

**Physics Radiology
In-Training Test Questions
for Diagnostic Radiology Residents**



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March, 2013

Sponsored by:

Commission on Education

Committee on Residency Training in Diagnostic Radiology

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1. What is the primary benefit of using rotating anode x-ray tubes rather than stationary anode tubes?
 - A. Decreases radiation exposure
 - B. Reduced voltage ripple
 - C. Ability to use higher kVp
 - D. Ability to use higher mAs

Rationales:

A. *Incorrect.*

B. *Incorrect.* The voltage ripple is dependent on the high voltage circuit, not the x-ray tube.

C. *Incorrect.* The maximum kVp is dependent on the high voltage circuit and the cathode-anode spacing (to prevent HV arcing), not stationary versus rotating anode.

D. **Correct.** Rotating anode tubes allow for very high mA for relatively short exposure times by spreading the heat over a larger surface area. This permits high-intensity short exposures.

Citations:

A. Wolbarst, *Physics of Radiology* (1993) E, Chapter 10.

J.T. Bushberg, et al., *The Essential Physics of Medical Imaging* (2002), Chapter 5.

2. A radioactive spill of Tc-99m results in a contamination level of 1000 cpm at 2 PM. What would you expect the contamination level to be at 8 AM the following day?
 - A. < 10 cpm
 - B. 125 cpm
 - C. 250 cpm
 - D. 500 cpm

Rationales:

A. *Incorrect.*

B. **Correct.** Technetium-99m is the most commonly used radionuclide in nuclear medicine with a half-life of 6 hours. By 8 AM the contamination will have decayed over 18 hours or 3 half-lives, reducing the activity to one eighth ($0.5 \times 0.5 \times 0.5$). Therefore the count rate should be around 125 cpm (counts per minute).

C. *Incorrect.*

D. *Incorrect.*

Citations:

A. Wolbarst, *Physics of Radiology* (1993), Chapter 39

J.T. Bushberg, et al., *The Essential Physics of Medical Imaging* (2002), Chapter 18

3. As the main magnetic field strength increases and maintains homogeneity, which one of the following relaxation constants increases MOST?
- A. T1
 - B. T2
 - C. T2*
 - D. Spin Density

Rationales:

Spin-lattice relaxation occurs when the molecular vibrational frequencies of the tissues approximate the angular precessional frequencies of the protons. With increasing precessional frequencies resulting from increasing magnetic field strength, there is less overlap of the precessional/vibrational frequencies, thus requiring a longer time for the protons to release their energy back to the lattice.

A. **Correct.** As explained above.

B. *Incorrect.* As T2 is little affected by variations in the static magnetic field.

C. *Incorrect.* As T2 is not significantly affected, since homogeneity is maintained.

D. *Incorrect.* Spin-density is unchanged by changes in the magnetic field

4. Which of the following increases MR chemical shift artifact for a given slice thickness?

- A. Increasing RF receiver bandwidth
- B. Decreasing readout gradient strength
- C. Decreasing matrix size
- D. Decreasing field strength (B0)

Rationales:

Chemical shift occurs as a result of the difference in the resonant frequency of protons associated with very hydrogenous (fat) tissues compared to protons associated with water molecules. Protons are localized by the variation of resonance frequencies under the influence of an external magnetic gradient over a specific field of view. This results in a net range of precessional frequencies across the field of view, which is sampled according to the matrix size. If the gradient strength is low, that means that a small range of frequencies will be manifested over the FOV, and for a given matrix size, the bandwidth across a single pixel will be similarly small. Since the chemical shift results in frequency shifts of about 3 parts per million, for a 1 T magnet, the frequency differences in fat versus water protons is about $1 \text{ T} \times 42.58 \text{ MHz} / \text{T} \times 3 \times 10^{-6} = \sim 125 \text{ Hz}$. If the bandwidth across the pixel is small, then the signals due to fat can potentially be mapped into adjacent (or even further away) pixels, and the anatomical presentation will manifest “chemical shift” artifacts.

