

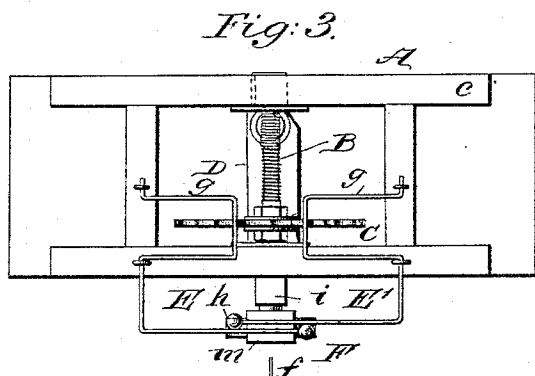
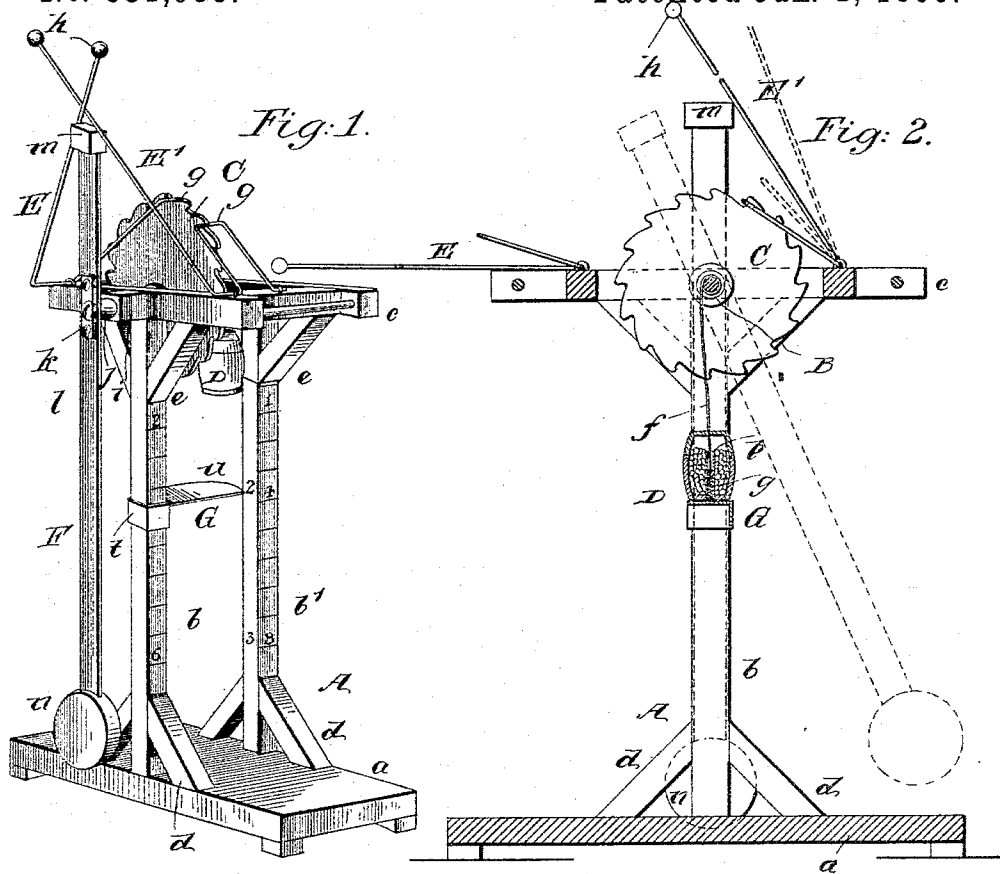
(No Model.)

J. S. HEMENWAY.

APPARATUS FOR DEMONSTRATING LAWS OF GRAVITY AND MECHANICS.

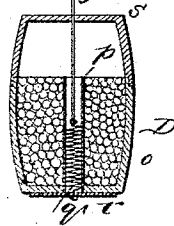
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WITNESSES:
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Fig. 4.



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APPARATUS FOR DEMONSTRATING LAWS OF GRAVITY AND MECHANICS.

SPECIFICATION forming part of Letters Patent No. 531,935, dated January 1, 1895.

Application filed March 21, 1894. Serial No. 504,553. (No model.)

To all whom it may concern:

Be it known that I, JUSTIN SAMUEL HEMENWAY, of River Falls, in the county of Pierce and State of Wisconsin, have invented new and Improved Apparatus for Demonstrating the Laws of Gravity and Mechanics, of which the following is a specification, reference being had to the annexed drawings, forming a part thereof, in which—

Figure 1 is a perspective view of my improved apparatus. Fig. 2 is a side sectional elevation. Fig. 3 is a plan view; and Fig. 4 is a vertical transverse section of the weight.

