

EEE 491 - Biomedical Engineering

Ultrasound Physics, Imaging and Therapy



Taha Ahmed

MCQ Questions

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)

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)

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?

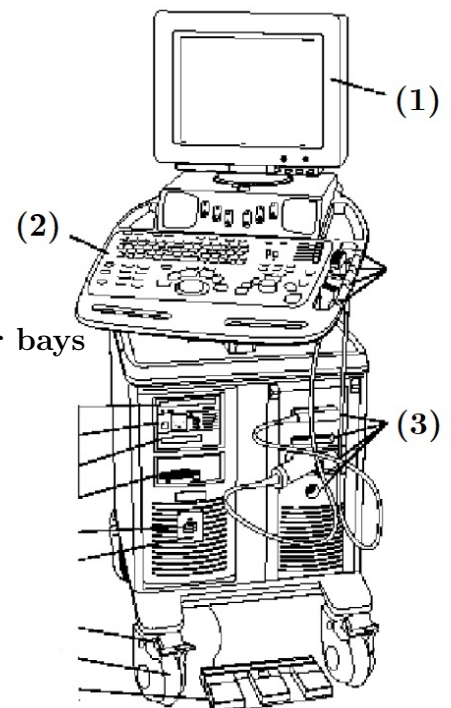
- (a) By changing the brightness of the image
- (b) By using different shades of gray
- (c) By plotting a graph of the velocity vs the direction
- (d) By using different colors

11. A (d)

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

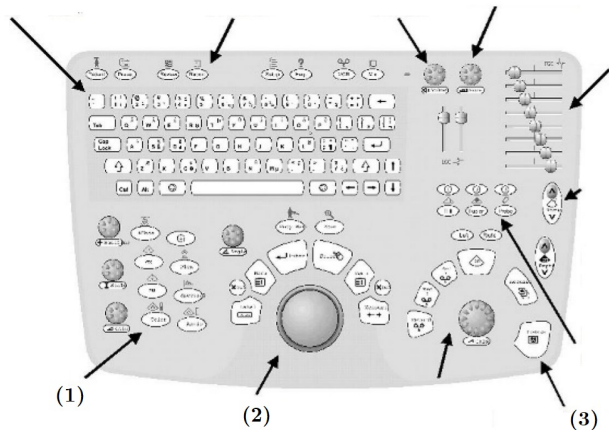
- (a) Transducer connector bays, Reset, Pedal
- (b) Peripheral device, System control panel, Display
- (c) System control panel, Reset, Peripheral device
- (d) Display, System control panel, Transducer connector bays

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?

- (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

$$c = f\lambda \quad (1)$$

Where

c : speed of sound

f : frequency

λ : wavelength

$$c = \sqrt{\frac{k}{\rho}} \quad (2)$$

Where

c : speed of sound

k : coefficient of stiffness

ρ : density

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

- Ⓐ 2-15 MHz
- Ⓑ 20-150 MHz
- Ⓒ 2-20 MHz
- Ⓓ 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

$$z = \frac{p}{v} \quad (3)$$

Where

p : local pressure

v : local particle velocity

Or more commonly

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

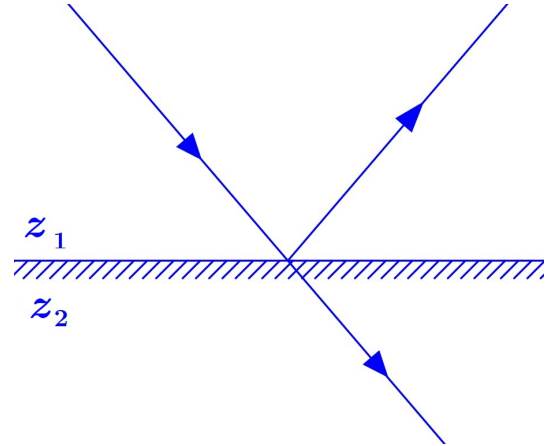
Ultrasound Reflection

For an acoustic wave that passes from one substance with refractive index z_1 into another with refractive index z_2 , we define **amplitude reflection coefficient** as:

$$R_A = \frac{P_r}{P_i} = \frac{z_2 - z_1}{z_2 + z_1} \quad (5)$$

therefore the **intensity reflection coefficient** :

