

TWO NEW TIME CONTROL INSTRUMENTS

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The two instruments described below were designed to meet the requirements of a research problem which were not satisfied by any existing forms of time control apparatus. Inasmuch as accessory apparatus for measuring out and controlling time intervals is of a considerable utility in a psychological laboratory in regulating the duration and sequence of stimuli and operations, in actuating certain types of exposure apparatus, in operating a series of instruments as is necessary in the finer measurements of reaction times and in numerous other well-arranged measurements, and in checking the accuracy of other instruments; and since these to be described possess several unique and desirable features over other forms it is well that they be placed at the disposal of laboratory psychologists in general.

I. AN ACCELERATION TIME CONTROL APPARATUS

Time control apparatus based upon the action of gravity on falling bodies has been in use almost since the beginning of laboratory psychology. In the present device, however, the physical phenomena of acceleration is utilized. The essential construction of the apparatus consists of an inclined U-shaped groove upon which a steel sphere rolls. The inner edges of this groove, which form the track for the sphere, are constructed of alternating strips of insulating and conducting material placed in such a manner that the sphere in its passage along the inclined track completes the circuit through the conducting strips arranged opposite each other.

Knowing the angle of inclination of the groove (ϕ), the distance the sphere travels before coming into contact with the conductors (d^1), the distance the ball travels over the conducting strips (d^2), the radius of the sphere (r), the distance

separating the edges of the strips (s), and the acceleration of gravity (g) it is possible to compute the time required for the passage of the sphere over the conductors by the following formula:¹

$$T = \sqrt{\frac{1}{g \sin \phi} \left[2 + \frac{4}{5 \left(1 - \left[\frac{s}{2r} \right]^2 \right)} \right] (\sqrt{d^1 + d^2} - \sqrt{d^1})}.$$

Theoretically the time consumed by the ball in passing over the conductors could be varied in several ways. The distance over which the ball passes before coming into contact with the conductors could be varied, the actual length of the conductors altered, the angle of inclination increased or decreased, the size of the sphere varied, or the distance separating the edges of the groove changed. In practical experience it was found that the instrument operated with the greatest reliability, *i.e.*, made the most secure contacts, when the inclination of the groove was about 3 degrees. Some of the other possible sources of alteration of the time intervals being measured out are obviously out of the question with a firmly constructed instrument, as, for example, changes in the distance separating the strips. Theoretically, also, if a V-shaped groove, the sides of which formed a constant and known angle, were used the acceleration would be independent of the size of the sphere; but again, as a matter of experience, it was soon found that a much better contact and a more uniform track was secured when the strips were placed on edge.

The point at which the sphere is started on its downward journey is kept constant and the initial velocity kept at zero by means of a release attachment, consisting of an electro-magnet arranged so that it can be securely fastened at any point along the track. To start the sphere it is only necessary to break the circuit through the magnet. The best results were obtained when a laminated core was used and a thin mica sheet attached to the end with which the ball comes into contact. This precaution avoids the undesirable in-

¹ This formula was arrived at in collaboration with Mr. Victor Hoersch, of the Department of Physics of the University of Oklahoma.

fluence which any appreciable residual magnetism might have.¹ Certain other precautions should also be noted:

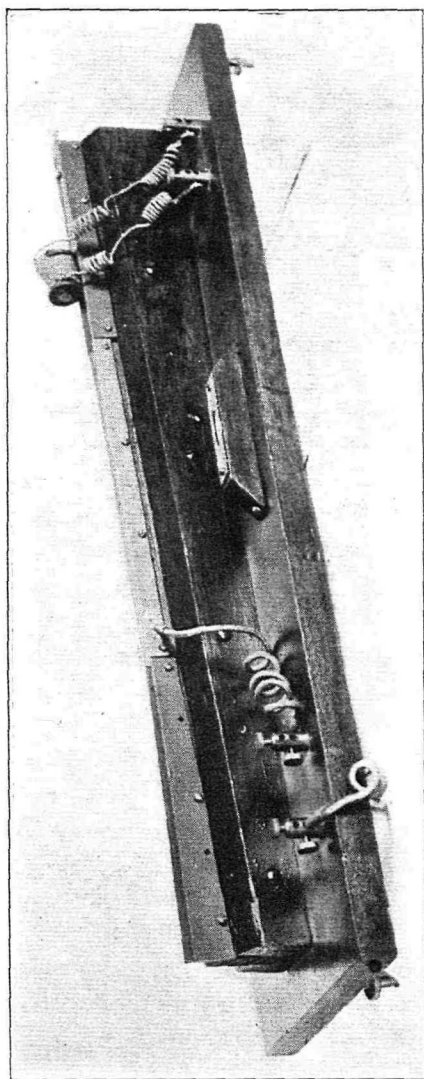


FIG. 1. Acceleration apparatus.

