EEE 491 - Biomedical Engineering

Ultrasound Physics, Imaging and Therapy

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MCQ Questions

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1. Q What can modern ultrasound systems be used for?

(a) Images of unborn babies

(b) Detailed measurements of blood movements in blood vessels and tissues

(c) Visualize moving structures in 3D

(d) All of the above

1. A (d)

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2. Q What can be visualized in 3D using modern ultrasound systems?

(a) Blood cells

(b) Moving structures

(c) Bacteria

(d) Rocks

2. A (b)

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3. Q How is a B-mode image constructed?

(a) It is created from x-rays passing through the body

(b) It is generated by RF waves reflecting off the body's surface

(c) It is formed from echoes generated by ultrasound waves reflecting off tissue boundaries

(d) It is made from magnetic fields interacting with atoms in the body

3. A (c)

4. Q **What generates the echoes used to create a B-mode image?**

(a) X-rays passing through the body

(b) Scattered light waves within the body

(c) Ultrasound waves reflecting off tissue boundaries and small irregularities within tissues

(d) All of the above

4. A (c)

5. Q **What is the primary axis used to represent depth in B-mode imaging?**

(a) x-axis

(b) y-axis

(c) z-axis

(d) None of the above

5. A (c)

6. Q **In B-mode imaging, what is the primary axis used to represent azimuth?**

(a) x-axis

(b) y-axis

(c) z-axis

(d) None of the above

6. A (a)

7. Q **How is the position of an echo in B-mode imaging determined?**

(a) By its depth and angle of incidence

(b) By its frequency and amplitude

(c) By its acoustic transit time and beam direction in the plane

(d) All of the above

7. A (c)

8. Q **In M-mode imaging, what is the primary axis used to represent depth?**

(a) x-axis

(b) y-axis

(c) z-axis

(d) None of the above

8. A (b)

9. Q **What is the main difference between B-mode and M-mode imaging?**

(a) B-mode imaging shows a cross-sectional image,
while M-mode imaging shows a time history of a single line

(b) B-mode imaging is brightness-modulated,
while M-mode imaging is frequency-modulated

(c) B-mode imaging uses the x-axis to represent depth,
while M-mode imaging uses the y-axis

(d) B-mode imaging uses the z-axis to represent time,
while M-mode imaging uses the x-axis

