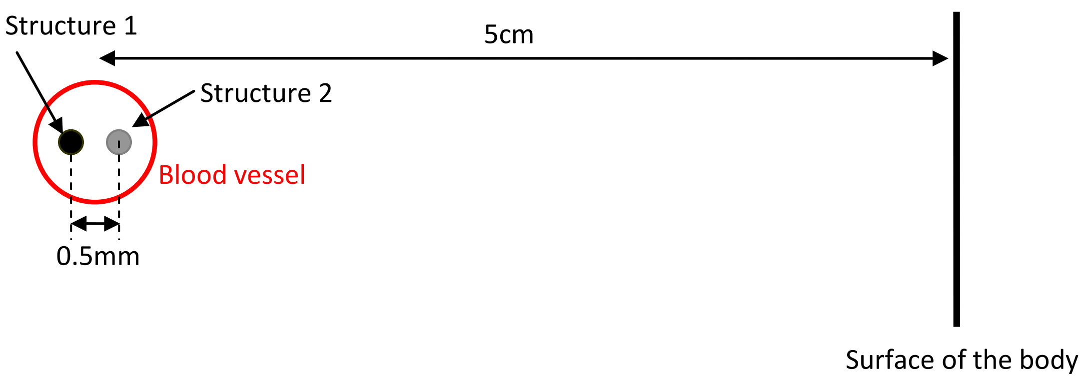
Ultrasound

Problem 1

An experimentalist wants to use ultrasound to separately detect small structures in a blood vessel that are about 0.5 mm apart. The vessel runs parallel to the surface and lies at a depth of 5 cm. Given is that the attenuation is 1 dB/(MHz·cm). The attenuation at which an image can still be obtained is 10^{10}. The pulse duration of the ultrasound beam is 2 periods. The speed of sound in the tissue is 1580 m/s.

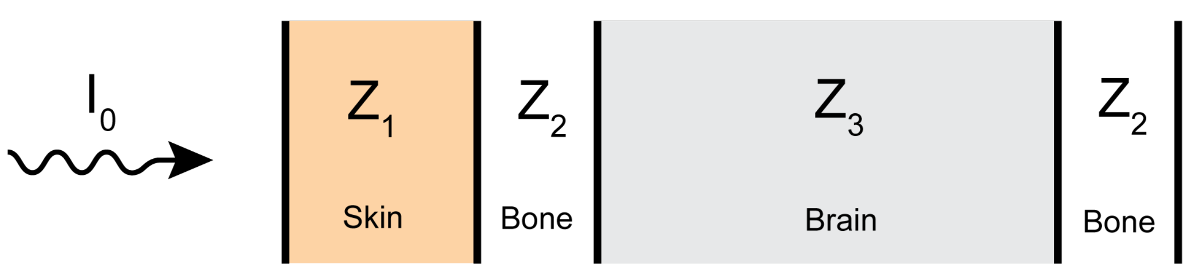
a. What is the minimum frequency needed to spatially dissolve the structures?
b. What is, based on the attenuation, the highest allowed frequency?
c. If besides the resolution the signal-to-noise ratio (SNR) needs to be as high as possible, which transducer frequency would you use (qualitative answer)?



Problem 2

Consider the schematic view (figure below) of a profile in depth of a head scanned with ultrasound imaging. The structures are successively skin, bone, brain and bone again, characterized by impedances Z_1, Z_2, and Z_3 (=$1.12 \cdot 10^6$, $7.8 \cdot 10^6$ and $1.09 \cdot 10^6$ rayls respectively). We consider that the transducer is in close contact with the skin and we neglect absorption as well as signal coming from multiple reflections.

a. What is the portion of signal coming back from the brain (i.e. from the second brain/bone interface) to the transducer?
b. What do you conclude on the efficiency of ultrasound imaging for brain studies?
c. In practice, gel is always spread between the transducer and the skin. Explain why.



X-rays interactions and production

Problem 3

a. What is the relation between Joule and electron volt?
b. Calculate the energy in Joule of a photon emitted by the Tc_{99m} isotope (see table at the end of this series).
c. Find the frequency and the energy of blue light with a wavelength of 400 nm.
d. What is the energy equivalent to the mass of an electron (assume that the electron is at rest)?

Problem 4

a. Why is the distinction between ionizing and non-ionizing radiation important?
b. What is the critical wavelength for ionizing radiation? Is it a maximal or minimal limit?
c. Compare this limit with the visible spectrum. What can you conclude on the use of sunscreen?
d. K- and L-shell binding energies for cesium are 28 keV and 5 keV, respectively. What are the kinetic energies of photoelectrons released from the K and L shells when 40-keV photons interact in cesium?

Constants

Energy of a Tc_{99m} photon	141 keV
Electron charge	$e = 1.6 \cdot 10^{-19}$ C
Speed of light	$c = 3.0 \cdot 10^{8}$ m/s
Electron mass	$m_e = 9.1 \cdot 10^{-31}$ kg
Planck constant	$h = 6.6 \cdot 10^{-34}$ J·s