

1. *Unlike* CT, in nuclear medicine

- A. Bremsstrahlung is not used to produce high-energy photons.
- B. signal can be increased by increasing the radiation dose.
- C. crystals are used to convert high energy photons into light photons.
- D. electromagnetic radiation, not particulate radiation, is used to image.
- E. causing cancer is not a risk.

Explanation: Bremsstrahlung is only used in x-ray and CT. High-energy photons are due to nuclear events in nuclear medicine.

[*imaging0477.mcq*]

2. Regarding two atoms of the same isotope, the following is (are) true:

- I. They have the same number of protons.
- II. They have the same number of neutrons.
- III. They may have different energy levels, with at least one being considered metastable, and thereby represent different isomers.

- A. I, II, and III
- B. I and III
- C. II and III
- D. I and II
- E. I

Explanation: The classic example is Technetium-99 and Technetium-99m, which are different isomers of the same isotope.

[*imaging0126.mcq*]

3. Which of the following statements is (are) TRUE about detector crystals in Anger cameras?

- I - Thick detectors are less efficient than thin detectors, but they provide greater spatial resolution.
- II - Each gamma ray produces a scintillation consisting of many light photons.
- III - Multiple small crystals are arranged in a grid to permit determination of the location of the radiation.

- A. only II
- B. I and II
- C. II and III
- D. I and III
- E. only III

Explanation: Thick detectors are *more* efficient than thin detectors, and they provide *less* spatial resolution, so I is false. Anger cameras use one or two large crystal detectors, so III is false.

[*imaging0121.mcq*]

4. The spatial resolution of a gamma camera can be improved by many factors, including:

- A. Decreasing the thickness of the scintillation crystal
- B. Increasing the distance between the patient and the camera
- C. Decreasing the length of the lead septa in the collimator
- D. Increasing the distance between the lead septa in the collimator
- E. None of the other choices

Explanation: Decreasing the thickness of the crystal improves resolution, though it also decreases the efficiency of detection. The other options would actually decrease the spatial resolution of the camera.

[*imaging0265.mcq*]

5. Which of the following is (are) *true* about both SPECT and PET?

- I. Each has a corresponding projection modality.
- II. Each is a tomographic imaging modality based on the emission of gamma particles from within the patient.
- III. Each involves the annihilation of matter and antimatter

- A. only II.
- B. I and II.
- C. I and III.
- D. II and III.
- E. I, II, and III.

Explanation: PET is not based on a projection modality, though SPECT is. Only PET involves the annihilation of matter and antimatter.

[*imaging0476.mcq*]

6. The following are true of Radioactive Decay *except*

- A. It is primarily a process involving the configuration of electrons in an atom.
- B. It is driven by a change in nuclear binding energy, which holds the protons and neutrons together in a nucleus.
- C. It is accompanied by a change in mass that is converted into energy according to $E = MC^2$
- D. Energy is released in the process, by particle motion and radiation.
- E. It can be viewed as the attempt of a radionuclide off the “line of stability” (on the graph of the number of neutrons vs. the number of protons) to reach the line of stability.

Explanation: Radioactive Decay involves the configuration of the nucleus rather than that of the electrons.

[*imaging0097.mcq*]

7. Regarding PET, which of the following statements about the equation below is *false* (or all are true)?

$$N_c(s_0) = N_0 \exp \left\{ - \int_{-R}^R \mu(x(s'), y(s'); E) ds' \right\}$$

- A. It assumes a *homogeneous* tissue in terms of attenuation.
- B. It assumes no random coincidences at the 2 detectors from different positron decays.
- C. All are true.
- D. The effect of attenuation along a given line of response on the number of coincident detections is *independent* of where the positron decay occurs along the line of response.
- E. It assumes *mono-energetic* photons, which is a good assumption with positron decay.

Explanation: It assumes a *heterogeneous* tissue in terms of attenuation.

[*imaging0515.mcq*]

8. *Unlike* in x-ray based imaging modalities, in nuclear medicine

- A. orienting the patient with the desired organ near the detector reduces total attenuation in the intervening tissue.
- B. to get more signal we can increase dose.
- C. we can increase detector efficiency by making it thicker, but this reduces resolution.
- D. high energy photons are used to image.
- E. tomographic slices may be reconstructed.

