May 9, 1933. P. E. KLOPSTEG 1,908,258

VIBRATING STRING APPARATUS

Filed Sept. 27, 1929

Fig. 1

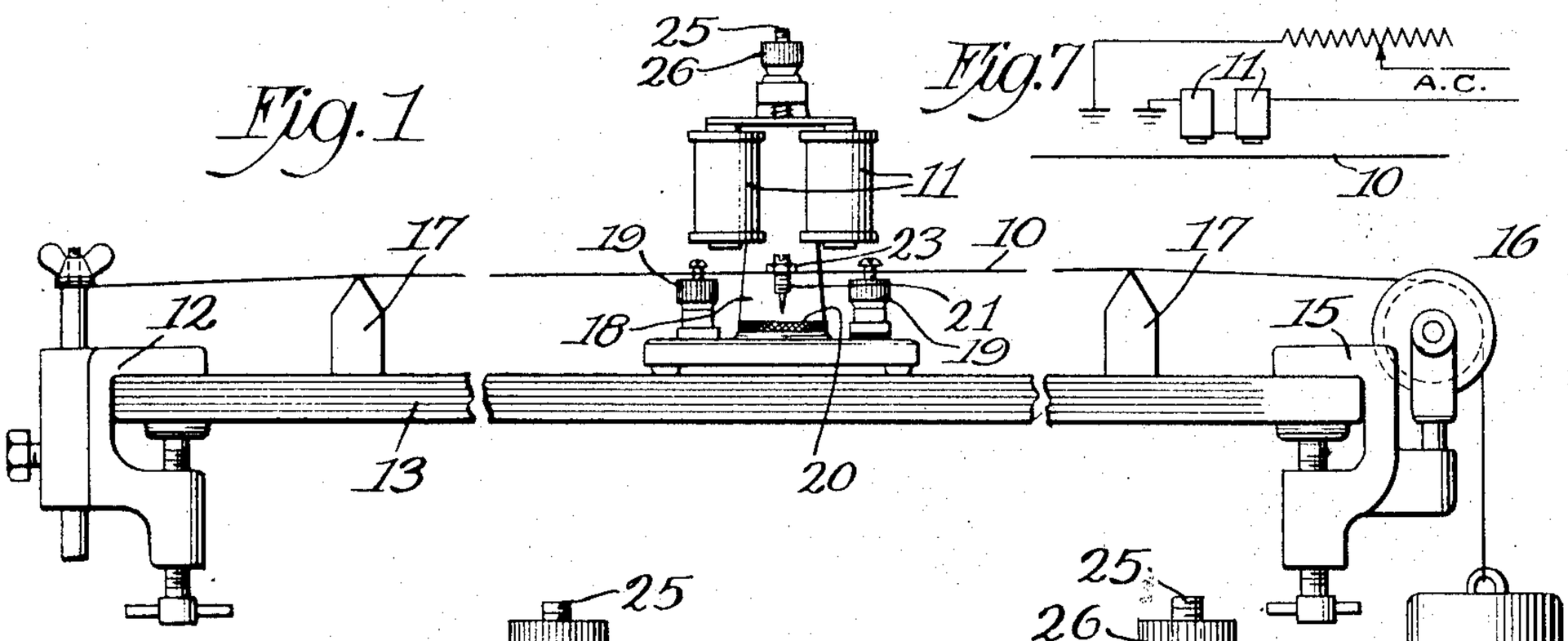


Fig. 7

Fig. 3

