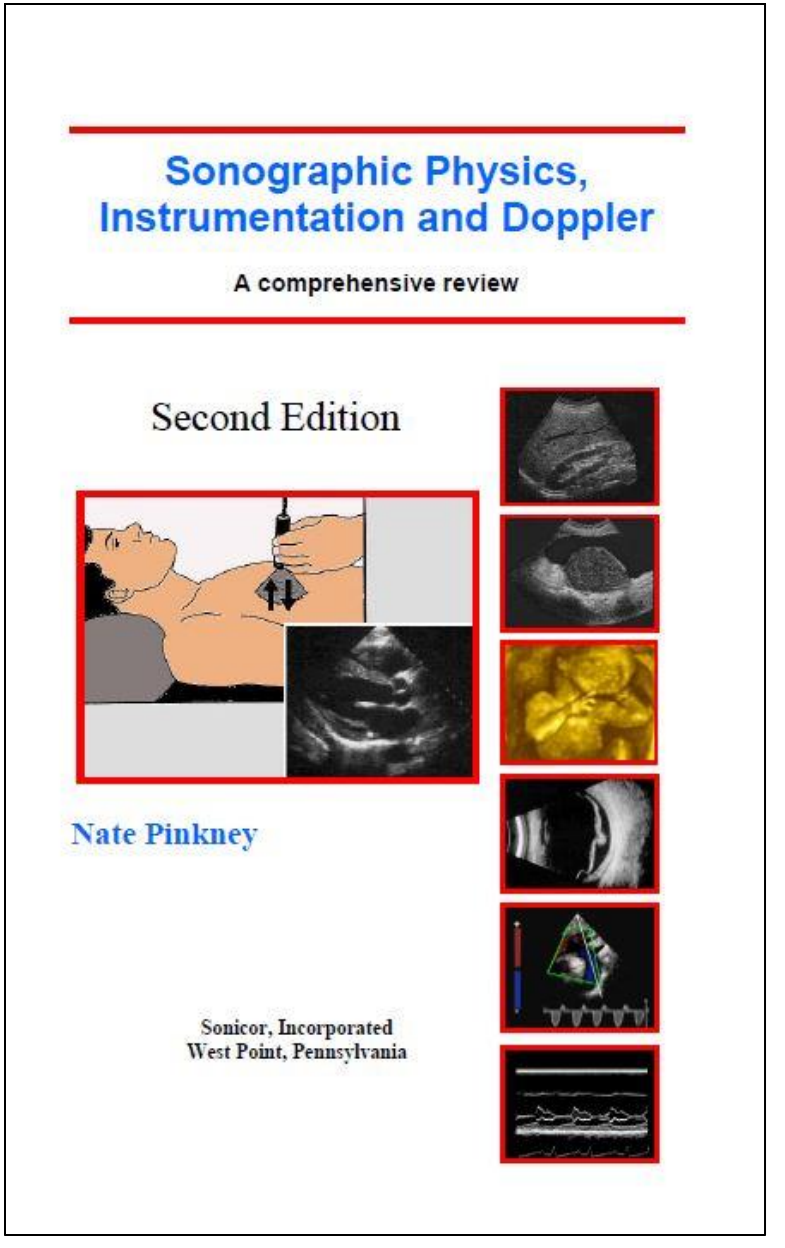
Lesson 02:

