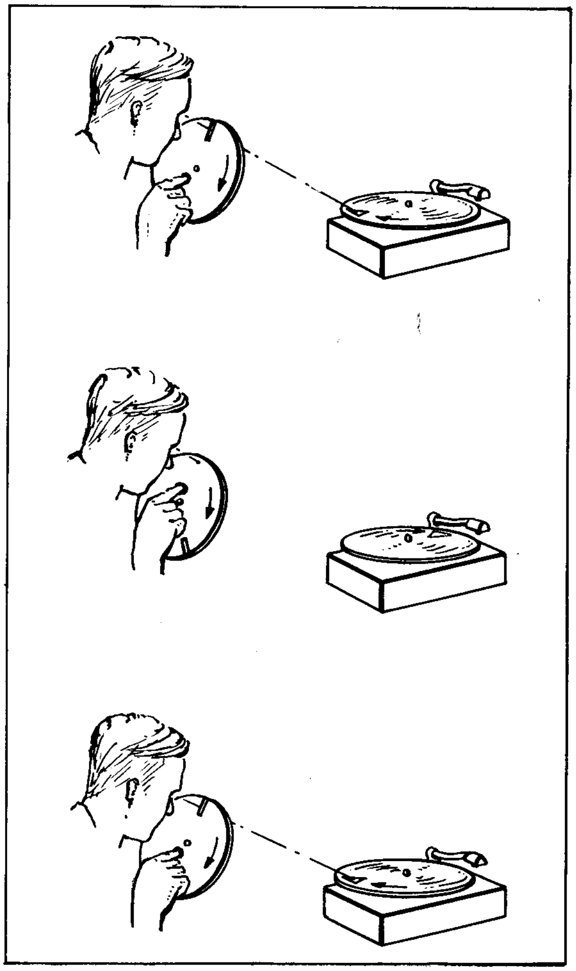
2–5. The Stroboscope

The blades of an electric fan and the clapper of an electric bell both exhibit a motion that repeats over and over in exactly the same way. You can measure the short time intervals involved in these motions by a simpler method than multiple-flash photography. For this purpose we use a stroboscope. One form of this instrument is shown in the Laboratory Guide. It consists of a large disc with slits spaced at equal intervals around the circumference.

To see how this device allows us to measure short time intervals, consider first a disc stroboscope with only one slit. We can use this one-slit stroboscope to measure the time it takes the turntable of a record player to go through one rotation. First we mark the turntable with an arrow and let the record player settle down to its steady motion. Then we set the stroboscope spinning and look through the slit as shown in Fig. 2–7. Each time the slit passes we get a glimpse of the turntable.

Now suppose that we spin the stroboscope so that the slit goes all the way around in exactly the time of rotation of the turntable. Then, each time that we can see through the slit the arrow on the turntable will be in the same position. It will appear to stand still even though it is really rotating. In this instance, then, the time for one rotation of the stroboscope measures the time for one rotation of the turntable. On the other hand, if the stroboscope spins faster than the turntable, the arrow on the turntable will not get all the way around between glimpses, so it will not seem to stand still. Also, if the stroboscope goes too slowly, the arrow will move around by more than one rotation between glimpses; so again it will appear to move. Consequently, by adjusting the speed of the stroboscope to make the arrow stand still, we automatically set the times of rotation equal; and we can use the stroboscope speed — at our control — to measure an unknown time of rotation.

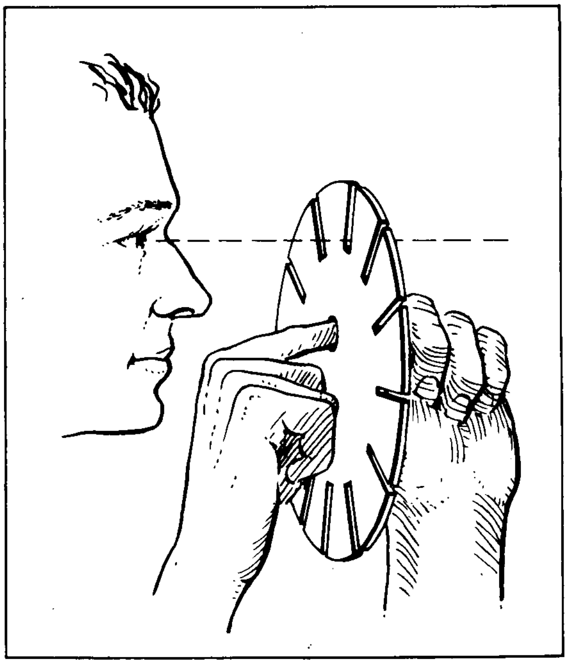
The stroboscope can be used to measure the time for one rotation of an object that is turning too fast for this time to be measured directly. If the disc has twelve equally spaced viewing slits then the viewer gets twelve glimpses for each rotation of the disc. This means that a stroboscope with many slits can measure a time interval much shorter than the disc's rotation time — as many times shorter as there are equally spaced slits in the disc.