9. A (a)

10. Q **What is the primary purpose of Doppler-mode imaging?**

(a) To create 3D images of internal organs

(b) To visualize the movement of tissues in the body

(c) To estimate blood flow through blood vessels

(d) To detect the presence of tumors in the body

10. A (c)

11. Q **How is the direction of blood flow encoded in the CFM mode?**

(a) By changing the brightness of the image

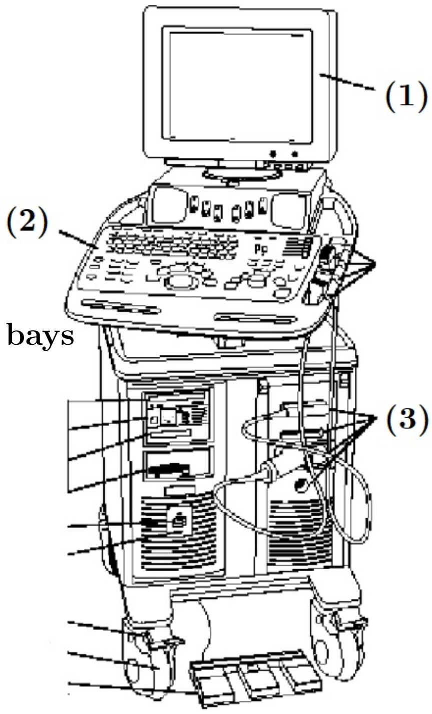
(b) By using different shades of gray

(c) By plotting a graph of the velocity vs the direction

(d) By using different colors

11. A (d)

12. Q **In the following figure, what (1), (2), (3) represents respectively?**



(a) Transducer connector bays, Reset, Pedal

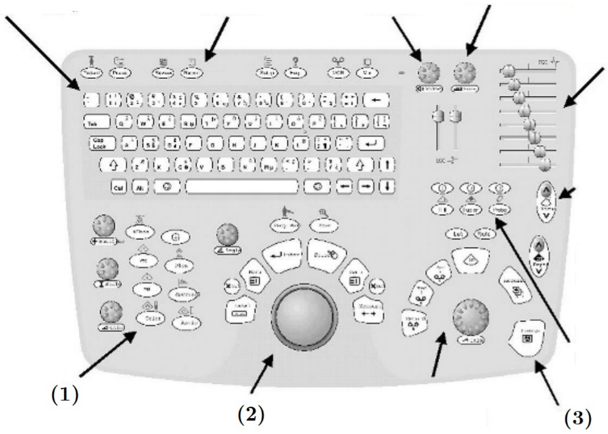
(b) Peripheral device, System control panel, Display

(c) System control panel, Reset, Peripheral device

(d) Display, System control panel, Transducer connector bays

12. A (d)

13. Q In the following figure, what (1), (2), (3) represents respectively?



(a) Focus, Freeze, Mode Selection

(b) Mode Selection, Trackball, Freeze

(c) Freeze, Trackball, Probe select

(d) TGC, Scan depth, Focus

13. A (b)

14. Q What type of waves are used to form medical images with ultrasound?

(a) Transverse waves

(b) Longitudinal waves

(c) Electromagnetic waves

(d) Radio waves

14. A (b)

15. Q What is the frequency range of ultrasound waves used in medical imaging?

(a) 2-15 MHz

(b) 20-150 MHz

(c) 2-20 MHz

(d) 20-200 MHz

15. A (c)

16. Q Is ultrasound an electromagnetic wave?

(a) Yes

(b) No

16. A (b)

Speed of sound

$$c = f\lambda \tag{1}$$

Where

c : speed of sound

f : frequency

λ : wavelength

$$c = \sqrt{\frac{k}{\rho}} \tag{2}$$

Where

c : speed of sound

k : coefficient of stiffness

ρ : density

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17. Q What is the typical frequency range of medical ultrasound?

(a) 2-15 MHz

(b) 20-150 MHz

(c) 2-20 MHz

(d) 20-200 MHz

17. A (a)

18. Q How does the wavelength of ultrasound waves affect the resolution of the imaging system?

(a) Longer wavelengths give rise to improved resolution

(b) Shorter wavelengths give rise to improved resolution

(c) Wavelength has no effect on resolution

(d) Wavelength affects only the penetration depth of ultrasound waves

18. A (b)

19. Q Is the resolution of ultrasound imaging proportional or inversely proportional to penetration?

(a) Proportional

(b) Inversely proportional

19. A (b)

Acoustic impedance

Analogous to electrical impedance

$$z = \frac{p}{v} \tag{3}$$

Where

p : local pressure

v : local particle velocity

Or more commonly

$$z = \sqrt{\rho k} = \rho c \quad (\text{Rayls} = \text{kg m}^{-2}\ \text{s}^{-1}) \tag{4}$$

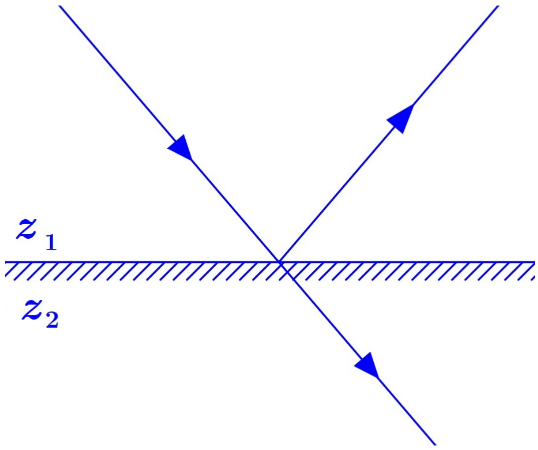
Ultrasound Reflection

For a acoustic wave passes from one substance with refractive index z_1 into another with refractive index z_2, we define amplitude refraction coefficient as:

$$R_A = \frac{P_r}{P_i} = \frac{z_2 - z_1}{z_2 + z_1} \tag{5}$$

therefore the intensity refraction coefficient :

$$R_i = \frac{I_r}{I_i} = R_A^2 = \left(\frac{z_2 - z_1}{z_2 + z_1}\right)^2 \tag{6}$$



