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Time and Timing - Time is the forth dimension of our reality, along with the three dimensions of space. Or, as we move through space, we simultaneously move through time. Physics is a study of all motion, of mass and/or energy moving from point A to point B in a certain amount of time; thus, all motion is partially described by its velocity.

During most of the 20th century, teachers and students measured time with analog clocks and stopwatches. A few teachers and their students had the luxury of spark timers, usually keyed to 60 cycle AC or producing 60 sparks per second. With waxed red or blue paper tape, a spark timer could produce excellent lab results using special apparatus for measuring g and $a = F/m$. Of course, the electronic (digital) era has ushered in many new ways of measuring time, velocity, and acceleration.

Despite all of the recent innovations in timing devices, one grand old piece of timing apparatus still holds a special place, a fascination, for students, the stroboscope. It remains dramatic and stimulating, almost magical. It can reveal unseen happenings in motions too fast for the eye to see and the mind to comprehend; it reveals an additional "world", a world of "Wow!" You can try it out on almost anything that moves fast. Special stage and movie productions have used strobes since the 1950's. You can go back much earlier to the beginning of motion pictures when they were called "the flicks". Even today movie film strobes 24 flashes or frames per second.

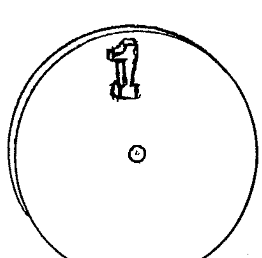
If you don't already have a stroboscope, here's some thoughts to consider. They are an enhancement, a nice addition to a physics program but are not essential. Even an uncalibrated, general purpose strobe with coarse and fine adjustments is not cheap; a simple Winsco E-77 has filled my needs for 40 years. Calibrated (digital), extremely bright, and special purpose strobes get very expensive.

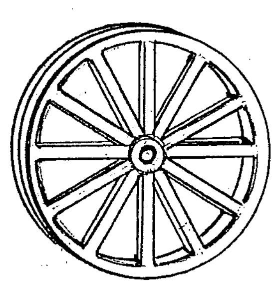
When I addressed the topic of time and its importance near the beginning of the year, I would show the students the range of timing instruments they would be using during the year. In conclusion, I would introduce the stroboscope and show them the first three timing or synchronization demonstrations listed below and a hint of those to follow. Very important - for best results, all strobe demonstrations should be presented in a well-darkened room!

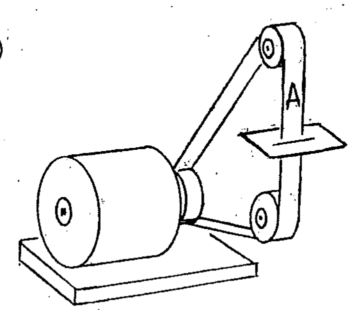
For several of these demonstrations, a variable speed rotator is required. If you do not have one, see "The rotator" elsewhere on this website for instructions on how to assemble an inexpensive, reliable, homemade version. Included are its many uses.

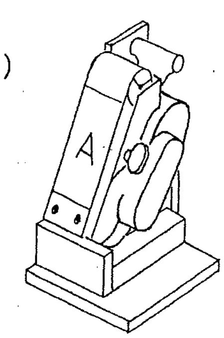
Warning: Strobe lights (flashes) may induce (trigger) seizure activity in individuals with seizure disorders. As a precaution, ask your school nurse if you have any students in your classes who might have a seizure disorder so you can plan accordingly. Be safe rather than sorry.

1. This group of demonstrations shows what the strobe can do, i.e., slow down and/or stop the action and how it does it via synchronization, i.e., the motion of the object vs the strobe's flash rate. It requires a "tuning" or matching of the two entities, closely or exactly.
   (a) Begin with a 10" diameter, $\frac{1}{4}$" thick masonite or plywood disc (1a) with a 5/16"dia. hole in the center. Using 1/8" masonite, make a $2\frac{1}{4}$" high number "1" to be glued to the outer edge of the disc. Paint the number white and the rest of the disc flatblack. Make a steel shaft 2 5/8" long for the disc out of a 5/16" x 18 bolt by cutting off the head. Add nuts and washers on each side of the disc to hold it securely. To demonstrate, choose a good rpm. You will quickly learn how to adjust the strobe for the effects that you want. An interesting procedure is to match, then double, then halve the flash rate with the disc's rpm. An historic note: part of "tuning" an old car engine was to strobe (match) a notch on the crank shaft while the engine was running to adjust the ignition timing up or down to run more smoothly.