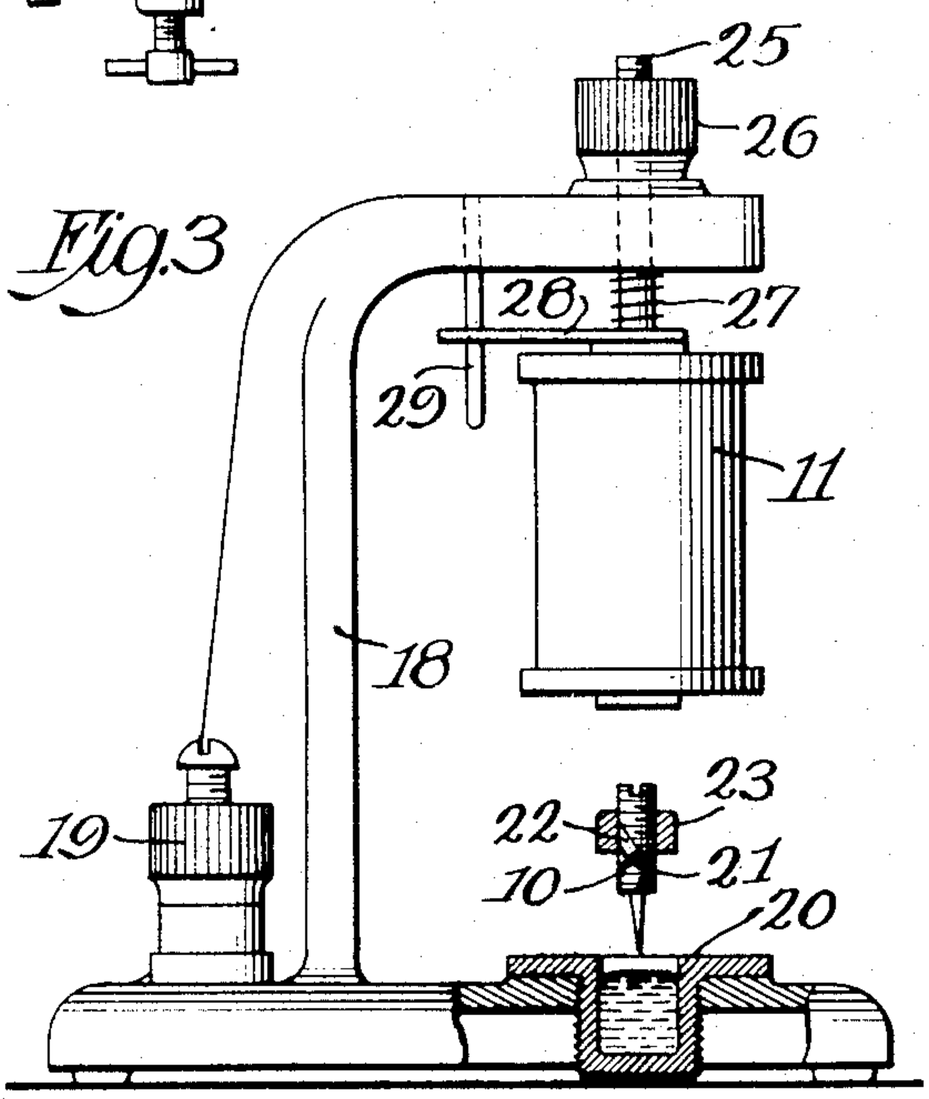


Fig. 2

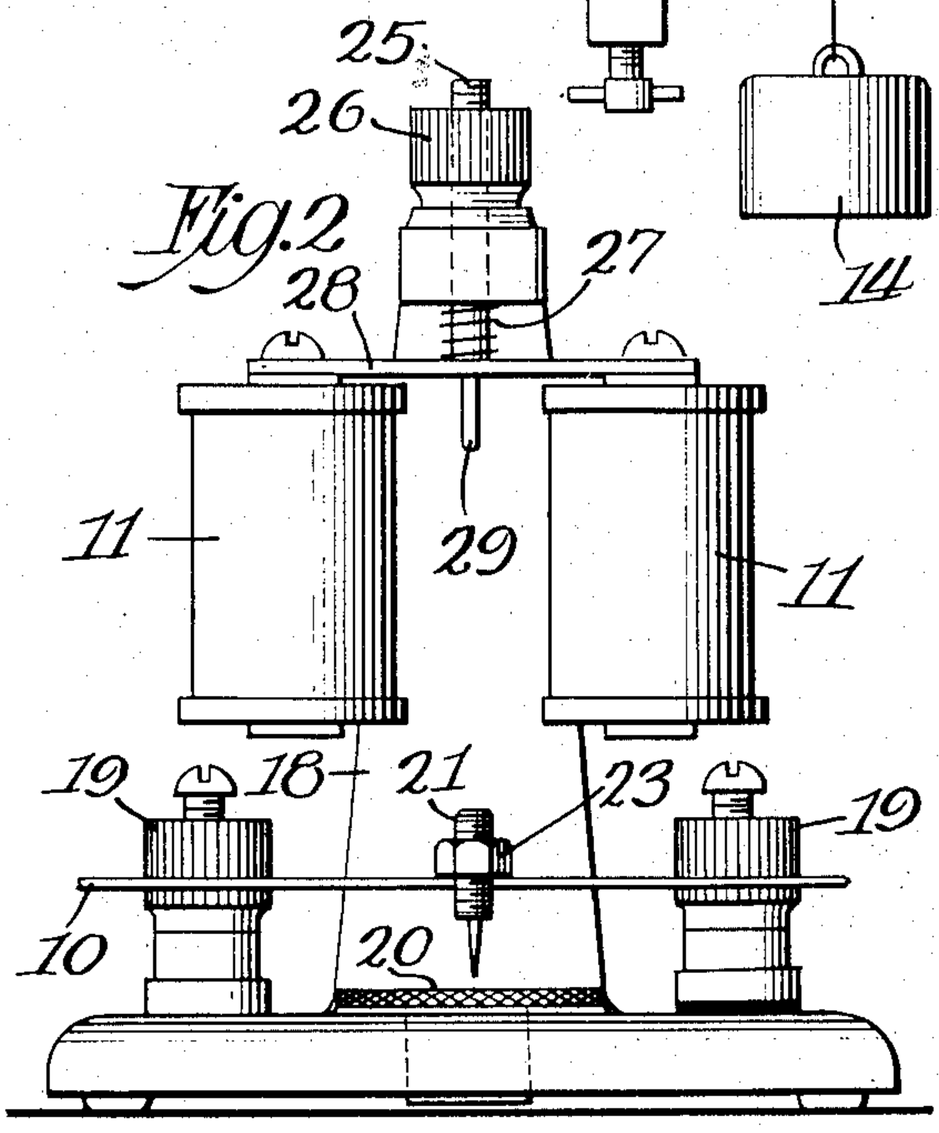


Fig. 4

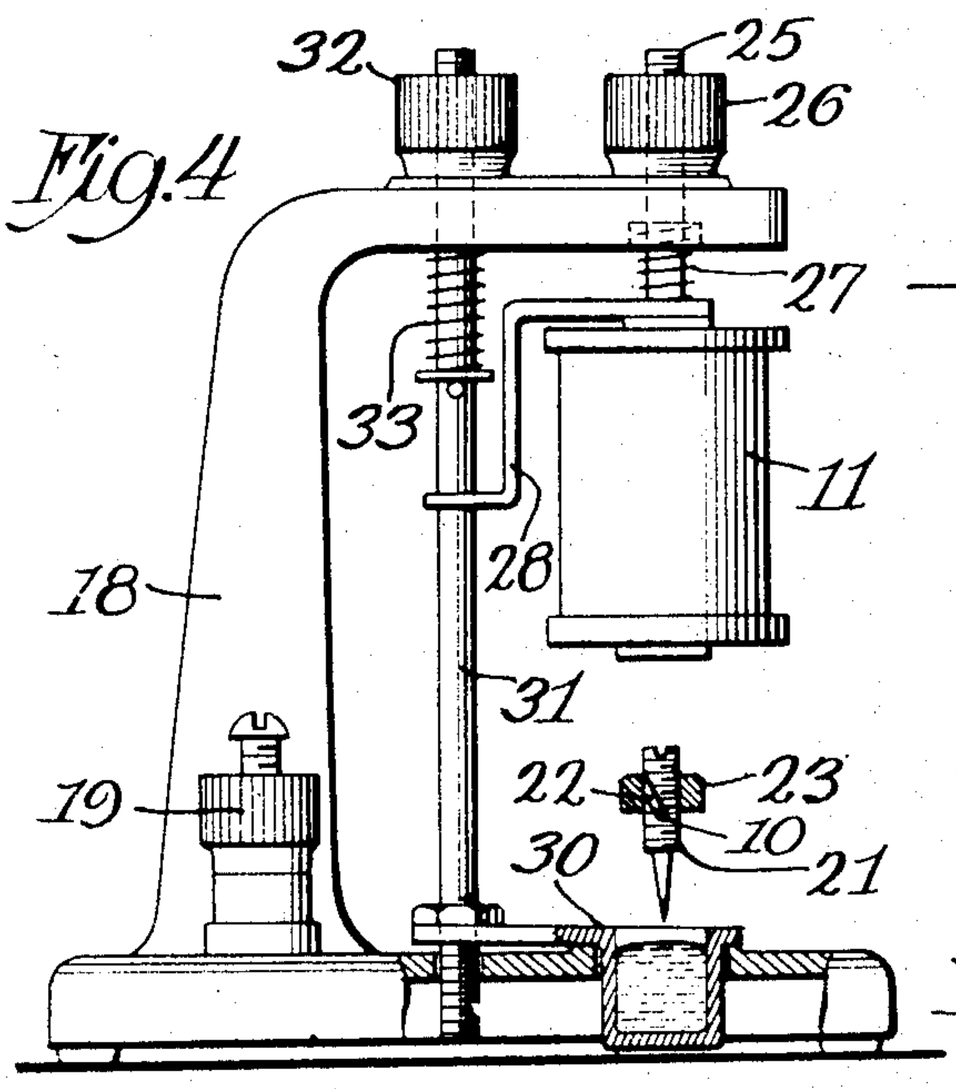


Fig. 5

