Name

1. (8 pts)
2. (8 pts)
3. (4 pts)
4. (4 pts)
5. (4 pts)
6. (4 pts)
7. (4 pts)
8. (4 pts)
9. (4 pts)
10. (8 pts)
11. (8 pts)
12. (4 pts)
13. (4 pts)
14. (4 pts)
15. (4 pts)
16. (4 pts)
17. (4 pts)
18. (4 pts)
19. (12 pts)

Total (100 pts)

<table>
<thead>
<tr>
<th>Tissue</th>
<th>c (m/s)</th>
<th>ρ (kg/m³)</th>
<th>α (db/MHz/cm)</th>
<th>B (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>344</td>
<td>1.16</td>
<td></td>
<td>0.137</td>
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<tr>
<td>Blood</td>
<td>1584</td>
<td>1060</td>
<td>0.14</td>
<td>1660</td>
</tr>
<tr>
<td>Fat</td>
<td>1430</td>
<td>928</td>
<td>0.6</td>
<td>1900</td>
</tr>
<tr>
<td>Liver</td>
<td>1578</td>
<td>1050</td>
<td>0.5</td>
<td>2610</td>
</tr>
<tr>
<td>Muscle</td>
<td>1580</td>
<td>1041</td>
<td>1</td>
<td>2600</td>
</tr>
<tr>
<td>Bone</td>
<td>3198</td>
<td>1990</td>
<td>10</td>
<td>18100</td>
</tr>
</tbody>
</table>
1. (8 pts) You are an ultrasound technologist imaging the liver and you’d like to image the whole liver all the way to the diaphragm (the connective tissue at the liver/lung border).

   a. Given a 80 dB receiver dynamic range and an operating frequency of 6 MHz, what is the maximum depth that the diaphragm can be detected?

\[
\text{att} = 80 \text{ db} = 0.5 \text{ db/cm/MHz} \times 6 \text{ MHz} \times 2 \times \text{ depth} \\
\text{depth} = 13 \text{ cm}
\]

   b. how much smaller is the received signal than the transmitted signal? Give your answer in percent.

\[
\frac{I_r}{I_t} = 10^{-8} \text{ or } 10^{-60} \%
\]

2. (8 pts) If you know the peak pressure at your focus in the liver is 2 MPa, what is the peak intensity at that location?

\[
I = \frac{P^2}{Z} \\
Z = 1.5 \text{ MRayl} \\
I = \frac{2 \text{ MPa} \times 2 \text{ MPa}}{1.66 \text{ MRayl}} = \frac{4}{1.66 \times 10^6} \text{ W/m}^2 = 2.4 \times 10^6 \text{ W/m}^2 = 240 \text{ W/cm}
\]
3. (4 pts) What are the two major contributors to attenuation?
   a. __________________________ absorption
   b. __________________________ scattering

4. (4 pts) Give an example of
   a. a good acoustic window: __________________________ bladder
   b. a poor acoustic window: __________________________ ribs

5. (4 pts) What two parameters of tissue are related to the speed of sound
   a. __________________________ density
   b. __________________________ bulk modulus

6. (4 pts) What is the approximate wavelength of a 3 MHz beam in soft tissue?
   \( \frac{1}{2} \) mm

7. (4 pts) You have an interface between two tissues with different acoustic impedances as shown in the figure. Which of the following is true (may be more than one)?
   a. \( P_i + P_r = P_t \)
   b. \( P_i = P_r + P_t \)
   c. \( I_i + I_r = I_t \)
   d. \( I_i = I_r + I_t \)  
      a and d
8. (4 pts) Compared to normal incidence, incidence at an angle changes the transmitted pressure how?

decreases it

9. (4 pts) What tissue is most sensitive to the incidence angle?

bone

10. (8 pts) If you put a transducer right up against the skin, you will have a huge reflection right at that interface. Other than using coupling gel, transmission can be improved with a matching layer on the transducer. How do you design the matching layer to ensure perfect transmission?

a. width = quarter wavelength

b. $Z_m = \sqrt{Z_1 \cdot Z_2}$

11. (8 pts) For the following plot, label the horizontal and vertical axes. Label the position of the transducer. Indicate the range over which the Fraunhaufer approximation is held to be true.

12. (4 pts) How does the Fraunhaufer approximation simplify the pressure field?

$P(x, y) = FT (\text{aperture})$
13. (4 pts) What does the Radar equation tell you?
System sensitivity = transmitted pressure * receive sensitivity

14. (4 pts) How is the two way beam sensitivity related to the aperture?
Two way beam sensitivity = FT(aperture)^2

15. (4 pts) How can you maximize your lateral resolution?
higher frequency or wider aperture

16. (4 pts) How can you maximize your axial resolution?
either higher frequency or wider bandwidth

17. (4 pts) Which is more problematic for a single element transducer?
   a. side lobes
   b. grating lobes

18. (4 pts) Where does speckle come from?
2D convolution of the PSF with random scatterers, then take the magnitude

19. (12 pts) Give at least six steps in ultrasound image formation
   a. TGC
   b. Beamforming or phasing on receive
   c. Rectification
   d. Hilbert Transform or Quadrature
   e. Demodulation
   f. Absolute value
   g. Image Compression
   h. Scan Conversion