PRACTICAL 1.15

RESONANCE MEASUREMENT OF THE WAVELENGTH AND THE SPEED OF SOUND WAVES IN SOLIDS

Objective: study of the acoustic resonance and measurement of the speed of sound in solids.

Equipment: Kundt's tube, metal rods, ruler, cork saw-dust, flannel, rosin.

INTRODUCTION

When a sound wave is propagated from one medium to another, the frequency remains unchanged but the wavelength changes because the speed of sound depends on the elastic properties of the medium, which leads to the relation

$$\frac{s_1}{s_2} = \frac{\lambda_1}{\lambda_2}, \tag{1}$$

where s is the speed of sound and λ is the wavelength, and the subscripts 1 and 2 refer to the different media.

If medium 2 is air, then

$$s_2 = s_0\sqrt{\frac{\Theta}{273}}, \tag{2}$$

where s_0 = 332 m/sec is the speed of sound in the air at normal temperature and pressure, and Θ is the absolute temperature of the air during the experiment.

In this practical, speed of sound in solids is measured with the use of Kundt's apparatus, where longitudinal oscillations in the rod excite acoustic waves in the air column.

EXPERIMENTAL SETUP

Referring to Fig. 15.1, Kundt's apparatus consists of a rod B with a small disk D fixed at one of its ends. The end of the rod with the disk is inserted into the glass tube A sealed at the opposite end. The rod is fixed in the middle with the screw C. The longitudinal oscillations in the rod drive longitudinal oscillations in the air column.

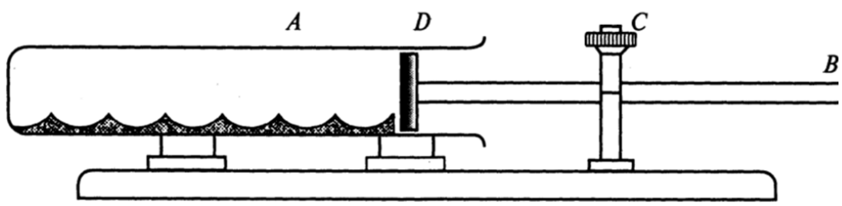

Fig. 15.1.

By varying the length of the air column (by moving the rod with respect to the tube), one can create conditions corresponding to the acoustic resonance and thus set up a standing wave in the air column. This causes the saw-dust, initially distributed uniformly along the tube, to form a periodic pattern, with more dust at points corresponding to zeros of the displacement of the air particles. These points are the nodes of the standing wave. The natural frequency of the rod oscillations is the same as the natural frequency of the oscillations in the air column.

The wavelength of the sound wave in the air column λ_1 can be deduced if one measures the distance x between the standing wave nodes: $\lambda_1/2 = x$. The wavelength of the fundamental mode of the rod of length l is equal to $\lambda_2 = 2l$. Using λ_1 and λ_2, together with Eqs. (1) and (2), the sound speed in the rod can be found.

MEASUREMENT AND DATA PROCESSING

After the setup has been assembled, excite longitudinal oscillations in the rod of the material that is being studied. In order to do this hold firmly the rod through the piece of rosined flannel and then pull the flannel towards the free end of the rod. By gradually changing the position of the rod with respect to the tube, ensure a clear picture of standing waves in the tube.

T a s k . Make the necessary measurements and compute the sound speed in brass, iron and wood. Make a table of the measured and calculated values. Compare your results with the data from a handbook.

QUESTIONS AND EXERCISES

1. Draw plots of the displacement, velocity and stress corresponding to a standing wave in a rod for an arbitrary moment. How do these plots change $T/4$ later, where T is the period of oscillations?

2. Which of the rods that you used in the experiment has the greatest fundamental frequency?

3. What is the mechanism of setting up excitations in the rod?

4. Why does the saw-dust collect in places corresponding to zeros of the displacement of the air particles in the tube?

5. Is it necessary to change the position of the rod with respect to the tube (see Fig. 1) when the next rod is taken (for a clear picture of the standing wave)?