SEVERAL LECTURE DEMONSTRATIONS

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Usp. Fiz. Nauk **79**, 745-749 (April, 1963)

I. DEMONSTRATION OF THE FORM OF HARMONIC OSCILLATIONS

THERE exists a number of experiments for the demonstration of the form of harmonic oscillations, all of which suffer from one defect or another. For example, the demonstration of the form of harmonic oscillations with the aid of fine sand escaping from an oscillating cup onto a board moving with constant velocity cannot be seen well by a large audience.

It is well known that when a point moves with constant angular velocity along a circumference its projection on a diameter performs a harmonic oscillation. We have used this as the basis for several pieces of equipment for demonstrating the form of harmonic oscillations, in particular: 1) a piece of equipment utilizing a disc with rods; 2) a piece of equipment utilizing a disc with drilled holes.

1. Apparatus utilizing a disc with rods. The principal part of the apparatus is a disc (Fig. 1a) which is attached to the axle of an electric motor and is rotated by it at a constant angular velocity. The disc has a number of holes 1—9 (Fig. 1b) into which rods can be inserted perpendicular to the plane of the disc.

If a rod is fixed in hole 1 and a beam of light from a projection lantern is sent parallel to the surface of the disc, then as the disc undergoes uniform rotation the shadow from rod 1 will perform harmonic oscillatory motion. At a certain distance from the disc there is placed a rotating many sided mirror (Fig. 2) with the aid of which these oscillations are spread out into a sinusoidal curve (Fig. 3a) which can be easily seen on a large screen.

With the aid of this apparatus one can also demonstrate the following:

1) The form of the oscillations of the displacement S and the velocity v of a harmonic oscillation shifted by $\pi/2$ in phase (Fig. 3b); in this case the rods are placed in holes 1 and 2 (cf. Fig. 1b);

2) The form of the oscillations of the displacement S and of the acceleration a shifted by π in phase

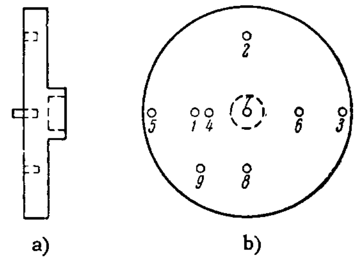


FIG. 1

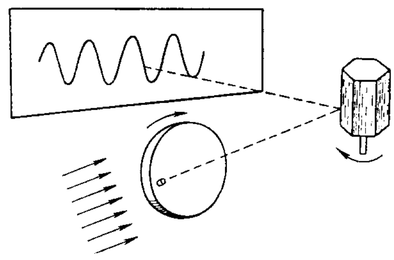


FIG. 2

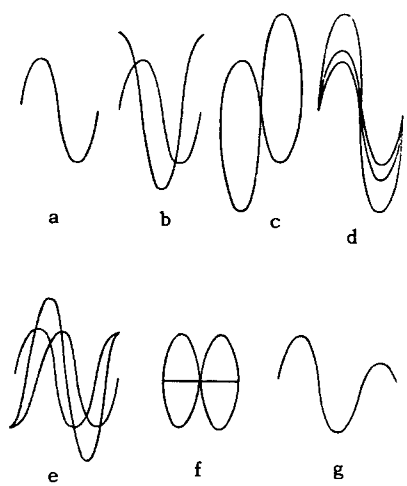


FIG. 3

(Fig. 3c); the rods are placed into holes 1 and 3;

3) Addition of oscillations with the same periods, amplitudes and phases (Fig. 3d); the rods are placed into holes 1, 4 and 5;

4) Addition of oscillations with the same periods, amplitudes but different phases (Fig. 3e); the rods are placed in holes 1, 8 and 9;

5) Addition of oscillations with the same periods, amplitudes but opposite phases (Fig. 3f); the rods are placed in holes 1, 6 and 7.

With the aid of this disc it is also possible to demonstrate the form of damped oscillations. In order to do this a spring is placed between rods 3 and 5 and a rod is attached to its central portion. If the disc is stationary and the rod oscillates, then the form of damped oscillations is well visible on the screen (Fig. 3g).

2. Apparatus utilizing a disc with drilled holes. A circle of radius r is drawn on the disc as shown in Fig. 4a. Then the circumference is divided into a number of equal parts. From the point O lines are drawn towards the points dividing the circumference. Then holes are drilled inside the disc in these directions. A parallel beam of light is directed towards the disc from a projection lantern. If the disc is set into rotation with constant angular velocity then the light spot passing through the disc will begin to execute harmonic oscillatory motion. Its amplitude will be r. This harmonic oscillatory motion can be spread out into a dotted sinusoidal curve easily visible on the screen by means of a many sided mirror situated a certain distance from the disc. Figure 5 shows the principle of the installation.

