BioE 1330 - Review Chapters 10 and 11 (Ultrasound) 9/27/2018

Instructions: On the Answer Sheet, enter your 2-digit ID number (with a leading 0 if needed) in the boxes of the ID section. *Fill in the corresponding numbered circles.* Answer each of the numbered questions by filling in the corresponding circles in the numbered question section. Print your name in the space at the bottom of the answer sheet. Sign here stating that you have neither given nor received help.

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your signature

1. In ultrasound, with an incident planar wave that is not perpendicular to a boundary where the acoustic impedance Z changes, the following are true:

I. Reflection will always occur.
II. Refraction will occur if and only if the wave velocity c changes.
III. Particle velocity v will always equal wave velocity c on either side of the boundary

A. I, II, and III

B. I and III

C. II and III

D. I

E. I and II

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

A. Their pressure is attenuated by $1/r$ where r is the distance traveled.

B. They can be viewed equally well as functions of time or of distance.

C. Their general solution includes the superposition of a forward-traveling wave and a backward-traveling wave.

D. Spatial variation occurs only along one particular dimension.

E. They are approximated within the Very Near Field near the center of the ultrasound transducer, where the transducer appears very large.

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

A. They are generally produced in short bursts.

B. They are primarily shear rather than compression waves.

C. They do not travel well through air or bone.

D. Distance to a target is determined by time of flight.

E. Their absorption coefficient in biological tissue is roughly proportional to frequency.

4. In ultrasound, the space being imaged is organized into three regions. In each region, a particular approximation best describes the beam pattern. Those approximations are

I - the Fraunhofer approximation
II - the geometric appoximation (the very near field)
III - the Fresnel approximation

In what order do the corresponding regions of space occur, as one moves *away from the transducer*?

A. III, I, II

B. I, II, III

C. II, III, I

D. I, III, II

E. II, I, III

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

A. It is also known as the "far field".

B. The field pattern is basically a function of angle off the axis.

C. There are *no* null points due to destructive interference along the axis in this zone.

D. There *are* null points due to destructive interference off the axis in this zone.

E. All are true.

6. Which of the following statements is *false* about the use of the complex exponential in modeling ultrasound?

A. It is also the foundation of much of modern optics.

B. It allows for the imaginary component of a physical quantity, by assuming that the imaginary component will be canceled by a complex conjugate.

C. It permits mathematically tenable integration of many sources of ultrasound waves converging on a single point to determine the extent of constructive or destructive interference.

D. It applies only to single crystals and not to phased arrays.

E. It generally assumes superposition of the ultrasound waves.

7. Which of the following statements is *false* about the piezoelectric crystals used in ultrasound transducers?

A. The strain produced by a unit electric field ("transmitting constant" in meters per volt) and the potential produced by unit stress ("receiving constant" in volt-meters per Newton) are always numerically equal values.

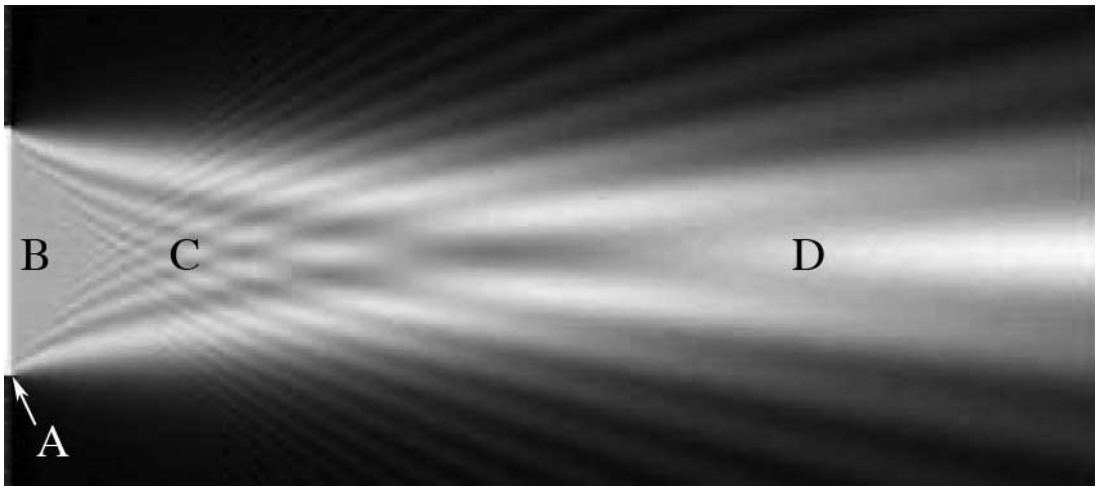
B. Energy is mainly lost due to damping by the acoustic backing behind the crystal, which is intentionally included to shorten the duration of the transmit pulse.

C. An incoming acoustic wave creates mechanical displacement, which creates an electrical potential.

D. The resonant frequency of a crystal (typically 1-20 MHz in medical ultrasound) is largely determined by the thickness of that crystal

E. An induced electric field produces strain (mechanical displacement), which causes an acoustic wave.

8. In ultrasound, which of the following is *not* true about the *field pattern*, an example of which is shown below (the figure actually shows a field pattern for light, but is analogous to that found with ultrasound).



A. The label "B" marks the Very Near Field, where the aperture appears infinitely large.

B. The field pattern represents a pattern of standing waves of constructive and destructive interference for a given aperture and wavelength, and is independent of the particular target being scanned.

C. The label "C" marks the Fraunhofer zone.

D. The label "A" marks the aperture (or indicator function) of the transducer.

E. In the region labeled "D" the field pattern becomes a function simply of angle from the axis.

9. In ultrasound, with an incident planar wave that is not perpendicular to a boundary where the acoustic impedance Z changes, which of the following is (are) TRUE?

I. Refraction will always occur.
II. Reflection will always occur.
III. Particle velocity v is generally much less than wave velocity c.

A. II and III

B. I, II, and III

C. only III

D. I and III

E. I and II

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

A. Spatial variation occurs only along one particular dimension orthogonal to the plane of the wave.

B. Their general solution includes the superposition of a forward-traveling wave and a backward-traveling wave.

C. They are approximated within the Fraunhofer zone.

D. They can be viewed equally well as functions of time or of distance.

E. No attenuation occurs with distance along the direction of propagation.

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

A. Their absorption coefficient in biological tissue is largely independent of wavelength.

B. They are used primarily to detect changes in acoustic impedance.

C. They are primarily compression rather than shear waves.

D. Distance to a target is determined by time of flight.

E. Velocity in soft tissue (not air or bone) is fairly constant at around 1540 meters/second ($< \pm 10\%$).

12. 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. It generally assumes superposition of the ultrasound waves in a linear system.

C. It permits mathematically tenable integration of many sources of ultrasound waves converging on a single point to determine the extent of constructive or destructive interference.

D. It is also the foundation of much of modern optics.

E. It allows for the imaginary component of a physical quantity, by requiring that the imaginary component will be canceled by a complex conjugate.

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

A. Resolution in the range direction generally stays constant with increasing range.

B. Resolution is manifested by a "resolution cell" within which many actual reflectors create a total reflection of variable brightness, accounting for speckle.

C. Resolution increases (gets better) with increasing frequency.

D. Lateral resolution generally increases (gets better) with increasing range.

E. Resolution in the range direction is limited by the duration of the envelope of the transmitted pulse.

14. Which of the following statements is (are) *true* about the pulse-echo mode of operation in a phased array ultrasound scanner?

I. The same transducers usually generate and receive the ultrasound pulses.
II. The beam is steered by changing the duration of the transmit pulse envelope.
III. Color Doppler is possible with pulse-echo ultrasound.

A. I and II.

B. II and III.

C. I.

D. I, II, and III.

E. I and III.

15. Posterior enhancement (through transmission) is a type of ultrasound artifact often used in diagnosis because

A. it enables speckle tracking of cells within the fluid in any direction, even orthogonal to the ultrasound beam.

B. it can measure the blood volume of the ventricle.

C. it helps determine the velocity of blood flowing through a vessel.

D. it can differentiate a solid mass vs a fluid filled cyst, where this may not be possible CT.

E. it can cause a reflection of the image at a very large discontinuity in acoustic impedance, such as between the lung and the diaphram.

16. Which of the following statements is *false* about phased arrays in ultrasound?

A. Timing between the elements can be used to steer a beam both for transmitting and receiving.

B. Grating lobes will occur if the spacing between the elements of the array is greater than a wavelength of the ultrasound.

C. Given a two-dimensional array of transducer elements, 3D ultrasound images may be acquired by steering the beam in both azimuth and elevation.

D. Timing between the elements can be used to focus a beam both for transmitting and receiving.

E. Dynamic focusing of the array, i.e., during the transmission and reception of a single pulse, is possible for both transmission and reception.

17. Which of the following statements is *false* about Doppler in ultrasound?

A. Doppler shift is due to the relativistic effect of phonons.

B. In Color Doppler, pulses of ultrasound are analyzed as to their phase shift over the period between pulses, and therefore aliasing can result if enough phase shift occurs.

C. Motion away from the transducer results in a shift to a lower frequency, but motion orthogonal to the ultrasound beam results in no Doppler shift.

D. In continuous-wave Doppler, discrete pulses of ultrasound are not used, but rather a continuous sinusoid is transmitted, received, and shifted by the transmit frequency down to the audio range, where motion may simply be heard as a "whooshing" sound.

E. Power Doppler delivers a more sensitive measure of absolute motion but cannot determine the direction of that motion.

18. Which of the following statements regarding the Doppler effect is (are) true?

I Given a stationary source, moving the receiver toward the source will result in a higher frequency heard by the receiver than if the receiver were stationary.

II Given a stationary receiver, moving the source toward the receiver will result in a lower frequency heard by the receiver than if the source were stationary.

III If the source and receiver are moving in the same direction at the same speed, the receiver will not hear any change in frequency.

