On Mechanical Devices for Demonstration of Vibrations of String and Spring

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By

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(1)

In some cases it is very desirable to have a source of a sound whose pitches can easily be varied. The present writer recently deviced such an instrument and found very convenient both for demonstration and investigation. Fig. 1 shows its cross section, M being a horse-shoe permanent magnet to which two pieces of soft iron P are attached, and C the coil of the magnet. The coil, whose one end is connected to the insulated gas carbon at G, an electric cell and an endless wire W forms a circuit.

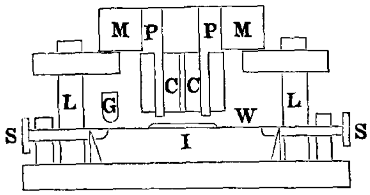

Fig. 1.

In front of the coil a circular iron plate I attached to the wire W is placed, its tension being adjusted by means of two screws at S. The instrument is thus a kind of a modified telephone, so that when an electric current is sent through the circuit, the plate I will vibrate and the sound will be emitted, its pitch depending on the tension of the wire and the mass of the iron plate. Therefore if a set of such wires with different masses is prepared, it serves as a convenient instrument producing sound of various pitches.

With this instrument it is very easy to produce a sound having frequency as high as 5000 per sec., and the amplitude of vibrations may be increased up to about 1/2 mm. when the carbon point was displaced nearer to the leg L.

(II)

To obtain Lissajous' figures in most simple manner, the writer recently deviced an improved vibrator. The cross section of this vibrator is shown in Fig. 2, where C is a coil, S an iron core, H and G are made of soft iron, and E is a spring clamped at D, its length being adjusted by the screw at D, and its distance from the coil, by the screw B. When an intermittent electric current produced by an electrically driven tuning fork is sent through this coil, the spring will vibrate. The amplitude of the vibration will reach a sufficiently larg value when the frequency of the spring just coincides with one of the integral multiples of that of the fork. Thus by adjusting length of the spring and distance from the coil, the vibration having a proper amplitude and a higher frequency will be produced with this simple instrument. With a pair of such vibrators composition of vibrations can easily be effected. Photographs given in Fig. 3, represent composition of vibrations at right angles. Next, the resultant of two parallel vibrations was photographed with the arrangement shown in Fig. 4. S represents a slit, *a* and *b* small mirrors attached to the free ends of the springs of two vibrators described above and facing toward one another, *c* and *d* fixed mirrors placed in the position as indicated in the Fig. 4, the former facing toward *b* and the latter toward *a*. Parallel rays of light passing through the slit are reflected by the system of the mirrors and collected by the lens at L, and form the image of the slit on a moving photographic plate. The rays reflected from a pair of mirrors (*a*, *d*) and from (*b*, *c*) record oscillations of each vibrator, while the image formed by the rays reflected from *a* and *b* gives their resultant vibrations, the light reflected from a set of fixed mirrors (*c*, *d*) giving a straight line on the photographic plate. Photographs shown in Fig. 5 were thus obtained.

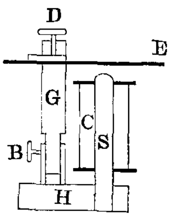

Fig. 2.

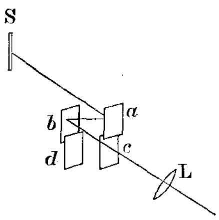

Fig. 4.

(III)

In the case of vibrations of a piano-fort wire strucked by a hammer, it is very difficult to observe initial stages of the configuration of the wire. Kaufmann,[1] in his theoretical treatment of the vibration of a piano-fort wire assumed that every point of the wire starts their periodic vibration as soon as the hammer left the wire. But he was not able to determine the exact instant at which the wire just begins to vibrate. In order to test the above assumption of Kaufmann, the writer recently deviced a special hammer and succeded in photographing initial stages of the vibration at any point of the wire.

