Paper Tape Motion Timer

Timing is Everything!

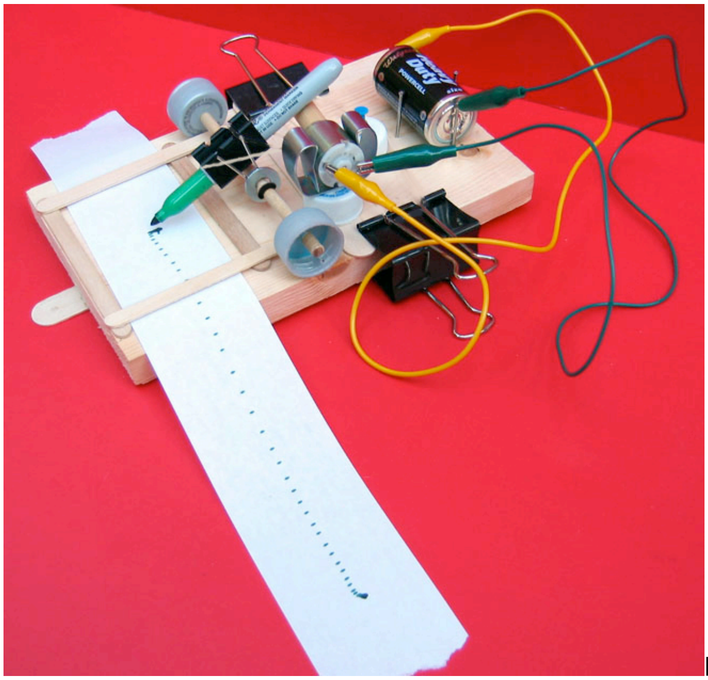

Figure 1

A strip of adding machine paper tape is passed underneath the tip of a marking pen that is being repeatedly bumped by a wooden dowel mounted off-center on the spinning shaft of an electric motor operating at constant speed. Every time the pen is bumped, it makes a mark on the paper tape. Since the motor speed is constant, the time interval between marks is constant. If the paper is dragged rapidly, the marks on the paper are far apart; if the paper is dragged slowly, the marks are close together. The resulting record of marks on the tape can be used to tell the story of the motion, create graphical representations of the motion, and obtain information about displacement, velocity and acceleration for things like toy cars, falling objects, etc.

Materials

- wood base, 3/4 in x 5 1/2 in x 9 in (in Home Depot terms, a piece of "1x6" pine shelving that is 9 inches long)
- 4 wooden craft sticks (popsicle stick size)
- 2 wooden craft sticks (tongue depressor size)
- motor, dc, (e.g., Radio Shack 273-223, 1.5-3 v, or Kelvin 850647 1.5-6 v – Kelvin is cheaper, but Radio Shack is more accessible)
- 2 alligator clip leads -- e.g., Kelvin 330114, 10/pack, or Radio Shack 278-1157, 8/pack – or can improvise by using ordinary hookup wire (approximately #20 or #22), twisting ends to make connections, and devising some way to conveniently connect and disconnect the motor
- spring clip broom holder (available from Home Depot and other home improvement and hardware stores)
- machine screw, 6-32 x 1/2 in
- screwdriver, Phillips
- electric drill
- 3 bottle caps from 2-liter plastic soda bottle, or other bottles with same kind of cap -- the caps should be the harder, rigid plastic kind, not the softer, more flexible kind typically found on 500 mL water bottles
- 1 bottle cap from 500 mL water bottle, or other bottles with same kind of cap -- the cap should be the softer, more flexible plastic kind, not the harder, rigid kind typically found on 2-liter plastic soda bottles
- 2 binder clips, large (2 in, 51 mm)
- 2 binder clips, medium (1 1/4 in, 33 mm)
- push pin
- hot glue gun and hot glue sticks
- paper adding machine tape, 2 1/4 in wide
- stop nut w/ nylon insert, 6-32
- 2 washers, ordinary zinc-plated steel, 1/4 in
- drill bits -- 3/16 in, 9/64 in, #50 wire gauge (1.78 mm)
- 2 rubber bands, narrow, approx 3 1/2 in, e.g., size 19
- 1.5 volt D battery

Don Rathjen....Exploratorium Teacher Institute....3601 Lyon St., San Francisco, CA 94123...donr@exploratorium.edu