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20. Q Two tissue types have speed of sound and density of
(a) 1580 m s^{-1} and 1.1×10^3 kg m^{-3}
(b) 1460 m s^{-1} and 0.9×10^3 kg m^{-3}.
Calculate the intensity reflection coefficient for a large interface between them.

(a) 0.2189

(b) 0.3714

(c) 0.138

(d) 0.0235

$$z_1 = \rho_1 c_1 = 1.738 \times 10^6 \text{ kg m}^{-2}\text{s}^{-1}$$

$$z_2 = \rho_2 c_2 = 1.314 \times 10^6 \text{ kg m}^{-2}\text{s}^{-1}$$

$$R_I = (R_A)^2 = \left(\frac{z_2 - z_1}{z_2 + z_1}\right)^2 = 0.138$$

20. A (c)

Ultrasound Scattering

$$W_s \propto \frac{d^6}{\lambda^4} \propto d^6 f^4 \tag{7}$$

Ultrasound Refraction (Refraction)

$$\frac{\sin \theta_i}{\sin \theta_t} = \frac{c_1}{c_2} \tag{8}$$

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21. Q What is attenuation in medical ultrasound?

(a) The gradual gain of beam energy

(b) The abrupt loss of beam energy

(c) The gradual loss of beam energy

(d) The abrupt gain of beam energy

21. A (c)

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22. Q What is the unit of attenuation

(a) dB cm^{-1} MHz^{-1}

(b) dB^{-1} cm^{-1} MHz

(c) dB cm MHz

(d) dB^{-1} cm^{-1} MHz^{-1}

22. A (a)

23. Q attenuation is .... proportional to frequency and distance respectively

(a) inversely, inversely

(b) inversely, directly

(c) directly, inversely

(d) directly, directly

23. A (d)

24. Q A medium attenuates ultrasound at a rate of 0.7 dB cm^{-1} MHz^{-1} .A target at a depth of 5 cm below the transducer is imaged with a 3 MHz ultrasound pulse. By how many dB will the echo from the target be attenuated?

(a) 10.5 dB

(b) 7 dB

(c) 21 dB

(d) 28.5 dB

The total distance traveled d is $2x = 2\times$ 5 cm = 10 cm

$\therefore$ Attenuation is $\alpha \times d \times f = 0.7 \times 10 \times 3 = 21$ db

24. A (c)

25. Q Recalculate for a target at a depth of 1 cm

(a) 12.3 dB

(b) 2.1 dB

(c) 4.2 dB

(d) 8.4 dB

The total distance traveled d is $2x = 2\times$ 1 cm = 2 cm

$\therefore$ Attenuation is $\alpha \times d \times f = 0.7 \times 2 \times 3 = 4.2$ db

25. A (c)

26. Q **Which type of tissue tends to show high absorption of ultrasound waves?**

(a) Tissues with high fat content

(b) Tissues with low fat content

(c) Tissues with high collagen content

(d) Tissues with low collagen content

26. A (c)

27. Q **How does tissue composition affect absorption of ultrasound waves?**

(a) It has no effect on absorption

(b) Tissues with high water content show higher absorption

(c) Tissues with high collagen content show higher absorption

(d) Tissues with high fat content show higher absorption

27. A (c)

28. Q **What does the term B-mode stand for in medical imaging?**

(a) Brightness-mode

(b) Blood-flow mode

(c) Bone-density mode

(d) Brain-activity mode

28. A (a)

29. Q How is a B-mode image constructed?

(a) From transmission of waves through tissue

(b) From absorption of waves by tissue

(c) From echoes of waves reflected and scattered by tissue

(d) From refraction of waves by tissue

29. A (c)

30. Q What is the relationship between brightness and echo strength in a B-mode image?

(a) Brightness is unrelated to echo strength

(b) Brightness is directly proportional to echo strength

(c) Brightness is inversely proportional to echo strength

(d) Brightness is unrelated to the strength of echoes from tissue boundaries

30. A (b)

31. Q What are the two pieces of information required for the B-mode system to display each echo in a position corresponding to that of the interface or feature that caused it?