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



20. Q Two tissue types have speed of sound and density of

(a) 1580 m s^{-1} and $1.1 \times 10^3 \text{ kg m}^{-3}$

(b) 1460 m s^{-1} and $0.9 \times 10^3 \text{ kg m}^{-3}$.

Calculate the intensity reflection coefficient for a large interface between them.

- (a) 0.2189
- (b) 0.3714
- (c) 0.019
- (d) 0.0235

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

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

$$R_I = (R_A)^2 = \left(\frac{z_2 - z_1}{z_2 + z_1} \right)^2 = (0.138)^2 = 0.019$$

20. A (c)

Ultrasound Scattering

$$W_s \propto \frac{d^6}{\lambda^4} \propto d^6 f^4 \quad (7)$$

Ultrasound Refraction (Refraction)

$$\frac{\sin \theta_i}{\sin \theta_t} = \frac{c_1}{c_2} \quad (8)$$

21. Q What is attenuation in medical ultrasound?

- Ⓐ The gradual gain of beam energy
- Ⓑ The abrupt loss of beam energy
- Ⓒ The gradual loss of beam energy
- Ⓓ The abrupt gain of beam energy

21. A (c)

22. Q What is the unit of attenuation

- Ⓐ dB cm⁻¹ MHz⁻¹
- Ⓑ dB⁻¹ cm⁻¹ MHz
- Ⓒ dB cm MHz
- Ⓓ 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 $0.7 \text{ dB cm}^{-1} \text{ MHz}^{-1}$. 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 $2x = 2 \times 5 \text{ cm} = 10 \text{ cm}$

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

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 $2x = 2 \times 1 \text{ cm} = 2 \text{ cm}$

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

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

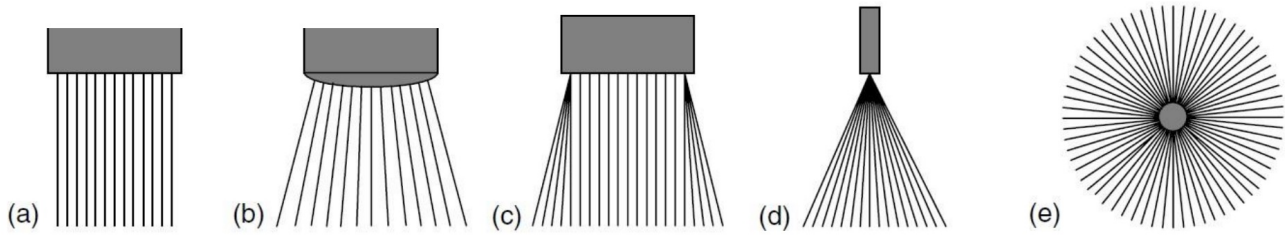
30. A (b)

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

$$\text{near field length} = \frac{a^2}{\lambda} \quad (9)$$

Where a : diameter of transducer

Angle of divergence

$$\sin \theta = 0.61 \frac{\lambda}{a} \quad (10)$$

Foucsing

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

$$W = \frac{F\lambda}{a} \quad (11)$$

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) $2 \mu\text{m}$
- (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?

- Ⓐ To convert electrical transmission pulses into ultrasonic pulses
- Ⓑ To determine the shape and position of the beams
- Ⓒ To convert ultrasonic echo pulses into electrical signals
- Ⓓ 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?

