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# CERTAIN NEW DEMONSTRATIONS FOR THE PHYSICS COURSE

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## 1. DIRECTIVITY PATTERN OF ACOUSTIC RADIATOR

The radiation from an acoustic radiator (loudspeaker) has a noticeable directivity, if the wave parameter of the radiator $\lambda/D$ ($\lambda$—length of radiated sound wave, D—diameter of loudspeaker diffuser) is much smaller than unity.

The distribution of the radiated energy (or of the amplitude) is a function of the angle $\theta$ between the symmetry axis of the diffuser and the straight line drawn through the observation point and the radiator.

In an experiment demonstrating the directivity pattern of an acoustic radiator, we used a dynamic speaker 1GD-11 (bandwidth 70–10,000 Hz), excited by an audio generator ZG-10. The sound receiver was a microphone, the signal from which was fed to the vertical amplifier of an ÉO-7 oscilloscope. The distance from the radiator to the microphone was ~2 m.

The intensity of the radiation in any particular direction can be assessed from the amplitude of the signal on the oscilloscope screen. To plot the directivity pattern it is possible to vary the position of the radiator and receiver relative to each other either by moving the microphone over a circle, in the center of which is placed the dynamic speaker, or else by keeping the receiver stationary and rotating the radiator about the vertical axis. The variation of the distance L does not change the directivity pattern. In the experiment we measured the angles $\theta$ and the corresponding signal amplitude on the oscilloscope screen.

Directivity patterns for the frequencies $f_1 = 8000$ Hz (1) ($\lambda = 0.041$ m) and $f_2 = 800$ Hz (2) ($\lambda_2 = 0.41$ m) are shown in Fig. 1.

From a comparison of the diagrams it is seen that a change of the wave parameter (by changing the radiative wavelength) leads to a change in the sharpness of the directivity of the radiation; at the higher frequency, small side bands of radiation become noticeable.

## 2. INFLUENCE OF MEDIUM ON ACOUSTIC PROPERTIES OF A RESONATOR

The Helmholtz resonator is an oscillating system with one degree of freedom, and is therefore capable of responding to one definite frequency corresponding to its natural frequency. The latter depends, in particular, on the properties of the medium filling the volume of the resonator.

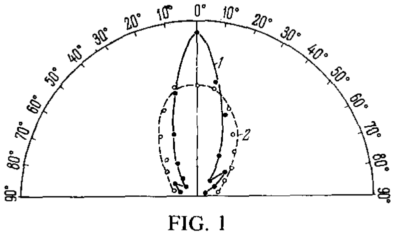

FIG. 1

We compare in the experiment the natural frequencies of a Helmholtz resonator alternately filled with air or helium. For such a case, the ratio of the natural frequencies of the resonator is determined by the expression

$$\frac{f_{\mathrm{He}}}{f_{\mathrm{air}}}=\sqrt{\frac{\gamma_{\mathrm{He}} M_{\mathrm{air}}}{\gamma_{\mathrm{air}} M_{\mathrm{He}}}},$$

where $\gamma = c_p/c_V$ and M is the molecular weight of the substance filling the resonator. For pure helium $f_{\mathrm{He}}/f_{\mathrm{air}} \approx 3$.

A Helmholtz resonator having a natural frequency $f_{\mathrm{air}} = 560$ Hz in air was excited with a loudspeaker fed with a signal from a ZG-10 audio generator.

At resonance, a light paper vane placed at the output of the resonator started to rotate, this being evidence of the equality of the excitation frequency to the natural frequency of the resonator.

If the cavity of the resonator is filled with helium (without stopping the action of the loudspeaker on the resonator), the rotation of the paper vane stops, as a result of the change of the natural frequency of the resonator. By varying the excitation frequency it is possible again to obtain intense rotation of the vane, thus evidencing resonance at another frequency. The helium-filled resonator resonated at $f_{\mathrm{He}} = 1250$ Hz.

The experimentally obtained frequency ratio $f_{\mathrm{He}}/f_{\mathrm{air}}$ turned out to be smaller than the theoretical one, since by virtue of the conditions of our experiment it was difficult to fill the resonator with pure helium. But the difference between the frequencies at which the resonator responds can be easily monitored by ear; the demonstration is therefore quite convincing.

After the supply of helium to the resonator is cut off, the rotation of the vane slows down and eventually stops as the helium becomes replaced by air. When practically all the helium is removed, it is possible to return to the 560 Hz frequency, to which the resonator will again respond.

It is best to feed the helium to the resonator cavity at a pressure somewhat larger than atmospheric, in order to displace more rapidly the air from the resonator cavity and to fill the latter with helium.