Explanation: Since the gamma photons in nuclear medicine originate within the body, the amount of attenuation depends on the distance between the organ and the detector.

[*imaging0052.mcq*]

9. Which of the following statements is *false* about photomultiplier tubes (or all are true)?

- A. Is designed to be extremely sensitive to high energy photons, including gamma and x-ray photons.
- B. Used in an Anger camera to produce an electrical signal whose pulse height is related to the number of light photons generated by a gamma event.
- C. All are true.
- D. Uses a series of dynodes at successively more positive voltage within the tube to create increasing numbers of cascading electrons from an initial few electrons.
- E. Uses a photocathode to generate electrons from incoming photons.

Explanation: Photomultiplier tubes are designed to detect light photons. To detect gamma or x-ray photons, a photomultiplier tube requires a scintillation crystal or other device to produce light photons.

[*imaging0474.mcq*]

10. Which of the following statements is *false* about Anger cameras?

- A. Multiple photomultiplier tubes, one for each pixel in the image, are arranged in a grid behind a large crystal.
- B. Lead septa are required to generate a projection image
- C. Each gamma particle produces a scintillation consisting of many light photons.
- D. The contribution from Compton scattering to the image is reduced by analyzing the pulse height of the combined responses of the photomultiplier tubes to each detected gamma particle.
- E. Gating acquisition to the electrocardiogram reduces motion artifact from cardiac motion.

Explanation: Multiple photomultiplier tubes are indeed used, but not one for each pixel. Rather, they act in concert to determine the actual location of the gamma particle with a spatial resolution greater than that of the tubes.

[*imaging0264.mcq*]

11. In terms of isotopes, the following are true about the gamma emitters vs. positron emitters commonly used in nuclear medicine, *except*

- A. They are detected by inherently different types of scanners, in that the same devices are not capable of detecting both positrons and gamma photons.
- B. Gamma emitters are often isotopes of elements not normally found in organic molecules, whereas positron emitters include isotopes of elements common in organic molecules.
- C. Relative to the “line of stability,” positron emitters tend to have too *few* neutrons, whereas gamma emitters tend to have too *many* neutrons.
- D. In both types of isotopes, decay eventually leads to the production of gamma photons.
- E. Only one of these types of isotopes involves the creation of antimatter.

Explanation: In PET, the scanners do not directly detect positrons, but rather gamma photons created when the positron finds a nearby electron leading to the creation of two 511 keV gamma photons.

[*imaging0516.mcq*]

12. Which of the following is (are) *true* about *mass defect*?

- I. It is the difference between the sum of the masses of the isolated protons, neutrons, and electrons of an atom and the actual mass of the atom.
- II. It is translated via $E = mc^2$ into the binding energy holding the atom together, which may also be expressed in MeV.
- III. It is expressed in unified atomic mass units (u), where 12 u = the mass of Carbon-12

- A. I, II, and III.
- B. I and II.
- C. I and III.
- D. II and III.
- E. Only I.

Explanation: All are true.

[*imaging0268.mcq*]

13. Which of the following statements is *false* about Anger cameras?

- A. Lead septa are not required to generate a projection image.
- B. Individual gamma photons are counted and located.
- C. Each gamma particle produces a scintillation consisting of many light photons.
- D. The contribution from Compton scattering to the image is reduced by analyzing the pulse height of the combined responses of the photomultiplier tubes to each detected gamma particle.
- E. Multiple photomultiplier tubes are arranged in a grid behind a large crystal that act in concert to determine the location of the incoming photons with a spatial resolution greater than that of the tubes.

Explanation: Lead septa are indeed required to generate a projection image.

[*imaging0416.mcq*]

14. Which of the following statements is *false*?

- A. None of the others is false.
- B. Coincidence detection in PET is used to determine the direction of travel of the two simultaneously emitted gamma photons, and hence to decide on which line of response the radioactivity occurs.
- C. In PET imaging the attenuation factor for the pair of photons generated on a given line of response is independent of the location of the activity along that line of response.
- D. An uncertainty always exists as to the location of the positron decay due to the distance the positron travels before annihilating with an electron.
- E. Random occurrences in which two different decays each contribute a photon that is detected within the same time window constitute a source of noise in PET imaging.

Explanation: They're all true.