• wood dowel, 1/2 in, 1 in long
• wood dowel, 3/16 in, 5 1/2 in long
• marking pen (e.g. Sharpie Fine Point) with pointed or bullet (not chisel-point) tip, and body size that can be held by a medium binder clip
• 2 faucet washers, size 1/4L flat, or similar -- the washer must have a center hole that will fit snugly on a 3/16 in dowel (see Figures 3b and 3c) -- many common faucet washers will do this
• hammer
• 4 finishing nails, 1 1/2 in

Assembly Photos, Notes and Comments

probably best to hammer nails for battery holder before putting other items on the board -- see Figures 1, 5 and 6 for location

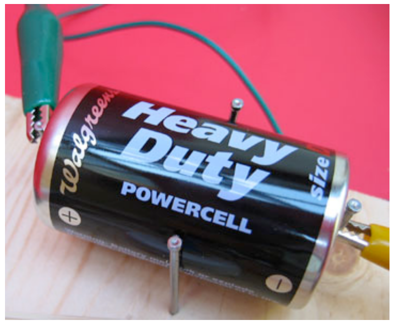

Figure 3

adjust washers so unit is held in middle of axle, but is completely free to turn on axle

assemble components as shown in Figures 3a,b,c, -- glue bottoms of end caps to board 4 in from end of board -- see Figure 6 for labeled location


Figure 3a

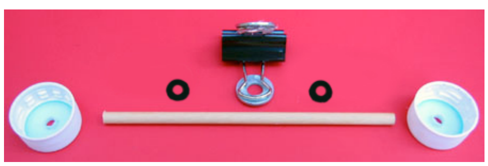
Figure 3b

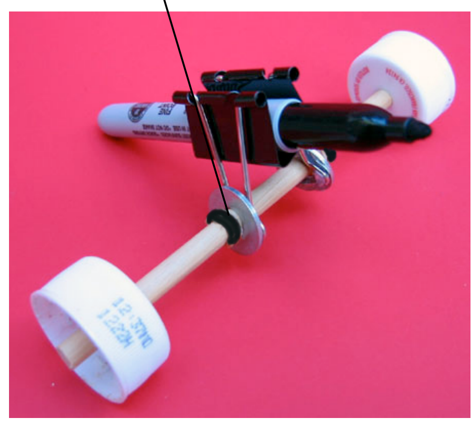
Figure 3c

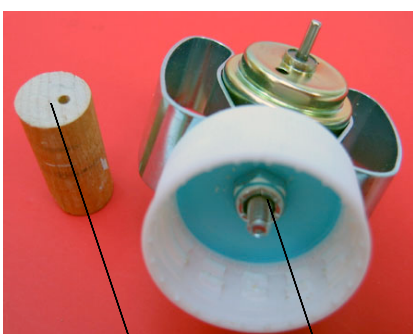
Figure 4a

#50 wire gauge (1.78 mm) hole drilled off-center

stop nut with nylon insert

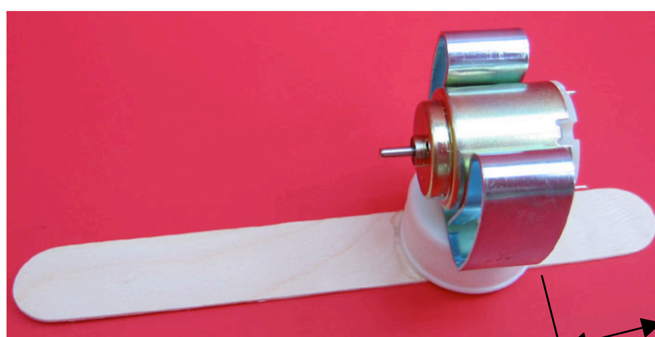
Figure 4b

1 in

glue bottom of cap to tongue depressor -- edge of cap (not visible) should be 1 in from end of tongue depressor