This experiment can be supplemented by illustration in which the pitch of the voice is changed when helium is inhaled in place of air.

## 3. NATURAL OSCILLATIONS OF A NONLINEAR OSCILLATING SYSTEM

An oscillating circuit is a linear oscillating system if in the equation of its state

$$L\frac{di}{dt}+Ri+\frac{1}{C}\int i\,dt=0$$

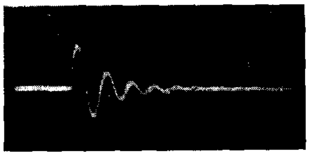

FIG. 2

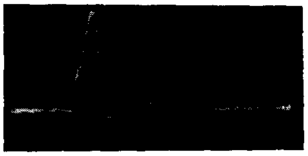

FIG. 3

the coefficients L, R, and 1/C are constants. In this case, as is well known, the natural oscillations of the circuit are harmonic oscillations which attenuate in time, and their frequency is determined essentially by L and C.

In the case when L depends on the current or C depends on the voltage, additional frequencies appear in the oscillations, distorting the temporal characteristic of the circuit oscillations.

Thus, if a coil with an iron core is introduced into the oscillating circuit, and a sufficiently large voltage is applied to the circuit to charge the capacitor, then the alternating magnetization of the core will cause the inductance L of the coil to cease to be a constant, and the free oscillation picture will differ greatly from that in the linear mode.

Figures 2 and 3 show the natural oscillations of the current in the resonance circuit at charging voltages $U_1 = 6$ V (Fig. 2, linear mode) and $U_2 = 100$ V (Fig. 3, nonlinear mode).

The circuit consists of a capacitance $C = 4 - 16\ \mu F$ connected in series with an inductance, which is the secondary winding of a high-voltage transformer with $L \approx 10$ H; the ohmic resistance of the circuit is $R = 300\ \Omega$.

Voltage from part of the active resistance, proportional to the current in the circuit, is fed to the input of an S1-29 oscilloscope with a long-persistance screen. An oscilloscope of this type is convenient for the investigation and photography of slow electric oscillations.

Similar distortions are observed also when the capacitance of the circuit (or part of it, if e.g., a varicond of the D811 type is applied parallel to the fixed capacitor) depends on the voltage.

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## INFLUENCE OF MOTION OF THE MEDIUM ON THE PHASE DIFFERENCE BETWEEN THE OSCILLATIONS OF A SOUND SOURCE AND A SOUND RECEIVER

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RECENTLY Baranskiĭ and Zubareva[1] described a demonstration of the Fizeau and Michelson–Morley experiments using sound waves. In their demonstrations, the loudspeaker and the microphone are mounted on the base of a pendulum at a distance $l$ from each other. When the loudspeaker and the microphone are in the plane of the swing of the pendulum, moving with velocity v relative to the air, an additional phase difference arises between the oscillations radiated by the loudspeaker and received by the microphone:

$$\Delta\varphi = \frac{\omega l}{c-v} - \frac{\omega l}{c} \approx \frac{\omega l v}{c^2},$$

where $\omega$ is the circular velocity of the sound generator and c is the speed of sound. When the line of sound propagation is rotated relative to the plane of the swinging of the pendulum, no phase difference is observed.

The described demonstration is difficult to perform in a small auditorium. When the setup moves, the Doppler shift of the reflections of the sound in the room may distort the required results. Suspension of a long pendulum together with a plank is also difficult: reduction of the length of the pendulum not only decreases v, but also makes it is impossible to observe distinctly the alternations of the phase differences in the to-and-fro swings, since they occur too rapidly.

A more compact and convenient variant of the experiment is to mount the loudspeaker and the microphone on a table and to produce an artificial "ether wind" with the aid of a table fan. Such an experimental setup excludes practically the influence of reflections inside the room. A fan of 30 cm diameter produces a directed stream of air with a velocity of approximately 3 m/sec extending approximately 1 m. Since this velocity exceeds the velocity that can be conveniently obtained with the aid of a pendulum, the observation of the phase shift becomes more distinct. For a frequency of 10 kHz and an average air speed of 3 m/sec over an extent of 1 m, $\Delta\varphi$ is approximately 90°. If $\omega$ is chosen such that a straight-line Lissajous figure is produced, an almost circular figure is obtained after the fan is turned on. The air speed is measured by a simple anemometer. The sensitivity of the setup is such that the transformation of the line into a narrow ellipse on the oscilloscope screen can be observed even without a fan, by blowing strongly with the mouth along the sound propagation direction. A selective amplifier or a simple high-frequency filter in the microphone circuit will help eliminate the noise of the fan and of the room.

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