(a) Frequency and amplitude of the ultrasound wave

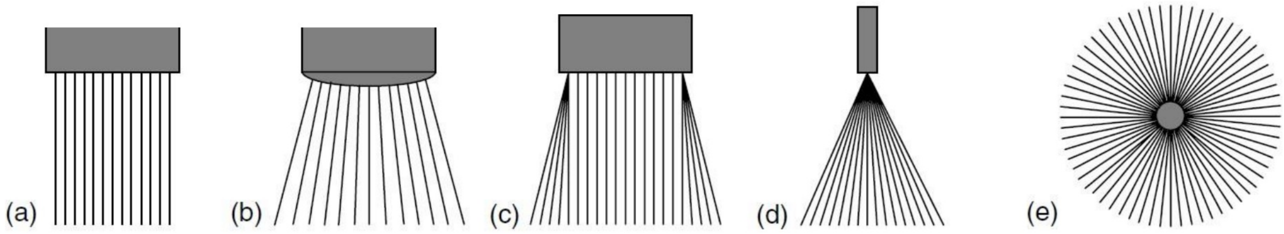
(b) Range and position of the transducer

(c) Amplitude and intensity of the echo

(d) Scattering and reflection of the ultrasound wave

31. A (b)

32. Q which of the following transducers is a reposoidal transducer



32. A (c)

Note :

(a) Rectangular Transducer.
(b) Curvilinear Transducer.
(c) Reposoidal Transducer.
(d) Sector Transducer
(e) Radial Transducer

Near field length

$$\text{near field length} = \frac{a^2}{\lambda} \tag{9}$$

Where a : diameter of transducer

Angle of divergence

$$\theta = 0.61\frac{\lambda}{a} \tag{10}$$

Foucsing

The beam width W at the focus for strong focusing is given approximately by the equation

$$W = \frac{F\lambda}{a} \tag{11}$$

Where F : the focal length

33. Q How is focusing achieved in ultrasound imaging using a single-element source?

(a) By using a flat source

(b) By using a source with a sharp edge

(c) By using a curved source or an acoustic lens

(d) By using a rotating source

33. A (c)

34. Q When is focusing considered weak in ultrasound imaging?

(a) When the focal length is less than half of the near-field length

(b) When the focal length is more than half of the near-field length

(c) When the B-mode is used

(d) When the M-mode is used

34. A (b)

35. Q A plane disc transducer, with a diameter of 1.5 cm, is driven at 3 MHz to produce a continuous-wave beam in tissue with a speed of sound of 1500 m/s Calculate the near-field length of the beam

(a) 0.45 m

(b) 1.125 m

(c) 0.45×10^{-7} m

(d) 1.125×10^{-7} m

$$\lambda = \frac{c}{f} = \frac{1500}{3 \times 10^6} = 5 \times 10^{-4} \text{ m}$$

$$\text{near-field length} = \frac{a^2}{\lambda} = \frac{(1.5 \times 10^{-2})^2}{5 \times 10^{-4}} = 0.45 \text{ m}$$

35. A (a)

36. Q In the previous question, calculate its angle of divergence in the far field.

(a) 0.163°

(b) 1.163°

(c) 2.163°

(d) 3.163°

$$\sin\theta = 0.61\frac{\lambda}{a} = 0.61 \times \frac{5\times 10^{-4}}{1.5\times 10^{-2}}$$
$$\theta = 1.163^\circ$$

36. A (b)

37. Q In the previous question, estimate the beam width at the focus if a lens is added with a focal length of 6 cm.

(a) 2 μm

(b) 2 mm

(c) 2 cm

(d) 2 m

$$W = \frac{F\lambda}{a} = \frac{6\times 10^{-2}\times 5\times 10^{-4}}{1.5\times 10^{-2}} = 2 \text{ mm}$$