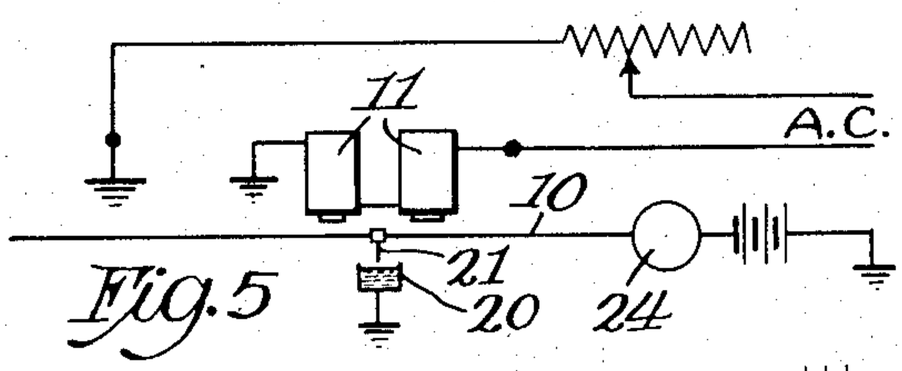
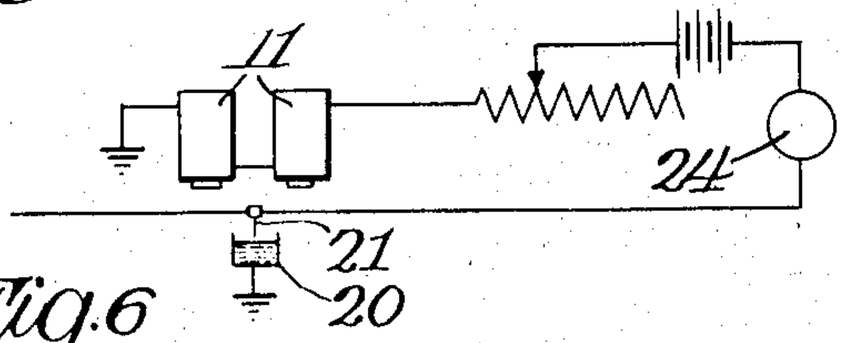


Fig. 6



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Patented May 9, 1933 1,908,258

UNITED STATES PATENT OFFICE

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VIBRATING STRING APPARATUS

Application filed September 27, 1929. Serial No. 395,730.