1a)


1b)


1c)


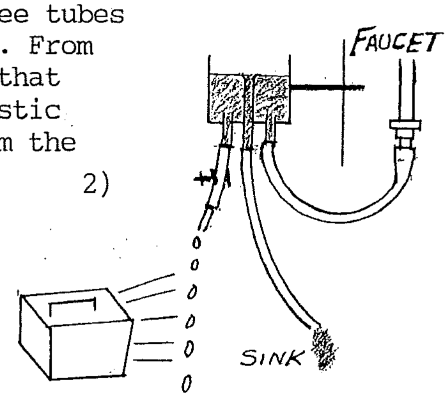
1d)


(b) If your students watch old movies occasionally, they will have observed rapidly turning wagon wheels slowing, "stopping", and then reversing their rotation relative to the wagon's travel direction. Remember, movies act as stroboscopes, synchronizing or not, with the rotating wheels' motion, a little ahead, exactly, and a little behind. It is the spokes in the wheels that catch our eye and reveal the changing timing. You can replicate this event with a strobe and a "spoked wheel". To construct a simple "wagon wheel", use a 10" dia. disc of 3/8" plywood glued to an 1/8" masonite back with a 5/16" dia. hole in the center (1b). A scroll or jig saw is required to cut out the wheel and spokes. Paint the wheel and the 12 spokes yellow and the back flatblack. Note: these two discs are purposely made to be slightly "3-D", with <u>thickness</u>, to show up better to the observing audience from different angles. They do require, however, more effort to make.

(c) Another "old movie" experience. Especially in the 1930's, many movies were made showing newspapers being printed on high speed rolling presses, with the printed paper flying by the observer so you couldn't read it, even the big print. Yet at certain points in the process, the paper was being read and checked for any printing problems while running at full speed. How was it done? The use of stroboscopes, of course. To replicate this special event, choose an old belt for a belt sander or grinder and paint a single, clear letter (word?) on it. Run the machine normally up to speed. Can you read the painted letter? Turn on and adjust the strobe rate so you can. (You will learn, however, that these machines' speeds aren't terribly constant.) (1c) is a 3-wheel, stationary (bench) belt sander/grinder. (1d) is a portable (hand) belt sander in a homade stand.

2. Early in the year when you are teaching about free-fall and the value of "g", try this arrangement with a strobe. It consists of a constant level tank" (Cenco?) with a constant water supply from a faucet or large container with a spout (valve) at its base. (A C-clamp on the hose could regulate the flow, also.) The "tank" has three tubes (pipes) fastened to it, an "inlet" tube and two "outlet" tubes. From the diagram (2), the longer center tube is an "overflow" tube that empties into a catch basin (sink, pail, etc.). A rubber or plastic hose goes from the faucet to the "inlet" tube. A hose goes from the "overflow" tube into the sink. A short piece of hose extends down from the "outlet" tube. At its end is a medicine dropper and in its middle is a small C-clamp to regulate the rate of formation of droplets. With everything adjusted properly for continuous operation, turn on and adjust the strobe for best "spacing" pattern. The result is a beautiful free-fall, acceleration pattern, and the droplets look like diamonds, a sight to behold! Galileo would have loved it. Note: the tank can be made from a tin can, three short pieces of 3/8" OD copper tubing, and epoxy putty.

2)

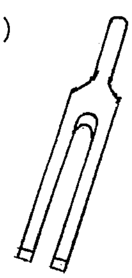


3. An old favorite strobe demo is studying the vibrations of a tuning fork (3). For best results, choose a long, low frequency fork. The way the prongs vibrate may surprise you. Closely related, study a good-sized, vibrating speaker cone that is producing a constant, medium frequency generated by an audio oscillator. Vary the frequency, even octaves, up or down. Interesting?

4. Mechanical standing waves in a string or cord can be generated in several ways. Any of these ways can be studied with a stroboscope and will produce interesting results. One example is (4).

In conclusion, the use of the stroboscope is only limited by your imagination. Keep looking for more possibilities and more fun!

3)



4)