37. A (b)

38. Q What is a transducer in ultrasound imaging?

(a) A device that determines the shape and position of the beams

(b) A part of the scanner that controls the electrical signals

(c) A device that converts electrical transmission pulses into ultrasonic pulses and vice versa

(d) A part of the scanner that determines the brightness of the image

38. A (c)

39. Q What is the function of the beamformer in ultrasound imaging?

(a) To convert electrical transmission pulses into ultrasonic pulses

(b) To determine the shape and position of the beams

(c) To convert ultrasonic echo pulses into electrical signals

(d) To determine the brightness of the image

39. A (b)

40. Q Which part of the scanner determines the size, shape, and position of the beams in ultrasound imaging? A)

(a) Transducer

(b) Processor

(c) Display

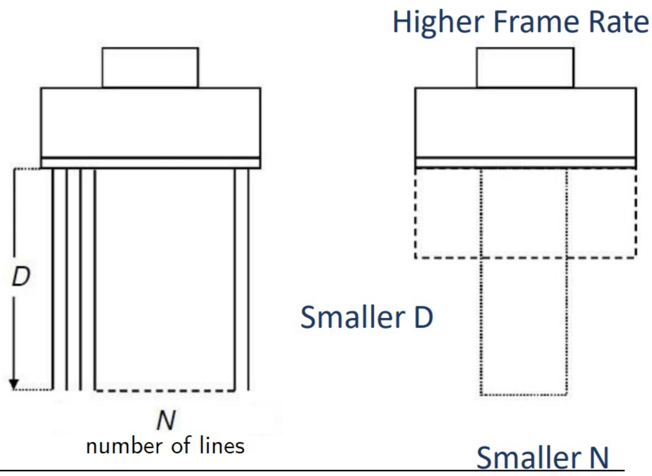
(d) Beamformer

40. A (d)

Frame time / Frame rate

$$\text{frame time} = \frac{2DN}{c} \quad (12)$$

$$\text{frame rate} = \frac{c}{2DN} \quad (13)$$



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41. Q What is the frame time to scan 20 cm depth with 128 lines ?

(a) 0.0083

(b) 0.0166

(c) 0.0416

(d) 0.0332

$$\text{frame time} = \frac{2 \times 20 \times 10^{-2} \times 128}{1540} = 0.0332 \text{ s}$$

41. A (d)

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42. Q In the previous question, what is the frame rate

(a) 24 fps

(b) 30 fps

(c) 60 fps

(d) 120 fps

frame rate = 1 / frame time = 30 fps

42. A (b)

43. Q Which of the following is a cause of the Doppler effect?

(a) Changes in the medium through which the wave is travelling

(b) Changes in the frequency of the source

(c) Changes in the amplitude of the wave

(d) Relative motion between the observer and the source

43. A (d)

Doppler Shift

$$f_d = f_r - f_t = \frac{2 f_t v \cos\theta}{c} \tag{14}$$

Therefore

$$v = \frac{c f_d}{2 f_t \cos\theta} \tag{15}$$

44. Q Which of the following is not a Doppler display mode? a) b) c) d) Answer: d) Brightness Doppler

(a) Color Doppler

(b) Spectral Doppler

(c) Brightness Doppler

(d) All of the above

44. A (c)

45. Q **Which of the following Doppler modes has a limitation on maximum velocity and accuracy?**

(a) Color Doppler

(b) Spectral Doppler

(c) Continuous Wave Doppler

(d) Pulsed-Wave Doppler

45. A (d)

46. Q **Which of the following is a limitation of Continuous Wave Doppler?**

(a) No range information

(b) Limitations on maximum velocity and accuracy

(c) Only a small region for Doppler sensitivity

(d) No limitation on maximum velocity and high velocity accuracy

46. A (a)

Pulse Repetition Frequency - Pulse Repetition Interval

PRI : the time interval between pulses

$$\text{PRI} = t_2 - t_1 \tag{16}$$

PRF : the number of pulses transmitted in 1 s (Hz or pps (pulses per second))