A. *Incorrect.* A broad bandwidth receiver setting will result in similarly larger bandwidth across each pixel, reducing the effects of the chemical shift.

B. **Correct.** The lower readout gradient strength for a given FOV will result in a smaller range of frequencies across each pixel, and therefore will more likely map signals due to fat in different pixels than signals due to water.

C. *Incorrect.* A smaller matrix size mapped to a given FOV will have larger pixels, and therefore will have larger bandwidth across each pixel. The larger bandwidth per pixel will reduce the effects of chemical shift.

D. *Incorrect.* Lower main magnetic strength will cause the absolute chemical shift to also be lower (actual chemical shift = relative chem. Shift (ppm) $\times$ B0 $\times$ γ).

5. What is the latent image in computed radiography (CR)?

- A. Optical density patterns on a digital laser film
- B. Absorbed x-ray photons in the phosphor
- C. Electrons trapped in semi-stable energy wells
- D. Digitally stored values in each pixel of the image

Rationales:

The latent image is the unobservable change of the detector arising from x-ray interactions in the object and the absorption of the x-ray pattern onto the detector. CR (computed radiography) is a modality that uses photostimulable storage phosphor (PSP) technology to acquire the x-ray information and subsequently render a visible image after stimulating the latent image electrons that are stored in semistable traps within the PSP (typically made of barium fluoro bromide (BaFBr)).

- A. *Incorrect.* The laser film represents the final image, not the temporary unobservable latent image.
- B. *Incorrect.* X-ray photons induce the storage of electrons, but do not comprise the latent image information.
- C. **Correct.** Electrons are trapped by the storage phosphor upon excitation by locally absorbed x-rays. The latent image information is subsequently rendered visible by excitation of a laser beam (diameter typically 100 mm) and emission of shorter wavelength light photons upon return to the ground state.
- D. *Incorrect.* The digitally stored values represent the final, observable image, not the unobservable image.

Citations:

J.T. Bushberg, et al. *The Essential Physics of Medical Imaging*, (Second Edition), Lippincott Williams and Wilkins, 2002, Chapter 11.

6. The digital radiography system that employs direct conversion of x-rays into a signal (electrons) is best represented by which one of the following?
- A. Photostimulable storage phosphor imaging system (computed radiography)
 - B. Optically coupled charge-coupled device (CCD) camera
 - C. CsI – TFT flat panel array
 - D. Amorphous selenium – TFT flat panel array

Rationales:

A. *Incorrect.* X-rays are converted to latent image electrons in the BaFBr storage phosphor, then “processed” by a scanning laser beam which then produces light photons that are reconverted to electrons by a photomultiplier tube, and then digitized.

B. *Incorrect.* X-rays are converted to light photons in an x-ray scintillator, which are subsequently focused onto a small CCD camera photosensitive layer, where the light photons are converted to electrons, amplified, and then digitized.

C. *Incorrect.* X-rays are converted to light photons in the cesium-iodide scintillator, and channeled to photodiodes attached to each detector element in the thin-film-transistor array. Electrons are produced, captured by storage capacitors at each element, and then actively read by the electronic switching of the transistors. Although the flat panel array directly reads out the signal, the x-rays go through a conversion to light photons before the final signals are captured.

D. **Correct.** Amorphous selenium is a semi-conductor material that directly produces electron-hole pairs in proportion to the number of x-ray photons incident on the detector. A high-voltage bias placed across the semiconductor actively collects the electrons and holes, thereby producing the signal that is amplified and digitized, without any secondary signal conversion.

Citations:

Essential Physics of Medical Imaging. Second Edition. Bushberg, Seibert, Leidholdt, Boone, Lippincott Williams and Wilkens, 2002.