A. III only

B. II only

C. I and III

D. II and III

E. I and II

19. Ultrasound is useful for non-invasive imaging of all of the following, it except:

A. Fetus
B. Lungs
C. Heart
D. Liver
E. Blood vessels

20. Which of the following statements about clinical ultrasound is *false*?

A. Ultrasound transmits well through air.
B. Ultrasound operates in the megahertz range.
C. Ultrasound does not expose the patient to ionizing radiation.
D. Most of the delivered energy becomes heat.
E. Ultrasound detects changes in acoustic impedance.

21. As the frequency of an ultrasound beam increases:

A. Resolution decreases and depth of penetration increases
B. Resolution increases and depth of penetration remains the same
C. Resolution increases and depth of penetration increases
D. Resolution increases and depth of penetration decreases
E. Resolution decreases and depth of penetration decreases

22. Ultrasound is sound with frequencies above

A. 20 Hz
B. 20 MHz
C. None of them
D. 2000 Hz
E. 20 kHz

23. In ultrasound imaging, SNR increases with

A. Increasing transducer focal distance because intensity is lower
B. Decreasing transducer focal distance because intensity is higher
C. Decreasing transducer focal distance because intensity is lower
D. Increasing transducer focal distance because intensity is higher
E. None of them

24. The following is true about resolution in ultrasound

A. None of them

B. Transverse resolution degrades with shorter focal distance and longitudinal resolution degrades with shorter pulses.

C. Transverse resolution improves with shorter focal distance and longitudinal resolution improves with shorter pulses.

D. Transverse resolution improves with shorter focal distance and longitudinal resolution degrades with shorter pulses.

E. Transverse resolution degrades with shorter focal distance and longitudinal resolution improves with shorter pulses.

25. 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 in the range direction is limited by the duration of the envelope of the transmitted pulse.

C. Resolution increases (gets better) with increasing frequency.

D. Lateral resolution generally decreases (gets worse) with increasing range.

E. Resolution is manifested by a "resolution cell" within which many actual reflectors create a total reflection of variable brightness, accounting for speckle.

26. 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.

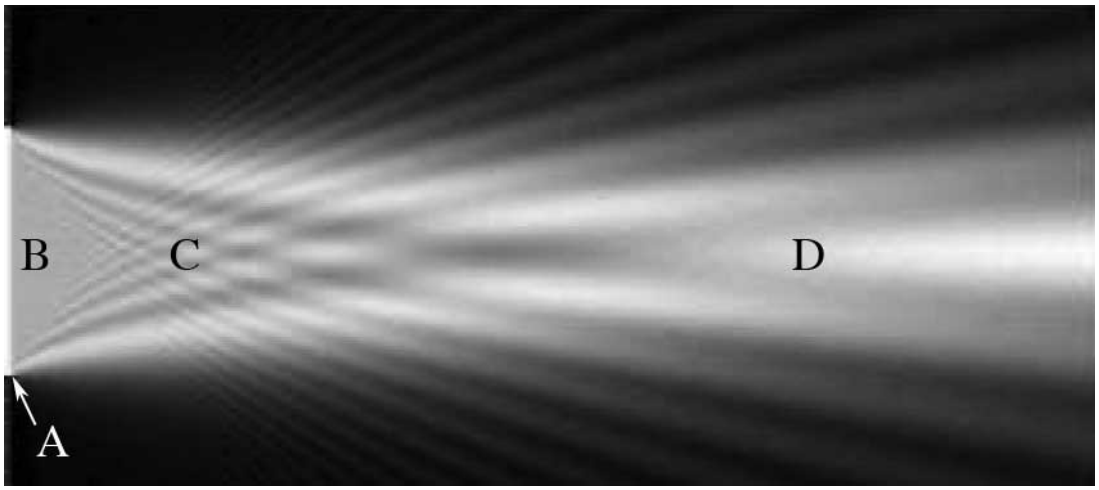
B. It permits the mathematical manipulation of an imaginary component of a physical quantity, by always requiring the presence of a complex conjugate for each complex exponential.

C. It leads directly to the use of Fourier transform, especially in the far field.

D. It may be used for compression waves as found in ultrasound, but is not applicable to optics, where the electromagnetic waves are transverse.

E. It permits mathematically tenable integration over an aperture of an infinite number of ultrasound sources according to Huygen's principle.

27. 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. The label "B" marks the Very Near Field, where plane waves are approximated, at least near the center axis, and thus do not create significant standing waves.

B. All are true.

C. 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.

D. In the Fraunhofer zone the field pattern becomes a function basically of angle from the axis.

E. In the Fresnel zone no null points exist along the central axis.

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

A. They can be viewed equally well as functions of time or of distance.

B. Spatial variation occurs only along radial directions from the center of the spherical wave.

C. They are central to Huygen's principle.

D. No attenuation occurs with distance along the direction of propagation.

E. 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.

29. 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 and II.

B. None of the other answers

C. I, II, and III.

D. II and III.

E. I and III.

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

A. Velocity of ultrasound waves in soft tissue (not air or bone) is fairly constant at around 1540 meters/second ($< \pm 10\%$).

B. The frequency of reflected ultrasound waves is independent of the velocity of moving target in the tissue.

C. They are primarily compression rather than shear waves.

D. Distance to a target is determined by time of flight.

E. Absorption in biological tissue is roughly proportional to frequency.

31. Which of the following statements is (are) *true* about the pulse-echo mode of operation in a phased array ultrasound scanner?

I. The transmit beam is steered and focussed by controlling the relative timing of the transmit pulses to the elements of the array.
II. The receive beam pattern can be changed even after the transmit pulse has been sent.
III. Grating lobes result if the spacing between transducer elements is too large.

A. I, II, and III.

B. II and III.

C. I and II.

D. None of the others is correct.

E. I and III.

32. Which of the following statements is *false* about Doppler in ultrasound (or all of the others are true)?

A. Power Doppler delivers a more sensitive measure of absolute motion but cannot determine the direction of that motion.

B. All of the others are true

C. In Color Doppler, pulses of ultrasound are analyzed as to their phase shift over the period between pulses, and therefore aliasing can result if enough phase shift occurs.

D. Motion orthogonal to the ultrasound beam results in Doppler shift to a lower frequency.

E. In continuous-wave Doppler, discrete pulses of ultrasound are not used, but rather a continuous sinusoid is transmitted, received, and shifted by the transmit frequency down to the audio range, where motion may simply be heard as a "whooshing" sound.

33. Ultrasound is commonly used in adults for non-invasive imaging of all of the following, it except:

A. Kidney

B. Brain

C. Fetus

D. Heart

E. Liver

34. Which of the following statements is (are) *true* about resonance in an ultrasound transducerr?

I. The resonant frequency is largely determined by the thickness of the transducer and the speed of sound within it.
II. The longer the resonance lasts for a given transmit pulse, the better the resolution in the range direction of the resulting image .
III. Resonant energy is primarily and intentionally lost out the back of the transducer.

A. I, II, and III.

B. II and III.

C. None of the others is correct.

D. I and III.

E. I and II.

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

A. The lateral resolution in this zone falls off linearly with distance to the transducer.

B. It is also known as the "far field".

C. There are null points due to destructive interference along the axis in this zone.

D. All are true.

E. The field pattern is basically a function of angle off the axis.

36. Which of the following statements is (are) *true* about the pulse-echo mode of operation in a phased array ultrasound scanner?

I. Grating lobes are possible with phased arrays, but not with single array transducers.
II. The transmit beam as well as the receive field pattern is steered by changing the relative timing between the elements of the array.
III. Dynamic focusing is possible during the reception of echos from a given ultrasound pulse, but not during its transmission.

A. I and III.

B. I, II, and III.

C. I and II.

D. II and III.

E. II

37. In ultrasound, with an incident planar wave that is not perpendicular to a boundary where the acoustic impedance Z changes, the following are true *except* (or all are true).

A. All are true

B. Reflection will always occur.

C. Refraction will occur if and only if the wave velocity c changes, as governed by Snell's Law.

D. Particle velocity on both sides of the boundary v is independent of (and generally much slower than) wave velocity c

E. The direction of wave propagation will bend *towards* the perpendicular to the boundary, if the speed of sound decreases across the boundary.

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

A. They are approximated within the Very Near Field of the ultrasound transducer, where the transducer face appears infinitely large.

B. Their pressure in not attenuated as the distance traveled increases.

C. Their general solution includes the superposition of a forward-traveling wave and a backward-traveling wave.

D. They can be viewed equally well as functions of time or of distance.

E. Spatial variation occurs only along directions perpendicular to the direction of propagation.

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

A. They are primarily compression rather than shear waves.

B. Distance to a target is determined by time of flight.

C. Their absorption coefficient in biological tissue is roughly proportional to frequency.

D. Scattering of the waves from targets smaller than the acoustic wavelength is primarily a source of noise in the image.

E. They are generally produced in short bursts.

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

A. There *are* null points due to destructive interference off the axis in this zone.

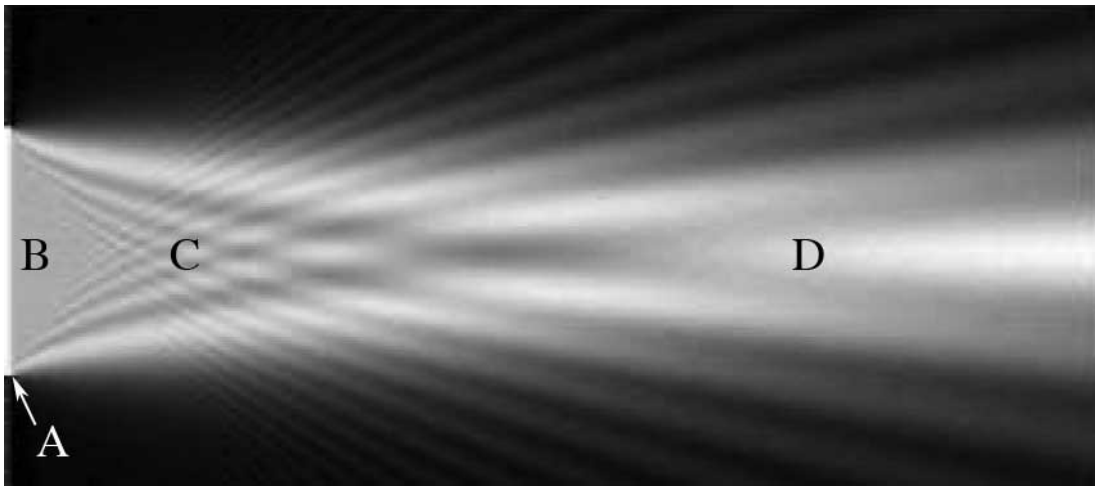
B. There are *no* null points due to destructive interference along the axis in this zone.