The arrangement of the wire and the hammer is shown in Fig. 6. The wire whose position indicated by W is stretched horizontally perpendicular to the plane of the paper and is placed at such a height as it is just struck when the hammer was released by switching off the current in an electromagnet E shown in Fig. 6 and pushed down by a bent spring S. Immediately after the hammer struck the wire, the hinged head of it is held back by means of another spring R and takes the position indicated by the dotted lines. The motion of the wire caused by such an impulse was studied by means of a special camera with a photographic plate moving horizontally, its sections being illustrated in Fig. 7. F is the camera with a vertical slit at S and contains a photographic plate G. A string having a weight W at one end was attached to the plate holder and another string connected to the same weight was fastened to an iron plate in a viscous liquid contained in a vertical tube, both strings hunging over the same pulley P. By this means the horizontal velocity of the photographic plate was regulated. The motion of the plate was started by switching off the current in the electromagnet E which has attracted the iron plate. A is wooden disc having

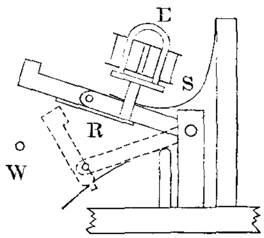

Fig. 6.

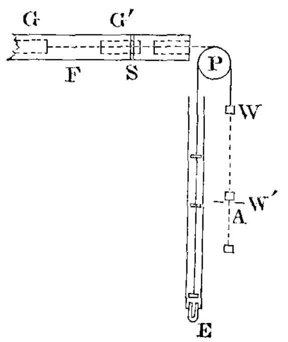

Fig. 7.

[1] Wied. Ann. **54**, 674, (1895).

a circular hole and it is placed at such a position that GG′=WW′, so that when the plate just reached the slit, the weight enters the hole. On this disc the two pieces of a metal are placed symmetrically about the centre along a certain diameter, and a narrow strip of tin foil was bridged over to connect them electrically, one end of which was pressed by a spring, while the other lightly resting on the metal electrode. This formed a part of the electric circuit of the electro-magnet in the hammer. Now if the circuit of the electro-magnet E in Fig. 7 was broken, the photographic plate began to move and at the instant when the plate came to the slit, the weight W fell down to A and pushed off the tin foil and broke the circuit of the electro-magnet attracting the hammer, and consequently the piano-wire was hammered and its subsequent motion was recorded by an optical means shown in Fig. 8. AB represents the stretched piano-wire, and F the moving plate camera. Two points *a*, *b* on wire were illuminated by an intense lights from electric arcs and their images were formed on the slit by lens, a needle point being placed just before the point *a* to give a reference line on the photograph. The hammer was adjusted to strike the point *b*, such that the image formed by the lens L_2 recorded the motion of the point *b* of the wire and head of the hammer. The same images of the point *a* and a needle, one above the image *b* and one below it, were formed by the lens L_1. The photographs shown in Fig. 9 and Fig. 10 were thus obtained. Four curves are seen in each photograph, the fine one in the middle part representing the vibration of the point struck by the hammer and the thick one the motion of the head of the hammer. Curves in the upper and the lower parts show the vibration of a certain point of the wire, so that a line connecting two corresponding points in these curves represents the position of the slit at same instant. The lines α and β were drawn parallel to the position of the slit on the photograph through the points at which the head of the hammer just touched on the wire and left it.

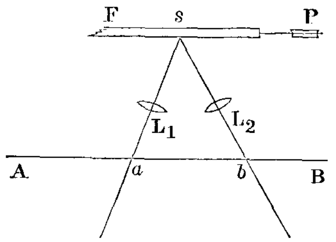

Fig. 8.

The intersections of the line α with these curves represent the state of the point *a* at the moment when the hammer just touched the wire and the corresponding point for the line β represents that of the same point when it lefts the wire.

Thus from the photographs we observe that the vibration of a point on the wire takes place as soon as the hammer lefts the wire, so that Kaufmann's assumption seems to be correct.

From the photograph taken, it is very easy to determine the instant at which a point of the wire enters into vibrations.

