etc., etc. After setting forth the scheme, and preparing an illustration of it graphically, as shown on the plate, its publication, as a matter of public interest, was advised by Prof. Hilgard. While going to press, I have been favored by the Professor with a copy of a communication addressed to him on October 26th, from the Department of Standards, Board of Trade, England, asking if there is any official gauge or standard measure in the United States for wire and sheet metals, and whether more than one gauge is used by manufacturers in America; and saying that in the German Empire there is some agitation for the establishment of a better gauge than the Birmingham or Dillingen gauges now in use, and adverting to the *unsatisfactory* Birmingham gauge now in use in England. From all this it would appear that the present time is auspicious for the consideration of the subject of the paper in this and other countries.

A NEW SINE PENDULUM.

By THOMAS WILLIAM TOBIN, Professor of Physics and Chemistry,
Central University, Richmond, Kentucky.

Having occasion to illustrate the properties of motion in my department of instruction, it occurred to me, as no doubt it has occurred to others, that the pendulum afforded many practical advantages usually overlooked in general illustrations. This, coupled with the fact that one of my brother professors, L. G. Barbour, was about to introduce the celebrated Foucault experiment as a lecture illustration, suggested to my mind the following instrument. I have worked at it with a degree of devotion which can only be repaid by the gratification afforded in the revelation of natural laws, and, I think, brought an instrument to a state of completion fitted for the use of those who, like myself, are engaged in scientific education. To such I present freely the results of these labors, in the hope that they may be the means of affording as much pleasure as I experienced in their pursuit:

DESCRIPTION OF THE INSTRUMENT.

The following description and drawing is intended to record the apparatus used in actual experiments, and which, having given satis-

factory results, I prefer to adopt rather than embody any improvements or additions which I would introduce in constructing another instrument. Such improvements or additions I will, however, record, leaving their incorporation discretionary on the part of the future manufacturer.

The pendulum is constructed of steel-rod, $\frac{1}{4}$ in. in diameter, and measuring, from the points of support to the extreme lower end, 5 ft. 6 ins.; it is tightly screwed together, so that the parts are compact; indeed, the whole instrument, when set up, must be in similar condition—firm and rigid in all its parts. There are two steel points, hardened and polished, at *b* and *b*, with adjustable check screws. When the pendulum is suspended from these points in perfect equilibrium, they must be in a truly horizontal plane; this condition is indispensable in obtaining accurate results. The pendulum is supported upon, but in no way attached to, a cross-piece, *g*, made of hardened steel or brass, having four agate cups equally distant from its centre. These cups are accurately ground and polished and set, two into the upper surface of two opposite arms, and two in the under surface of the other arms, in such a manner that the crowns or extremities of the sinkings of all four cups are in the same plane. Below this is an oblong piece of steel, *k*, having two adjustable polished steel points, *a*, *a*, of like construction to those in the pendulum-head, and corresponding to the lower surface agate cups, in *g*, to receive them. Thus fitted together, the whole is supported upon a strong tripod with a circular opening, as shown. Attached to the cross-piece, *g*, at the extreme corner of the right arm, is an index, *i*. A scale, *d*, is mounted upon the tripod; this scale may be divided in .01 of an inch, or other convenient units.

Front View.

To adjust the pendulum, it should be mounted as shown in the drawing, all the parts being leveled, and whatever plane the pen-

dulum is started in, that plane must be preserved by it without variation. Should the vibration become elliptical, the cause may be found in imperfect mounting. Before actual use it may be started in a circular direction, and if that quality of rotation is preserved, the indication points to perfect equilibrium of the parts. Should it, however, degenerate into a lineal motion, then the points parallel with the plane of oscillation will probably be found imperfect. Any quality of vibratory motion ought to be preserved for at least twelve hours.

Having the parts in perfect order, the instrument may be started. It does not matter in which position the plane of vibration is situated, but, for reference, the following is suggested. The observer standing in front of the instrument, the opposite direction may be called north; that towards him, south; the right hand, east; and left, west. A hook should be attached firmly to an adjoining wall, about five feet or more distant, due north, and a thin silk cord passing

through the hook and attached to the pendulum at *m*, the other end being held in the hand of the observer. This cord may be detached when the ball is in motion, without disturbing the quality of the vibration.