C. All are true.

D. The field pattern is basically a function of angle off the axis.

E. Lateral image resolution within this zone is constant with distance from the transducer.

41. In ultrasound, which of the following is *not* true about the *field pattern*, an example of which is shown below (the figure actually shows a field pattern for light, but is analogous to that found with ultrasound).



A. The field pattern is for the transmission of ultrasound by the transducer, not for the reception of echoes.

B. The field pattern represents a pattern of standing waves of constructive and destructive interference for a given aperture and wavelength, and is independent of the particular target being scanned.

C. The label "C" marks the Fresnel zone.

D. The label "B" marks the Very Near Field, where the transducer appears infinitely large.

E. The label "D" marks the Fraunhofer zone.

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

A. They generally operate in the 100-200 MHz range.

B. The use piezoelectric crystals, which both transmit and receive ultrasound.

C. All are true.

D. Ultrasound gel is required to avoid air between the transducer and the patient, which would prevent the ultrasound wave from traveling efficiently.

E. Resonance in the transducer element is measured by the Q factor, which is the height of the equivalent bandpass frequency response over the width, and which increases with the length of the resulting pulse.

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

A. All are true.

B. 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.

C. The resonance of the transducer is intentionally dampened, primarily from behind (the side away from the patient).

D. 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.

E. A matching layer 1/4 wavelength thick is used so that reflected waves within the layer are 180° out of phase and cancel.

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

A. They are a general solution to first-order differential equations, such as the attenuation of a signal by absorption over a distance.

B. All are true.

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.

E. 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.

45. Huygen's principle is best stated as

A. The amplitude of a spherically propagating wave must be equal in all directions.

B. A spherical wave can propagate in an outward or inward direction

C. Interference patterns are best approximated by assuming a constant speed of wave propagation throughout the space.

D. A wavefront may be interpreted as a collection of the centers of spherically propagating waves that interfere with each other.

E. The imaginary component of a complex exponential is not linear.

46. Which of the following statements is *false* about the pulse-echo mode of operation (or all are true)

A. The same transducers usually generate and receive the ultrasound pulses.

B. All are true.

C. Short-duration collections of cycles are generally used, representing the underlying frequency of the ultrasound.

D. In the frequency domain, the spectrum of the transmitted signal appears as a band of frequencies whose width is inversely related to the duration of the transmitted signal.

E. Color Doppler is not possible with pulse-echo ultrasound, since the underlying frequency of the ultrasound cannot be accurately determined after just a few cycles.

47. Which of the following statements is *false* about phased arrays in ultrasound (or all are true)?

A. Timing between the elements can be used to steer a beam both for transmitting and receiving.

B. All are true.

C. Grating lobes, which occur with single element transducers that are mechanically moved, will not occur with phased arrays.

D. Dynamic focusing of the array is possible during the reception of the echo from a single transmitted pulse, but is not possible for the transmitted pulse itself.

E. Given a two-dimensional array of transducer elements, 3D ultrasound images may be acquired by steering the beam in both azimuth and elevation.

48. Which of the following statements is *false* about phased arrays in ultrasound (or all are true)?

A. All are true.

B. They are not capable of being used for Doppler imaging.

C. Given a two-dimensional array of transducer elements, 3D ultrasound images may be acquired by steering the beam in both azimuth and elevation.

D. Timing between the elements can be used to steer a beam both for transmitting and receiving.

E. Dynamic focusing of the array is possible during the reception of the echo from a single transmitted pulse, but is not possible for the transmitted pulse itself.

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

A. 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.

B. All are true.

C. They generally are used to translate differences in path-length into differences in phase, given a certain frequency.

D. They are also the foundation of much of modern optics, which has many similarities to ultrasound.

E. They allow for the imaginary component of a physical quantity, but generally require that the imaginary component will be canceled by a complex conjugate.

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

A. The field pattern is basically a function of angle off the axis.

B. All are true.

C. There are *no* null points due to destructive interference along the axis in this zone.

D. The resolution cell expands laterally (orthogonal to the range direction) with distance from the transducer, but remains constant in the range direction.

E. There *are* null points due to destructive interference off the axis in this zone.

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

A. Distance to a target is determined by time of flight.

B. They travel with so little attenuation through bone and air that no echoes are generated in these tissues.

C. Echoes are generated primarily because of changes in the acoustic impedance of the tissue

D. They are primarily compression rather than shear waves.

E. Scattering of the waves from targets smaller than the acoustic wavelength is the primary source of useful information in the image.

52. In ultrasound, with an incident planar wave that is not perpendicular to a boundary where the acoustic impedance Z changes, the following are true *except* (or all are true).

A. All are true

B. The direction of wave propagation will bend *towards* the perpendicular to the boundary if the speed of sound *increases* across the boundary.

C. Refraction will occur if and only if the wave velocity c changes, as governed by governed by Snell's Law.

D. Reflection will always occur.

E. Particle velocity on both sides of the boundary v is independent of (and generally much slower than) wave velocity c

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

A. Lung

B. Breast

C. Kidney

D. Testicle

E. Fetus

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

A. c is dependent on both κ and ρ.

B. Z is dependent on both κ and ρ.

C. c decreases as ρ increases.

D. All are true.

E. Z increases as ρ increases.

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

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

A. It contains derivatives of pressure in space.

B. It contains derivatives of pressure in time.

C. The equation describes the creation and propagation of pressure waves.

D. The "del" or "nabla" symbol squared indicates the Laplacian operator, which is the divergence of the gradient.

E. All are true.

56. The following is true about Time-Gain Compensation (TGC), *except* (or all are true)

A. It controls the gain of the amplifier as the echoes return from an individual transmit pulse.

B. All are true.

C. It is often represented by a column of slidable adjustments on the ultrasound scanner that are manually adjusted during operation.

D. It is used to compensate for the enormous attenuation of ultrasound to the target and back again.

E. It permits the brightness of the image to be adjusted at various depths.

57. In ultrasound, with an incident planar wave whose direction of motion is not perpendicular to a planar boundary where the acoustic impedance Z changes, the following are true *except* (or all are true).

A. Reflection, if it occurs, will be in the same direction as the incident wave.

B. Particle velocity on both sides of the boundary v is different (and generally much slower) than wave velocity c

C. Reflection will always occur.

D. All are true

E. Refraction will occur if and only if the wave velocity c changes, as governed by Snell's Law.

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

A. They are approximated at a great distance from the point source of a spherical wave.

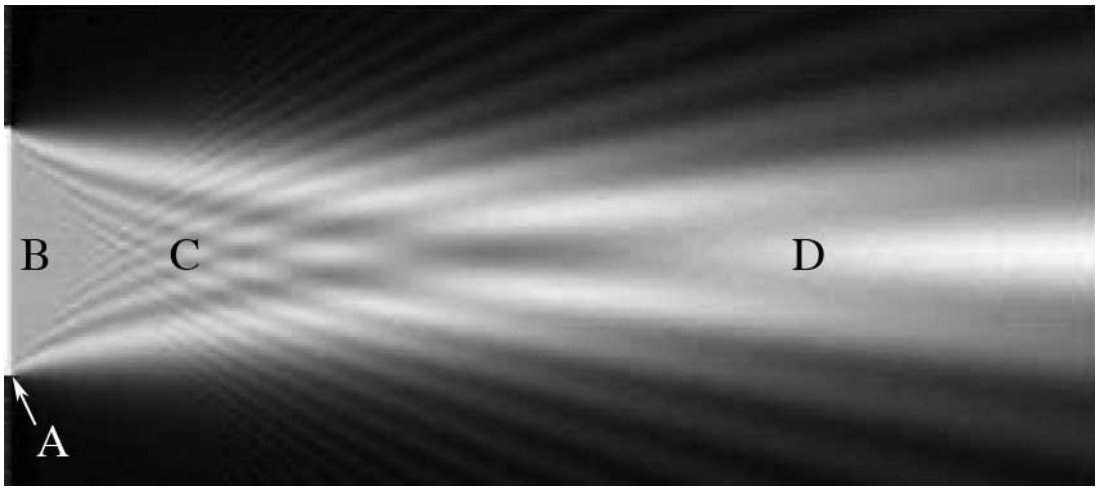
B. They are inherently stationary (standing waves).

C. Spatial variation occurs only along the direction of motion for the wave.

D. Their general solution includes the superposition of a forward-traveling wave and a backward-traveling wave.

E. No attenuation occurs with distance along the direction of propagation.

59. 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. 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.

B. In the Fresnel zone null points may exist along the central axis.

C. In the Fraunhofer zone the field pattern becomes a function basically of angle from the axis.

D. 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.

E. All are true.

60. 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 allow for the imaginary component of a physical quantity, by requiring that the imaginary component will be canceled by a complex conjugate.

C. They are the general solution to *second* order differential equations, such as resonating systems and waves.

D. 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.

E. They are also the foundation of much of modern optics, where waves are transverse rather than longitudinal, but still sinusoidal in nature.