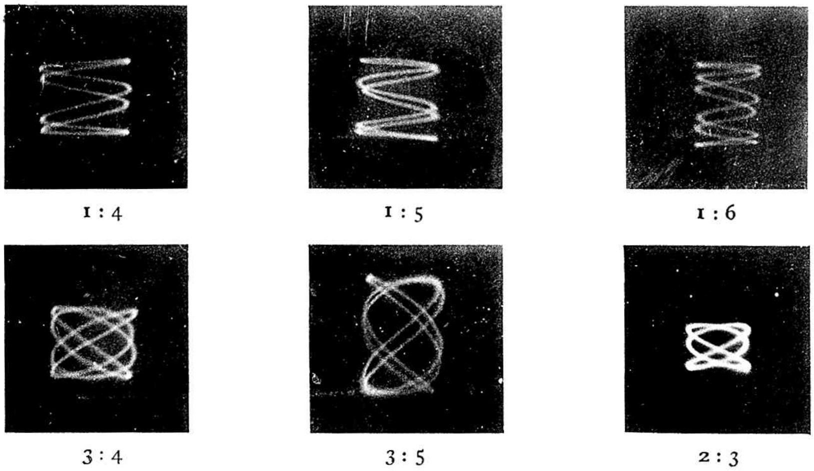

Fig. 3.

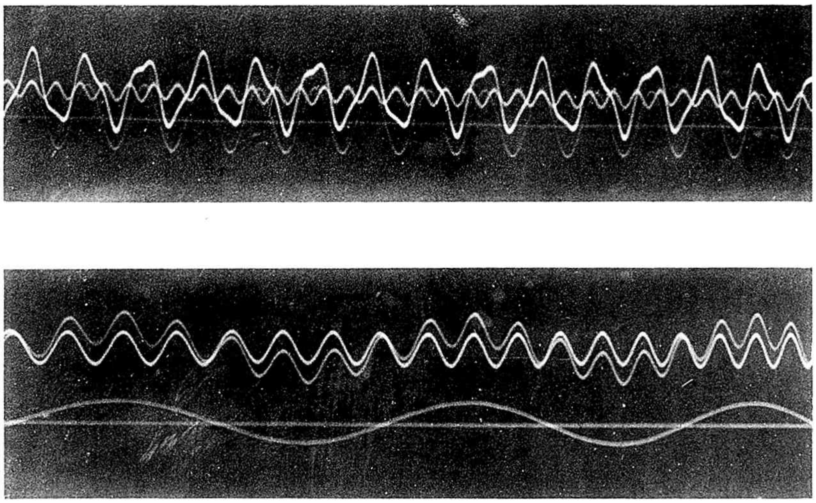

Fig. 5.

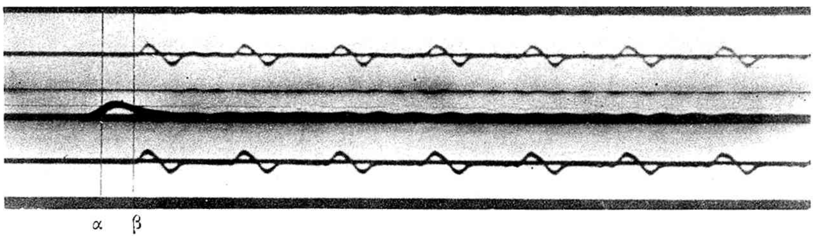

Fig. 9.

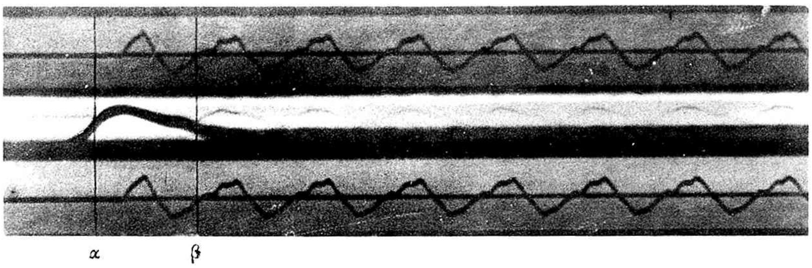

Fig. 10.