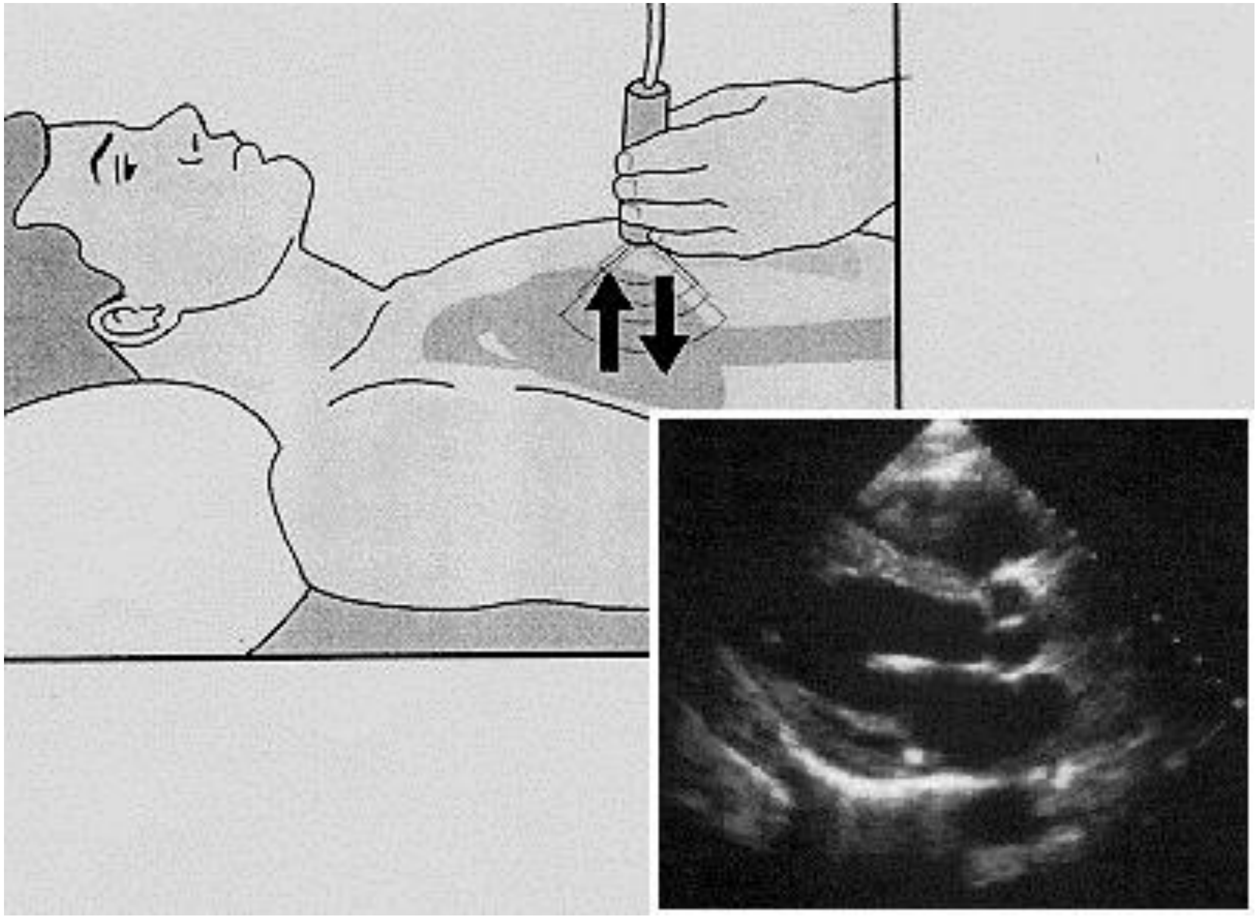
Sound Wave Production

This lesson contains 24 slides plus 11 multiple-choice questions.

Accompanying text for the slides in this lesson can be found on pages 2 through 7 in the textbook:

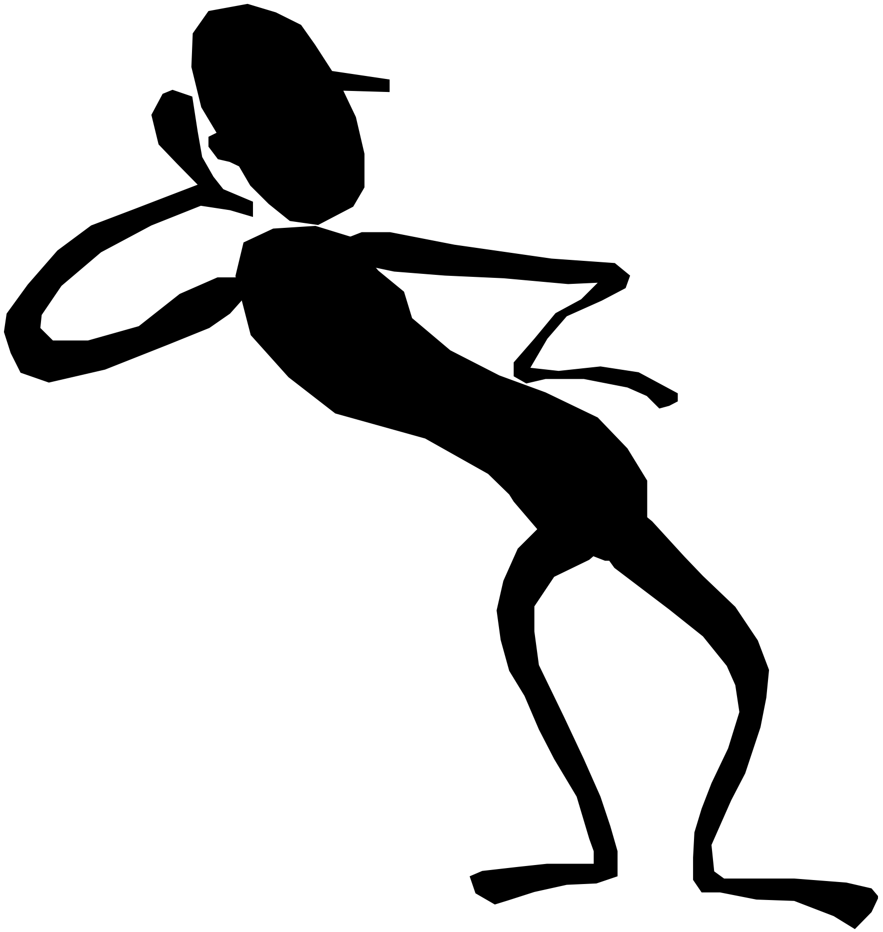


ULTRASOUND



Sound Wave Production

SOUND



CATEGORIES OF SOUND

INFRASOUND (subsonic) = below 20 Hz

AUDIBLE SOUND = 20 Hz to 20 kHz

ULTRASOUND = above 20 kHz

MEDICAL DIAGNOSTIC ULTRASOUND

ABOVE 1 MHz

SOUND VELOCITY

STIFFNESS

(velocity *increases* with stiffness)

DENSITY

(velocity *decreases* with density)

SOUND VELOCITIES

Material	Meters per second
Air	330
Pure Water	1430
Fat	1450
Soft Tissue	**1540**
Muscle	1585
Bone	4080

SOUND VELOCITIES

STIFFNESS OF MEDIUM	DENSITY OF MEDIUM	SOUND VELOCITY
Increase	—	Increase
Decrease	—	Decrease
—	Increase	Decrease
—	Decrease	Increase