[*imaging0263.mcq*]

15. Which of the following statements is *false* about PET (or all are true)?

- A. The difference in traveling times of the two coincident gamma photons is used to determine the location of the radioactivity.
- B. Coincidence detection in PET is used to determine the direction of travel of the two simultaneously emitted gamma photons, and hence to decide on which line the radioactivity occurs.
- C. In PET imaging the attenuation factor for the combination of the two photons is independent of the location of the activity along the line of response (LOR), and therefore that factor can be measured for each LOR.
- D. An uncertainty on the order of millimeters always exists as to the location of the positron decay due to the distance the positron travels before annihilating with an electron.
- E. All are true

Explanation: The traveling times may indeed be different (if the radioactivity is not exactly in the middle between the detectors) but the difference is slight and not used in computing location along the LOR.

[*imaging0214.mcq*]

16. Which one of the following statements is *false*?

- A. As in CT, nuclear medicine produces images whose useful information relates primarily to the attenuation of gamma photons.
- B. Gamma photons in nuclear medicine and X-ray photons in CT differ in their method of creation, but both are fundamentally photons and their energy spectra overlap.
- C. Both nuclear medicine and CT involve risk to the patient in terms of radiation.
- D. Planar scintigraphy is the 2D basis for SPECT in a manner analogous to projection radiography being the 2D basis for CT.
- E. Nuclear medicine involves counting individual photons whereas CT involves measuring the flux of radiation intensity from many photons.

Explanation: As opposed to CT, nuclear medicine produces images that depict the distribution of the radiotracer; attenuation is just a confounding factor.

[*imaging0517.mcq*]

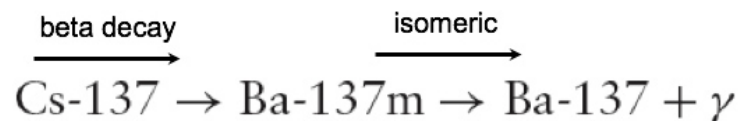
17. Which of the following statements about combined PET/CT scanners is *false* (or all are true)?

- A. The primarily physiological, higher-resolution information from the CT scanner is combined with the primarily anatomical, lower-resolution information from the PET scanner.
- B. Registration of the two imaging modalities is greatly facilitated since the patient only needs to be slid a short distance between the actual scanners.
- C. The CT scanner is used to determine the attenuation along each Line of Response in the PET scanner.
- D. Virtually every PET scanner sold today also contains a CT scanner.
- E. All are true.

Explanation: The primarily *anatomical* higher-resolution information from the CT scanner is combined with the primarily *physiological* lower-resolution information from the PET scanner.

[*imaging0415.mcq*]

18. Regarding the following nuclear reactions, which of the following statements is *false* (or all are true)?



- A. Both reactions occur within the patient
- B. All are true.
- C. The first reaction involves a neutron converting into a proton.
- D. The second reaction involves a conversion within the nucleus from a higher energy state to a lower energy state, without a change in the number of neutrons or protons in the isotope.
- E. The γ particle shown at the end is used to image the patient.

Explanation: The first reaction yields dangerous beta radiation and is performed outside the patient to produce the metastable isotope Ba-137m for use in the patient.

[*imaging0518.mcq*]

19. Regarding single photon emitters, which of the following statements about the equation below is *false* (or all are true)?

$$\phi(x, y) = \int_{-\infty}^0 \frac{A(x, y, z)}{4\pi z^2} \exp \left\{ - \int_z^0 \mu(x, y, z'; E) dz' \right\} dz$$

- A. $A(x, y, z)$ is the attenuation at location (x, y, z) .
- B. It assumes mono-energetic photons, which is a good assumption assuming a given nuclear decay.
- C. It assumes a heterogeneous tissue in terms of attenuation, and a perfect collimator.
- D. The contribution from each location falls off as the square of the distance, and is attenuated by the material along the line between that location and the detector.
- E. All are true.

