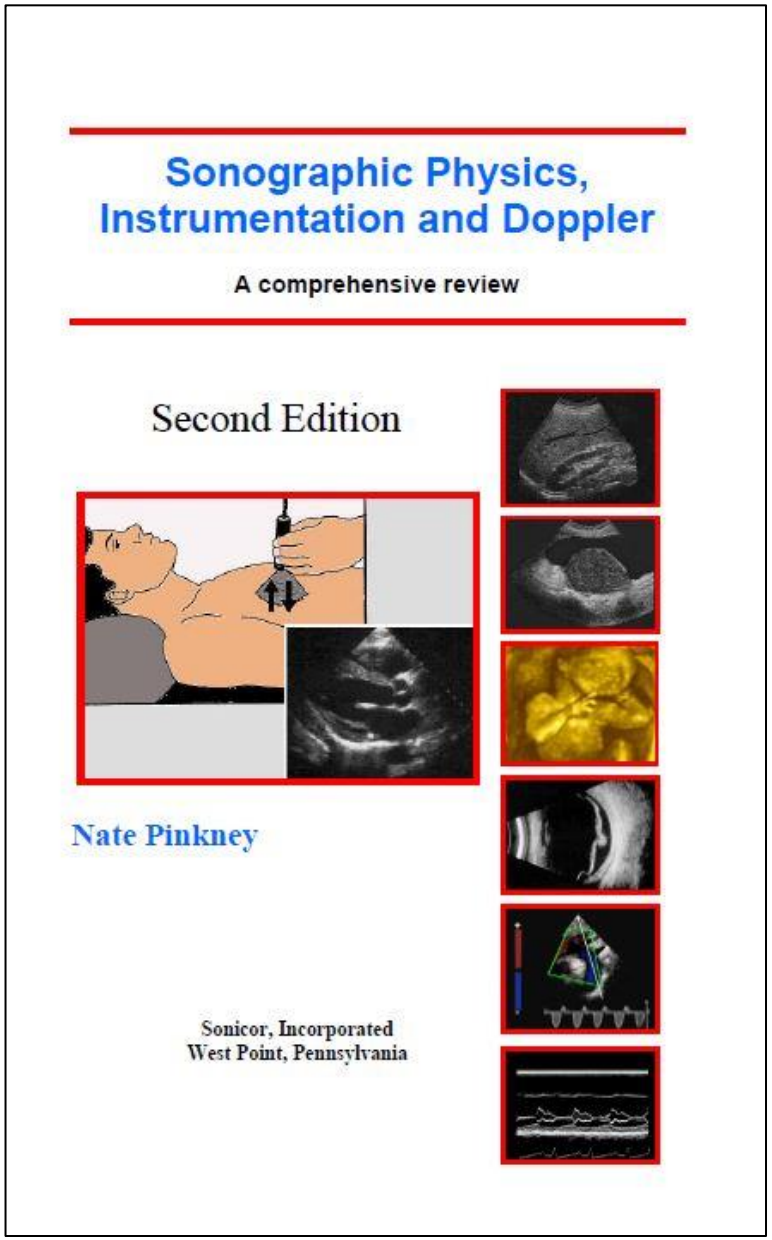
# Lesson 03:

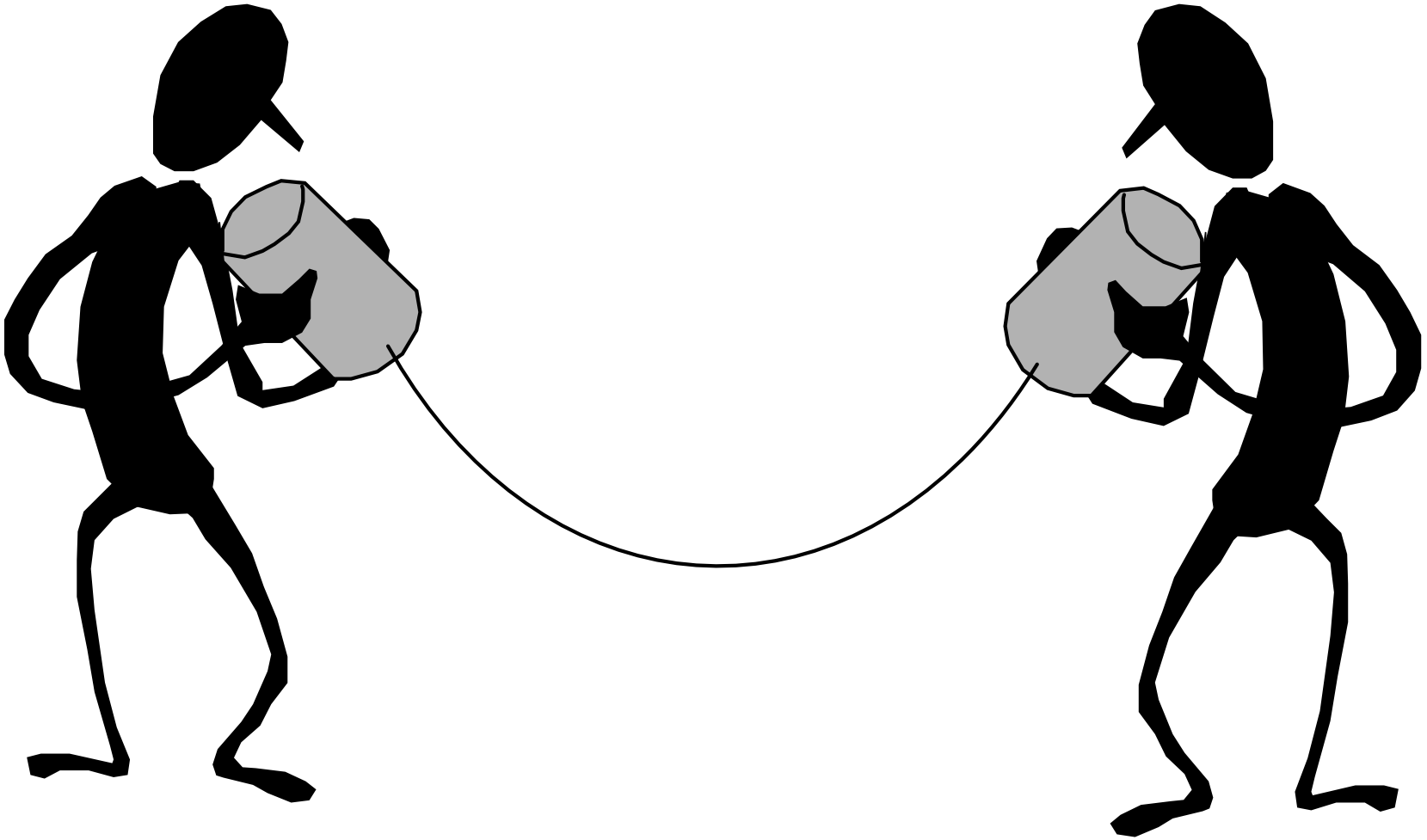
## Sound Wave Propagation and Reflection

This lesson contains 15 slides plus 14 multiple-choice questions.

