…medical physicist not actually required. See the ACR technical spec on Doppler and Accreditation Manual
US artifacts…	Feldman, Myra K., Sanjeev Katyal, and Margaret S. Blackwood. "US artifacts 1." *Radiographics* 29.4 (2009): 1179-1189. Pozniak, Myron A., James A. Zagzebski, and Kathleen A. Scanlan. "Spectral and color Doppler artifacts." *Radiographics* 12.1 (1992): 35-44. “Bushberg” (chapter 14)

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Topic	Reference
Informatics infrastructure	General guidelines for purchasing and acceptance testing of PACS equipment Radiographics 2004
Standards	Google → Know DICOM, HL7, know dose structured reporting, (spend some time on www.dclunie.com)
Patient safety/security	Google → Know HIPAA, Know the Belmont report
PACS modality connectivity	"Bushberg" (chapter 5) Read a DICOM conformance statement with your IT staff and ask questions Digital Imaging and Communications in Medicine by Oleg Pianykh (probably overkill, but good reference, if you don't have it try www.dclunie.com)
Workflow/display/archive functions	"Bushberg" (Chapter 5)
Image display requirements	ACR–AAPM–SIIM TECHNICAL STANDARD FOR ELECTRONIC PRACTICE OF MEDICAL IMAGING AAPM TG 18 Assessment of display performance for medical imaging systems Technological and Phychophysical Considerations for digital mammographic displays Radiographics 2005
Monitor calibration requirements	**"Bushberg" (chapter 5) DICOM GDSF**
Image processing	http://www.optics.rochester.edu/workgroups/cml/opt307/spr05/chris/
ROC analysis	"Bushberg" (chapter 5)
Imaging fundamentals/sampling theory	"Bushberg" (chapter 4), "Handbook of Medical Imaging" (chapter 2)

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Topic	Reference
Radiation biology	“Bushberg” (chapter 20)
Radiation effects	“Bushberg” (chapter 20)
Age gender specific risks	“Bushberg” (chapter 20…bigger for kids…function of cancer type)
Radiation protection principles	“Bushberg” (chapter 21) Radiation Management for interventions using fluoroscopic or computed tomography … Journal of Interventional Radiology 2012
Guidelines and principles of radiation protection	NCRP Report No. 116 - Limitation of Exposure to Ionizing Radiation Balter, Stephen, et al. "Fluoroscopically Guided Interventional Procedures: A Review of Radiation Effects on Patients’ Skin and Hair 1." *Radiology* 254.2 (2010): 326-341. NCRP 168 Radiation Dose Management for Fluoroscopically guided interventional medical procedures 2010 ACR–AAPM PRACTICE PARAMETER FOR DIAGNOSTIC REFERENCE LEVELS AND ACHIEVABLE DOSES IN MEDICAL X-RAY IMAGING
Dosimetry	**Jones, A. Kyle, and Alexander S. Pasciak. "Calculating the peak skin dose resulting from fluoroscopically guided interventions. Part I: Methods." *Journal of Applied Clinical Medical Physics* 12.4 (2011).** Landauer “Special Dose Calculations” worksheet Fetal Dose Calculations by Mark Rzeszotarski AAPM Review Course
Detectors	“Bushberg” (chapter 21) I recommend going to one of the vendors websites and reading the tech specs on all of their chambers covering solid state, ion chamber, etc. for all applications like shielding verification, CTDI, exposure, kV, etc.
Standard/units	Covered by other topics
Shielding	**NCRP 147 Structural Shielding design for medical x-ray imaging facilities**
Patient safety/error prevention	Covered by other topics
Sentinel event	1500 rads to a single field (defined by Joint Commission Bulletins)
MR safety	“Bushberg” (chapter 13) ACR Guidance Document on MR Safe Practices: 2013, Wikipedia article on NSF
US safety	“Bushberg” (chapter 14)

After the exam

- I had a few issues with my part 2 exam which I emailed to the ABR
  - All related to monitor quality. There was an MR pulsatile flow artifact that was invisible to me until I bent down and viewed the monitor from a different angle…Not good. I urged them to make these artifacts higher contrast (artificially if needed). I got no response from them.
    - I do not advise arguing over test questions. If the question is bad, they will figure that out in their robust statistical analysis of the responses and throw it away.
- On August 17th (~10 days after the part 2 exam) I received an email from the ABR via survey monkey asking to complete an exit survey. Same day I emailed the ABR my monitor issues…so it could have been a coincidence or that could be their mechanism to facilitate collecting exam feedback.

Conclusion

- If you want a magic bullet for this test, study “The Essential Physics of Medical Imaging” by Bushberg, Seibert, Leidholdt, and Boone
- Part 2 should be viewed as a primer for Part 3
- Part 3 requires hands on time.