If one takes the disc in which the holes are drilled as shown in Fig. 4b then one can demonstrate the form of oscillations of the displacement S and of the velocity v shifted in phase by $\pi/2$.

A disc with holes drilled as shown in Fig. 4c enables one to demonstrate the form of the oscillations of the displacement S and of the acceleration a shifted in phase by π.

II. DEMONSTRATION OF LISSAJOUS FIGURES

For the demonstration of Lissajous figures we propose an apparatus the principle of whose arrangement is shown in Fig. 6. Its principal component part consists of two identical cylinders I and II with slots. The slots are made in the following manner. On a cross section of the cylinder a circle of radius R is drawn (Fig. 7). Then the length of the circumference is divided into a certain number of equal parts, for example into 16 parts, but for better visibility in Figs. 6 and 7 the cylinders are shown to have eight slots. Through the point O and through the points into which

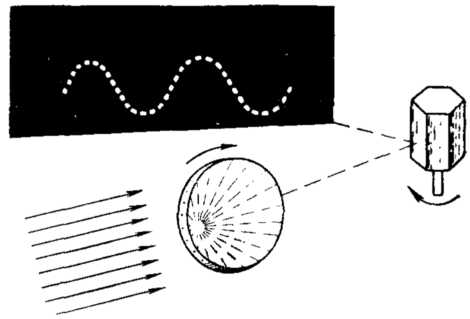


FIG. 5

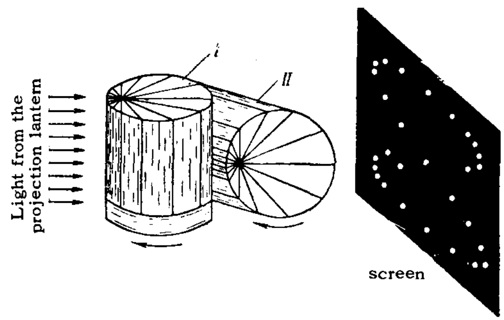


FIG. 6

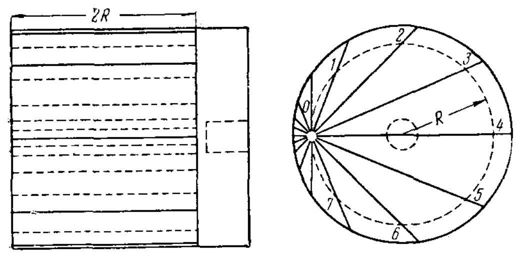
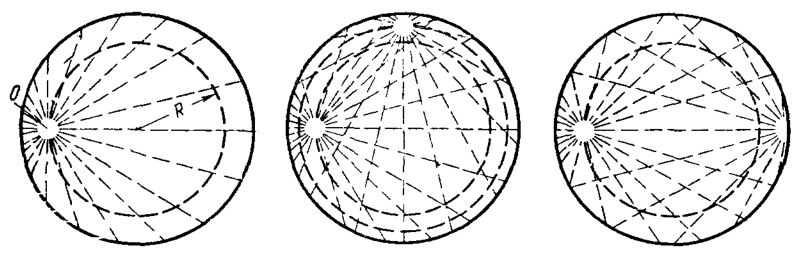


FIG. 7



a) b) c)

FIG. 4

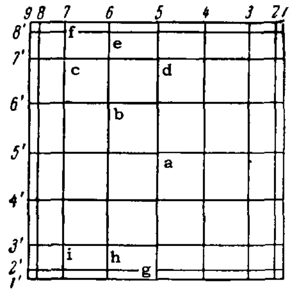


FIG. 8

the circumference has been divided the lines 01, 02, 03, . . . , 07 are drawn and also a line perpendicular to the diagonal line 04 (cf. Fig. 7). Then slots are made in these directions perpendicular to the cross section of the cylinder and of depth 2R.

Cylinder I is placed near a projection lantern and a parallel beam of light is directed at it. The cylinder is attached to the axle of an electric motor. As the cylinder is rotated with constant angular velocity a bright band of light appears on the screen which executes harmonic oscillatory motion. Its different positions 1—9 are shown in Fig. 8. A similar cylinder II is placed perpendicular to the first one and it is set into rotation with constant angular velocity (with the first cylinder removed from the projection lantern). Then the bright band on the screen will occupy positions 1′, 2′, 3′, 4′, 5′, 6′, 7′, 8′, 9′ (cf. Fig. 8).

