AUTOMATIC DEVICE FOR CONTROLLING LENGTHS OF LIGHT AND DARK PERIODS IN CYCLES OF ANY DESIRED DURATION

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Since the discovery of photoperiodism by Garner and Allard (2), scientists have been concerned with controlling the length of day to which experimental plants or animals are exposed. If plants or animals are grown in rooms with artificial illumination it is possible to control day length precisely by operating lamps on an ordinary time clock. The experiment becomes more complicated, however, if one wishes to expose a series of experimental organisms to different day lengths in order to compare the effects of different treatments. One may operate a series of small chambers each containing an experimental group and control illumination of each chamber by a time clock. This becomes expensive; problems of temperature control often become serious. Another procedure is to have an experimentally controlled illuminated room with an adjacent dark room so the organisms can be moved from the illuminated room to dark room and back again at desired intervals. This requires manual manipulation at specified times, twice a day for each treatment, and care must be exercised that the treatments are shifted at exactly the correct time each day.

Most of the literature on photoperiodism has dealt with the influence of duration of light and dark periods in cycles of 24 hours. Recently, however, considerable interest has developed in the effects of cycle lengths other than 24 hours duration (1, 3). Such experiments have presented extreme difficulties in manipulation. If the organisms are to be transferred manually from light to dark room or vice versa, it is necessary for someone to be available night and day throughout the experimental period. Failure to shift one group of organisms at the correct time may lead to failure of the entire experiment.

We have devised a simple apparatus for automatically shifting plants from light to darkness and vice versa with cycle lengths of any desired duration. While the apparatus was designed for work with plants, it should work equally well with most small animals. We have called this apparatus a photocycler.

MATERIALS AND METHODS

The basic unit of the photocycler is a four-drawer filing cabinet. This steel cabinet is 52 in high, 18 in wide, and 26.5 in deep. The upper two drawers and bottom drawer of the cabinet are discarded while the third drawer is left intact. The third drawer holds the plants. It is also used as a carrier drawer to move plants in and out of the cabinet body. A plywood facing is placed on the front side of the third drawer so that when the drawer is closed the chamber becomes a perfect darkroom. A separate cover is fixed over the opening of the fourth drawer to make the bottom side of the chamber light tight. When

![Circuit Diagram](https://example.com/circuit_diagram.png)

**FIG. 1. CIRCUIT DIAGRAM.** The wiring diagram in a unit of photocycler is shown in the figure. The circuit represents the operation when the relay is just de-energized and the drawer which was completely open, has started to close. When the drawer was completely open, the motor was stopped because the yellow switch (MS1) was open. At this position the relay was energized and the current was being fed to the relay coil (RC) through the clock micro switch (MS3) which was closed. As soon as the clock micro switch (MS3) was opened by the clock motor (m), the relay was de-energized and the motor (M) was reversed. Consequently the drawer started closing. Before the drawer will be completely closed the motor (M) will stop because micro switch (MS2) will open. The two micro switches (MS1 and MS2) are normally closed. The drawer will remain closed as long as the relay remains de-energized. During the period when the relay was energized the pilot light was on. This light is also used to adjust the clock timings without disturbing the carrier drawer. After the clock is disconnected the drawer can be opened and closed manually through a switch (S2). A separate switch (S3) is provided to disconnect the clock motor after the experiment in a particular unit is over. The reversible motor can be stopped at any desired position by another switch (S1).

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the carrier drawer is opened the plants are exposed to illumination from power-groove fluorescent lamps (fig 2).

The space provided by removal of the fourth drawer houses the necessary machinery. A rack is mounted on the bottom of the carrier drawer, which is moved by a pinion mounted on a reversible motor. The carrier drawer is opened and closed automatically by activating the reversible motor in one or the other direction through a magnetic relay. When the relay is energized the drawer moves out until stopped by a limit switch and remains in open position while the relay is not de-energized (see fig 1). As soon as this relay is de-energized the motor is reversed and the drawer is automatically closed. The current to the magnetic relay coil is controlled by an electric clock.

Two micro-switches are provided to limit the travel of the carrier drawer while moving in or out of the cabinet body. Before the drawer is fully open a knob attached to the bottom of the drawer hits a micro-switch which opens the circuit of the motor. The motor stops and the drawer remains in the open position. Similarly, before the drawer is completely closed the knob on the bottom of the drawer hits and opens another micro-switch which breaks the circuit of the motor. The drawer remains in closed position till the motor is again reversed (fig 1). To safeguard the motor from damage by overtravel of the carrier drawer, a clutch mechanism is provided on the pinion mounted on the motor.

An automatic watering system is provided. A steel tray is placed in the bottom of each drawer and the pots stand in it. Water flows into the tray through an inlet connected by a dark flexible tubing from outside of the cabinet. This flexible tubing allows free movement of the drawer and is connected to a main supply pipe. The valve on this pipe is controlled by a time clock which turns the water on for a predetermined period twice a day. The plants in the tray are watered by subirrigation. The excess of water drains out of the tray through an outlet to the outside of the cabinet. Plants in all the 18 photocyclers are watered automatically twice a day whether they are in light or darkness (fig 2).

Two timing methods have been used to activate the motor to close or open the drawer. One method involves the use of a time clock for each cabinet. Time clocks can be obtained which operate on almost any desired cycle length. Two discs on the face of the clock may be adjusted to turn a circuit to the relay coil on or off at any desired period during the cycle. With such time clocks a given cabinet may be set to operate indefinitely on a given cycle length with a desired light period and dark period in each cycle.

Another method provides more flexibility, but the control program for all cabinets must be set for each experiment. In this method a roll of paper tape which is used on an automatic recording potentiometer serves as a time chart for an entire set of cabinets. The relay circuit switch (fig 1 MS3) which controls the operation of a cabinet is activated by an impulse relay. The circuit of the impulse relay passes through

**Fig. 2. Photocycler.** The picture was taken when all the 18 photocyclers were in actual operation. One unit shows the plants under illumination. The tubing through which plants are watered automatically is also seen. Beneath the drawer of each photocycler an attached time clock is shown.

**Fig. 3. Paper-tape Timing Mechanism.** Potentiometer with paper tape mechanism (right), and control panel (left). Each of the 18 Photocyclers is connected to the potentiometer by a separate wire. Opening and closing of a particular unit is shown by the pilot light provided for each circuit separately on the control panel.
a wire in contact with the surface of the paper on the face of the recording device (fig 3). Underneath the paper is a metal plate and when the wire is in contact with the plate, the controlling switch is moved on or off and the cabinet drawer either opens or closes depending upon its position. By punching a series of holes in the paper tape, the opening and closing of the drawer may be controlled for any desired period of time in any given experiment.

An entire experiment involving 18 different cabinets has been set up on a single roll of paper. Experiments can be devised whereby the cycle lengths of a given cabinet may be varied from one cycle to the other. Short cycles may be alternated with long cycles. In fact, any conceivable regime of alternating light and darkness may be set up in this control mechanism provided, of course, the photoperiods and the dark periods are not too short. The opening and closing of the drawer takes approximately ten to fifteen seconds. Although a recording potentiometer is used in our apparatus to move the paper tape at a desired speed, separate units are available on which the paper tape may be used for setting the operation of the experiment. An independent clock unit using the paper tape mechanism can be easily furnished for an entire set of photocyclers.

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Literature Cited