(1) The current must not vary, otherwise the arcing at the bottom of the conductors will produce variations in the

¹ This residual lag could be entirely eliminated if a simple, coreless, magnetic coil were used.

contact length of the strips, (2) with the size and material of the sphere used in the present arrangement a secure contact is not obtained when less than three dry cells are used, (3) the track itself must be kept free from dust, grease, and all foreign matter.

The original instrument as illustrated in Fig. 1 is made of wood with the inclined track of brass and fiber and at an angle of 3 degrees with the base. A one-inch steel sphere is used and the inner edges of the track separated by 12.0 mm. The base is adjustable by means of the three leveling screws and constancy of position is assured by a small spirit level attached to the upper surface. No attempt was made to provide for an adjustment in the inclination of the track as preliminaries had demonstrated the limits of the arrangement. The instrument was planned so that one second would be consumed while the sphere is traveling over the conductors and regardless of the inaccuracies attendant upon amateurish construction it consistently measured intervals of 1.01 second. With a slight adjustment of the position of the release magnet this interval was quickly changed to 1.00 second. The instrument was checked only to the hundredth but it successfully measured intervals between 0.5 and 1.0 seconds accurately within the limits of the checking set up.

The merits of this instrument are:

1. A wide range of times in comparison with other forms of time control devices.
2. A greater flexibility. This instrument is not limited to a make and a break but a variety of electrical combinations is possible in sequence.
3. Accuracy to at least the hundredth.
4. Few adjustments and none to get out of order.
5. Certainty of operation within the limits mentioned.¹
6. Cheapness and ease of construction. The model illustrated was constructed in six hours. The materials are available around even a modestly equipped laboratory.

¹ Increasing the mass of the rolling body would increase the working limits.

II. A DISC COMMUTATOR TIME CONTROL INSTRUMENT

This instrument utilizes the principle of the staggered commutator combined with the magnetic friction clutch as applied by Dunlap. The chief claim to originality is in the

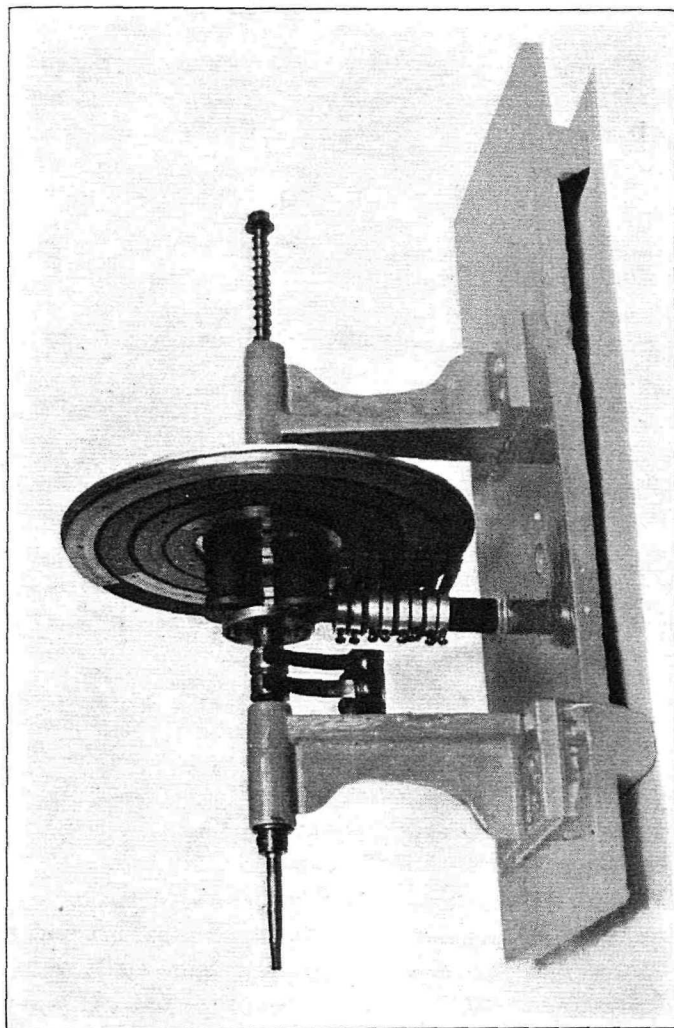


FIG. 2. Disc commutator apparatus.

use of a disc rather than a drum for the commutator and in the matter of the electrical system of the clutch control. The use of a disc makes possible a more compact and a lighter

instrument requiring less power and attention in addition to simplifying the calculations necessary for adjusting the collector sectors for varying time intervals. By the system of electrical connections the instrument can be synchronized with the observer or experimenter, it not being necessary to get the human element into step with a steadily revolving drum or constantly swinging pendulum. This feature is especially desirable in all work with children. The electrical control is such that the apparatus requires no attention and the noise incident to its operation can be removed, with the instrument, into a distant room and all auditory disturbance will be removed from the vicinity of experimentation.