Then the cylinders I and II are placed in front of the projection lantern perpendicular to each other (cf. Fig. 6). If the cylinders I and II are at rest, then a bright spot is obtained on the screen. As the cylinders are rotated the bright spot which participates simultaneously in two mutually perpendicular oscillations will begin to describe Lissajous figures on the screen.

By rotating the cylinders with the same angular velocity ($T_1/T_2 = 1/1$), we shall obtain the first series of Lissajous figures (Fig. 9) depending on the phase difference $\varphi_1 - \varphi_2$, i.e., on the initial mutual position of the slots in the two cylinders. Thus, for example, in the case $\varphi_1 - \varphi_2 = 0$ the bright spot will occupy positions a, b, c, etc. (cf. Fig. 8) and will execute an oscillation in a straight line (Fig. 9). In the case of the phase difference $\varphi_1 - \varphi_2 = \pi/4$ the bright spot will occupy positions d, e, f etc. (cf. Fig. 8) and will describe an ellipse on the screen (cf. Fig. 9). However, if the phase difference $\varphi_1 - \varphi_2 = \pi/2$, then the bright spot will start moving occupying positions g, h, i, etc. A circle will be obtained on the screen (cf. Fig. 9).

If the cylinders are rotated in such a way that the angular velocity of one cylinder is twice as large as the angular velocity of the other one ($T_1/T_2 = 1/2$), then we shall obtain a second set of Lissajous figures (cf. Fig. 9). For a different ratio of the velocities of rotation, for example $T_1/T_2 = 1/3$, and for different phase differences $\varphi_1 - \varphi_2$ one obtains a third series of Lissajous figures (cf. Fig. 9).

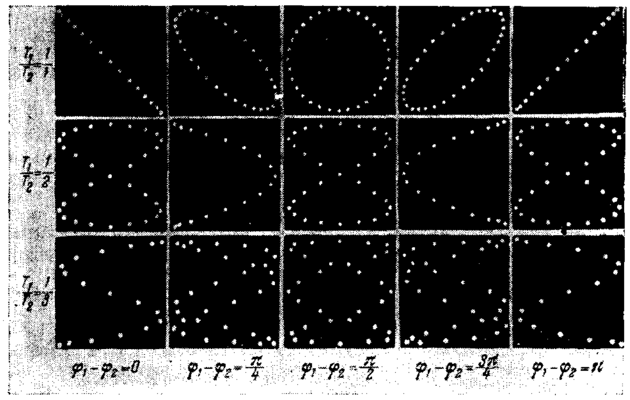


FIG. 9

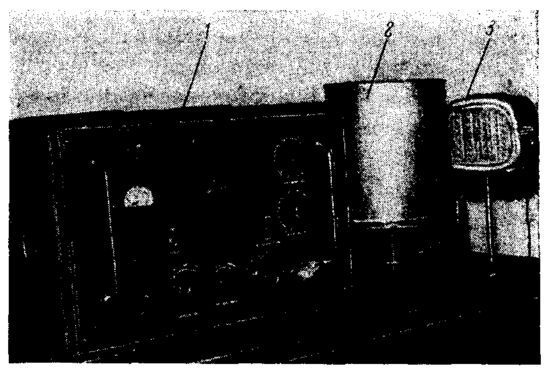


FIG. 10

The apparatus enables one to observe the direction in which the Lissajous figures are traced.

III. DEMONSTRATION OF THE DOPPLER EFFECT IN ACOUSTICS

It is well known that if an object reflecting waves is moving, then, because of the Doppler effect, the wavelength, and, consequently, the frequency of the waves reflected from it will differ from the wavelength and the corresponding frequency of the incident waves. This is used as the basis of a demonstration of the Doppler effect in acoustics.

Figure 10 shows the external appearance of the installation where 1 is an audio oscillator ZG-3, 2 is a cylinder attached to a centrifugal force apparatus, 3 is a dynamic speaker. The sound waves from the dynamic speaker driven by the audio oscillator are directed towards the cylinder rotating about a vertical axis. As the cylinder rotates the sound waves reflected from the cylinder will consist of signals with frequencies greater than and less than the frequency of the incident sound wave. As a result of superposition of these reflected waves beats of sound waves are obtained which can be easily heard by a large audience.

Translated by G. Volkoff