This invention relates to vibrating string apparatus, and among other objects, aims to provide a simple apparatus for studying and effectively demonstrating the behavior of vibrating strings.

The nature of the invention may be readily understood by reference to one illustrative apparatus embodying the invention and shown in the accompanying drawing, in which:

Fig. 1 is a front elevation of the apparatus;

Fig. 2 is an enlarged front elevation of the mechanism for maintaining the vibrations of the string;

Fig. 3 is a side elevation partly in section of said mechanism;

Fig. 4 is a view similar to that of Fig. 3 of a modified form of the vibrating mechanism;

Fig. 5 is a diagrammatic view illustrating electric circuits arranged for determining the frequency of an alternating current circuit by means of the illustrative apparatus

Fig. 6 is a similar diagrammatic view showing an electric circuit employed in connection with determining the frequency of vibrations of a vibrating string; and

Fig. 7 is a diagrammatic view showing an electric circuit employed in connection with an experiment to secure resonance between an alternating current of known frequency and that of a vibrating string.

In the illustrative apparatus vibrations of a specimen string 10 are maintained and determined by electrical mechanism employing an electromagnet 11 through the field of which the specimen string passes. The specimen or that portion passing through the field is made responsive thereto. This is conveniently effected in the present case by employing a specimen composed of magnetic material, such as an iron wire. The latter is shown connected at one end to a bracket 12 removably clamped to the base 13 of the apparatus and at its other end to a device for maintaining a known tension in the wire, here represented by a weight 14 connected to the string. The bracket 15 clamped to this end of the apparatus base carries a pulley 16 over which the string passes. Adjustable nodal points for the vibrating string are provided by movable bridges 17 carried on the base.

The electromagnet 11 is supported in relatively close proximity to the wire, at a point substantially midway between the bridges, by a pedestal 18 resting on the base 13. The terminals of the magnet are connected with binding posts 19 on the pedestal.

It is apparent that changes in the magnetic field of magnet 11 will influence the wire 10,—for example, the string may be made to vibrate at its natural frequency by interrupting a direct current through the electromagnet in synchronism with the vibrations of the string. This is effected in the present instance by employing a current interrupter controlled by the string itself. Such interrupter is herein shown as a mercury pool 20 in series with the magnet circuit and a contact device 21 carried by the vibrating string and also in series (through the string itself) with the same circuit. The contact device can be made so light in weight that its mass will have no appreciable influence on the natural frequency of the string. The contact device in this instance comprises a screw 21 pointed at its lower end and provided with a slot 22 in which the vibrating string is seated, and clamped by the nut 23. The mercury pool 20 is vertically adjustable relative to the contact device 21.

In Fig. 6 is illustrated a direct current circuit wherein the magnet is in series with the contact 21 and the mercury pool 20 for maintaining the vibrations of the string without effecting its natural frequency. In other words, when energized the electromagnet pulls upwardly on the string until the circuit is broken when the contact leaves the mercury pool; the wire then falls naturally, again closing the electric circuit and receiving another impulse from the magnet. The current interruptions and, therefore, the vibrations of the string because of their synchronous relationship may be advantageously counted by an electric impulse counter 24 in series with the circuit (see Fig. 6). Such impulse counters may be obtained from the Central Scien-

tific Company, 460 E. Ohio Street, Chicago, Illinois.

To vary the strength of the magnetic field on the vibrating string the magnet is in this instance mounted for vertical adjustment on its pedestal by means of a screw 25 and thumb nut 26. A spring 27 between the magnet and the under face of the pedestal arm serves to react against the thumb nut 26 and thus secure a positive adjustment of the electromagnet. The guide arm 28 projecting from the magnet through which rod 29 passes, serves to prevent twisting of the magnet relative to its pedestal.