Two shafts placed with their centers opposite each other are mounted on a base (Fig. 2). End thrust is eliminated from the drive shaft by shoulders placed each side of the bushings. One end of the drive shaft is fitted to carry the follower of a set of 45-degree spiral gears which meshes with the driver on the motor shaft. The other end of the drive shaft carries two small electromagnets.¹ A small double ring commutator on the drive shaft carries the current from the brushes to the magnets. The disc shaft is held in place by a shoulder on the end nearest the clutch magnets and by a light compression spring on the other end. The tension of this spring is adjustable by the nut at the end of the shaft. The disc commutator is normally about $1/32$ inch from the magnets, so that upon the energization the disc shaft springs laterally $1/32$ inch and is firmly gripped by the magnets before beginning to revolve with them. When released by the clutch the tension of the spring brings the disc back into normal position and stops it almost instantly. The two outer overlapping conductors on the disc complete the circuit for the clutch magnets through the two lower pair of brushes. All the pairs of brushes are of four receding leaves of spring brush brass and are always in firm contact with the commutator. The brushes are fully adjustable so that the take off is on a line with the radius of the disc perpendicular to the

¹ In order that eddy currents may be avoided both shafts are supported by aluminum castings.

base. Compensation for wear is provided for in the case of the time brushes (two upper pair) by having the end bent at an angle of 90 degrees.

The disc itself is made of aluminum and is attached to the disc shaft by means of machine screws. Being constructed of a light material it gains less momentum than if it were heavier and consequently less tension is required to bring the disc to a full stop than would otherwise be the case. In

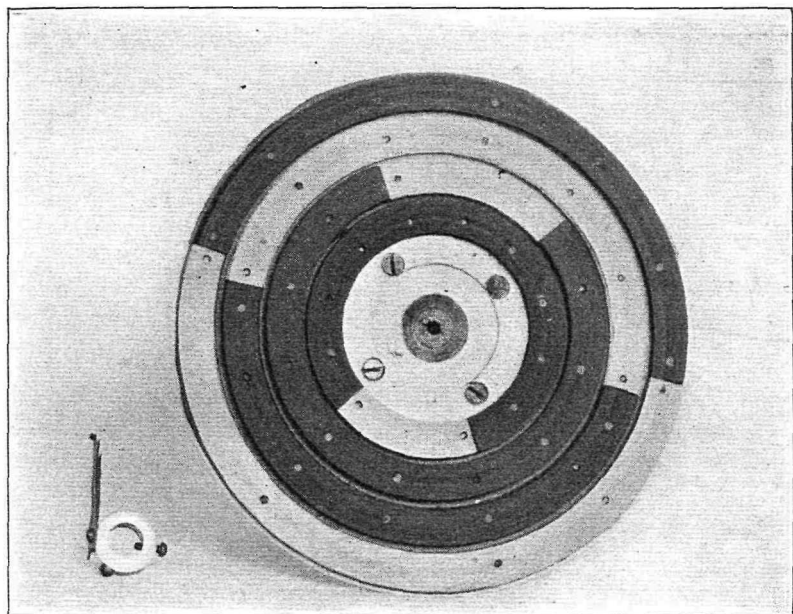


FIG. 3. Face of disc commutator; brush showing holder and adjusting screws.

other terms, less power is used and a smoother operation is attained. The collector sectors are insulated from the disc proper by a sheet of fiber on the face of the disc and fiber washers and bushings are used on the attaching screws.

As arranged in the present instrument the shafts make one complete revolution in 3.6 seconds. At this rate one degree passes the brushes in 0.01 second. Since the time collectors are 70 degrees, seven tenths of a second is measured out in each phase or half revolution.

A wide range of flexibility and a convenient method of change is provided by having holes drilled and tapped in the disc in a symmetrical arrangement on the line of each con-