61. Huygen's principle is best stated as

A. Wavefronts are always parallel.

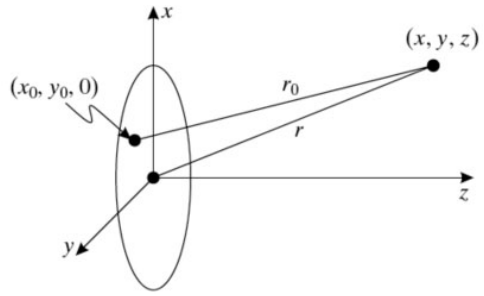
B. The amplitude of a spherically propagating wave must be equal in all directions.

C. Energy can be seen as traveling in discrete packets, or "particles".

D. Any wavefront may be interpreted as a collection of the centers of spherically propagating waves that interfere with each other to form the particular wavefront.

E. A spherical wave can propagate in an outward or inward direction

62. Which of the following is *not* true about the diagram below, showing an ultrasound transducer, and a point (x, y, z) in space (or all are true)?



A. The distance between point $(x_0, y_0, 0)$ on the transducer and point (x, y, z) is governed by the Pythagorean theorem.

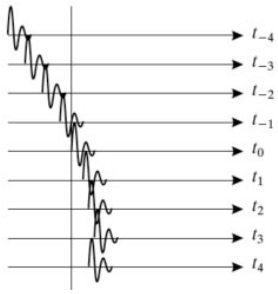
B. The field pattern at point (x, y, z) is determined by an integration over the all possible points $(x_0, y_0, 0)$ on the transducer, each with its own particular relative phase determined by r_0.

C. All are true.

D. The actual signal received by the ultrasound transducer will involve an integration of signals generated from all points (x, y, z) weighted by various factors.

E. The diagram can be applied to both transmission and reception between the transducer and point (x, y, z).

63. Which of the following is *not* true about the diagram below, showing the timing of electronic pulses sent to the elements of a phased ultrasound array, ordered t_{-4} to t_4 (or all are true)?



A. The wavefronts generated from the individual transducer elements combine to create an overall wavefront whose form is governed by the relative delays between the pulses to the transducer elements.

B. The array acts analogous to a prism, sending the wave off to one side of the central axis.

C. The transmitted ultrasound pulse that is generated can be dynamically focused by changing the relative delays after the transmission.

D. The array acts analogous to a lens, focusing the wave at some finite distance.

E. All are true.

64. Which of the following statements is *false* about phased arrays in ultrasound (or all are true)?

A. All are true

B. Timing between the elements can be used to steer a beam both for transmitting and receiving.

C. 3D ultrasound images are usually acquired by mechanically rotating a one-dimensional array, when high-speed is not required.

D. Given a two-dimensional array of transducer elements, 3D ultrasound images may be acquired by steering the beam in both azimuth and elevation.

E. They are capable of being used for Doppler imaging.

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

A. It results in a pseudorandom pattern of intensity variation.

B. It arises due to multiple scatterers within a single resolution cell.

C. All are true.

D. It results from multiple Doppler shifts from individual targets (such as red blood cells) moving in different directions.

E. It moves with tissue and can be used to track that motion.

66. Which of the following statements is *false* about phased arrays in ultrasound (or all are true)?

A. All are true

B. Timing between the elements can be used to steer a beam both for transmitting and receiving.

C. They can perform dynamic focusing, in which the focus is moved further out in range while receiving echoes from a single transmitted pulse to follow the expected location of targets.

D. They are capable of being used for Doppler imaging.

E. They present a fixed beam pattern and thus must be physically moved to create an image.

67. The following is true about Time-Gain Compensation (TGC), *except* (or all are true)

A. It is used to compensate for the enormous attenuation of ultrasound to the target and back again.

B. It controls the gain of the amplifier as the echoes return from an individual transmit pulse.

C. It permits the brightness of the image to be adjusted at various depths, usually by means of a set of slider controls.

D. It allows for refocusing at different depths.

E. All are true.

68. The following are true about standing waves, *except*

A. They consist of regions of constructive and destructive interference.

B. They are functions that change in time.

C. They occur in the very near field (geometric zone), where only plane waves are present.

D. They are responsible for the field patterns generated by an ultrasound transducer

E. They are created when waves of the same frequency, but traveling in different directions, are superimposed.

69. The following are true about non-linear effects in ultrasound, *except* (or all are true).

A. Peaks in the pressure waves actually move faster than the average speed of sound.

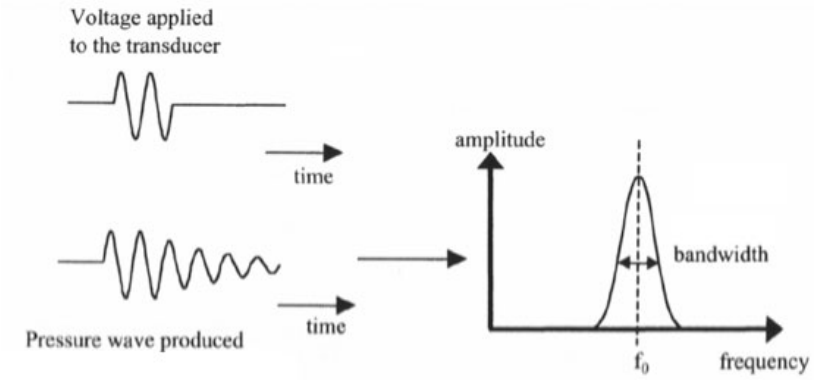
B. Differences in the velocity variation due to tissue type form the basis of "harmonic imaging."

C. All are true.

D. Troughs in the pressure waves actually move slower than the average speed of sound.

E. They cause harmonics to appear that are not in the original waveform generated at the transducer.

70. 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. Improved spatial resolution for the ultrasound image is obtained by lowering the Q of the crystal.

B. A greater value for Q corresponds to a narrower band of frequencies.

C. All are true.

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. Damping the resonance of the ultrasound crystal lowers the value of Q.

71. The attenuation coefficient α is modeled as some constant a times the frequency f raised to the power b, that is, $\alpha = af^b$. Given that the amplitude of an ultrasound wave is reduced from A_0 at range $z = 0$ to A_z at range z, and that

$\alpha = -\frac{1}{z} 20 \log \frac{A_z}{A_0}$

which of the following is *not* true (or all are true)?

A. The value of b tends to be about 1 in biological tissue.

B. All are true.

C. Attenuation falls off exponentially, since each unit length of tissue removes a certain percentage of the remaining signal.

D. The value of *alpha* increases with frequency, causing penetration to be *deeper* for ultrasound scanners with *better* resolution.

E. The value of a varies from tissue to tissue, and is extremely high for lung.

72. Regarding the signal received by an ultrasound transducer, which of the following statements about the equation below is *false* (or all are true)?

$$\mathrm{r}(t) = K \iiint R(x, y, z)\mathrm{n}(t - 2c^{-1}z)e^{-2\mu_a z}[q(x, y, z)]^2 dx\, dy\, dz$$

A. It assumes homogeneous attenuation throughout the tissue.

B. All are true.

C. $q(x, y, z)$ is the field pattern at location (x, y, z), a standing wave consisting of regions of constructive and destructive interference, which determines the location being imaged by a particular transmitted ultrasound pulse.

D. The received signal $\mathrm{r}(t)$ and the underlying signal $\mathrm{n}(t - c^{-1}z)$ are real, because they represent real phenomena.

E. The occurrence of the number 2 three times in the equation is due, each time, to the fact that the ultrasound pulse travels from the transducer to the target and then back again to the transducer.

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BioE 1330 - Review Chapters 10 and 11 (Ultrasound) 9/27/2018
Answer Sheet - Correct answer is A for all questions

1. In ultrasound, with an incident planar wave that is not perpendicular to a boundary where the acoustic impedance Z changes, the following are true:

I. Reflection will always occur.
II. Refraction will occur if and only if the wave velocity c changes.
III. Particle velocity v will always equal wave velocity c on either side of the boundary

A. I and II

B. I and III

C. II and III

D. I, II, and III

E. I

Explanation: Refraction depends only on c. Reflection depends only on Z and the angle of incidence. Particle velocity v is generally much slower than wave velocity c.
[*imaging0044.mcq*]

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

A. Their pressure is attenuated by $1/r$ where r is the distance traveled.

B. Their general solution includes the superposition of a forward-traveling wave and a backward-traveling wave.

C. They can be viewed equally well as functions of time or of distance.

D. Spatial variation occurs only along one particular dimension.

E. They are approximated within the Very Near Field near the center of the ultrasound transducer, where the transducer appears very large.

Explanation: Whereas spherical waves spread out attenuating pressure by $1/r$, planar waves do not spread out, and thus maintain their full amplitude.
[*imaging0045.mcq*]

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

A. They are primarily shear rather than compression waves.

B. Their absorption coefficient in biological tissue is roughly proportional to frequency.

C. They are generally produced in short bursts.

D. Distance to a target is determined by time of flight.

E. They do not travel well through air or bone.

Explanation: Clinical ultrasound uses compression waves.
[*imaging0046.mcq*]

4. In ultrasound, the space being imaged is organized into three regions. In each region, a particular approximation best describes the beam pattern. Those approximations are

I - the Fraunhofer approximation
II - the geometric appoximation (the very near field)
III - the Fresnel approximation

In what order do the corresponding regions of space occur, as one moves *away from the transducer*?

A. II, III, I

B. I, II, III

C. I, III, II

D. II, I, III

E. III, I, II

Explanation: The order is geometric (very near field), Fresnel (near field), and then Fraunhofer (far field).
[*imaging0053.mcq*]

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

A. All are true.

B. It is also known as the "far field".

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: These are all true. Null points on the axis do occur in the Fresnel zone, but in the far field the aperture appears small enough that the field pattern is only fall off with distance squared and otherwise only varies with angle off the axis.
[*imaging0054.mcq*]

6. Which of the following statements is *false* about the use of the complex exponential in modeling ultrasound?

A. It applies only to single crystals and not to phased arrays.

B. It permits mathematically tenable integration of many sources of ultrasound waves converging on a single point to determine the extent of constructive or destructive interference.