Similar letters of reference indicate corresponding parts in all the views.

The object of my invention is to provide simple apparatus for demonstrating the laws of falling bodies, and some of the laws of mechanics.

My invention consists of certain features of construction and combinations of parts that will be hereinafter described and claimed.

The frame A, which supports the various parts of the apparatus, is formed of the base *a*, the uprights *b b'*, the top frame *c*, braces *d* attached to the base and uprights, and braces *e* attached to the top frame and the uprights. In the top frame is journaled a shaft B, on which is placed a disk C having a toothed periphery, the said disk being clamped to the shaft by screw collars, said disk being preferably constructed of aluminum. The shaft B is screw-threaded to guide a cord *f*, which is wound upon the shaft, the said cord being attached to the center of the shaft at one end, and connected with a weight D at the opposite end.

To the cross bars of the top frame *c* are pivoted two independent detents E, E', each formed of a rod bent twice at right angles, forming a crank *g*, one extremity being bent at right angles and extending beyond the shaft B, and provided at its free end with a small weight *h*. To the side of the frame *c* is attached a block *i*, from which projects a stud *j* on which is pivoted a clamp *k*, formed of two similar plates connected by screws. Between these plates is placed the pendulum rod *l* of the pendulum F, the said rod being slotted to allow the passage of the screws of the clamp *k*. The upper end of the rod is provided with a head *m* upon which the de-

tents E E' may rest. On the lower end of the pendulum rod *l* is placed an adjustable pendulum bob *n*. The detents are employed for arresting the disk C after any predetermined number of vibrations of the pendulum. When for instance, it is desired to stop the wheel after one vibration of the pendulum, the latter is brought into an inclined position, and the detent toward which the upper end of the pendulum is inclined, is turned to rest on the head *m*, while the other detent is thrown back into the position shown in Fig. 2 for the detent E. When it is desired to allow the disk to revolve during more than one vibration, the detents are both lifted off the disk and the pendulum, and when the pendulum has made the desired number of vibrations less one, the detent which at that time is adjacent to the upper end of the pendulum, is laid on the head *m*, so as to arrest the motion of the disk at the end of the next vibration of the pendulum. I prefer to employ two independent detents in order to enable the operator to give the pendulum an initial vibration in either direction and yet arrest it after any desired number of vibrations. It will be obvious that when but one detent is employed, the initial vibration of the pendulum must take place in a predetermined direction when an even number of vibrations is desired, and in the opposite direction when the intended number of vibrations is an odd one.

Another method of using the apparatus, which is preferable on account of its greater accuracy, is as follows: When for instance it is desired to allow the disk to revolve during one vibration of the pendulum, the latter is brought into an inclined position and the detent toward which the upper end of the pendulum is inclined is thrown back into the position shown in Fig. 2 for detent E. The other detent is turned so as to rest on the disk C. The pendulum is then released, and as it swings, its head *m* comes in contact with the end of the detent which rests on the disk C, and lifts the said detent off the disk so as to release the latter. (See position of detent E' shown in dotted lines in Fig. 2). When the pendulum swings back, it allows the lifted detent to return into contact with the disk C and thereby arrest the latter. When it is desired to allow the disk to revolve during more

than one vibration of the pendulum, the disk is released in the same manner as I have just described, and then the operator throws back the detent which has been lifted by the pendulum, before this detent again engages the toothed disk C. When the pendulum has made the desired number of vibrations, less one-half of one, the detent which at that time is adjacent to the upper end of the pendulum, is laid on the head *m* so as to arrest the motion of the disk at the end of the last vibration.

The weight D, which is attached to the end of the cord *f*, is made in the form of a hollow vessel *o* provided with a central tube *p* containing a spiral spring *q*, the lower end of which is attached to a plate *r*, on the bottom of the hollow vessel *o*, the upper end being attached to the cord *f*. The vessel *o* is provided with a cover *s*. The space in the vessel around the central tube *p*, is filled with lead, shot or other heavy material. The uprights *b b'* are graduated so as to represent the distance through which the weight falls, the said graduations being related to the vibrations of the pendulum F. A weight-support G, consisting of a short sleeve *t* surrounding the standard *b*, and a shelf *u* attached to the sleeve may be clamped in any desired position upon the standard *b*.