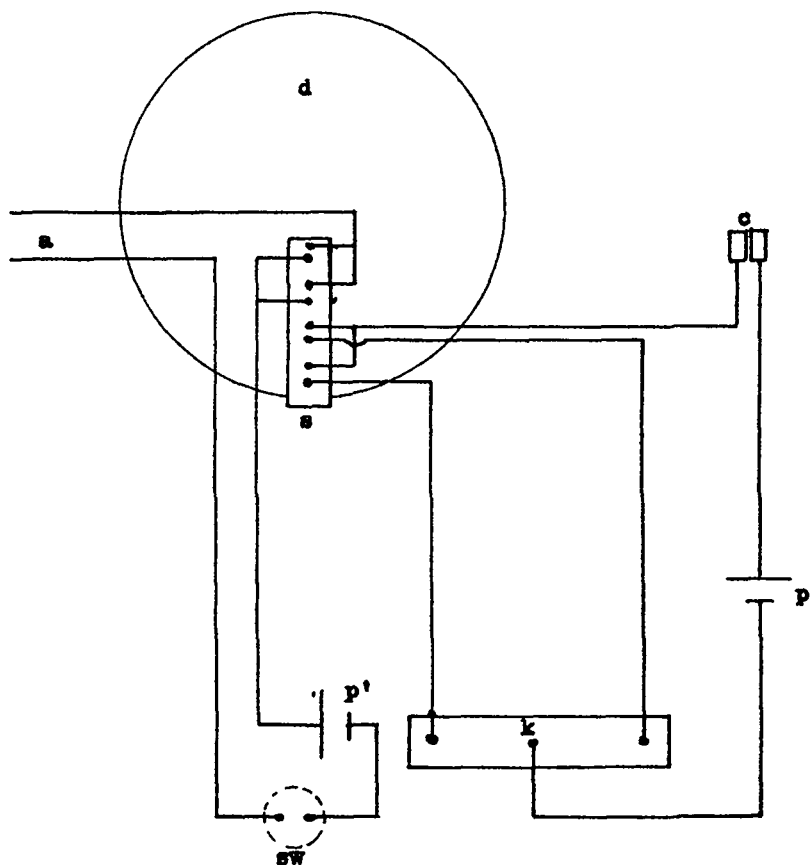


FIG. 4. Diagram of the electrical connections of the disc commutator apparatus. *p* is the source of the primary circuit which passes through the electromagnets by means of the two lower pair of brushes on the brush support, *s*, and the magnet commutator, *c*. *k* is the foot key which shifts the current from the lower to the next above pair of brushes to start the exposure between the phases of revolution of the disc commutator, *d*. *p'* the source of the secondary circuit which passes to the timed apparatus, *a*, through the two inner pair of brushes. *sw*, snap switch for breaking secondary circuit when the control apparatus is not in use.

centric ring. Supplementary sets' of collector and insulating rings are threaded all ready to be cut and matched and can

be fastened at any point and for any length on the disc, provided that they are on a line with the circle of openings corresponding to their curvature.

By means of a double throw switch the current can be made to pass through either of the primary (overlapping) collector sectors, as shown in Fig. 4. When the switch is once thrown the disc begins its revolution and continues until its first phase is completed when the circuit is broken by the one primary collector passing the brushes. When the switch is again thrown the other primary conductor is brought into the circuit and the disc again revolves for another phase, completing one revolution. Due to the overlapping of the primary sectors a start is always assured. By this arrangement any initial lag has no effect upon the interval being measured, for the disc travels several degrees before the timing collectors come into contact with their brushes.

Any desired range of speed intervals can be produced by altering the speed of the drive shaft or by changing the sector degrees of the collectors, or by a combination of both. A series of intervals can be produced by providing a series of conducting strips in line with one pair of brushes if it is desired to use the same line, or more than one collector circle can be used.

As a source of power for the motor a $1/6$ h.p. motor of the constant speed, repulsion-induction type is recommended. A synchronous motor of the same power could also be used, but the portability and sureness of operation of the former in addition to its reliability and simplicity of operation lead me to prefer the former. No accessory apparatus is needed for the operation of a constant speed motor and alternating current is always available. When operated on alternating current the synchronous motor reacts to the fluctuations in pulsation rate which are constantly occurring and if the motor is delicately adjusted a slight decrease in potential will cause the motor to stop and 'sing.' The higher types of constant speed motors on the other hand, do not react to fluctuations of less than 10 per cent. and very rarely is the electrical service such that this limit is approached and on ordinary

city current a repulsion-induction motor of good construction will operate with a maximum error of only $1/4$ of one per cent., even when influenced by the peak load. On an interval of one second this would lead to a possible maximum error of 0.0025 second. It is well known that unless a thermostat is used with a synchronous motor when operated in tandem a gradual but persistent decrease occurs in the rate of rotation.

This disc commutator instrument is more difficult to construct but on the whole is more desirable than the acceleration apparatus for laboratories that can afford the more expensive construction. Its chief points of superiority over the acceleration apparatus and other forms of apparatus for measuring out time intervals are:

1. A range of intervals with a lower limit of about 0.01 second and practically no upper limit.
2. Any combination of connections desired is possible within the time circuits either simultaneously or in sequence.
3. Accuracy. The instrument is as accurate as the source of power.
4. Operation is certain with any currents within the range of laboratory use.
5. Freedom from distraction in the sphere of experimentation.
6. Simplicity of operation. There is nothing to do but throw a switch or press a key when the interval is desired.
7. The intervals can be given at any moment desired and in rapid succession.

The designer of the instrument has the patterns from which the original was constructed and will coöperate with other laboratories in the construction of similar instruments or of adaptations.