**Accompanying text for the slides in this lesson can be found on pages 8 through 14 in the textbook:**

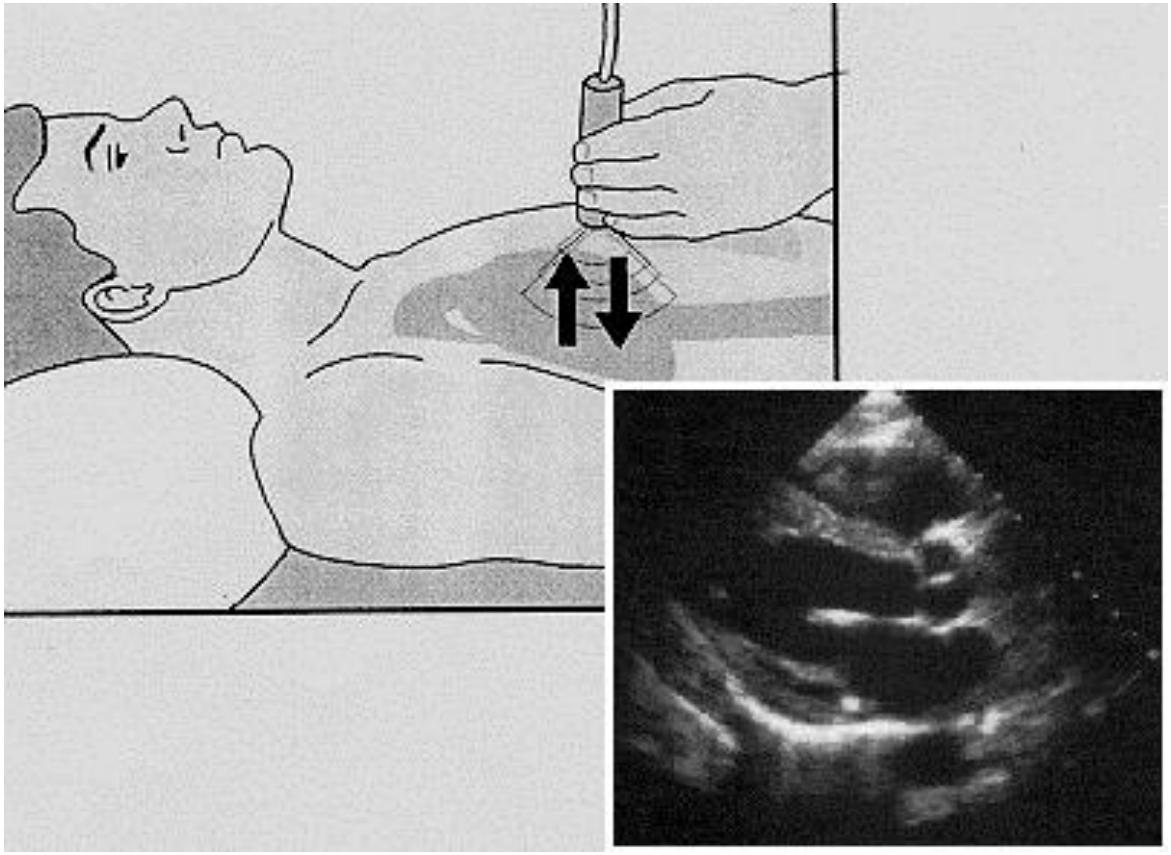


# Sound Wave Propagation and Reflection



# PROPAGATION

# PULSE-ECHO



# RANGE EQUATION:
# (in tissue)

| TIME TO THE REFLECTOR (ONE WAY) | DISTANCE TO THE REFLECTOR (ONE WAY) | ROUND TRIP TIME | ROUND TRIP DISTANCE |
|---|---|---|---|
| 6.5 µs | 10 mm (1 cm) | 13 µs | 20 mm (2 cm) |
| 5 µs | 7.7 mm (0.77 cm) | 10 µs | 15.4 mm (1.54 cm) |

# PULSE-ECHO FORMULAS

**Pulse Repetition Period = 1 ÷ Pulse Repetition Frequency**

| PRF | PRP |
|---|---|
| 1000 Hz | 1/1000 sec (0.001 sec) |
| 2000 Hz | 1/2000 sec (0.0005 sec) |
| 4000 Hz | 1/4000 sec (0.00025 sec) |

# PULSE-ECHO FORMULAS

**Duty Factor = Pulse Duration ÷ Pulse Repetition Period**

| PRF | PRP | PULSE DURATION | DUTY FACTOR |
|---|---|---|---|
| Increase | Decrease | ——— | Increase |
| Decrease | Increase | ——— | Decrease |
| ——— | ——— | Increase | Increase |
| ——— | ——— | Decrease | Decrease |

# ACOUSTIC IMPEDANCE:

**Acoustic Impedance = Density x Velocity**

| DENSITY | VELOCITY | ACOUSTIC IMPEDANCE |
|---|---|---|
| Increase | ——— | Increase |
| Decrease | ——— | Decrease |
| ——— | Increase | Increase |
| ——— | Decrease | Decrease |

# ACOUSTIC IMPEDANCE

**(Rayls)**

| | |
|---|---|
| Air | 400 |
| Fat | 1,380,000 |
| Water | 1,430,000 |
| Soft Tissue | 1,630,000 |
| Muscle | 1,700,000 |
| Bone | 7,800,000 |

