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
ABOVE 1 MHz
STIFFNESS
(velocity *increases* with stiffness)

DENSITY
(velocity *decreases* with density)
<table>
<thead>
<tr>
<th>Material</th>
<th>Meters per second</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>330</td>
</tr>
<tr>
<td>Pure Water</td>
<td>1430</td>
</tr>
<tr>
<td>Fat</td>
<td>1450</td>
</tr>
<tr>
<td><strong>Soft Tissue</strong></td>
<td><strong>1540</strong></td>
</tr>
<tr>
<td>Muscle</td>
<td>1585</td>
</tr>
<tr>
<td>Bone</td>
<td>4080</td>
</tr>
</tbody>
</table>
## SOUND VELOCITIES

<table>
<thead>
<tr>
<th>STIFFNESS OF MEDIUM</th>
<th>DENSITY OF MEDIUM</th>
<th>SOUND VELOCITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase</td>
<td>___________</td>
<td>Increase</td>
</tr>
<tr>
<td>Decrease</td>
<td>___________</td>
<td>Decrease</td>
</tr>
<tr>
<td>___________</td>
<td>Increase</td>
<td>Decrease</td>
</tr>
<tr>
<td>___________</td>
<td>Decrease</td>
<td>Increase</td>
</tr>
</tbody>
</table>
PIEZOELECTRIC EFFECT

• TRANSMIT – electrical energy to mechanical energy

• RECEIVE – mechanical energy to electrical energy
The fundamental frequency of a transducer
### Resonant Frequency

<table>
<thead>
<tr>
<th>Piezoelectric Element Thickness</th>
<th>Resonant Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase</td>
<td>Decrease</td>
</tr>
<tr>
<td>Decrease</td>
<td>Increase</td>
</tr>
</tbody>
</table>
• lead zirconate titanate
• barium titanate
• lead metaniobate
• lead titanate
PIEZOELECTRIC EFFECT

Piezoelectric Element

Electrical energy

Transmitted pulse

Mechanical energy

Returning echo

Interface
PIEZOELECTRIC EFFECT

Piezoelectric Element

Transmitted pulse

Electrical energy

Mechanical energy

Returning echo

Interface
PIEZOELECTRIC EFFECT

Piezoelectric Element

Transmitted pulse

Electrical energy

Mechanical energy

Returning echo

Interface
LONGITUDINAL WAVE PROPAGATION
WAVE PARAMETERS

- WAVELENGTH (\(\lambda\))
- PERIOD (\(P\))
- SPATIAL PULSE LENGTH (SPL)
- PULSE DURATION (PD)
- DISTANCE
- TIME
- AMPLITUDE (A)
WAVE PARAMETERS

- **WAVELENGTH** (λ)
- **DISTANCE**
- **AMPLITUDE** (A)
- **PERIOD** (P)
- **TIME**

**Spatial Pulse Length (SPL)**
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

<table>
<thead>
<tr>
<th>DAMPING</th>
<th>FREQUENCY</th>
<th>PERIOD</th>
<th>WAVELENGTH</th>
<th>NUMBER OF CYCLES</th>
<th>PULSE DURATION</th>
<th>SPATIAL PULSE LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>______</td>
<td>Increase</td>
<td>Decrease</td>
<td>Decrease</td>
<td>______</td>
<td>Decrease</td>
<td>Decrease</td>
</tr>
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<td>Increase</td>
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</tr>
</tbody>
</table>

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.
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 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
SAME FREQUENCY, AMPLITUDE, & PHASE
DIFFERENT DAMPING

3-cycle pulse
same periods
same wavelengths
shorter pulse duration
shorter spatial pulse length

4-cycle pulse
same periods
same wavelengths
longer pulse duration
longer spatial pulse length

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 = 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
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

<table>
<thead>
<tr>
<th>DAMPING</th>
<th>BANDWIDTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>Decrease</td>
<td>Decrease</td>
</tr>
</tbody>
</table>
HIGH DAMPING vs. NO DAMPING

SAME FREQUENCY. DIFFERENT DAMPING

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

Pulse-echo
Damped
Wide Bandwidth

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

CW
Not damped
Narrow Bandwidth
Answers to the following ELEVEN practice questions were derived from material in the textbook:
Ultrasound waves that are traveling through a medium consist of:

- compressions and refractions
- condensations and refractions
- electromagnetic and ionizing frequencies
- compressions and rarefactions
Ultrasound waves that are traveling through a medium consist of:

- compressions and refractions
- condensations and refractions
- electromagnetic and ionizing frequencies
- compressions and rarefactions
Audible sound waves are ionizing
Audible sound has a higher frequency
Ultrasound has a higher frequency
Ultrasound waves are ionizing
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
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
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
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
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
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
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
Question 7

If the frequency is doubled, the:

- period will double
- lateral resolution will be poorer
- wavelength will double
- wavelength will be one-half
Question 7

If the frequency is doubled, the:

- period will double
- lateral resolution will be poorer
- wavelength will double
- wavelength will be one-half
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
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
If the frequency is doubled, the propagation speed is:

- quadrupled
- doubled
- halved
- unchanged
Question 10

The propagation speed is highest in:

- bone
- tissue
- fat
- water
The propagation speed is highest in:

- bone
- tissue
- fat
- water
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
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