PIEZOELECTRIC EFFECT

- **TRANSMIT – electrical energy to mechanical energy**

- **RECEIVE – mechanical energy to electrical energy**

RESONANT FREQUENCY

- The fundamental frequency of a transducer

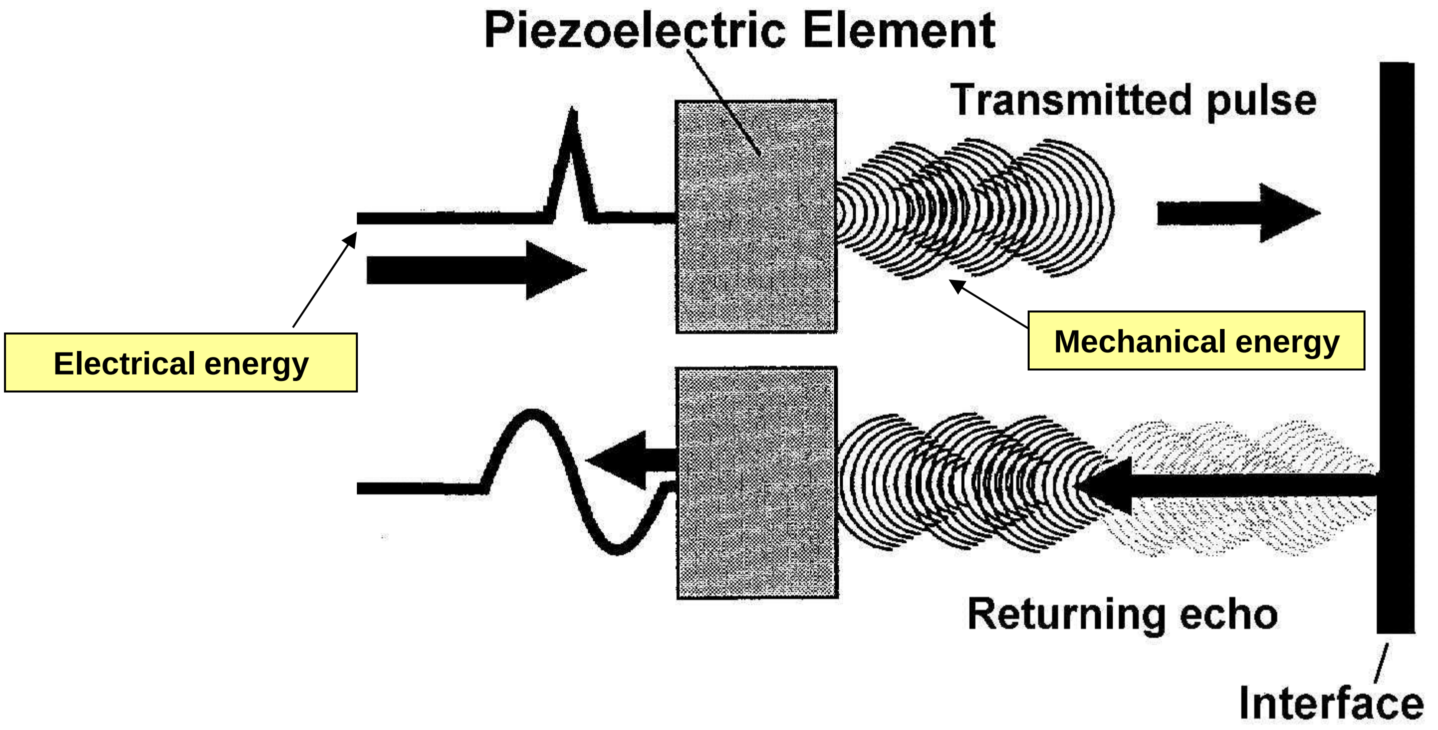
RESONANT FREQUENCY

PIEZOELECTRIC ELEMENT THICKNESS	RESONANT FREQUENCY
Increase	Decrease
Decrease	Increase

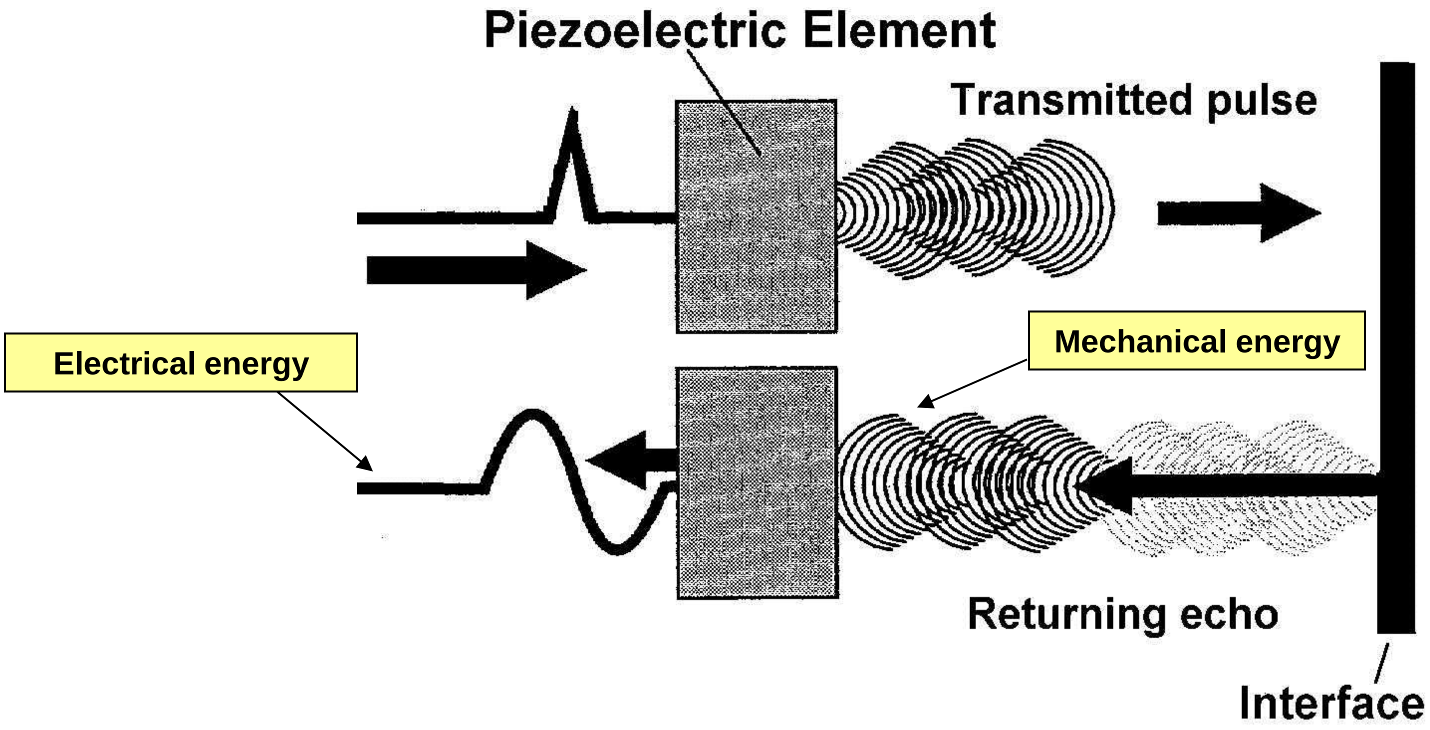
PIEZOELECTRIC CERAMICS

- **lead zirconate titanate**
- **barium titanate**
- **lead metaniobate**
- **lead titanate**