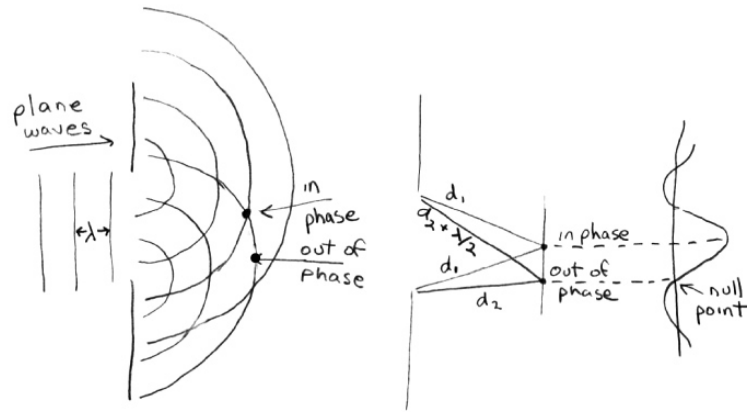
Explanation: $A(x, y, z)$ is the radioactivity (number of atoms disintegrating per unit time) at location (x, y, z) .
[*imaging0499.mcq*]

20. The following are true about the waves used in clinical ultrasound imaging, *except*

- A. They travel with so little attenuation through bone and air that no echoes are generated in these tissues.
- B. Echoes are generated primarily because of changes in the acoustic impedance of the tissue
- C. Scattering of the waves from targets smaller than the acoustic wavelength is the primary source of useful information in the image.
- D. Distance to a target is determined by time of flight.
- E. They are primarily compression rather than shear waves.

Explanation: Attenuation in bone and air is very high at the frequencies of ultrasound used in medicine. This accounts for the lack of ability to image these tissues.
[*imaging0424.mcq*]

21. Regarding the following diagram from lecture, which of the following statements is *false* (or all are true)?



- A. All are true.
- B. It illustrates Huygens Principle.
- C. Each point of the advancing plane waves reaching the aperture acts as the center of a fresh spherical disturbance.
- D. The aperture will create standing waves of constructive and destructive interference.
- E. The wavelength λ and the differences in path length between 2 points in the aperture to a given point beyond the aperture completely determines the relative phase of the corresponding 2 waves as they arrive at that point.

Explanation: All are true.
 [*imaging0519.mcq*]

22. The following are true about theoretical spherical waves in ultrasound, *except*

- A. No attenuation occurs with distance along the direction of propagation.
- B. Their general solution includes the superposition of an outward-traveling wave and an inward-traveling wave, although often only the outward-traveling wave is used.
- C. They can be viewed equally well as functions of time or of distance.
- D. Spatial variation occurs only along radial directions from the center of the spherical wave.
- E. They are central to Huygen's principle.

Explanation: Attenuation of amplitude occurs as $1/R$ with distance along the direction of propagation.
 [*imaging0273.mcq*]

23. The following are true about the transducers used in clinical ultrasound imaging, *except* (or all are true)

- A. All are true.
- B. The resonance of the transducer is intentionally dampened, primarily from behind (the side away from the patient).
- C. Although early transducers were physically moved to create an image, the great majority of modern transducers use an array of transducer elements to *both* steer and focus the ultrasound waves.
- D. To increase transmission and reception, a special matching layer is placed between the transducer and the patient of intermediate impedance between that of the transducer elements and the patient.
- E. A matching layer $1/4$ wavelength thick is used so that reflected waves within the layer are 180° out of phase and cancel.

Explanation: All are true.

[*imaging0345.mcq*]

24. The following are true about *speckle* ultrasound imaging, *except* (or all are true)

- A. It results from multiple Doppler shifts from individual targets (such as red blood cells) moving in different directions.
- B. It arises due to multiple scatterers within a single resolution cell.
- C. It results in a pseudorandom pattern of intensity variation.
- D. It moves with tissue and can be used to track that motion.
- E. All are true.

Explanation: Answer A is false. This describes continuous wave (CW) Doppler used to hear a fetal heart.

[*imaging0461.mcq*]

25. In clinical ultrasound, regarding the *Pulse Repetition Rate* f_R , *Pulse Repetition Interval* T_R , and *Speed of Sound* c , which one of the following statements is *false*?

- A. $c = \frac{1}{f_R}$
- B. $T_R = \frac{1}{f_R}$.
- C. For a depth of penetration d_p , $T_R \geq \frac{2d_p}{c}$.
- D. The Pulse Repetition Rate is the rate of acquisition of single A-mode scan.
- E. B-mode scans, each made up of N A-mode scans, will have a frame-rate $F = \frac{1}{T_R N}$.

Explanation: A is incorrect... the Speed of Sound will be $c = 2d_p f_R$.

