1. Debye frequency in solids

Calculate the Debye frequency for

a) water
b) silicon
c) gold
d) air
e) diamond

Assume NTP conditions.

2. Phonons in liquids

According to Bolmatov *et al.*, Annals of Physics 2015, the Frenkel frequency for a material can be written as

$$\omega_F = \sqrt{\frac{\sigma^2}{\theta}} = \frac{2\pi}{\tau} = \frac{2\pi G_\infty}{\eta}$$

where G is the infinite-frequency shear modulus, η is the viscosity and τ is the average time between two consecutive atomic jumps at one point in space.

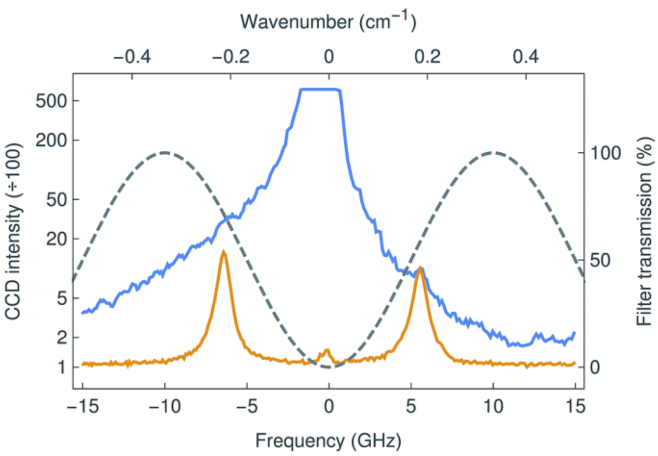
Calculate the approximate (order of magnitude) Frenkel frequency for

a) water
b) honey
c) oil

If you cannot find exact values, approximate based on the values you find.

3. Brillouin scattering

You are using a λ = 671 nm DPSS laser to do a Brillouin spectroscopy measurement in a backscattering geometry. The measurement result is depicted in the following picture (the orange one, the blue one is measured without a filter).



You measure a refractive index of 1.34. Determine the speed of sound, and from that, deduce what is the material you are studying?

4. Brillouin oscillations

A paper by Yang *et al*., Journal of Applied Physics 2010, describes an experiment in which they study the properties of a liquid. They obtained the following result:

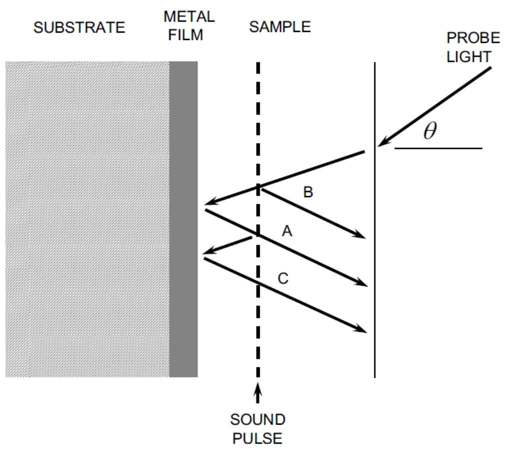


FIG. 1. Schematic diagram of the picosecond acoustic interferometry experiment.

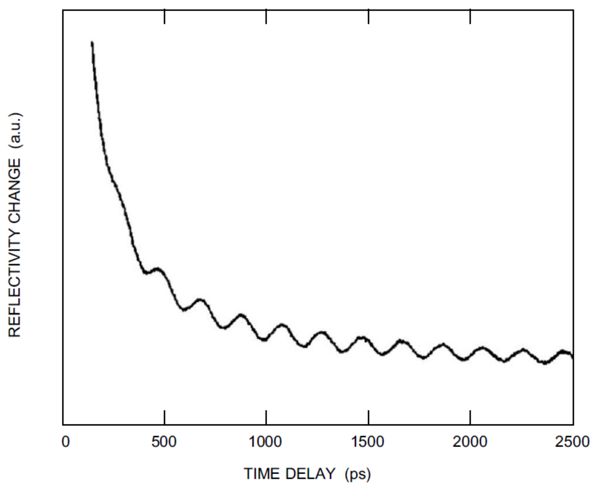


FIG. 2. Change in reflectivity of the probe light pulse as a function of the time delay. These data were taken at 89 °C.

Describe the results – calculate the speed of sound in the material based on the measured Brillouin oscillation (assume that the refractive index is n = 1.33).