In Fig. 4 is illustrated a form of impulse mechanism in which the mercury cup may be moved vertically either for purposes of adjustment or to close the circuit to start the vibrations. In this construction the receptacle 30 carrying the mercury is secured to a threaded rod 31 which may be moved vertically by means of thumb nut 32. By vertically adjusting the pool the amplitude of the string vibration may be varied.—For example, by lowering the pool so that the contact member barely enters, the duration of the magnetic impulse is short and the amplitude of vibration is correspondingly small. The spring 33 while normally holding the pool in adjusted position, permits it to be vertically raised by grasping the thumb nut 32 (without turning it) in order to close the circuit and start vibrations.

The mass, length and tension of the wire being known, its frequency may be determined according to the following formula:

$$n = \frac{1}{2L}\sqrt{\frac{T}{M}}$$

This formula may be checked, and the relationship between the frequency of the wire, its mass, length and tension may be studied and demonstrated, by employing the impulse counter 24 in series with the impulse circuit, as illustrated in Fig. 6.

Further demonstration of the aforesaid relationship may be effected by using an alternating current of known frequency in circuit with the electromagnet. (Fig. 7.) In such case the circuit interrupter is not employed.

The forced vibrations imposed upon the wire by the alternating magnetic field can be readily distinguished from the sustained vibrations thereof as resonant frequency is approached.

The beats visible to the eye afford another means for deriving resonance. In other words, string vibrations in resonance with the alternating current frequency becomes apparent not only by the absence of the beats but by the sustained character of the vibrations. Adjustment to resonant frequency may be effected by varying the separation of the bridges or by varying the tension on the wire. The former method is preferable since the length of the wire may be so readily measured. The adjusted vibrations being that of the alternating current, the above formula may be checked by comparing the calculated frequency with the known frequency of the alternating current.

The frequency of an alternating current may be determined by utilizing a circuit such as that shown in Fig. 5 wherein the impulses to the string are effected by the alternating current and the vibrations of the string are counted by the impulse counter which is located in a direct current circuit in series with the contact breaker.

The frequency of vibrations in the wire are adjusted as aforesaid until resonance with the alternating frequency is secured, whereupon by means of the impulse counter 24 (which is in a direct current circuit in series with the current interrupter) the frequency may be read.

It is apparent from the foregoing that the illustrative apparatus provides a simple means for demonstrating the influence of mass, length and tension on the frequency of vibrations of the string.

Obviously the invention is not limited to the details of the apparatus since these may be variously modified. Moreover, it is not indispensable that all features of the invention be used conjointly since various features may be used in different combinations and sub-combinations.

I claim as my invention:

1. Vibrating string apparatus comprising in combination, a pair of adjustably spaced vibrating string bridges, a current interrupter controlled by the vibrations of the string, an electromagnet actuated by said current interrupter for supplying impulses to vibrate said string, and an impulse counter controlled by the current impulses in the magnet circuit for recording the frequency of vibrations of said string.

2. Vibrating string apparatus comprising in combination, a pair of adjustably spaced vibrating string bridges, an electromagnet for supplying impulses to vibrate said string, an alternating current circuit in series with said magnet for providing impulses on said string corresponding to the alternating current frequency, and means for placing a known tension on said string, said bridges being adjustable to vary the length of the string to place the latter in resonance with the impulses from said electromagnet.

3. Vibrating string apparatus comprising in combination, a pair of adjustably spaced vibrating string bridges, an electromagnet for supplying impulses to vibrate said string, a vibrating string across said bridges having means which adapt it to receive the impulses from said magnet, an alternating

current circuit in series with said magnet for providing impulses on said string corresponding to the alternating current frequency, and means for placing a known tension on said string, said bridges being adjustable to vary the length of the string to place the latter in resonance with the impulses from said electromagnet.