Don Rathjen....Exploratorium Teacher Institute....3601 Lyon St., San Francisco, CA 94123...donr@exploratorium.edu

when gluing these sticks, leave enough room between outside edge of stick and edge of board so that the bottle caps can fit

glue bottle cap to board so that edge shown is 2 in from edge of board

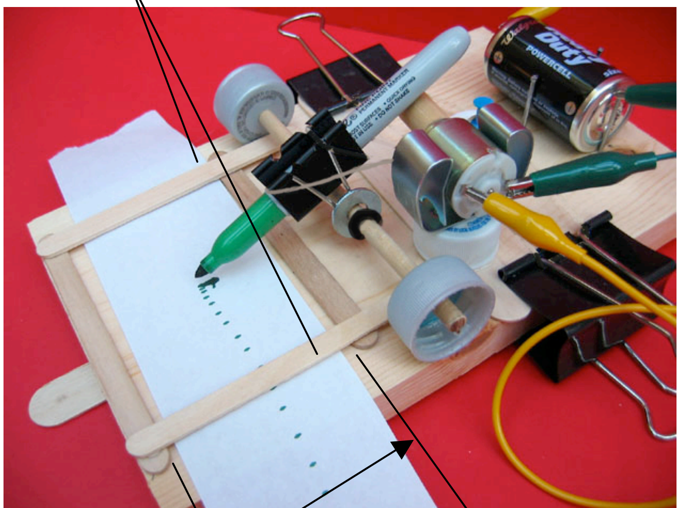

Figure 5

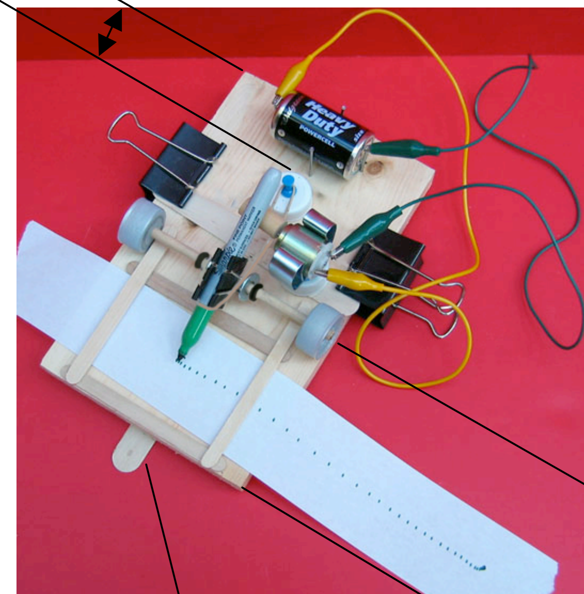

Figure 6

2 1/2 in between inside edges of sticks to handle 2 1/4 in adding machine tape

leave 1 in exposed so timer can be taped to table

pen assembly 4 in from end of board

you may get a cleaner mark if you connect motor and battery so dowel is turning clockwise as you look at its exposed end

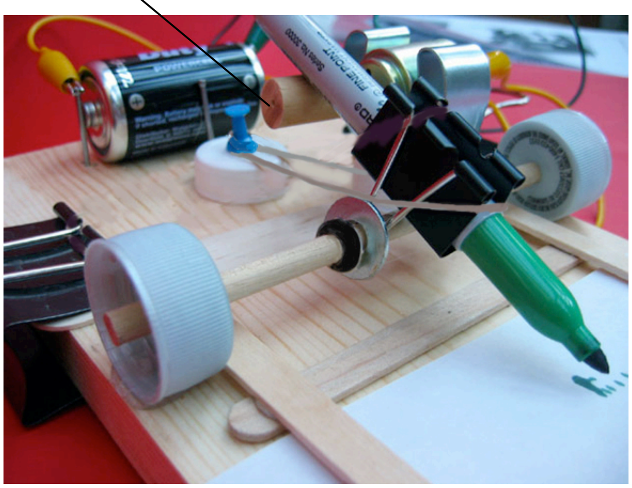

Figure 7a

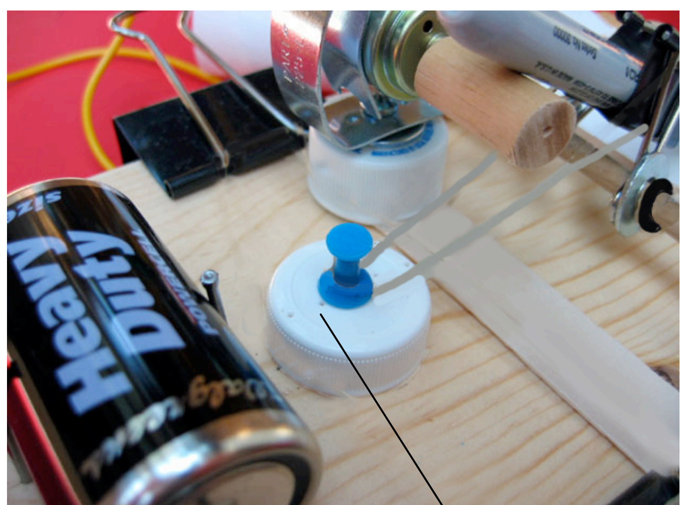

Figure 7b

push pin may be moved to adjust tension in rubber band if necessary

Don Rathjen....Exploratorium Teacher Institute....3601 Lyon St., San Francisco, CA 94123...donr@exploratorium.edu