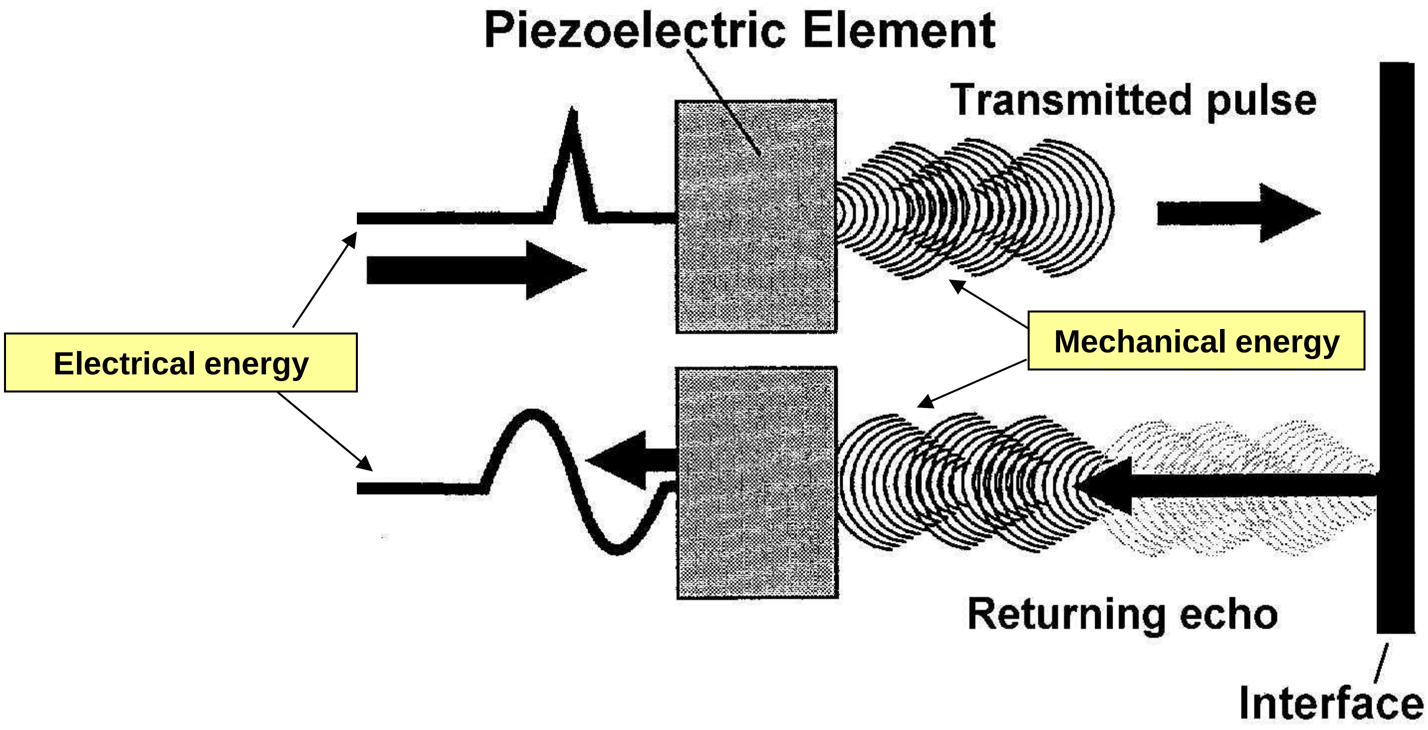
PIEZOELECTRIC EFFECT



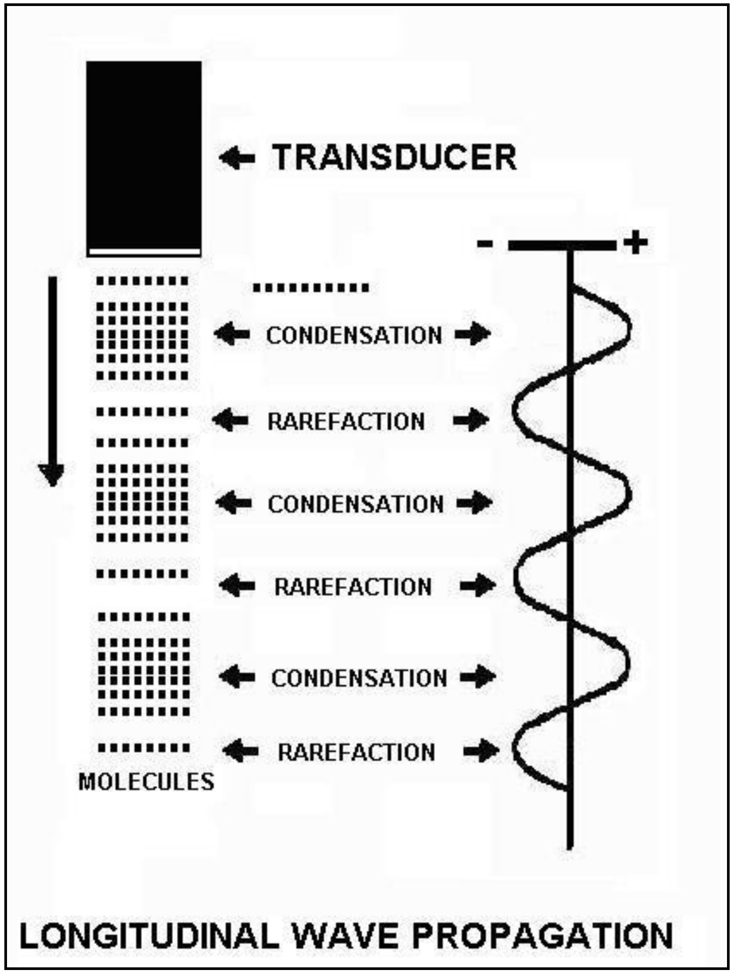
PIEZOELECTRIC EFFECT



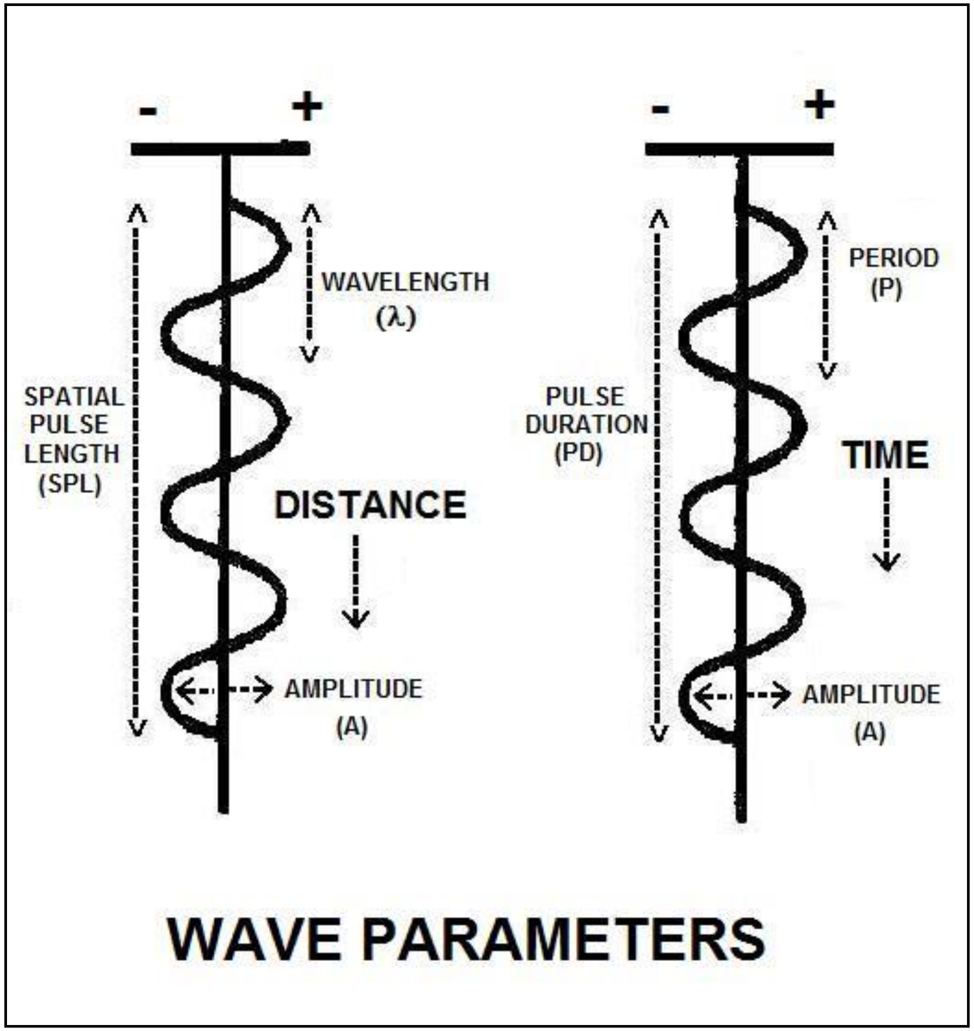
PIEZOELECTRIC EFFECT



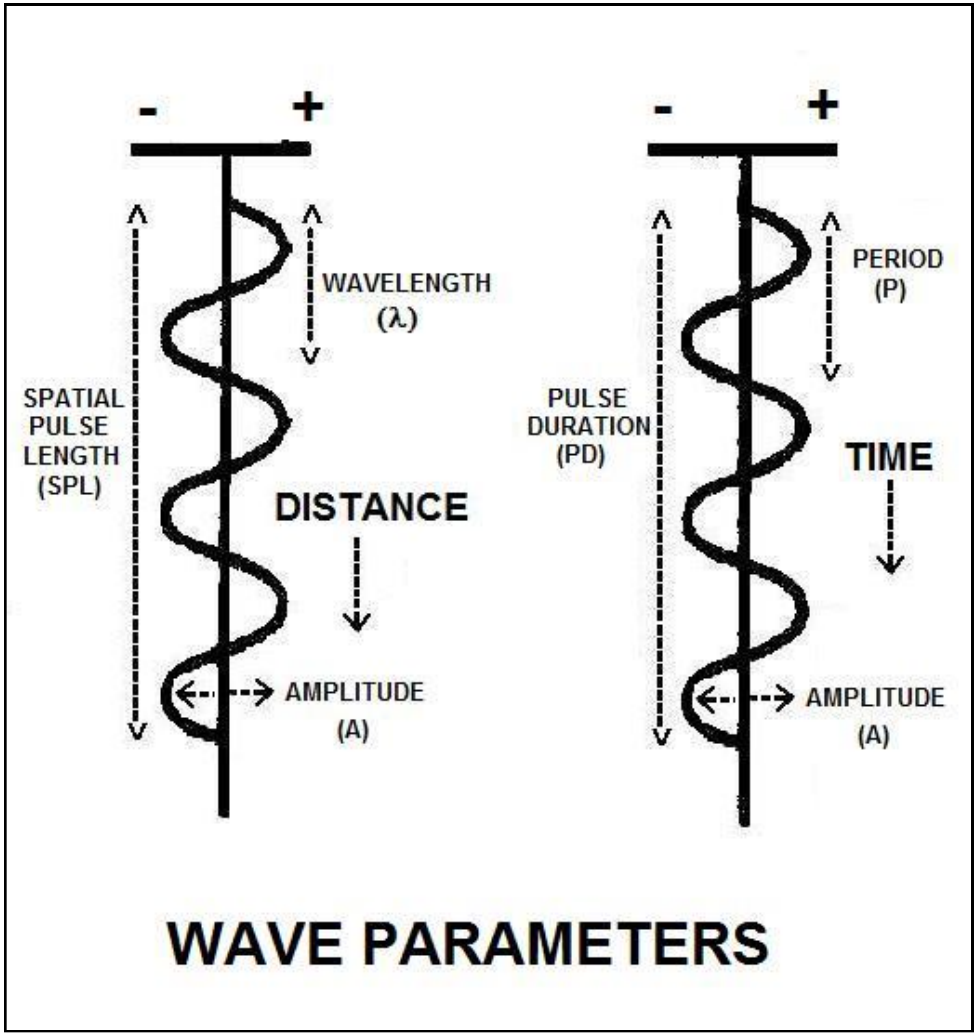
LONGITUDINAL WAVE PROPAGATION



WAVE PARAMETERS



WAVE PARAMETERS



WAVE PARAMETERS AND EXAMPLES

Period = 1 ÷ Frequency

Wavelength = Velocity ÷ Frequency

Pulse Duration = Period x Number of Cycles

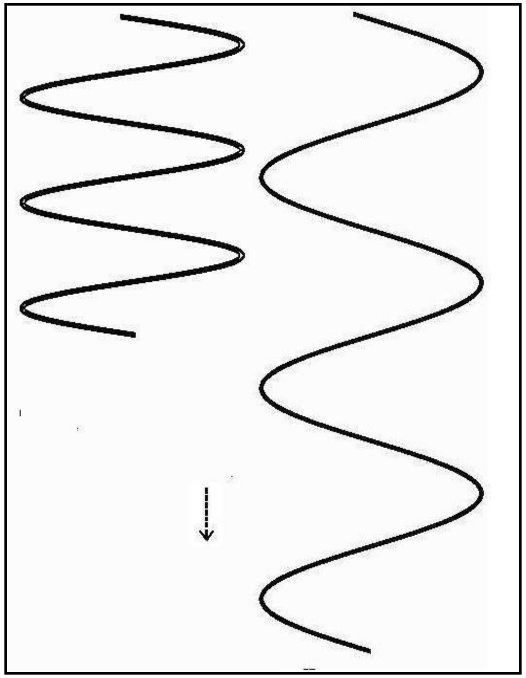
Spatial Pulse Length = Wavelength x Number of Cycles

DAMPING	FREQUENCY	PERIOD	WAVELENGTH	NUMBER OF CYCLES	PULSE DURATION	SPATIAL PULSE LENGTH
————	Increase	Decrease	Decrease	————	Decrease	Decrease
————	Decrease	Increase	Increase	————	Increase	Increase
Increase	————	————	————	Decrease	Decrease	Decrease