[*imaging0520.mcq*]

26. Which of the following statements is *false* about resolution in ultrasound?

- A. Resolution in the range direction decreases (gets worse) with increasing range.
- B. Resolution increases (gets better) with increasing frequency.
- C. Resolution is manifested by a “resolution cell” within which many actual reflectors create a total reflection of variable brightness, accounting for speckle.
- D. Lateral resolution generally decreases (gets worse) with increasing range.
- E. Resolution in the range direction is limited by the duration of the envelope of the transmitted pulse.

Explanation: Resolution in the range direction stays the same with increasing range.

[*imaging0270.mcq*]

27. Which of the following statements is *false* about the use of the complex exponential in modeling ultrasound, (or all are true)?

- A. All are true.
- B. They permit mathematically tenable integration of many sources of ultrasound waves converging on a single point to determine the extent of constructive or destructive interference.
- C. They allow for the imaginary component of a physical quantity, by requiring that the imaginary component will be canceled by a complex conjugate.
- D. They are also the foundation of much of modern optics, where waves are transverse rather than longitudinal, but still sinusoidal in nature.
- E. They are the general solution to *second* order differential equations, such as resonating systems and waves.

Explanation: They (as are the sinusoids they represent) are the general solution to *second* order differential equations, such as resonating systems and waves. The use of complex exponentials instead of real sinusoids encapsulates phase in such a way that algebra and calculus are straightforward, and is the heart of not only ultrasound design, but of modern optics.

[*imaging0456.mcq*]

28. Ultrasound is commonly used in adults for non-invasive imaging of all of the following, *except*

- A. Lung
- B. Breast
- C. Fetus
- D. Testicle
- E. Kidney

Explanation: Ultrasound does not penetrate air and thus is not normally used to image the lung.

[*imaging0426.mcq*]

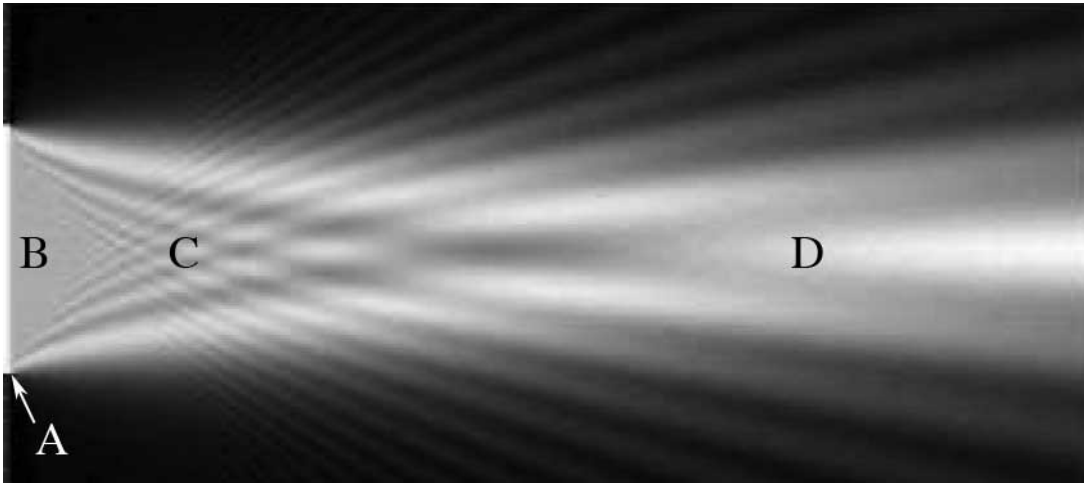
29. Regarding the first stage of a typical clinical ultrasound scanner after the transducer, which one of the following statements is *false*?

- A. It must compensate for a consistent lowering of frequency in echoes from greater depths.
- B. It uses a logarithmic amplifier to increase the dynamic range of the received signal.
- C. It detects the envelope of the received signal, discarding the high frequency, much in the same way as an Amplitude Modulated (AM) radio receiver.
- D. It uses Time Gain Compensation (TGC) to adjust pixel brightness as a function of depth, to compensate for fainter echoes further away.
- E. The signal usually represents the sum of a number of outputs from individual transducer elements in an array, each of which has an individual delay to define a desired beam.

Explanation: Frequency generally remains constant with depth, unless Doppler shift is generated by tissue motion away from the transducer at greater depths.