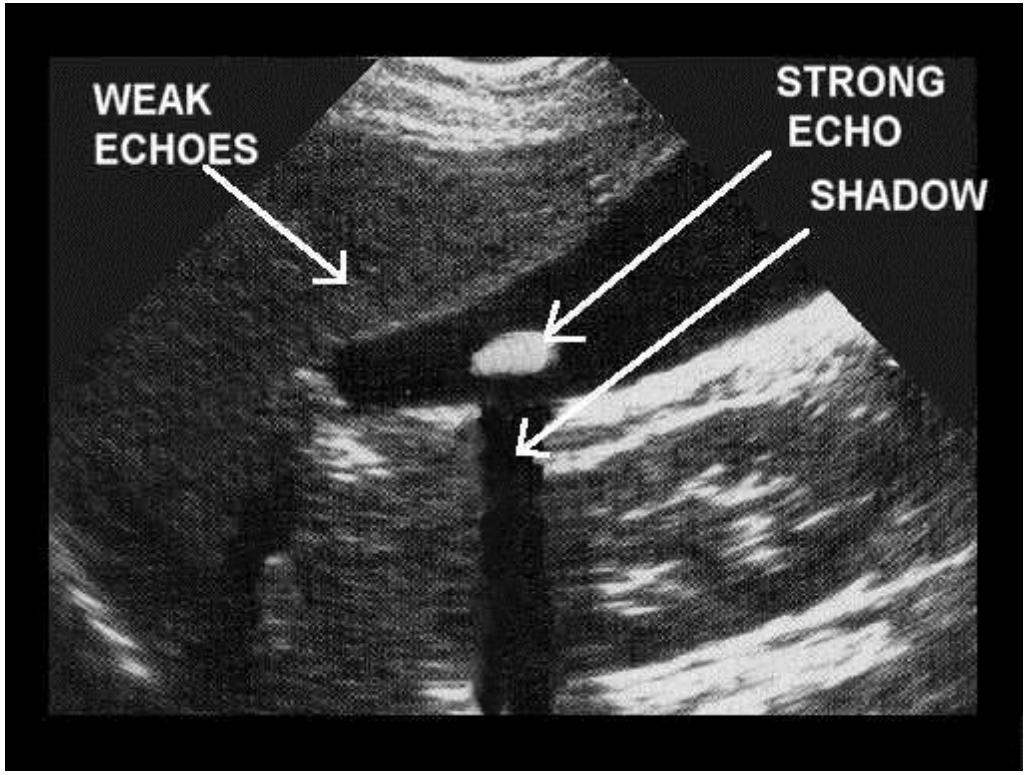
# INTERFACE MATERIALS & ECHO STRENGTH

**Soft Tissue to Muscle - Weak (1%)**
**Fat to Soft Tissue – Weak (1%)**

**Soft Tissue to Bone - Medium (50%)**
**Blood to Plaque – Medium (50%)**

**Soft Tissue to Air - Very Strong (100%)**

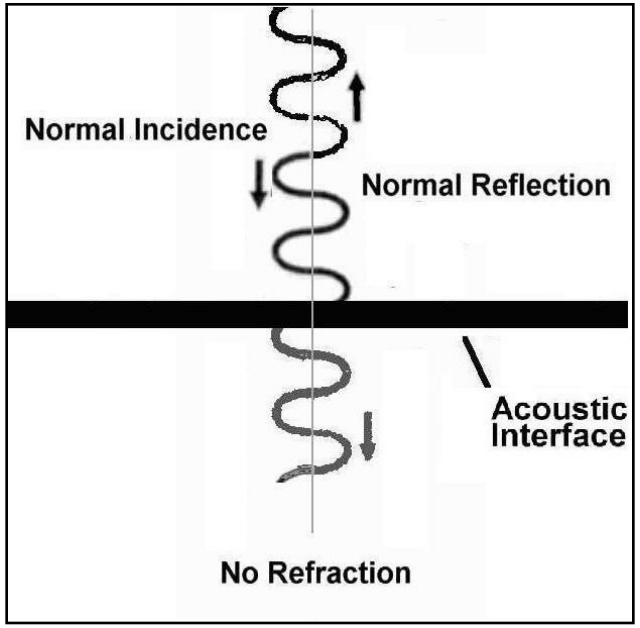
# SAGITTAL - LIVER, RIGHT KIDNEY

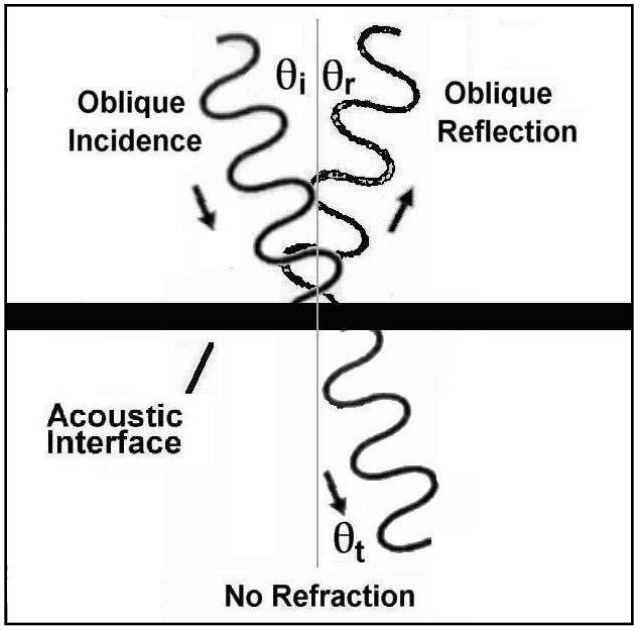



**ACOUSTIC SHADOW: THE RESULT OF A STRONG REFLECTION FROM A GALLSTONE**

# ACOUSTIC COUPLANT

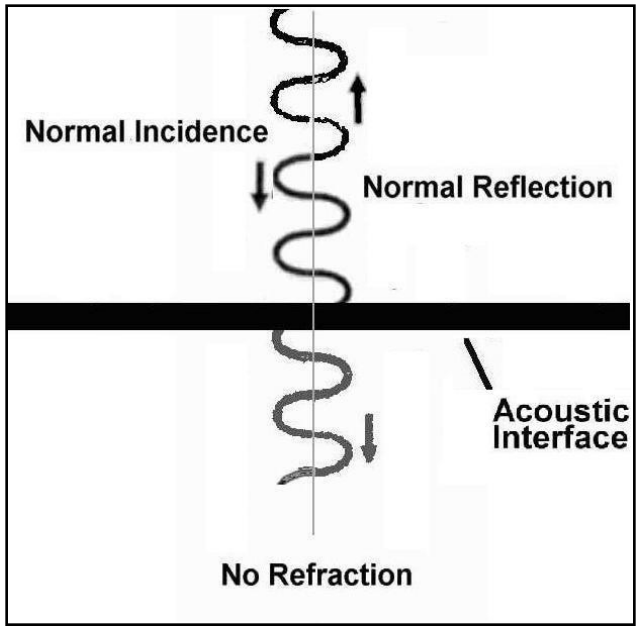
# SPECULAR REFLECTION

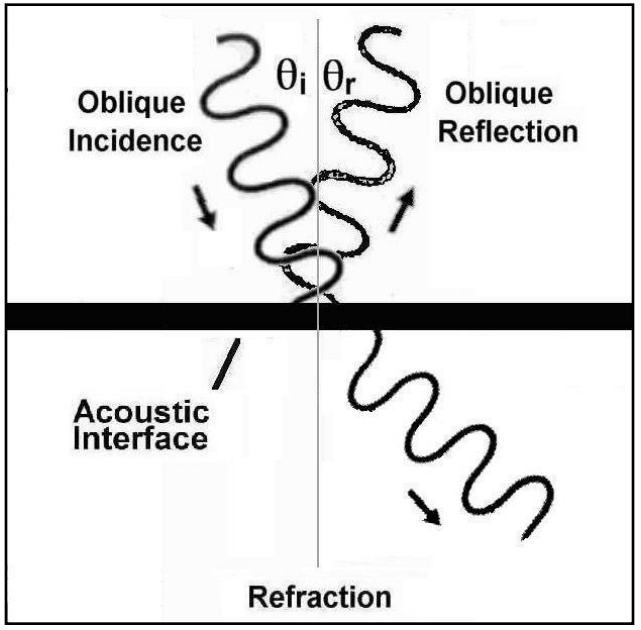



**Small change or no change in velocity**
**With $\theta_i$ normal or oblique, $\theta_t$ indicates no refraction**

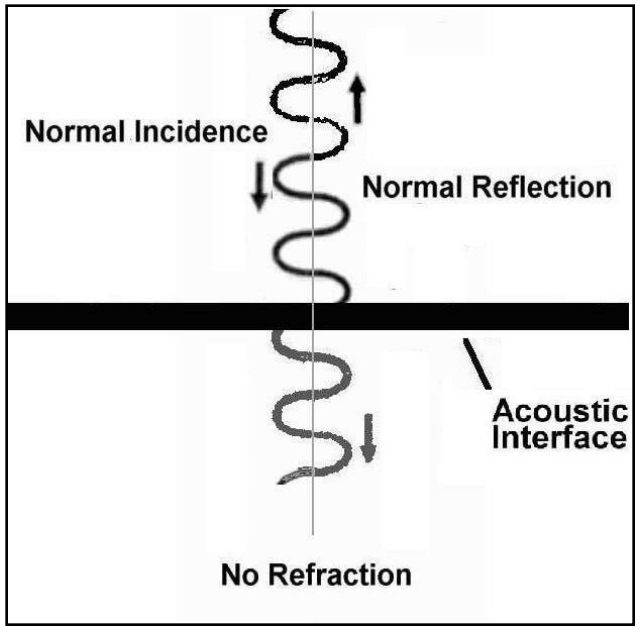
# SPECULAR REFLECTION

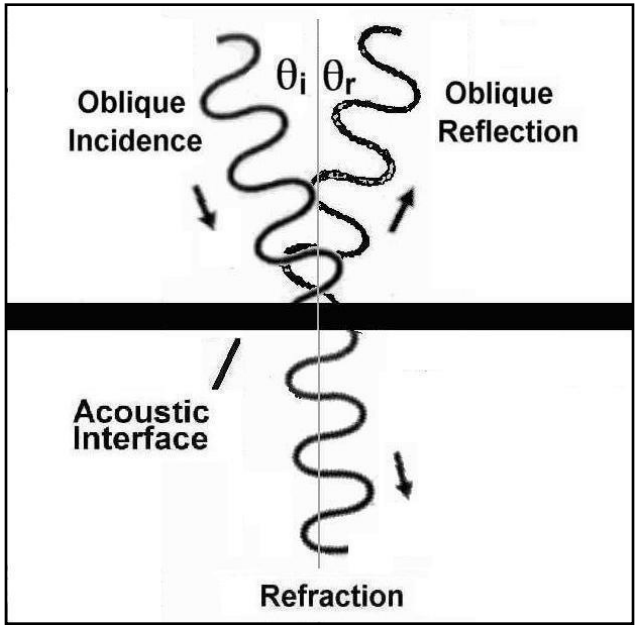