Decrease	————	————	————	Increase	Increase	Increase

The *number of cycles* in a pulse is *not* the same as the *frequency* of the sound, which is the number of cycles per unit time that a transducer, which is operating continuously, is designed to produce*.*

SAME DAMPING & AMPLITUDE
DIFFERENT FREQUENCY & PHASE

Frequency = 5.0 MHz
Number of Cycles = 3
Period = 0.2 μs
Pulse Duration = 0.6 μs
Wavelength = 0.308 mm
Spatial Pulse Length = 0.924 mm



Frequency = 2.5 MHz
Number of Cycles = 3
Period = 0.4 μs
Pulse Duration = 1.2 μs
Wavelength = 0.616 mm
Spatial Pulse Length = 1.848 mm

3-cycle pulse

shorter periods

shorter wavelengths

shorter pulse duration

shorter spatial pulse length

3-cycle pulse

longer periods

longer wavelengths

longer pulse duration

longer spatial pulse length

SAME FREQUENCY, AMPLITUDE, & PHASE
DIFFERENT DAMPING

Frequency = 5.0 MHz
Number of Cycles = 3
Period = 0.2 µs
Pulse Duration = 0.6 µs
Wavelength = 0.308 mm
Spatial Pulse Length = 0.924 mm

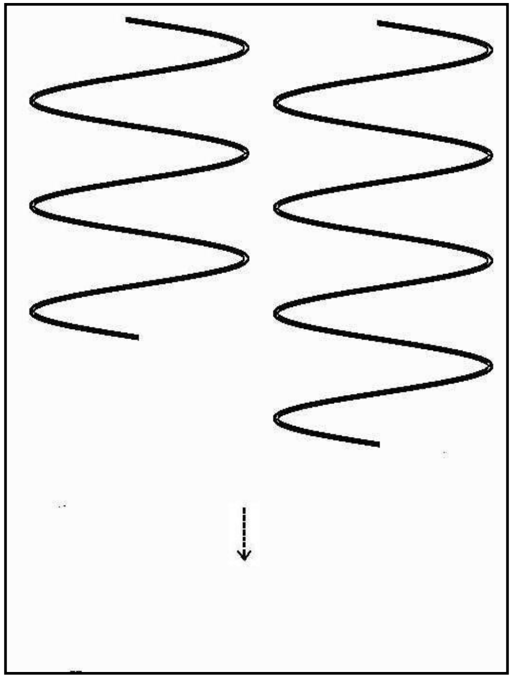
3-cycle pulse

same periods

same wavelengths

shorter pulse duration

shorter spatial pulse length



Frequency = 5.0 MHz
Number of Cycles = 4
Period = 0.2 µs
Pulse Duration = 0.8 µs
Wavelength = 0.308 mm,
Spatial Pulse Length = 1.232 mm

4-cycle pulse

same periods

same wavelengths

longer pulse duration

longer spatial pulse length

SAME FREQUENCY & DAMPING
DIFFERENT AMPLITUDE & PHASE

Frequency = 5.0 MHz
Number of Cycles = 4
Period = 0.2 μs
Pulse Duration = 0.8 μs
Wavelength = 0.308 mm
Spatial Pulse Length = 1.232 mm