[*imaging0521.mcq*]

30. Which of the following is *not* true about the *field pattern* shown below representing ultrasound produced by a flat transducer (marked "A"), or all are true.

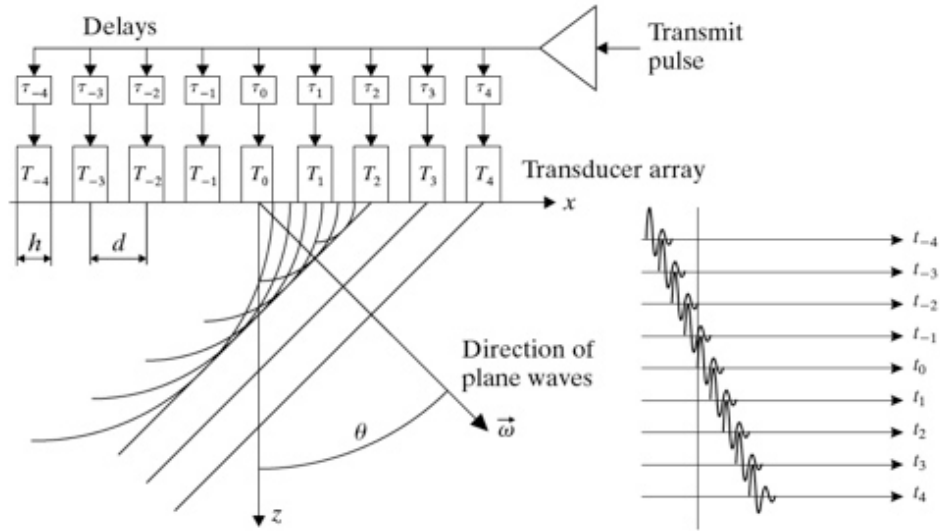


- A. All are true.
- B. The field pattern represents a pattern of standing waves of constructive and destructive interference for a given aperture and wavelength, and is equally applicable to either transmission or reception by the transducer.
- C. In the Fresnel zone null points may exist along the central axis.
- D. The label "B" marks the Very Near Field, where plane waves are approximated, at least near the center axis, where the planar transducer appears infinitely large.
- E. In the Fraunhofer zone the field pattern becomes a function basically of angle from the axis.

Explanation: All are true.

[*imaging0455.mcq*]

31. Regarding the following diagram, which of the following statements is *false*?



- A. All are true.
- B. This phased array is simulating a *prism*, because it is taking one “plane wave” parallel to the face of the array (the undelayed transmit pulse) and yielding another plane wave (the actual ultrasound wave) in a different direction.
- C. The transmit pulse reaches each element in the transducer array delayed by an individually adjustable amount of time.
- D. The same basic hardware with different delays is capable of simulating a *lens*, focusing the ultrasound waves at a desired depth.
- E. A receiver summing the signals produced by the same transducer array from ultrasound echoes, using the same individual time delay values, would form an identical spatial pattern for detecting echoes.

Explanation: All are true.

[*imaging0522.mcq*]

32. The following are true about theoretical plane waves in ultrasound, *except*

- A. They are inherently stationary (standing waves).
- B. Their general solution includes the superposition of a forward-traveling wave and a backward-traveling wave.
- C. They are approximated at a great distance from the point source of a spherical wave.
- D. Spatial variation occurs only along the direction of motion for the wave.
- E. No attenuation occurs with distance along the direction of propagation.

Explanation: Stationary planar waves (interference patterns) may occur when a forward and backward traveling waves interact, but planar waves are not inherently stationary.

[*imaging0454.mcq*]

33. Which of the following affects the intensity of a pixel in an ultrasound image ?

- I. changes in acoustic impedance of the tissue at the pixel location.
- II. the particular configuration of scatterers smaller than the resolution of the ultrasound within the pixel's resolution cell.
- III. attenuation, reflection, or scattering between the transducer and the pixel location.

- A. I, II, and III.
- B. I and II.
- C. I and III.
- D. II and III.
- E. None of the other answers

Explanation: All are true. Answer two describes speckle. Answer III effects the ultrasound energy reaching the location and thus the strength of the echo.