Now upon pulling the cord gently about 2 ins., and waiting until all incidental vibration has ceased, it may be loosed, and the index marked. If the instrument is set exactly in the plane of vibration,

the index will remain absolutely stationary; but this is seldom the case. It will probably move, and the movement must be noted. If the index moves east on the scale, while the pendulum is north, then the plane of vibration is east of north. The entire pendulum may be moved, by means of the plate, *k*, upon the tripod in a northeast direction. I would recommend a tangent screw for this purpose, but have not as yet used one, and, therefore, it is not shown in the drawing. If the index points west, while the pendulum is north, the plate, *k*, will of course have to be moved northwest, to bring it to a normal condition. These movements are of a very delicate nature, and require skill and patience in adjustment.

Having arranged the instrument so that upon starting the pendulum gently, the index remains perfectly still, the silk cord may then be detached by carefully lifting it off the hook, *m*, and the time noted. Vibrations of the index will become apparent in from one to two minutes; their value for the hourly motion of the earth, is estimated by the formula given as under.

Instead of the index a small mirror may be attached to the cross-piece, *g*, and, by means of a lamp, a spot of light reflected to a distance of several feet or more, and thus giving the indications greater amplitude. I would prefer a heavier pendulum-ball than that used hitherto, and a longer rod, say 6 ft., instead of 5 ft. 6 ins. The points of support might also be made nearer together, probably $\frac{1}{2}$ in. instead of 1 in., with advantage.

FORMULA.

If a physical pendulum be constructed capable of vibrating in one plane only, and this plane caused to revolve, the following results ensue :

Fig. 1.

In Fig. 1, let *AB* represent such plane, and in which the pendulum is started. On revolving the plane to *CD*, the pendulum will stop, or the vibrations be reduced to zero. At any intermediate position, as *ab*, the value of original vibration is represented by the component *cE*, being diminished by the component *ac*. Hence, the value of a vibration of one plane is represented

by the cosine of the angle of deviation from the original plane of oscillation.

Now if a pendulum is free to vibrate in two planes only, at right angles, and these planes capable of revolving, as *AB*, *CD*, Fig. 2, starting the pendulum in the direction *AB*, and revolving the planes to *ab*, *cd*, the value of the original vibration is, in *ab*, as cosine *eE*, and, in *cd*, as cosine *fE*; or, inversely, as the sines *ea* and *fd*. Hence, in planes at right angles, the values of a vibration to the two planes are directly as the cosines of the angles of deviation from starting, and inversely as their sines.

Fig. 2.

In the sine pendulum already described, any deviation from the original plane, AB , in which the pendulum is started, is, therefore, shown by the sine, as $e a$, of the angle of deviation. The movement of the index shows this quantity from a state of rest, and, therefore, twice this quantity in a complete vibration.

As it is convenient to have the index shorter than the length of the pendulum, the ratio of their lengths involves a proportion; or, P representing the length of the pendulum; I , the length of the index; i , the indication of index; v , the length of entire vibration of pendulum; and d , the angle of deviation; we have:

$$P : I :: i : v, 2 \sin d; \text{ or,}$$

$$2 \sin d = \frac{Ii}{Pv}.$$

When the index is the same length as the pendulum, the equation is simplified thus:

$$2 \sin d = \frac{i}{v}; \text{ or,}$$

the indication of index = twice the sine of the angle of deviation.

These statements may be verified by turning the plate, k (in diagram), about its central axis, through an angle corresponding to the above sine.

To find the angle of deviation of the pendulum, in any latitude, during a given time. (By Professor L. G. Barbour.)

The following simple equation will serve to verify the results obtainable by the sine pendulum, indicating the rotation of the earth:

$$\sin \frac{1}{2} d = \sin \text{lat} \times \sin \frac{1}{2} \text{ hour angle.}$$

Thus, in latitude of Richmond, Kentucky, $37^{\circ} 46'$ for one hour.

$$\text{Log sin lat. } 37^{\circ} 46' = 9.787069$$

$$\text{Log sin } \frac{1}{2} 15^{\circ} = 7^{\circ} 30' = 9.115698$$

$$\text{Log sin } \frac{1}{2} \text{ angle } d = \underline{8.902767}$$

$$\text{Or, } 4^{\circ} 35' \times 2 = 9^{\circ} 10' = d.$$