**Large increase in velocity**
**With $\theta_i$ oblique, refraction is present**

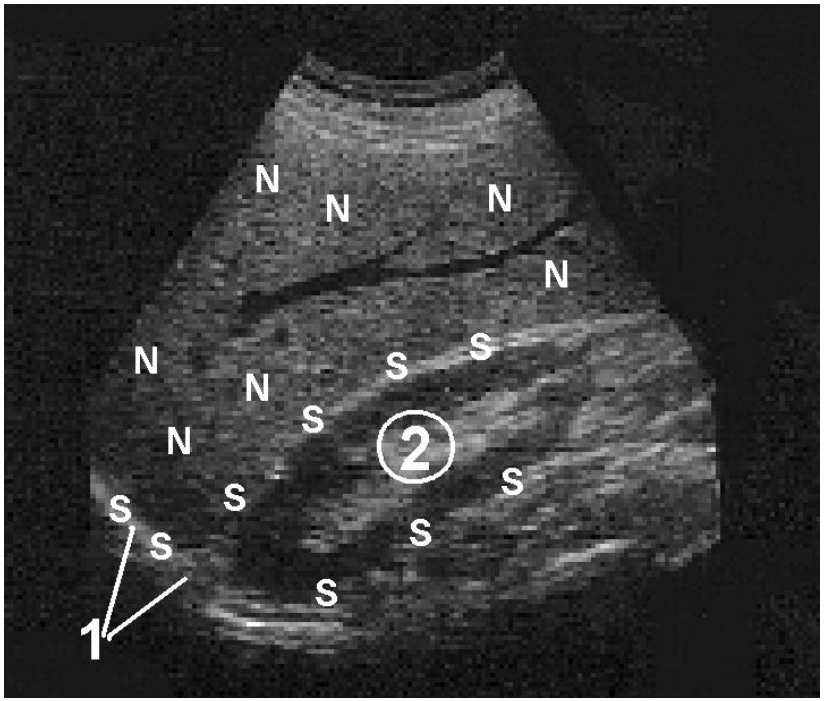
# SPECULAR REFLECTION




**Large decrease in velocity**
**With $\theta_i$ oblique, refraction is present**

# SAGITTAL - LIVER, RIGHT KIDNEY



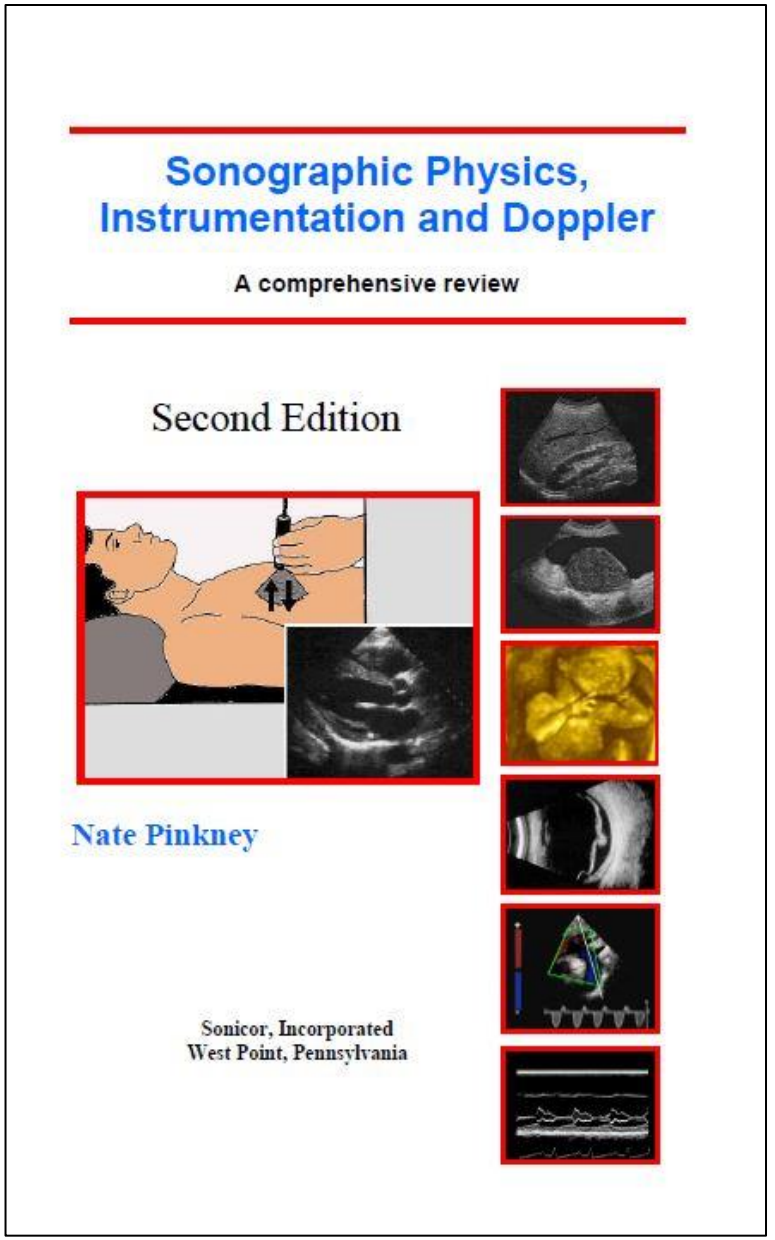

**N = non-specular reflector**

**S = specular reflector**

**1 = diaphragm**

**2 = kidney**

**Answers to the following FOURTEEN practice questions were derived from material in the textbook:**



# Question 1

A range of pulse repetition frequencies in a pulse-echo ultrasound system could be:

- 2,000 Hz to 20,000 Hz
- 20,000 Hz to 200,000 Hz
- 1,200 Hz  to 2,000 Hz
- 2 MHz to 20 MHz

# Question 1

A range of pulse repetition frequencies in a pulse-echo ultrasound system could be:

- 2,000 Hz to 20,000 Hz
- 20,000 Hz to 200,000 Hz
- 1,200 Hz  to 2,000 Hz
- 2 MHz to 20 MHz

# Question 2

If the number of cycles in a pulse is reduced,

- the spatial pulse length increases
- the period increases
- the duty factor is smaller
- the bandwidth is decreased

Pages 6, 7, and 9

# Question 2

If the number of cycles in a pulse is reduced,

- the spatial pulse length increases
- the period increases
- the duty factor is smaller
- the bandwidth is decreased

Pages 6, 7, and 9

# Question 3

Damping in a transducer:

- reduces the transducer's resonant frequency
- increases the number of cycles in a pulse
- causes poor axial and lateral resolution
- reduces the number of cycles in a pulse

Pages 5, 6, 7, and 9

# Question 3

Damping in a transducer:

- reduces the transducer's resonant frequency
- increases the number of cycles in a pulse
- causes poor axial and lateral resolution
- reduces the number of cycles in a pulse

Pages 5, 6, 7, and 9

# Question 4

The distance to a target is doubled. The total time for a pulse to travel to the target and back is:

- 4 times
- 2 times
- 8 times
- halved

# Question 4

The distance to a target is doubled. The total time for a pulse to travel to the target and back is:

- 4 times
- 2 times
- 8 times
- halved

# Question 5

If ultrasound energy leaves a transducer and travels through a large amount of fat and then encounters a reflector, the echo will appear on the display:

- to the right of where it should
- more superficial than it should
- deeper than it should
- to the left of where it should