[*imaging0274.mcq*]

34. Which of the following statements is *false* about the Fraunhofer zone? (or all are true)

- A. All are true.
- B. The resolution cell expands laterally (orthogonal to the range direction) with distance from the transducer, but remains constant in the range direction.
- C. The field pattern is basically a function of angle off the axis.
- D. There are *no* null points due to destructive interference along the axis in this zone.
- E. There *are* null points due to destructive interference off the axis in this zone.

Explanation: Lateral image resolution within this zone worsens with distance to the transducer, while range resolution stays the same.

[*imaging0423.mcq*]

35. Regarding the following equation (where p is pressure and c is the speed of sound), the following are true *except*

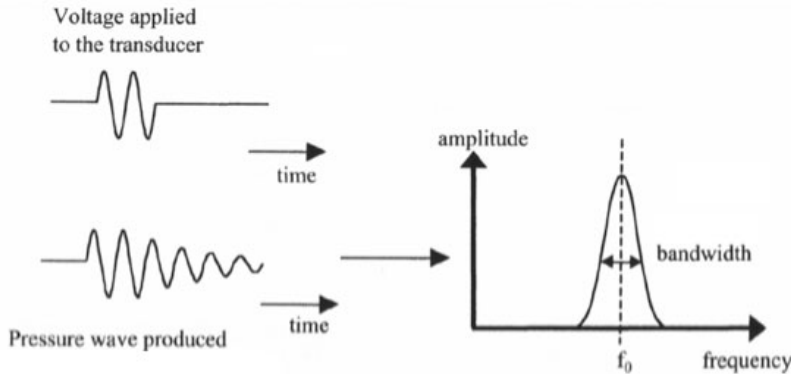
$$\nabla^2 p = \frac{1}{c^2} \frac{\partial^2 p}{\partial t^2}$$

- A. The variable p is a scalar, whereas $\nabla^2 p$ is a 3D vector.
- B. The “del” or “nabla” symbol squared indicates the Laplacian operator, which is the divergence of the gradient.
- C. The derivatives of pressure in space may be viewed as “causing” flows that “cause” to the corresponding derivatives of pressure in time.
- D. The inward pressure gradient at any point in space is summed from all sides by the Laplacian operator.
- E. The equation accounts for the creation and propagation of pressure waves.

Explanation: All are true.

[*imaging0523.mcq*]

36. The figure below shows the effect of damping a resonant ultrasound transducer crystal after activation with a voltage. Given the definition of Q as the height over the width of a filter in the frequency domain, which of the following is *not* true (or all are true)?



- A. All are true.
- B. A greater value for Q corresponds to a narrower band of frequencies.
- C. Damping the resonance of the ultrasound crystal lowers the value of Q .
- D. The variable Q demonstrates the underlying concept that stretching a signal in time (towards an infinite sinusoid) compresses it the frequency domain (towards a single frequency).
- E. Improved spatial resolution for the ultrasound image is obtained by lowering the Q of the crystal.

Explanation: Damping the resonance of the crystal improves resolution by shortening the pressure wave, thereby decreasing the Q of the crystal and broadening the band of frequencies.

[*imaging0483.mcq*]

37. In the lecture presented by our TA, Waqas Khalid, the following statements accurately represent an underlying principle of his research into new clinical techniques in ultrasound, *except*

- A. Ultrasonic waves traveling faster than the speed of sound create shockwaves tangential to the boundary layers between lipid bearing tissues and water bearing tissues.
- B. The speed of sound varies with temperature, and it varies in opposite directions for lipid bearing tissue vs. water bearing tissue.
- C. The temperature of a local region of tissue can be intentionally increased by focusing an ultrasound array and increasing the transmit power beyond what is typically used for imaging.
- D. High intensity focused ultrasound can displace tissue by means of acoustic radiation force, in essence, bouncing the sound waves off the tissue.
- E. Speckle-tracking can detect very small displacements in tissue.

Explanation: Answer A is nonsense.

[*imaging0514.mcq*]

38. Regarding the speed of sound c , impedance Z , compressibility κ , and density ρ , all of the following are true *except*

- A. All are true.
- B. c is dependent on both κ and ρ .
- C. Z is dependent on both κ and ρ .
- D. Z increases as ρ increases.
- E. c decreases as ρ increases.

Explanation: Higher density makes the tissue stiffer and slower to accelerate.
[*imaging0427.mcq*]