C. It allows for the imaginary component of a physical quantity, by assuming that the imaginary component will be canceled by a complex conjugate.

D. It is also the foundation of much of modern optics.

E. It generally assumes superposition of the ultrasound waves.

Explanation: 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. A linear system with superposition of the waves is generally assumed. This powerful mathematical approach applies as well to phased arrays as to single crystals.
[*imaging0055.mcq*]

7. Which of the following statements is *false* about the piezoelectric crystals used in ultrasound transducers?

A. The strain produced by a unit electric field ("transmitting constant" in meters per volt) and the potential produced by unit stress ("receiving constant" in volt-meters per Newton) are always numerically equal values.

B. An induced electric field produces strain (mechanical displacement), which causes an acoustic wave.

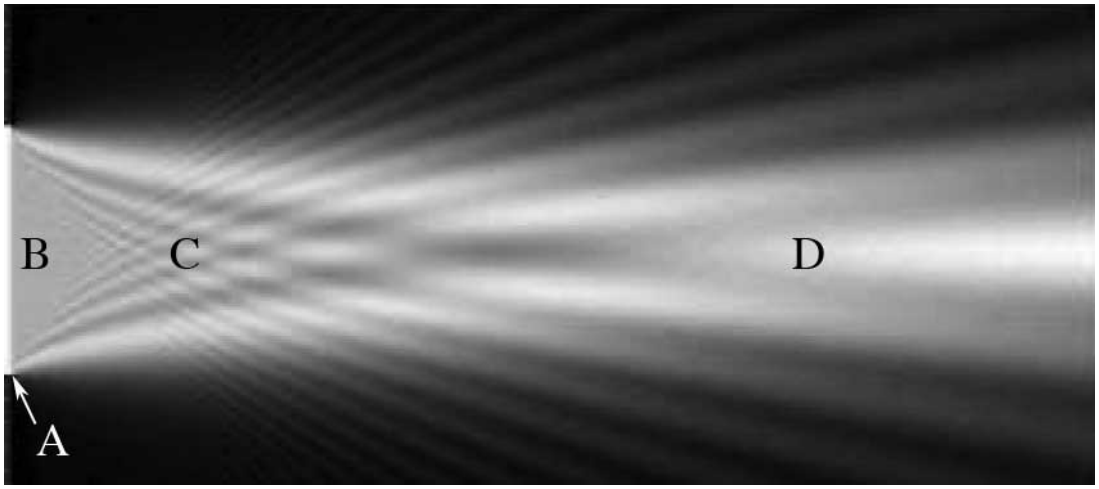
C. An incoming acoustic wave creates mechanical displacement, which creates an electrical potential.

D. The resonant frequency of a crystal (typically 1-20 MHz in medical ultrasound) is largely determined by the thickness of that crystal

E. Energy is mainly lost due to damping by the acoustic backing behind the crystal, which is intentionally included to shorten the duration of the transmit pulse.

Explanation: The transmitting constant and receiving constants don't even have the same physical units, so they will certainly *not* have the same numerical values.
[*imaging0056.mcq*]

8. In ultrasound, which of the following is *not* true about the *field pattern*, an example of which is shown below (the figure actually shows a field pattern for light, but is analogous to that found with ultrasound).



A. The label "C" marks the Fraunhofer zone.

B. The field pattern represents a pattern of standing waves of constructive and destructive interference for a given aperture and wavelength, and is independent of the particular target being scanned.

C. The label "A" marks the aperture (or indicator function) of the transducer.

D. The label "B" marks the Very Near Field, where the aperture appears infinitely large.

E. In the region labeled "D" the field pattern becomes a function simply of angle from the axis.

Explanation: The Fraunhofer zone, otherwise known as the *far field* is labeled "D."
[*imaging0119.mcq*]

9. In ultrasound, with an incident planar wave that is not perpendicular to a boundary where the acoustic impedance Z changes, which of the following is (are) TRUE?

I. Refraction will always occur.
II. Reflection will always occur.
III. Particle velocity v is generally much less than wave velocity c.

A. II and III

B. I and II

C. I and III

D. I, II, and III

E. only III

Explanation: Refraction requires a non-perpendicular angle and a change in the speed of propagation, $c = \rho Z$, where ρ is density. Therefore, c can still be the same in two materials, even though Z is different, if ρ is also different. Therefore I is false. Reflection depends only on a change in Z, so II is true. Particle velocity v is generally much slower than wave velocity c.
[*imaging0123.mcq*]

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

A. They are approximated within the Fraunhofer zone.

B. Their general solution includes the superposition of a forward-traveling wave and a backward-traveling wave.

C. They can be viewed equally well as functions of time or of distance.

D. Spatial variation occurs only along one particular dimension orthogonal to the plane of the wave.

E. No attenuation occurs with distance along the direction of propagation.

Explanation: They are approximated within the Very Near Field of the transducer, not in the Fraunhofer zone. In the Fraunhofer zone the waves diverge at a constant angle acting more like spherical waves.
[*imaging0124.mcq*]

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

A. Their absorption coefficient in biological tissue is largely independent of wavelength.

B. Velocity in soft tissue (not air or bone) is fairly constant at around 1540 meters/second ($< \pm 10\%$).

C. They are primarily compression rather than shear waves.

D. Distance to a target is determined by time of flight.

E. They are used primarily to detect changes in acoustic impedance.

Explanation: Absorption in biological tissue is roughly proportional to frequency and thus inversely proportional to wavelength, given that velocity (in soft tissue) is fairly constant at around 1540 meters/second.
[*imaging0125.mcq*]

12. 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. It permits mathematically tenable integration of many sources of ultrasound waves converging on a single point to determine the extent of constructive or destructive interference.

C. It allows for the imaginary component of a physical quantity, by requiring that the imaginary component will be canceled by a complex conjugate.

D. It is also the foundation of much of modern optics.

E. It generally assumes superposition of the ultrasound waves in a linear system.

Explanation: 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. A linear system with superposition of the waves is generally assumed.
[*imaging0128.mcq*]

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

A. Lateral resolution generally increases (gets better) 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. Resolution in the range direction generally stays constant with increasing range.

E. Resolution in the range direction is limited by the duration of the envelope of the transmitted pulse.

Explanation: Lateral resolution generally *decreases* (gets worse) with increasing range.
[*imaging0129.mcq*]

14. Which of the following statements is (are) *true* about the pulse-echo mode of operation in a phased array ultrasound scanner?

I. The same transducers usually generate and receive the ultrasound pulses.
II. The beam is steered by changing the duration of the transmit pulse envelope.
III. Color Doppler is possible with pulse-echo ultrasound.

A. I and III.

B. I and II.

C. II and III.

D. I, II, and III.

E. I.

Explanation: The beam is steered by changing the relative delay for each of the elements of the array, not the duration of the transmit pulse envelope.
[*imaging0130.mcq*]

15. Posterior enhancement (through transmission) is a type of ultrasound artifact often used in diagnosis because

A. it can differentiate a solid mass vs a fluid filled cyst, where this may not be possible CT.

B. it can measure the blood volume of the ventricle.

C. it can cause a reflection of the image at a very large discontinuity in acoustic impedance, such as between the lung and the diaphram.

D. it helps determine the velocity of blood flowing through a vessel.

E. it enables speckle tracking of cells within the fluid in any direction, even orthogonal to the ultrasound beam.

Explanation: Posterior enhancement makes tissue beyond a fluid filled structure appear brighter.
[*imaging0131.mcq*]

16. Which of the following statements is *false* about phased arrays in ultrasound?

A. Dynamic focusing of the array, i.e., during the transmission and reception of a single pulse, is possible for both transmission and reception.

B. Grating lobes will occur if the spacing between the elements of the array is greater than a wavelength of the ultrasound.

C. Timing between the elements can be used to steer a beam both for transmitting and receiving.

D. Timing between the elements can be used to focus a beam both for transmitting and receiving.

E. Given a two-dimensional array of transducer elements, 3D ultrasound images may be acquired by steering the beam in both azimuth and elevation.

Explanation: Dynamic focusing of the array is possible only for reception as the echoes from a single transmit pulse are being received. Once a pulse is transmitted it can no longer be controlled (like a bowling ball).
[*imaging0134.mcq*]

17. Which of the following statements is *false* about Doppler in ultrasound?

A. Doppler shift is due to the relativistic effect of phonons.

B. In continuous-wave Doppler, discrete pulses of ultrasound are not used, but rather a continuous sinusoid is transmitted, received, and shifted by the transmit frequency down to the audio range, where motion may simply be heard as a "whooshing" sound.

C. Motion away from the transducer results in a shift to a lower frequency, but motion orthogonal to the ultrasound beam results in no Doppler shift.

D. In Color Doppler, pulses of ultrasound are analyzed as to their phase shift over the period between pulses, and therefore aliasing can result if enough phase shift occurs.

E. Power Doppler delivers a more sensitive measure of absolute motion but cannot determine the direction of that motion.

Explanation: Although the quantum particle for sound is indeed called the phonon, the speeds involved are far below those at which relativistic effects come into play. Doppler shift is simply due to the motion of a body relative to the waves it is receiving or reflecting through a stationary medium.
[*imaging0135.mcq*]

18. Which of the following statements regarding the Doppler effect is (are) true?

I Given a stationary source, moving the receiver toward the source will result in a higher frequency heard by the receiver than if the receiver were stationary.

II Given a stationary receiver, moving the source toward the receiver will result in a lower frequency heard by the receiver than if the source were stationary.

III If the source and receiver are moving in the same direction at the same speed, the receiver will not hear any change in frequency.