$$\text{PRF} = \frac{1}{\text{PRI}} \tag{17}$$

$$d_1 = \frac{ct_1}{2} \tag{18}$$

$$d_2 = \frac{ct_2}{2} \tag{19}$$

$$d_m = d_2 - d_1 = \frac{c(t_2 - t_1)}{2} \tag{20}$$

$$v = \frac{d_m}{\text{PRI}} = \frac{c(t_2 - t_1)}{2\text{PRI}} \tag{21}$$

$$\text{(or) } v = d_m\text{PRF} = \frac{c(t_2 - t_1)\text{PRF}}{2} \tag{22}$$

$$f_{d\,\max} = \frac{\text{PRF}}{2} \tag{23}$$

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47. Q Consider Doppler imaging of a vessel at depth $d_1 = 10$ cm. derive the maximum detectable velocity if the transmitted signal frequency was 5 MHz and Doppler angle was 45°.

(a) 0.208 m/s

(b) 0.417 m/s

(c) 0.837 m/s

(d) 1.668 m/s

time to scan 1 cm :

$$t = \frac{2d}{c} = \frac{2 \times 1 \times 10^{-2}}{1540} = 13\,\mu\text{s}$$

Therefore PRI $= 13\,\mu\text{s} \times 10$ cm $= 130\,\mu\text{s}$

Sampling frequency $= \text{PRF} = \dfrac{1}{\text{PRI}} = 7692$ sample per second $= 2f_{d\,\max}$ max

Remember

$v = \dfrac{cf_d}{2f_t \cos\theta}$

Therefore

$v_{\max} = \dfrac{1540 \times 7692/2}{2 \times 5 \times 10^6 \times \cos 45°} = 0.837$ m/s

47. A (c)

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48. Q What is ultrasound treatment not used for?

(a) Treating bone fractures

(b) Treating kidney stones

(c) Treating joint sprains

(d) Treating muscle sprains

48. A (a)

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49. Q What are some benefits of ultrasound treatment?

(a) Reducing blood flow

(b) Increasing joint stiffness

(c) Increasing muscle spasms

(d) Reducing inflammation

49. A (d)

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50. Q How does ultrasound treatment work?

(a) By sending low frequency sound waves through the body

(b) By delivering medication directly to the injured area

(c) By creating a magnetic field around the injured area

(d) By vibrating tissues to create heat and draw more blood to the injured area

50. A (d)

51. Q **What is the purpose of Lithotripsy?**

(a) Treating benign and malignant tumors

(b) Cleaning teeth in dental hygiene

(c) Breaking up kidney stones

(d) Detecting prostate cancer early

51. A (c)

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52. Q **What is Focused Ultrasound Surgery (FUS) used for?**

(a) Treating benign and malignant tumors and other disorders

(b) Cleaning teeth in dental hygiene

(c) Detecting prostate cancer early

(d) Breaking up kidney stones

52. A (a)

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53. Q **What is Low intensity pulsed ultrasound used for?**

(a) Treating benign and malignant tumors

(b) Cleaning teeth in dental hygiene

(c) Detecting prostate cancer early

(d) Therapeutic tooth and bone regeneration

53. A (d)

54. Q **What is one of the potential dangers of ultrasound?**

(a) **Joint stiffness**

(b) **Headaches**

(c) **Development of heat in tissues**

(d) **Decreased appetite**

54. A (c)

55. Q **What happens when dissolved gases within the body come out of solution due to local heat caused by ultrasound?**

(a) **Formation of bubbles**

(b) **Increase in blood pressure**

(c) **Decrease in heart rate**

(d) **None of the above**

55. A (a)

56. Q **Have there been any substantiated ill-effects of ultrasound documented in studies?**

(a) **Yes, in both humans and animals**

(b) **No, in either humans or animals**

(c) **Only in animals, not humans**

(d) **Only in humans, not animals**

56. A (b)