2–7. The principle of the stroboscope. When the disc in front of the observer's eye is rotating at the same rate as the turntable, the observer will see the arrow only when it is in a particular position. The motion is then "stopped." What are the limitations of this device?

As an example, suppose we use the stroboscope to watch a small ball being whirled around on the end of a short string. We find that the ball appears to stop when the disc makes one rotation every two seconds. If our instrument has ten slits, then in 2 seconds we get ten glimpses — the time between glimpses is $\frac{1}{5}$ sec. Since the ball appears stopped at each glimpse, the time for one rotation of the ball is $\frac{1}{5}$ sec.

A stroboscope, like any other instrument, has its limitations. If the disc is spinning too fast or the slits are too numerous and small, so little light may pass through the slit that you cannot see.



2–8. Using a hand stroboscope. With twelve slits you can measure a time interval one twelfth of the time of one rotation of the disc.

There is a kind of confusion possible, too. Consider our example of the one-slit stroboscope "stopping" the motion of a record-player turntable. Since the turntable appeared at the same place each time we could see it, we assumed that its time for one rotation was equal to that of the disc. There are, however, other possibilities. The turntable could have gone around two, three, four . . . times during one rotation of the stroboscope; and we still would have observed the same effect. How can we be sure that we really see the turntable on successive rotations? This problem occurs quite frequently when using a stroboscope, but there is a simple way to get around it. When you have the motion stopped, simply increase the speed of the stroboscope. The motion may or may not appear to be stopped again at some higher speed. If it does not, then you know that the original speed of rotation of the stroboscope was the correct one. If it does, then continue increasing the speed of the stroboscope until you can no longer stop the motion. The highest speed of the stroboscope which stops the motion will give the time of rotation of the turntable.

2–6. Comparing Times; Counting Units

One of the physicist's big tasks is to find a way to talk clearly about all these time intervals. He must be able to compare them, to use them, to predict them, however large or small they may be. He needs a measure.

The measurement of time is familiar to everyone. We all know about the second, the day, week, month, year, century. All of these are built on a single simple principle: counting. The part of mathematics most important in physics is counting. To measure time intervals, physicists simply count off seconds.* Every time interval can be expressed as so many seconds. It is sometimes convenient to use days, just as it is sometimes convenient to count by dozens instead of by ones. A day is shorthand for 86,400 seconds. For time intervals shorter than one second we have to count by fractions of a second. The physicist uses decimal fractions, like tenths, hundredths, thousandths, and so on.

All of our time counts are in terms of seconds. What is a second and why was it chosen? There is no particular reason for the choice. It is completely arbitrary. We might as well have chosen a time unit twice as long, or half as long. It would have worked just as well. There is no natural division of time known to us that would apply throughout the universe. Perhaps the second is convenient because it is not very far from the interval between heartbeats. This is not fundamental, however. What is important is that a unit be clearly defined and easily reproduced so that it is available to everybody.

A second is approximately defined as the time between "ticks" on a clock which makes 86,400 ticks while the sun moves from its noon position on one day to its noon position the next day. From measurements of the sun's motion, astronomers can calculate with great accuracy just when it crosses the highest point in its journey, and from that they fix the time. Because the sun moves at somewhat different speeds across the sky during the year, an average is taken over all days, and this average defines the second.

The earth is ever changing. Earthquakes, floods, eruptions, freezing, and melting take

*A "minute" is a tiny part of an hour; $\frac{1}{60}$ of a minute is a kind of minute of a minute. In old time it was called a *second minute.* We have shortened our speech, and call it just a "second."