A. I and III

B. I and II

C. II and III

D. III only

E. II only

Explanation: If source and receiver move toward each other, the frequency heard by the receiver will be higher due to the Doppler effect.
[*imaging0183.mcq*]

19. Ultrasound is useful for non-invasive imaging of all of the following, it except:

A. Lungs

B. Liver

C. Fetus

D. Heart

E. Blood vessels

Explanation: Ultrasound does not penetrate air and thus is not used to image the normal lungs. The other tissues are commonly imaged with ultrasound.
[*imaging0186.mcq*]

20. Which of the following statements about clinical ultrasound is *false*?

A. Ultrasound transmits well through air.

B. Ultrasound detects changes in acoustic impedance.

C. Ultrasound operates in the megahertz range.

D. Most of the delivered energy becomes heat.

E. Ultrasound does not expose the patient to ionizing radiation.

Explanation: Ultrasound does not travel through bone very well, which is why "ultrasound gel" is used when scanning a patient (to remove any air from in between the probe and the patient).
[*imaging0191.mcq*]

21. As the frequency of an ultrasound beam increases:

A. Resolution increases and depth of penetration decreases

B. Resolution decreases and depth of penetration decreases

C. Resolution increases and depth of penetration increases

D. Resolution decreases and depth of penetration increases

E. Resolution increases and depth of penetration remains the same

Explanation: Higher frequency ultrasound yields greater spatial resolution at the cost of poorer depth of penetration.
[*imaging0195.mcq*]

22. Ultrasound is sound with frequencies above

A. 20 kHz

B. 20 MHz

C. 20 Hz

D. 2000 Hz

E. None of them

Explanation: 20 kHz
[*imaging0211.mcq*]

23. In ultrasound imaging, SNR increases with

A. Decreasing transducer focal distance because intensity is higher

B. Increasing transducer focal distance because intensity is lower

C. Increasing transducer focal distance because intensity is higher

D. Decreasing transducer focal distance because intensity is lower

E. None of them

Explanation: Decreasing transducer focal distance because intensity is higher due to less attenuation in tissue and 1/R effects.
[*imaging0217.mcq*]

24. The following is true about resolution in ultrasound

A. Transverse resolution improves with shorter focal distance and longitudinal resolution improves with shorter pulses.

B. Transverse resolution degrades with shorter focal distance and longitudinal resolution improves with shorter pulses.

C. Transverse resolution improves with shorter focal distance and longitudinal resolution degrades with shorter pulses.

D. Transverse resolution degrades with shorter focal distance and longitudinal resolution degrades with shorter pulses.

E. None of them

Explanation: Transverse resolution improves with shorter focal distance and longitudinal resolution improves with shorter pulses
[*imaging0219.mcq*]

25. 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*]

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

A. It may be used for compression waves as found in ultrasound, but is not applicable to optics, where the electromagnetic waves are transverse.

B. It permits mathematically tenable integration over an aperture of an infinite number of ultrasound sources according to Huygen's principle.

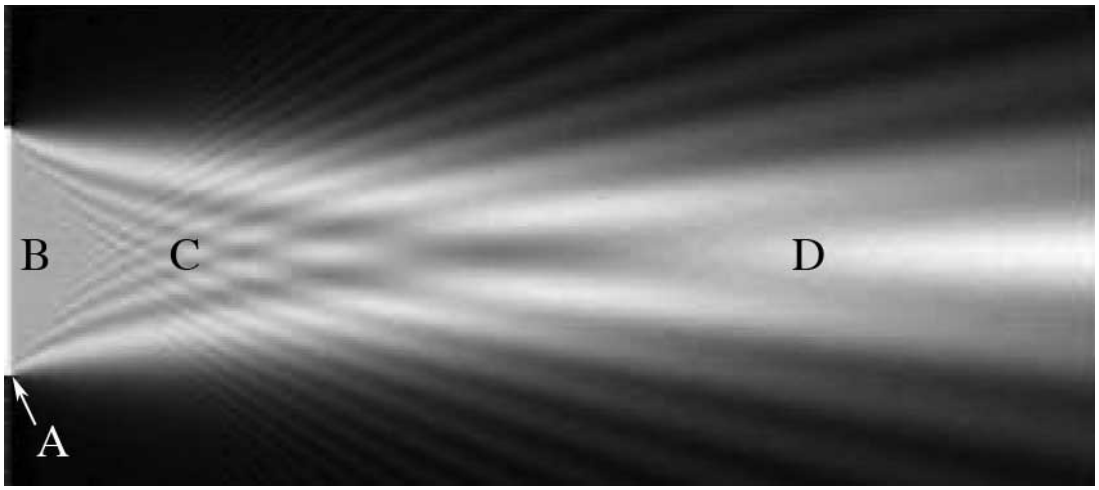
C. It permits the mathematical manipulation of an imaginary component of a physical quantity, by always requiring the presence of a complex conjugate for each complex exponential.

D. It leads directly to the use of Fourier transform, especially in the far field.

E. All are true.

Explanation: Complex exponentials are also the foundation of much of modern optics.
[*imaging0271.mcq*]

27. 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. In the Fresnel zone no null points exist along the central axis.

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. All are true.

D. The label "B" marks the Very Near Field, where plane waves are approximated, at least near the center axis, and thus do not create significant standing waves.

E. In the Fraunhofer zone the field pattern becomes a function basically of angle from the axis.

Explanation: The Fresnel zone, also known as the "*near* field" (labeled "C") has nodes along the central axis.
[*imaging0272.mcq*]

28. 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*]

29. 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*]

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

A. The frequency of reflected ultrasound waves is independent of the velocity of moving target in the tissue.

B. Velocity of ultrasound waves in soft tissue (not air or bone) is fairly constant at around 1540 meters/second ($< \pm 10\%$).

C. They are primarily compression rather than shear waves.

D. Distance to a target is determined by time of flight.

E. Absorption in biological tissue is roughly proportional to frequency.

Explanation: Answer A is false, because otherwise Doppler would not work.
[*imaging0275.mcq*]

31. Which of the following statements is (are) *true* about the pulse-echo mode of operation in a phased array ultrasound scanner?

I. The transmit beam is steered and focussed by controlling the relative timing of the transmit pulses to the elements of the array.
II. The receive beam pattern can be changed even after the transmit pulse has been sent.
III. Grating lobes result if the spacing between transducer elements is too large.

A. I, II, and III.

B. I and II.

C. II and III.

D. I and III.

E. None of the others is correct.

Explanation: The receive and transmit beams are both steered by changing the relative delay for each of the elements of the array, and the receive beam can be dynamically focussed during the reception phase. Grating lobes result when the wave from one transducer element can be 180 degree behind that of its neighbor.
[*imaging0276.mcq*]

32. Which of the following statements is *false* about Doppler in ultrasound (or all of the others are true)?

A. Motion orthogonal to the ultrasound beam results in Doppler shift to a lower frequency.

B. In continuous-wave Doppler, discrete pulses of ultrasound are not used, but rather a continuous sinusoid is transmitted, received, and shifted by the transmit frequency down to the audio range, where motion may simply be heard as a "whooshing" sound.

C. All of the others are true

D. In Color Doppler, pulses of ultrasound are analyzed as to their phase shift over the period between pulses, and therefore aliasing can result if enough phase shift occurs.

E. Power Doppler delivers a more sensitive measure of absolute motion but cannot determine the direction of that motion.

Explanation: Motion away from the transducer results in a shift to a lower frequency, but motion orthogonal to the ultrasound beam results in no Doppler shift.
[*imaging0277.mcq*]

33. Ultrasound is commonly used in adults for non-invasive imaging of all of the following, it except:

A. Brain

B. Liver

C. Fetus

D. Heart

E. Kidney

Explanation: Ultrasound does not penetrate bone and thus is not normally used to image the adult brain, although in the fetus it can be seen through the softer thinner skull.
[*imaging0278.mcq*]

34. Which of the following statements is (are) *true* about resonance in an ultrasound transducerr?

I. The resonant frequency is largely determined by the thickness of the transducer and the speed of sound within it.
II. The longer the resonance lasts for a given transmit pulse, the better the resolution in the range direction of the resulting image .
III. Resonant energy is primarily and intentionally lost out the back of the transducer.

A. I and III.

B. I and II.

C. II and III.

D. I, II, and III.

E. None of the others is correct.

Explanation: Longer resonance means a longer transmit envelope and poorer resolution in the range direction. Therefore the resonance is intentionally lost, primarily by using damping material behind the transducer.
[*imaging0279.mcq*]

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

A. There are null points due to destructive interference along the axis in this zone.

B. It is also known as the "far field".

C. The field pattern is basically a function of angle off the axis.

D. The lateral resolution in this zone falls off linearly with distance to the transducer.

E. All are true.

Explanation: Null points on the axis only occur in the Fresnel zone.
[*imaging0293.mcq*]

36. Which of the following statements is (are) *true* about the pulse-echo mode of operation in a phased array ultrasound scanner?

I. Grating lobes are possible with phased arrays, but not with single array transducers.
II. The transmit beam as well as the receive field pattern is steered by changing the relative timing between the elements of the array.
III. Dynamic focusing is possible during the reception of echos from a given ultrasound pulse, but not during its transmission.

A. I, II, and III.

B. I and II.

C. II and III.

D. I and III.

E. II

Explanation: All are true.
[*imaging0294.mcq*]

37. In ultrasound, with an incident planar wave that is not perpendicular to a boundary where the acoustic impedance Z changes, the following are true *except* (or all are true).

A. All are true

B. Reflection will always occur.

C. Refraction will occur if and only if the wave velocity c changes, as governed by Snell's Law.

D. Particle velocity on both sides of the boundary v is independent of (and generally much slower than) wave velocity c

E. The direction of wave propagation will bend *towards* the perpendicular to the boundary, if the speed of sound decreases across the boundary.

Explanation: Refraction depends only on c. Reflection depends only on Z and the angle of incidence. Particle velocity v is generally much slower than wave velocity c. Picturing the row of soldiers entering the cornfield at an angle shows them bending towards the perpendicular
[*imaging0339.mcq*]

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

A. Spatial variation occurs only along directions perpendicular to the direction of propagation.

B. Their general solution includes the superposition of a forward-traveling wave and a backward-traveling wave.

C. They can be viewed equally well as functions of time or of distance.

D. Their pressure in not attenuated as the distance traveled increases.

E. They are approximated within the Very Near Field of the ultrasound transducer, where the transducer face appears infinitely large.