- Ⓐ Transducer
- Ⓑ Processor
- Ⓒ Display
- Ⓓ Beamformer

40. A (d)

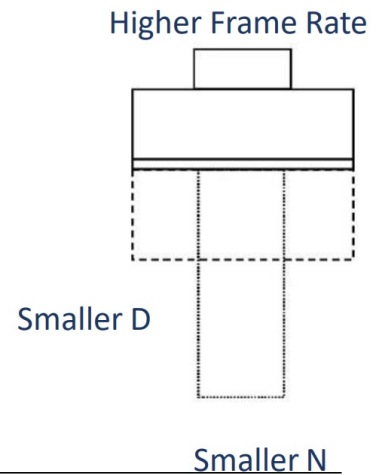
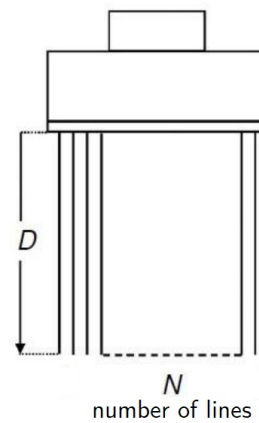
Frame time / Frame rate

$$\text{frame time} = \frac{2DN}{c}$$

$$\text{frame rate} = \frac{c}{2DN}$$

(12)

(13)



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)

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

- (a) 24 fps
- (b) 30 fps
- (c) 60 fps
- (d) 120 fps

$$\text{frame rate} = 1 / \text{frame time} = 30 \text{ fps}$$

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

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

Therefore

$$v = \frac{cf_d}{2f_t \cos \theta} \quad (15)$$

44. Q Which of the following is not a Doppler display mode?

- (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?

- Ⓐ Color Doppler
- Ⓑ Spectral Doppler
- Ⓒ Continuous Wave Doppler
- Ⓓ Pulsed-Wave Doppler

45. A (d)

46. Q Which of the following is not true about of Continuous Wave Doppler?

- Ⓐ No range information
- Ⓑ Limitations on maximum velocity and accuracy
- Ⓒ Only a small region for Doppler sensitivity
- Ⓓ No limitation on maximum velocity and high velocity accuracy

46. A (b)

Pulse Repetition Frequency - Pulse Repetition Interval

PRI : the time interval between pulses

$$\text{PRI} = t_2 - t_1 \quad (16)$$

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

$$\text{PRF} = \frac{1}{\text{PRI}} \quad (17)$$

$$d_1 = \frac{ct_1}{2} \quad (18)$$

$$d_2 = \frac{ct_2}{2} \quad (19)$$

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

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

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

$$f_{d \max} = \frac{\text{PRF}}{2} \quad (23)$$

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 :

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

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

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

Remember

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

Therefore

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

47. A (c)

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)

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)

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?

- Ⓐ Treating benign and malignant tumors
- Ⓑ Cleaning teeth in dental hygiene
- Ⓒ Breaking up kidney stones
- Ⓓ Detecting prostate cancer early

51. A (c)

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

- Ⓐ Treating benign and malignant tumors and other disorders
- Ⓑ Cleaning teeth in dental hygiene
- Ⓒ Detecting prostate cancer early
- Ⓓ Breaking up kidney stones

52. A (a)

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

- Ⓐ Treating benign and malignant tumors
- Ⓑ Cleaning teeth in dental hygiene
- Ⓒ Detecting prostate cancer early
- Ⓓ Therapeutic tooth and bone regeneration

53. A (d)

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

- Ⓐ Joint stiffness
- Ⓑ Headaches
- Ⓒ Development of heat in tissues
- Ⓓ 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?

- Ⓐ Formation of bubbles
- Ⓑ Increase in blood pressure
- Ⓒ Decrease in heart rate
- Ⓓ None of the above

55. A (a)

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

- Ⓐ Yes, in both humans and animals
- Ⓑ No, in either humans or animals
- Ⓒ Only in animals, not humans
- Ⓓ Only in humans, not animals

56. A (b)