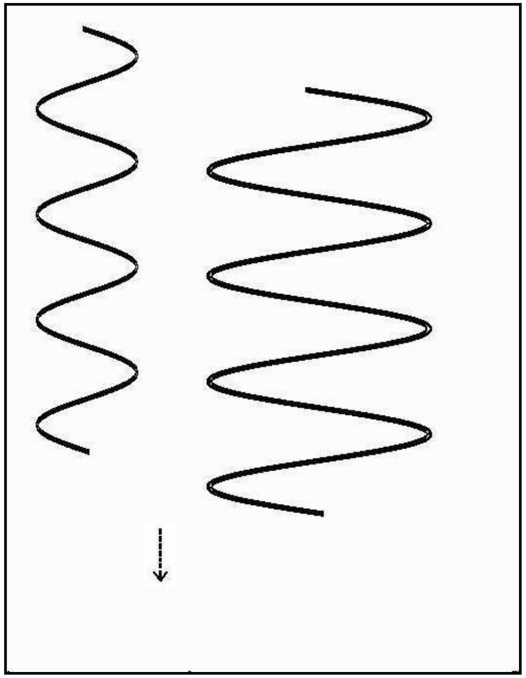
4-cycle pulse

same periods

same wavelengths

same pulse duration

same spatial pulse length



Frequency = 5.0 MHz
Number of Cycles = 4
Period = 0.2 μs
Pulse Duration = 0.8 μs
Wavelength = 0.308 mm
Spatial Pulse Length = 1.232 mm

4-cycle pulse

same periods

same wavelengths

same pulse duration

same spatial pulse length

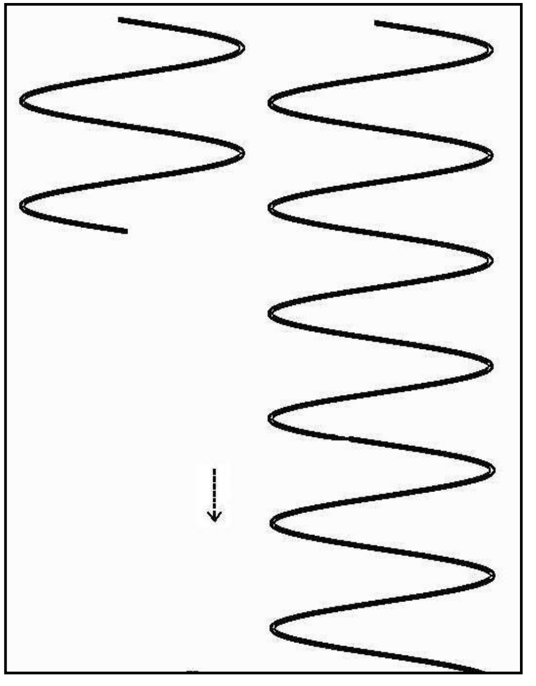
DAMPING vs. BANDWIDTH

DAMPING	BANDWIDTH
Increase	Increase
Decrease	Decrease

HIGH DAMPING vs. NO DAMPING

<u>SAME</u> FREQUENCY. <u>DIFFERENT</u> DAMPING

Center frequency = 5.0 MHz
Range = 3.75 MHz to 6.25 MHz
Number of Cycles = 2
Bandwidth = 2.5 MHz



Center frequency = 5.0 MHz
Range = 4.9 MHz to 5.1 MHz
Continuous Wave
Bandwidth = 0.2 MHz