4. Vibrating string apparatus comprising in combination, a pair of adjustably spaced vibrating string bridges, a vibrating string of magnetic material stretched across said bridges, an electromagnet for supplying impulses to vibrate said string, an alternating current circuit in series with said magnet for providing impulses on said string corresponding to the alternating current frequency, and means for placing a known tension on said string, said bridges being adjustable to vary the length of the string to place the latter in resonance with the impulses from said electromagnet.

5. Vibrating string apparatus comprising in combination, a pair of adjustably spaced vibrating string bridges, a vibrating string of magnetic material stretched across said bridges, an electromagnet for supplying impulses to vibrate said string, a light weight contact device carried by said string, another contact member with which said device makes and breaks contact upon vibration of said string, and an electric circuit in series with said magnet and said contact device and member for supplying impulses in synchronism with the natural vibration of said string.

6. Vibrating string apparatus comprising in combination, a pair of adjustably spaced vibrating string bridges, a vibrating string of magnetic material stretched across said bridges, an electromagnet for supplying impulses to vibrate said string, a light weight contact device carried by said string, a mercury contact adjustable relative to said contact device to vary the duration of contact, and an electric circuit in series with said magnet and controlled by the contact device to provide synchronous magnetic impulses to maintain the string in vibration.

7. Vibrating string apparatus comprising in combination, a pair of adjustably spaced vibrating string bridges, a vibrating string of magnetic material stretched across said bridges, an electromagnet for supplying impulses to vibrate said string, a light weight contact device carried by said string, a contact member with which said device makes and breaks contact upon vibration of said string, an electric circuit in series with said magnet and said contact device and member for supplying impulses in synchronism with the natural vibration of said string, and means for adjusting the distance between said string and magnet to vary the strength of the impulses on said wire.

8. The method of checking the frequency of an alternating current which is characterized by subjecting a magnetic vibrating string of known properties to a magnetic field having a frequency corresponding to that of the alternating current, and then adjusting the length of or tension in said string until it vibrates in resonance with the impulses of said magnetic field and then deducing the frequency of the alternating current from the known characteristics of the string.

9. Apparatus for studying the behavior of vibrating strings comprising in combination, a fixed string support, a pulley, a string secured at one end to the support and passing over the pulley, a weight for the free end of the string, a pair of bridges for adjusting the effective length of the string, and electromagnetic means intermediate the bridges for setting up and maintaining vibrations in the strings, said means including a mercury pool and a contact carried by the string dipping into the pool.

10. Apparatus for studying the behavior of vibrating strings comprising in combination a base, a pair of string supports, a relatively long string of magnetic material extending between the supports, and electric means for maintaining free vibrations of the string at its natural relatively low frequency, said means including a contact carried by the string and a mercury pool cooperating with the contact.

11. Apparatus for studying the behavior of vibrating strings comprising in combination a base, a string support at one end of the base, a pulley at the other end of the base, a string of magnetic material extending from the support over the pully and having a known weight secured to its free end and means controlled by the vibration of the string for creating electric impulses in synchronism with the natural vibration of the string for maintaining such vibrations, said means including a mercury contact.

12. Apparatus for studying the behavior of vibrating strings, comprising in combination a pair of string supports, a string of magnetic material extending between the supports and free to vibrate at its natural frequency and having properties of length, mass and tension that give it a relatively low natural frequency and an electromagnet associated in proximity to the string for supplying impulses to vibrate the string, said means including a contact carried by the string and a mercury pool cooperating with the contact.

13. Vibrating string apparatus comprising in combination, a pair of adjustably spaced vibrating string bridges, a current interrupter controlled by the vibrations of the string, said interrupter comprising a mercury cup and a contact member on said

string dipping into said cup, and an electromagnet actuated by said current interrupter for supplying impulses to vibrate said string, and means for supporting said electromagnet in proximity to, but out of contact with said string during its vibration, whereby during the operation of the device the string will vibrate at its natural frequency.

In testimony whereof, I affix my signature.

PAUL E. KLOPSTEG.