Pages 2 and 8

# Question 5

If ultrasound energy leaves a transducer and travels through a large amount of fat and then encounters a reflector, the echo will appear on the display:

- to the right of where it should
- more superficial than it should
- deeper than it should
- to the left of where it should

Pages 2 and 8

# Question 6

The reason most ultrasound systems are calibrated at 1540 meters per second is because:

- 1540 meters per second is the average speed of sound in the patient
- 1540 meters per second is the speed of sound most often encountered in a patient
- 1540 meters per second is the maximum speed of sound in a patient
- 770 meters per second is the average speed of sound in a patient

Pages 2 and 8

# Question 6

The reason most ultrasound systems are calibrated at 1540 meters per second is because:

- 1540 meters per second is the average speed of sound in the patient
- 1540 meters per second is the speed of sound most often encountered in a patient
- 1540 meters per second is the maximum speed of sound in a patient
- 770 meters per second is the average speed of sound in a patient

Pages 2 and 8

# Question 7

Which ultrasound system parameter is affected by variations in the speed of sound?

- pulse repetition frequency
- pulse repetition period
- distance accuracy
- duty factor

# Question 7

Which ultrasound system parameter is affected by variations in the speed of sound?

- pulse repetition frequency
- pulse repetition period
- distance accuracy
- duty factor

# Question 8

With an oblique angle of incidence at a non-specular reflector:

- it is not likely that an echo will return to the transducer
- Rayleigh scattering is not possible
- it is possible that an echo will return to the transducer
- the transmission coefficient will exceed 100%

Pages 12, 13, and 14

# Question 8

With an oblique angle of incidence at a non-specular reflector:

- it is not likely that an echo will return to the transducer
- Rayleigh scattering is not possible
- it is possible that an echo will return to the transducer
- the transmission coefficient will exceed 100%

Pages 12, 13, and 14

# Question 9

If the velocities of sound in the two materials that form an interface are **NOT** equal,

- the reflection coefficient will exceed 100%
- the reflected angle will be greater than the incident angle
- refraction may occur if the incident angle is oblique
- the incident angle will be greater than the reflected angle

Pages 12 and 13

# Question 9

If the velocities of sound in the two materials that form an interface are **NOT** equal,

- the reflection coefficient will exceed 100%
- the reflected angle will be greater than the incident angle
- refraction may occur if the incident angle is oblique
- the incident angle will be greater than the reflected angle

Pages 12 and 13

# Question 10

The redirection of sound energy in many directions as a result of a rough boundary between two media is:

- shadowing
- specular reflection
- scattering
- refraction

# Question 10

The redirection of sound energy in many directions as a result of a rough boundary between two media is:

- shadowing
- specular reflection
- scattering
- refraction

# Question 11

If the density is the same in materials A and B, but the speed of sound in material B is 10% greater than the speed of sound in material A,

- The acoustic impedance in B is 10% greater than the acoustic impedance in A
- The sound velocity in A is 10% higher than the propagation speed in B
- The acoustic impedance in A is equal to the acoustic impedance in B
- The acoustic impedance in A is 10% higher than the acoustic impedance in B

# Question 11

If the density is the same in materials A and B, but the speed of sound in material B is 10% greater than the speed of sound in material A,

- The acoustic impedance in B is 10% greater than the acoustic impedance in A
- The sound velocity in A is 10% higher than the propagation speed in B
- The acoustic impedance in A is equal to the acoustic impedance in B
- The acoustic impedance in A is 10% higher than the acoustic impedance in B

# Question 12

As the impedances of the two media forming an interface become vastly different, the:

- transmission increases
- reflection increases
- bandwidth increases
- refraction increases

Pages 10 and 11

# Question 12

As the impedances of the two media forming an interface become vastly different, the:

- transmission increases
- reflection increases
- bandwidth increases
- refraction increases

Pages 10 and 11

# Question 13

A typical reflection coefficient from soft tissue interfaces could be in the range of:

- 75%
- 1%
- 20%
- 50%

# Question 13

A typical reflection coefficient from soft tissue interfaces could be in the range of:

- 75%
- 1%
- 20%
- 50%

# Question 14

Matching layers in a transducer:

- improve axial resolution
- determine the operating frequency
- provide greater efficiency of sound transmission from the transducer to the patient
- improve lateral resolution

# Question 14

Matching layers in a transducer:

- improve axial resolution
- determine the operating frequency
- provide greater efficiency of sound transmission from the transducer to the patient
- improve lateral resolution

**END OF LESSON 03**

For information on the accompanying textbook, visit the Website:

www.Sonicorinc.com