To Do and Notice

1. Place a piece of adding machine tape about 3 ft long in the timer. Thread the paper through the craft stick paper guides.
2. Turn on the timer and slowly pull the paper a few inches. Inspect the paper to make sure that the pen is making distinct marks on the tape (see an example of a tape in Figures1, 5 and 6). If it doesn't, adjust the position of the tongue depressor that has the motor mount on it, and/or adjust the position of the dowel that hits the pen by turning the whole broom holder motor mount assembly.
3. Continue to run test tapes and make adjustments until the marks are satisfactory.
4. You can now use the timer to make a record of motion which will allow you to do such things as determining the displacement, velocity, and acceleration of a toy car and finding the acceleration of a freely falling object (i.e., the value of "g"). Just use masking tape to attach the paper tape to the object whose motion you wish to record, and let the object pull the tape through the timer.

Simple Velocity-Time Graph for a Spring-Driven Toy Car

Attach a paper tape to a spring-driven toy car with masking tape, and make a record of the motion as the car accelerates and then coasts to a stop.

Use an arbitrary time interval -- e.g., 3 "ticks" (a "tick" will be a single interval or space between successive marks on the tape) -- and mark the tape at these 3-tick intervals. Each 3-space section represents a velocity -- a distance which you can measure in cm, and a time of 3 "ticks." As noted in the introduction, each tick (and therefore each 3-tick interval -- which you could call a "tock") represents an equal amount of time.

Cut the tape at each dividing mark, and place each section vertically, with one end along a horizontal base line. Place each successive strip to the right of the one preceding it. See Figure 8.

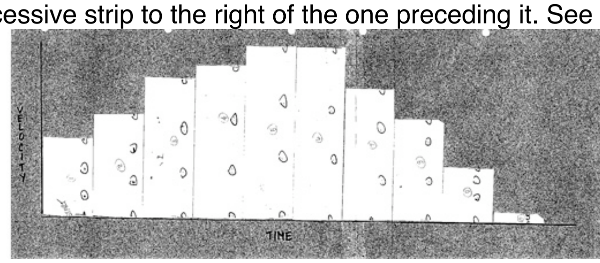

Figure 8

What you have made is a graph of velocity (vertical axis; units of cm/"tock") vs. time (horizontal axis; units of "tocks"). As the car accelerates, each successive section of tape gets taller, and as it slows down, each successive section gets shorter. At constant speed, the sections are the same height.

Using similar techniques, you can also construct displacement and acceleration graphs, but space precludes a detailed discussion here.

Timer Calibration

Turn the timer on, letting it run for a few seconds without pulling the tape so that a mark will be made at the beginning. Then pull the tape slowly through the timer for 5 seconds (as **exactly** as you can do this).

Starting at the beginning of the tape, draw a line through the first mark, and another line after each ten **intervals.** Count the number of 10-interval regions and multiply by 10, and then add on any remaining individual intervals. This will give the total number of intervals. (It's easier to keep track of things this way than by counting all the intervals individually, since there will likely be a large number.)

To find the **frequency** of the timer -- that is, **the number of intervals per second** -- divide the total number of intervals by the number of seconds you pulled the tape.

To find the **period** of the timer – that is, the **time for one interval, or seconds per interval --** divide 5 seconds by the total number of intervals.

NOTE: Remember that the **time between marks is always the same**, since the motor runs at constant speed. If the marks are farther apart, the larger distance just means that the tape was being pulled faster; if the marks are closer together, the smaller distance means that the tape was being pulled slower. The **distance between marks may vary**, but the **time is constant**.

Credit

This timer draws its inspiration from the PSSC Physics ticker tape timers of the 50's and 60's.

Don Rathjen....Exploratorium Teacher Institute....3601 Lyon St., San Francisco, CA 94123...donr@exploratorium.edu