Explanation: Whereas spherical waves spread out attenuating pressure by $1/r$, planar waves do not spread out, and thus maintain their full amplitude. Spatial variation occurs only along the direction of propagation, *not* along directions perpendicular to the direction of propagation.
[*imaging0340.mcq*]

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

A. Scattering of the waves from targets smaller than the acoustic wavelength is primarily a source of noise in the image.

B. Their absorption coefficient in biological tissue is roughly proportional to frequency.

C. They are generally produced in short bursts.

D. Distance to a target is determined by time of flight.

E. They are primarily compression rather than shear waves.

Explanation: Scattering of the waves from targets smaller than the acoustic wavelength is actually the primary source of useful information in the image.
[*imaging0341.mcq*]

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

A. Lateral image resolution within this zone is constant with distance from the transducer.

B. All are true.

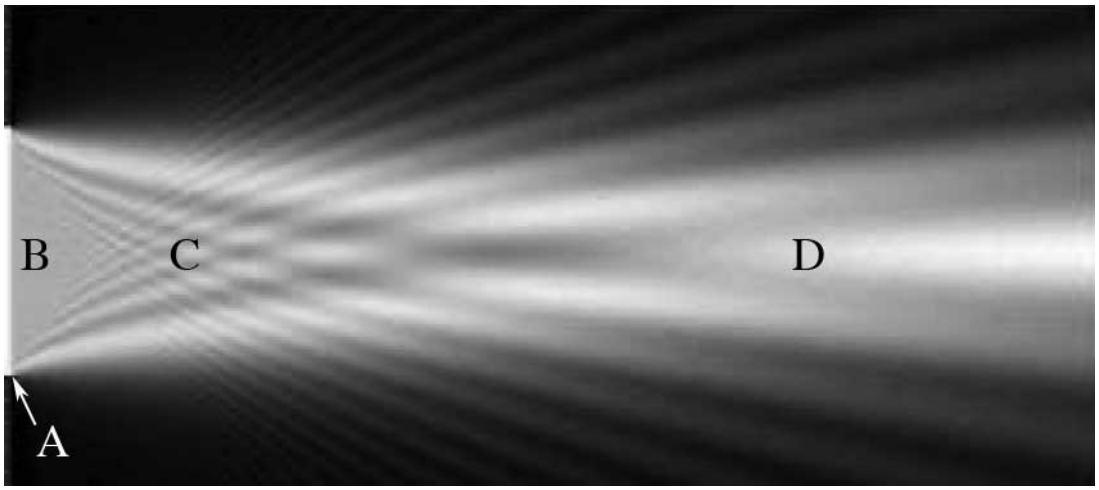
C. The field pattern is basically a function of angle off the axis.

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. Range resolution stays the same.
[*imaging0342.mcq*]

41. In ultrasound, which of the following is *not* true about the *field pattern*, an example of which is shown below (the figure actually shows a field pattern for light, but is analogous to that found with ultrasound).



A. The field pattern is for the transmission of ultrasound by the transducer, not for the reception of echoes.

B. The field pattern represents a pattern of standing waves of constructive and destructive interference for a given aperture and wavelength, and is independent of the particular target being scanned.

C. The label "C" marks the Fresnel zone.

D. The label "B" marks the Very Near Field, where the transducer appears infinitely large.

E. The label "D" marks the Fraunhofer zone.

Explanation: The field pattern is identical for transmission and reception.
[*imaging0343.mcq*]

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

A. They generally operate in the 100-200 MHz range.

B. The use piezoelectric crystals, which both transmit and receive ultrasound.

C. Resonance in the transducer element is measured by the Q factor, which is the height of the equivalent bandpass frequency response over the width, and which increases with the length of the resulting pulse.

D. Ultrasound gel is required to avoid air between the transducer and the patient, which would prevent the ultrasound wave from traveling efficiently.

E. All are true.

Explanation: Clinical ultrasound generally operates in the 1-20 MHz range.
[*imaging0344.mcq*]

43. 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*]

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

A. They are a general solution to first-order differential equations, such as the attenuation of a signal by absorption over a distance.

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.

E. All are true.

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.
[*imaging0346.mcq*]

45. Huygen's principle is best stated as

A. A wavefront may be interpreted as a collection of the centers of spherically propagating waves that interfere with each other.

B. The amplitude of a spherically propagating wave must be equal in all directions.

C. A spherical wave can propagate in an outward or inward direction

D. Interference patterns are best approximated by assuming a constant speed of wave propagation throughout the space.

E. The imaginary component of a complex exponential is not linear.

Explanation: B, D, and E are not true. C is true, but not Huygen's principle, which generally assume outward propagation.
[*imaging0347.mcq*]

46. Which of the following statements is *false* about the pulse-echo mode of operation (or all are true)

A. Color Doppler is not possible with pulse-echo ultrasound, since the underlying frequency of the ultrasound cannot be accurately determined after just a few cycles.

B. The same transducers usually generate and receive the ultrasound pulses.

C. Short-duration collections of cycles are generally used, representing the underlying frequency of the ultrasound.

D. In the frequency domain, the spectrum of the transmitted signal appears as a band of frequencies whose width is inversely related to the duration of the transmitted signal.

E. All are true.

Explanation: Color Doppler is possible with pulse-echo ultrasound, by comparing the phases of received signals compared to expected phases.
[*imaging0348.mcq*]

47. Which of the following statements is *false* about phased arrays in ultrasound (or all are true)?

A. Grating lobes, which occur with single element transducers that are mechanically moved, will not occur with phased arrays.

B. Dynamic focusing of the array is possible during the reception of the echo from a single transmitted pulse, but is not possible for the transmitted pulse itself.

C. Timing between the elements can be used to steer a beam both for transmitting and receiving.

D. All are true.

E. Given a two-dimensional array of transducer elements, 3D ultrasound images may be acquired by steering the beam in both azimuth and elevation.

Explanation: Grating lobes only occur with arrays.
[*imaging0349.mcq*]

48. Which of the following statements is *false* about phased arrays in ultrasound (or all are true)?

A. They are not capable of being used for Doppler imaging.

B. Dynamic focusing of the array is possible during the reception of the echo from a single transmitted pulse, but is not possible for the transmitted pulse itself.

C. Timing between the elements can be used to steer a beam both for transmitting and receiving.

D. All are true.

E. Given a two-dimensional array of transducer elements, 3D ultrasound images may be acquired by steering the beam in both azimuth and elevation.

Explanation: Doppler can be used with pulsed ultrasound to find the flow towards or away from a phased array at particular location in the image.
[*imaging0421.mcq*]

49. 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, but generally require that the imaginary component will be canceled by a complex conjugate.

D. They are also the foundation of much of modern optics, which has many similarities to ultrasound.

E. They generally are used to translate differences in path-length into differences in phase, given a certain frequency.

Explanation: 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.
[*imaging0422.mcq*]

50. 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*]

51. 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*]

52. In ultrasound, with an incident planar wave that is not perpendicular to a boundary where the acoustic impedance Z changes, the following are true *except* (or all are true).

A. The direction of wave propagation will bend *towards* the perpendicular to the boundary if the speed of sound *increases* across the boundary.

B. Reflection will always occur.

C. Refraction will occur if and only if the wave velocity c changes, as governed by governed by Snell's Law.

D. Particle velocity on both sides of the boundary v is independent of (and generally much slower than) wave velocity c

E. All are true

Explanation: Refraction depends only on c. Reflection depends only on Z and the angle of incidence. Particle velocity v is generally much slower than wave velocity c. Picturing the row of soldiers leaving the cornfield at an angle shows them bending away the perpendicular to the boundary.
[*imaging0425.mcq*]

53. 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*]

54. 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*]

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

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

A. All are true.

B. The "del" or "nabla" symbol squared indicates the Laplacian operator, which is the divergence of the gradient.

C. It contains derivatives of pressure in space.

D. It contains derivatives of pressure in time.

E. The equation describes the creation and propagation of pressure waves.

Explanation: All are true.
[*imaging0428.mcq*]

56. The following is true about Time-Gain Compensation (TGC), *except* (or all are true)

A. All are true.

B. It is used to compensate for the enormous attenuation of ultrasound to the target and back again.

C. It is often represented by a column of slidable adjustments on the ultrasound scanner that are manually adjusted during operation.

D. It permits the brightness of the image to be adjusted at various depths.

E. It controls the gain of the amplifier as the echoes return from an individual transmit pulse.

Explanation:
[*imaging0429.mcq*]

57. In ultrasound, with an incident planar wave whose direction of motion is not perpendicular to a planar boundary where the acoustic impedance Z changes, the following are true *except* (or all are true).

A. Reflection, if it occurs, will be in the same direction as the incident wave.

B. Reflection will always occur.

C. Refraction will occur if and only if the wave velocity c changes, as governed by Snell's Law.

D. Particle velocity on both sides of the boundary v is different (and generally much slower) than wave velocity c

E. All are true

Explanation: Reflection will follow the rule that the angle of incidence will equal the angle of reflectance, but on the other side of the normal to the boundary plane. Thus, since the direction of the incident wave is not perpendicular to the boundary plane, Answer A cannot be true.
[*imaging0446.mcq*]

58. 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.