7. Concerning inverse square law in chest fluoroscopy, if the patient's entrance dose is 20 mGy/min with the source-to-skin distance (SSD) of 65 cm and source-to-image distance (SID) of 90 cm. How much does the entrance dose change if the SID is increased to 120 cm while maintaining similar SSD?
- A. Increases by a factor of approximately 1.3
 - B. Remains unchanged
 - C. Decreases by a factor of approximately 2
 - D. Increases by a factor of approximately 1.8

Rationales:

A. *Incorrect.*

B. *Incorrect.*

C. *Incorrect.*

D. **Correct.** According to the inverse square law, if the exposure-rate from a source is X_1 at distance d_1 , the exposure rate X_2 at another distance d_2 will be $X_2 = X_1(d_1/d_2)^2$. Therefore, Increasing the SID requires an increased output from the X-ray tube. Using the inverse square law, you have two equations, $(X_{\text{patient90}}/X_{90}) = (d_{90}/d_{65})^2$ and $(X_{\text{patient120}}/X_{120}) = (d_{120}/d_{65})^2$. A constant dose rate is necessary at the image intensifier at any SID since auto brightness control is being used so $X_{90} = X_{120}$. So when you plug this into the equations and rearrange, you get $(X_{\text{patient120}}/X_{\text{patient90}}) = (120/90)^2 \approx 1.8$.

Citations:

The Essential Physics of Medical Imaging by Bushberg JT et. al., Second Edition, Chapter 23: Radiation Protection.

8. An interventional fluoroscopy procedure results in a patient skin entrance dose of 2 Gy. Which of the following radiation-induced skin injuries MOST LIKELY can occur?
- A. Necrosis
 - B. Main erythema
 - C. Dry desquamation
 - D. Early transient erythema

Rationales:

A. *Incorrect.* Necrosis of the skin has dose threshold of >16 Gy.

B. *Incorrect.* The dose threshold for main erythema is 6 Gy

C. *Incorrect.* Desquamation occurs above 14 Gy.

D. **Correct.** This effect has a lower dose threshold of 2 Gy. It may begin within hours after irradiation and peak at about 24 hour.

Citations:

Balter S. Interventional Fluoroscopy: Physics, Technology and Safety, p.167.

9. Regarding image intensifier design, which of the following results due to the combination of a curved input screen and flat output screen?
- A. Pincushion distortion
 - B. Increased contrast ratio
 - C. Reduced radiation dose
 - D. Increased brightness gain

Rationales:

- A. **Correct.** Mapping of an image from a curved input screen to a flat output screen results in increased magnification at the image periphery as compared to the image center.
- B. *Incorrect.* The shape of the input and output screens does not affect veiling glare.
- C. *Incorrect.* The shape of the input and output screens does not affect radiation dose.
- D. *Incorrect.* Brightness gain depends on electronic gain and minification gain.

Citations:

Bushberg JT, Seibert JA, Leidholdt EM, Boone JM. The Essential Physics of Medical Imaging, 2nd Edition, p. 235.

10. Concerning the reverberation artifact in ultrasound, which one of the following is TRUE?
- A. The echoes increase in intensity with distance.
 - B. Horizontally positioned linear echoes are superimposed on each other.
 - C. It occurs when the ultrasound signal reflects repeatedly between highly reflective interfaces.
 - D. The presence of air creates side-lobe artifacts and not reverberation artifact.

Rationales:

- A. *Incorrect.* In reverberation artifact echoes decrease in intensity with distance.
- B. *Incorrect.* Reverberation artifact has horizontally positioned linear echoes that are spaced equally.
- C. **Correct.** The highly reflective interfaces causing the reverberation artifact are usually, but not always, near the transducer. They allow identification of a specific type of reflector such as a surgical clip.
- D. *Incorrect.* Presence of air can be identified by the presence of reverberation artifact. Side lobes are due to radial vibration of the transducer crystal and not the presence of air. Side lobes arise from sound beams that are emitted from the side of the primary beam.

Citations:

Ryan K Lee. Grayscale Ultrasound artifacts. In :Dogra V, Rubens DJ(eds): Ultrasound Secrets. 1st Edition. Philadelphia; Hanley and Belfus; 2004, Page 8-14.

Rumack CM, Wilson SR, Charboneau JW. Diagnostic Ultrasound. 3rd ed. Mosby Yearbook Inc., St. Louis, MO. 2005, Page 19-22.