Pulse-echo

Damped

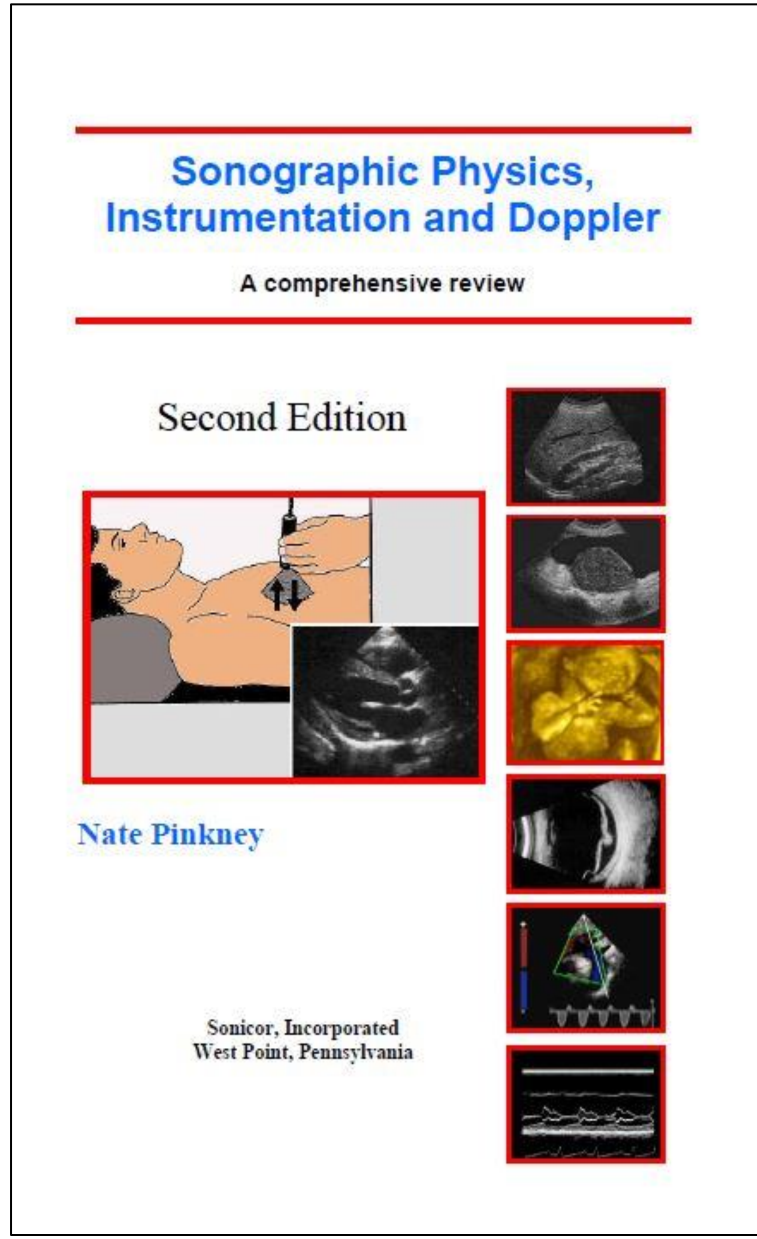
Wide Bandwidth

CW

Not damped

Narrow Bandwidth

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



Question 1

Ultrasound waves that are traveling through a medium consist of:

- compressions and refractions
- condensations and refractions
- electromagnetic and ionizing frequencies
- compressions and rarefactions

Pages 2 and 5

Question 1

Ultrasound waves that are traveling through a medium consist of:

- compressions and refractions
- condensations and refractions
- electromagnetic and ionizing frequencies
- compressions and rarefactions

Pages 2 and 5

Question 2

What is the difference between audible sound and ultrasound?

- Audible sound waves are ionizing
- Audible sound has a higher frequency
- Ultrasound has a higher frequency
- Ultrasound waves are ionizing

Question 2

What is the difference between audible sound and ultrasound?

- Audible sound waves are ionizing
- Audible sound has a higher frequency
- Ultrasound has a higher frequency
- Ultrasound waves are ionizing

Question 3

A piezoelectric element produces a voltage when:

- Sound velocity changes
- an acoustic pressure is present on its surface
- the receiver gain is increased
- the attenuation increases

Question 3

A piezoelectric element produces a voltage when:

- Sound velocity changes
- an acoustic pressure is present on its surface
- the receiver gain is increased
- the attenuation increases

Question 4

A decrease in the thickness of a piezoelectric element will result in:

- a greater pulse duration
- an increase in the propagation speed
- an increase in the frequency of the transducer
- a higher duty factor

Question 4

A decrease in the thickness of a piezoelectric element will result in:

- a greater pulse duration
- an increase in the propagation speed
- an increase in the frequency of the transducer
- a higher duty factor

Question 5

The resonant frequency of an ultrasound transducer is dependent on:

- damping
- the backing material
- the thickness of the piezoelectric element
- the amplitude of the voltage applied to the transducer

Question 5

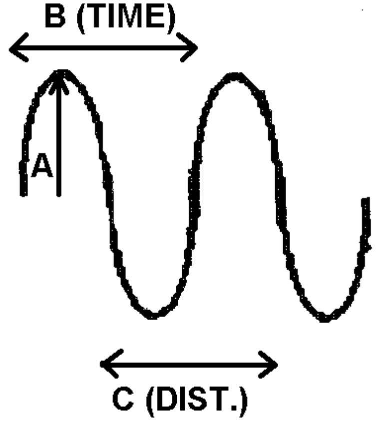
The resonant frequency of an ultrasound transducer is dependent on:

- damping
- the backing material
- the thickness of the piezoelectric element
- the amplitude of the voltage applied to the transducer

Question 6

What does A, B, and C represent on the graph?

- amplitude, period, wavelength
- pulse duration, duty factor, amplitude
- wavelength, duty factor, pulse duration
- period, wavelength, velocity

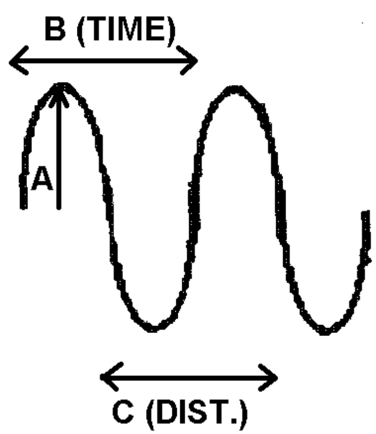


Pages 5 and 6

Question 6

What does A, B, and C represent on the graph?

- amplitude, period, wavelength
- pulse duration, duty factor, amplitude
- wavelength, duty factor, pulse duration
- period, wavelength, velocity



Pages 5 and 6

Question 7

If the frequency is doubled, the:

- period will double
- lateral resolution will be poorer
- wavelength will double
- wavelength will be one-half

Pages 5 and 6

Question 7

If the frequency is doubled, the:

- period will double
- lateral resolution will be poorer
- wavelength will double
- wavelength will be one-half

Pages 5 and 6

Question 8

The average speed of ultrasound in soft tissue is closest to:

- 330 m/sec
- 1450 m/sec
- 1540 m/sec
- 4080 m/s

Question 8

The average speed of ultrasound in soft tissue is closest to:

- 330 m/sec
- 1450 m/sec
- 1540 m/sec
- 4080 m/s

Question 9

If the frequency is doubled, the propagation speed is:

- quadrupled
- doubled
- halved
- unchanged

Pages 2 and 3

Question 9

If the frequency is doubled, the propagation speed is:

- quadrupled
- doubled
- halved
- unchanged

Pages 2 and 3

Question 10

The propagation speed is highest in:

- bone
- tissue
- fat
- water

Pages 2 and 3

Question 10

The propagation speed is highest in:

- bone
- tissue
- fat
- water

Pages 2 and 3

Question 11

A single pulse of ultrasound from a transducer:

- contains a range of frequencies
- does not result from damping
- has a narrow bandwidth
- contains continuous waves

Question 11

A single pulse of ultrasound from a transducer:

- contains a range of frequencies
- does not result from damping
- has a narrow bandwidth
- contains continuous waves

END OF LESSON 02

For information on the accompanying textbook, visit the Website:

www.Sonicorinc.com