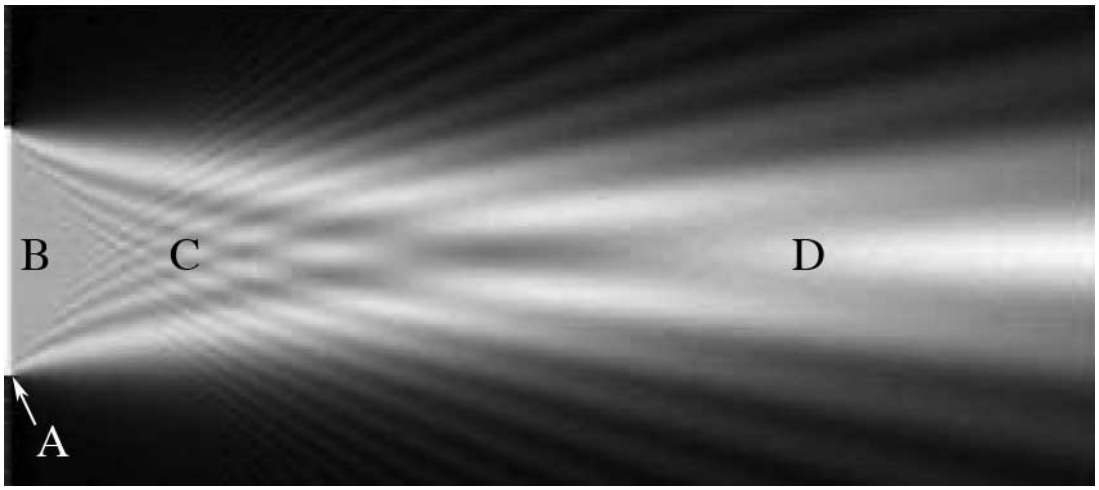
C. They are approximated at a great distance from the point source of a spherical wave.

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*]

59. 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*]

60. 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*]

61. Huygen's principle is best stated as

A. Any wavefront may be interpreted as a collection of the centers of spherically propagating waves that interfere with each other to form the particular wavefront.

B. The amplitude of a spherically propagating wave must be equal in all directions.

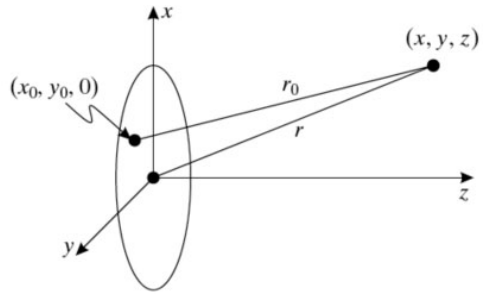
C. A spherical wave can propagate in an outward or inward direction

D. Energy can be seen as traveling in discrete packets, or "particles".

E. Wavefronts are always parallel.

Explanation: B and E are not true. C is true, but not Huygen's principle, which generally assume outward propagation. D is possible for photons or (in sound) "phonons", but this represents the particle end of the particle-wave duality, whereas Huygen's principle is the *wave* end.
[*imaging0457.mcq*]

62. Which of the following is *not* true about the diagram below, showing an ultrasound transducer, and a point (x, y, z) in space (or all are true)?



A. All are true.

B. The distance between point $(x_0, y_0, 0)$ on the transducer and point (x, y, z) is governed by the Pythagorean theorem.

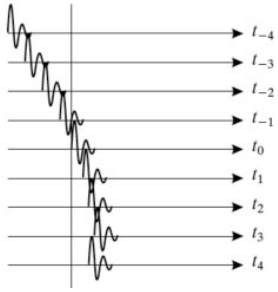
C. The field pattern at point (x, y, z) is determined by an integration over the all possible points $(x_0, y_0, 0)$ on the transducer, each with its own particular relative phase determined by r_0.

D. The diagram can be applied to both transmission and reception between the transducer and point (x, y, z).

E. The actual signal received by the ultrasound transducer will involve an integration of signals generated from all points (x, y, z) weighted by various factors.

Explanation:
[*imaging0458.mcq*]

63. Which of the following is *not* true about the diagram below, showing the timing of electronic pulses sent to the elements of a phased ultrasound array, ordered t_{-4} to t_4 (or all are true)?



A. The transmitted ultrasound pulse that is generated can be dynamically focused by changing the relative delays after the transmission.

B. The array acts analogous to a prism, sending the wave off to one side of the central axis.

C. The array acts analogous to a lens, focusing the wave at some finite distance.

D. The wavefronts generated from the individual transducer elements combine to create an overall wavefront whose form is governed by the relative delays between the pulses to the transducer elements.

E. All are true.

Explanation: Dynamic focusing only works when receiving ultrasound signals. Once an ultrasound wave is transmitted it cannot be altered by the transducer.
[*imaging0459.mcq*]

64. Which of the following statements is *false* about phased arrays in ultrasound (or all are true)?

A. All are true

B. 3D ultrasound images are usually acquired by mechanically rotating a one-dimensional array, when high-speed is not required.

C. Timing between the elements can be used to steer a beam both for transmitting and receiving.

D. They are capable of being used for Doppler imaging.

E. Given a two-dimensional array of transducer elements, 3D ultrasound images may be acquired by steering the beam in both azimuth and elevation.

Explanation: All are true
[*imaging0460.mcq*]

65. 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*]

66. Which of the following statements is *false* about phased arrays in ultrasound (or all are true)?

A. They present a fixed beam pattern and thus must be physically moved to create an image.

B. They can perform dynamic focusing, in which the focus is moved further out in range while receiving echoes from a single transmitted pulse to follow the expected location of targets.

C. Timing between the elements can be used to steer a beam both for transmitting and receiving.

D. They are capable of being used for Doppler imaging.

E. All are true

Explanation: The main advantage of a phased array is that it does *not* need to be physically moved to create an image.
[*imaging0479.mcq*]

67. The following is true about Time-Gain Compensation (TGC), *except* (or all are true)

A. It allows for refocusing at different depths.

B. It is used to compensate for the enormous attenuation of ultrasound to the target and back again.

C. All are true.

D. It permits the brightness of the image to be adjusted at various depths, usually by means of a set of slider controls.

E. It controls the gain of the amplifier as the echoes return from an individual transmit pulse.

Explanation: TGC has nothing to do with focusing, only with intensity.
[*imaging0480.mcq*]

68. The following are true about standing waves, *except*

A. They occur in the very near field (geometric zone), where only plane waves are present.

B. They are functions that change in time.

C. They are created when waves of the same frequency, but traveling in different directions, are superimposed.

D. They are responsible for the field patterns generated by an ultrasound transducer

E. They consist of regions of constructive and destructive interference.

Explanation: In the very near field, there are no interference patterns, because all waves are traveling in the same direction (plane waves).
[*imaging0481.mcq*]

69. The following are true about non-linear effects in ultrasound, *except* (or all are true).

A. All are true.

B. Peaks in the pressure waves actually move faster than the average speed of sound.

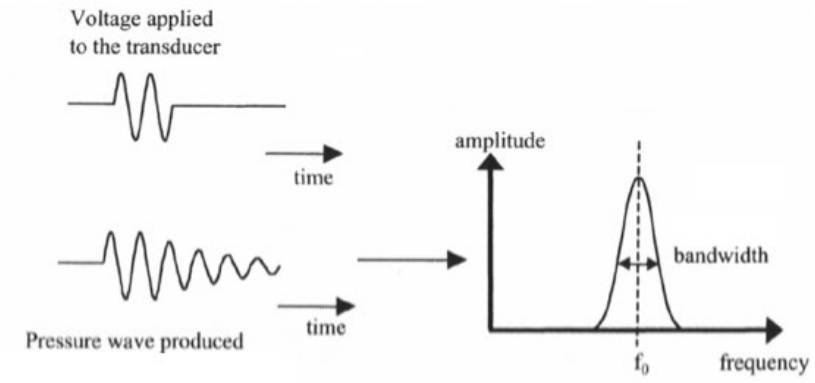
C. Troughs in the pressure waves actually move slower than the average speed of sound.

D. They cause harmonics to appear that are not in the original waveform generated at the transducer.

E. Differences in the velocity variation due to tissue type form the basis of "harmonic imaging."

Explanation: All are true.
[*imaging0482.mcq*]

70. 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*]

71. The attenuation coefficient α is modeled as some constant a times the frequency f raised to the power b, that is, $\alpha = af^b$. Given that the amplitude of an ultrasound wave is reduced from A_0 at range $z = 0$ to A_z at range z, and that

$\alpha = -\frac{1}{z} 20 \log \frac{A_z}{A_0}$

which of the following is *not* true (or all are true)?

A. The value of *alpha* increases with frequency, causing penetration to be *deeper* for ultrasound scanners with *better* resolution.

B. The value of b tends to be about 1 in biological tissue.

C. The value of a varies from tissue to tissue, and is extremely high for lung.

D. Attenuation falls off exponentially, since each unit length of tissue removes a certain percentage of the remaining signal.

E. All are true.

Explanation: Depth of penetration for ultrasound scanners must be traded off against resolution. Higher resolution give better resolution but shallower penetration.
[*imaging0484.mcq*]

72. Regarding the signal received by an ultrasound transducer, which of the following statements about the equation below is *false* (or all are true)?

$$\mathrm{r}(t) = K \int\int\int R(x,y,z)\mathrm{n}(t - 2c^{-1}z)e^{-2\mu_a z}[q(x,y,z)]^2 dx\, dy\, dz$$

A. The received signal $\mathrm{r}(t)$ and the underlying signal $\mathrm{n}(t - c^{-1}z)$ are real, because they represent real phenomena.

B. It assumes homogeneous attenuation throughout the tissue.

C. $q(x, y, z)$ is the field pattern at location (x, y, z), a standing wave consisting of regions of constructive and destructive interference, which determines the location being imaged by a particular transmitted ultrasound pulse.

D. The occurrence of the number 2 three times in the equation is due, each time, to the fact that the ultrasound pulse travels from the transducer to the target and then back again to the transducer.

E. All are true.

Explanation: The received signal $\mathrm{r}(t)$ and the underlying signal $\mathrm{n}(t - c^{-1}z)$ are complex, although they represent real phenomena. Within the ultrasound wave itself, the pressure is treated real and the particle velocity is treated as imaginary (ninety degrees out of phase).
[*imaging0502.mcq*]