The apparatus is designed for use in schools both in class demonstration and for private experiment and study. It is so constructed that it shows the way a body falls when falling freely through a vacuum. The moment the wheel is released by the lifting of the detents, the force of gravity pulling down on the body is transmitted through the cord to the shaft of the wheel, and the wheel revolves. The inertia of the wheel counteracts the force of gravity to such an extent, that although the body commences to fall immediately, it falls much slower than it would if it were falling freely in a vacuum. The velocities of a body falling freely through a vacuum, and this body falling and turning the wheel, are proportionally the same. Friction does not enter into the experiments, for reasons hereinafter explained. The circumference of the shaft being one inch, if the wheel turns around once the weight drops one inch, or one space represented on the upright of the apparatus. The circumference of the wheel, which is sixteen inches, is divided into sixteen equal parts by its teeth. A body will fall in a vacuum sixteen feet in a second. In dealing with the laws of falling bodies, one second is taken as the unit of time, and sixteen feet as the unit of space.

In this apparatus, one vibration of the pendulum corresponds to one second, one space on the columns corresponds to sixteen feet, and one notch on the wheel corresponds to one sixteenth of a space, or one foot. The body which falls is of such weight that the force of gravity pulling down on it during one vibration of the pendulum is sufficient to turn the wheel around just once, thus bringing

the body down one space, which represents a body falling freely in a vacuum sixteen feet in a second.

The pendulum is so attached in relation to the detents that, if operated as hereinafter described, it will free the wheel exactly at the beginning and stop it exactly at the end of one, two or three vibrations. If a body is allowed to fall during one vibration of the pendulum, it is found to fall one space. If a body is allowed to fall during two vibrations, it is found to fall four spaces. If a body is allowed to fall during three vibrations, it is found to fall nine spaces. It will be noticed in each one of these experiments, that the number of spaces through which the body falls in a certain time is equal to the square of that time times one space. From these facts we deduce our first law, viz: the total distance through which a body will fall in any given time, equals the square of the time times distance it will fall in one interval (time two by sixteen feet). From these same experiments we deduce our second law, viz: the distance which a body will fall during any particular interval of time equals twice the time, less one times one space ($2 \times \text{time} - 1 \times 1 \text{ space}$).

To find the velocity at which the body is falling at the end of some particular interval of time, I place the weight support on the upright, as represented in Figs. 1 and 2. The cord which supports the body, being wound around the shaft of the wheel, as the body falls it gives the outside of the shaft the same velocity as that of the falling body. If gravity is prevented from acting exactly at the end of the first or second interval of time, and the wheel is allowed to go on revolving for another interval of time, at the same rate which it had when gravity was prevented from acting, the velocity of the falling body will be shown by the length of cord which will unroll from the shaft.

If the shelf or support is placed at the end of the first space and the wheel is allowed to revolve during two vibrations of the pendulum, it is known by previous experiment, that it will take one interval of time for the weight to fall to the shelf or support. During the next interval of time the cord will run off from the shaft, showing the velocity which the body had at the end of the first interval of time. If the shelf or support be removed and the weight is let down to take up the slack cord, the weight will be found to hang just two spaces below where gravity was prevented from acting, which proves that at the end of the first interval of time, the body was falling at the rate of two spaces per interval of time.

If the shelf or support is placed on the upright, as represented in Fig. 2, and the wheel is allowed to revolve through three intervals of time, we know by previous experiment, that it will take two intervals of time for the body to fall to the support. During the third interval the shaft will run off a certain amount

of cord, which when the weight is let down, will be found to let the weight down four spaces below where gravity was prevented from acting. Hence the velocity of the falling body at the end of the second interval of time is found to be at the rate of four spaces per interval of time.

The velocity which a body has at the end of the first and second intervals is equal to twice the time times one space. Hence the third law. The velocity of a falling body at any time equals twice the time times one space (2 T) one space.)

The apparatus also proves that the force of gravity has the same effect upon a body during each interval of time. In the experiments last described, to show velocity, the weight falls one space less during the succeeding interval, on account of gravity being prevented from acting, that is, if gravity is prevented from acting at the end of the first interval of time, the weight will fall two spaces during the second interval, whereas, if gravity had not been prevented from acting, at the end of the first interval the weight would have fallen three spaces during the second interval; also if gravity is prevented from acting, at the end of the second interval the apparatus will represent the body as falling four spaces during the third interval, whereas if gravity had not been prevented from acting, the body would have fallen five spaces during the third interval of time. From these experiments, it will be seen that the effect of the force of gravity on a falling body, during each interval of time, is sufficient to take the body down just one space.

