Ultrasonics 2025
Exercise 1

Be prepared to present your solutions in the exercise session on Wed 22.1.

1. You have measured time of flights from a 25 mm ±1 mm thick object immersed in water. From the oscilloscope you read the following values for the time difference between the surface and bottom echoes of the object: 15.0 µs, 15.5 µs, 15.5 µs, 15.0 µs, 16.0 µs. Determine the speed of sound (with uncertainties) from the given data. What is the likely colour of the metal?

2. An ultrasound pulse is normally incident on the surface of a flat piece of aluminium immersed in water (NTP conditions). Calculate the reflection and transmission coefficients for the water-aluminium interface, for both pressure (amplitude) and power.
(Suggested reading: Kinsler, Chapter 6, Reflection and Transmission, on the course website.)

3. Explain the terms near and far field of a planar transducer. Calculate the depth of the near field and the beam diameter of a 5 MHz planar transducer (in water) with a diameter of 4 mm.
(Suggested reading, Olympus leaflet on the course website.)

4. You have measured the shear modulus G = 48 GPa and the Poisson's ratio ν = 0.34 of copper. Calculate the bulk modulus B and the Young's modulus E.

5. Plane waves propagating in an isotropic solid medium fulfil the dispersion relations:

$$k^2 c_{44} = \rho\omega^2 \tag{1}$$

$$k^2 c_{11} = \rho\omega^2 \tag{2}$$

where k = absolute value of the wave vector, c_{11} and c_{44} are elastic stiffness constants, ρ = density of the material and ω = the angular frequency. Equation 1 is valid for x- and/or y-polarized plane waves propagating in the direction of the z-axis (shear wave). Equation 2 is valid for a plane wave, whose particle displacement is parallel to the wave propagation (longitudinal wave).

A) Rewrite the phase velocities of the longitudinal and transverse waves, c_l and c_t, as a function of stiffness constants and density.

B) Compare these to the equations:

$$c_t = \sqrt{\frac{E}{2\rho(1+\nu)}} \qquad c_l = \sqrt{\frac{E(1-\nu)}{\rho(1+\nu)(1-2\nu)}}$$

C) Based on B), write the stiffness constants c_{11} and c_{44} as a function of Young's modulus E and Poisson's ratio ν.