For experiments illustrating energy, the apparatus will be graduated two spaces farther down than is shown in the drawings, and the length of the cord will be such that when it is all unwound from the shaft, the weight will hang at the lower gage mark. As the weight is lifted by the cord being wound up on the shaft, potential energy is given to it. Suppose the weight to be lifted up two spaces; the weight then, as it hangs suspended, contains a certain amount of energy, which is equal to the amount of work done upon it. This is potential energy, because it is ever ready to be transmitted into something else.

Suppose the detents to be lifted off the wheel; the potential energy which the weight had, immediately commences to change into kinetic energy, and is delivered over to the wheel which is made to revolve as the body falls. As soon as the weight reaches the limit of its downward movement, it has transmitted all of its energy over to the wheel. The energy which the wheel now has is kinetic energy, and the wheel immediately begins to deliver it back to the body again in the form of work, by raising the body again. Thus the energy is again changed from kinetic to potential energy. After the wheel has raised the body as far as it will, the wheel is held to prevent the body from falling back the dis-

tance through which the weight was raised. This distance can be used as a unit to represent the energy which is given to the wheel by the body falling two spaces. By letting the weight fall twice as far, the energy given to the wheel is found to be twice as great; and by letting the body fall three times as far, the energy given to the wheel is seen to be three times as great, always reckoning the energy of the wheel by the distance which it is able to lift the weight. From these experiments is deduced the following law, viz: the weight being the same, and disregarding friction, the kinetic energy of a body varies as the distance through which the force acts.

Doubling the weight doubles the energy. Doubling the distance doubles the energy. From these two facts we deduce our complete law, viz: kinetic energy equals the weight times the distance through which the force acts. The kinetic energy of a body varies as the square of its velocity. Previous experiments show that if the weight falls one space, it will have a velocity of two spaces per interval of time. If the weight falls one space before reaching the limit of its movement, and the distance which the weight is lifted again on account of energy which it gave to the wheel is noted, this distance will serve as a unit of energy.

If the body falls from such a height (four spaces) that its velocity will be double what it was in the first experiment, by the time it reaches the limit of its movement the distance through which it is lifted will show that its energy was four times as great as in the first experiment. If the weight falls from such a height (nine spaces) that the velocity will be three times as great as in the first experiment, it will be found by the distance through which the weight is lifted, that its energy is nine times as great as in the first experiment. From these experiments is deduced the following law, viz: the kinetic energy of a body varies as the square of its velocity.

Having thus described my invention, I claim as new and desire to secure by Letters Patent—

1. An apparatus for demonstrating the laws of gravity and mechanics, comprising a suitable frame, a shaft journaled therein, a cord connected to the shaft, a weight secured to the cord, a toothed wheel of the shaft, a pendulum fulcrumed on the frame, and a detent pivoted independently of the pendulum and having an arm adapted to rest on the pendulum, the detent being adapted to engage the toothed wheel to arrest the rotation thereof, substantially as described.

2. An apparatus for demonstrating the laws of gravity and mechanics, comprising a suitable frame, a shaft journaled therein, a cord connected to the shaft, a weight secured to the cord, a toothed wheel on the shaft, a pendulum arranged to vibrate in a plane essentially parallel to that of the wheel, and independ-

ent detents pivoted to the frame and each provided with an arm adapted to rest on the pendulum, the detents being adapted to engage the toothed wheel to arrest the rotation thereof; substantially as described.

3. An apparatus for demonstrating the laws of gravity and mechanics, comprising a suitable frame provided with a graduated upright, a horizontal shaft journaled in the frame, a cord connected to the shaft, a weight secured to the cord, a toothed wheel on the shaft, and a detent for arresting the rotation of the wheel, substantially as described.

4. In an apparatus for demonstrating the laws of gravity and mechanics, the combination with the frame of a shaft journaled therein and carrying a toothed wheel, whose teeth have a length equal to the circumference of the shaft, a weight and cord operatively con-

nected to the shaft, and means for arresting the rotation of the wheel, substantially as specified.

5. In an apparatus for demonstrating the laws of gravity and mechanics, the combination of a frame provided with graduated uprights, a shaft journaled in the frame and provided with a toothed wheel, a pendulum suspended from the frame with its axis of motion axially in line with the shaft, independent detents arranged to act on the toothed wheel, and in operative relation with the pendulum, and a weight and weight cord connected with the shaft, substantially as specified.

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Witnesses:

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A. P. FORSYTH.