Measuring a Millionth of a Second
Author(s): J. W. Beams
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SCIENCE SERVICE RADIO TALKS

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MEASURING A MILLIONTH OF A SECOND

By Dr. J. W. BEAMS

PROFESSOR OF PHYSICS, UNIVERSITY OF VIRGINIA

ONE of the surprises encountered by the student in science is his first realization of the amazing speed with which some of the elementary processes in nature occur. Accustomed as he is to observing things through his senses, it naturally imposes a considerable tax upon his imagination to visualize the rapidity with which these elementary phenomena are taking place round about him. For example, the average human eye can not distinguish between two light flashes that occur in less than about one sixteenth of a second of each other. In fact, it is this property of the eye that makes possible the smooth continuous moving pictures, or causes the familiar electric light or neon sign to seem continuous without flicker, even though their light usually consists of a series of flashes. On the other hand, experiments have shown that the actual time required for the light itself to stimulate the retina, or, in other words, to be absorbed by the eye, must be millions of times less than one sixteenth of a second.

The ordinary stop-watch with which we are accustomed to making our precise measurements of the time, between our every-day events, is seldom graduated in divisions of less than one tenth of a second because of the inability of the average individual to operate it in shorter times than this. However, when we compare this one tenth of a second, or the shortest time we could possibly measure with our ordinary stop-watches, with the time required for atomic or molecular interaction to take place we find that the former is very large indeed. For example, in the air that surrounds us the average time between two collisions of a molecule is about one five-billionth of a second, and the average time required for this same molecule to give off light after it is stimulated by means of, say, lightning or an electric spark, is around a hundred millionth of a second. In other words, these events take place in about the time it takes a fast rifle bullet to penetrate one one-hundredth of the thickness of a page of writing paper.

It therefore long ago became apparent to the physicist that if complete studies of many natural phenomena were to be made it would be necessary to devise direct methods of distinguishing between two events happening within a fraction of a millionth of a second. In other words, instruments must be constructed capable of recording events faster than they occur in the phenomena under investigation. Fortunately for this purpose nature has endowed us with some phenomena that take place much more rapidly than others, so that those occurring in shorter times may be utilized to study those of longer duration, or the faster moving things may be used to measure the slower ones.

At this time I can outline only one or two of the numerous methods used by the physicist for observing things that happen in these extremely short times, or to indicate briefly even a minute portion of the vast amount of valuable information both from the scientific and practical standpoint obtained by their use. An experiment any one can try is to look at the reflection of a light in a hand mirror and to rock the mirror rapidly. If the light is steady, like that of a candle, the reflection is strung out into a streak. On the other hand, if the light is not steady, like that of the familiar red neon sign, a row of separate images appear as the sign is lighted and extinguished. This results from the fact that as the mirror is turned the successive flashes of light from the sign enter the eye from different directions and hence fall at different places upon the retina.

If, instead of looking at the reflected light from the turning mirror, it is allowed to enter a camera, each flash falls in a different position on the photographic plate so that the photograph shows a row of pictures of the separate flashes. If then we know how fast the mirror is being turned we can find the time between the flashes. The faster the mirror is turned obviously the greater the distances between the images on the retina or the pictures on the photographic plate. This device of the rotating mirror is one of the simplest and most useful at our disposal, provided the mirror be spun with very great speed.

To do this we mount the mirror, which is usually made of stellite, on a cone-shaped piece of metal called a rotor, that looks something like a schoolboy's spinning top. This rotor fits into a similar hollow metallic cone containing openings from which jets of air at high pressure are blowing. However, the rotor is not blown out of the cone but floats on the air like a ball on a fountain jet, while small grooves on it conspire with the air jets to set it spinning. Rotors of this kind have been spun up to a half million revolutions per minute. To study an electric spark, for instance, the light of the spark is thrown into a camera by the spinning mirror or we may watch it in the mirror by the eye. We can make the image of the spark move so fast that two views of it one one-hundred millionth of a second apart appear as separate. With the aid of this rotating mirror it is found that the electric spark starts as a narrow thread and expands radially; also that the different colors of its light, called spectrum lines or bands by the physicist, do not all appear simultaneously but come off at different times, the light from the air atoms and molecules appearing before that from those of the metallic electrodes.

Light, together with the family of phenomena to which it belongs called electromagnetic radiation, travels with a velocity in excess of 180,000 miles per second. These are the fastest moving forms of energy known to man. Yet, the rotating mirror just described turns through a measurable angle while light travels less than ten feet. As a matter of fact, the velocity of light can now easily be demonstrated and roughly determined, utilizing a light path within the confines of an ordinary room.

We could spin these mirrors faster if our materials were strong enough, but at higher speeds the rotor would be torn apart by the very great centrifugal force developed. Incidentally, these rotors have found application as a centrifuge for separating heavy liquids from light ones, as in the case of the cream separator. So great is the centrifugal force that the outward pull on the material is more than a million times its weight. Under such conditions, for example, cream should rise from milk in a very small fraction of a second.

Fast as the rotating mirror is, there are devices which work still more quickly. You are probably familiar with the fact that the vibrations of light are crosswise, like waves in a stretched cord, not forward and backward like sound waves. Ordinary light is a mixture of vibrations in all directions, at right angles to its line of propagation, but certain crystals can single out one of these directions. If a stretched horizontal rope is confined between two vertical guides you can send an up-and-down wave along it but not a crosswise one. Our crystal devices, called Nicol prisms after their inventor, put the light waves, so to speak, between guides. If we send a beam of light upon two such prisms crossed at right angles no light will come through, although each prism by itself seems transparent.

If we put certain transparent liquids, such as water or carbon disulfide, in the light path between these two crossed Nicol prisms nothing is changed, but if an electric field is properly applied to the liquid, light will come through. This phenomenon is called the Kerr effect, after its discoverer, and the arrangement in which the electric field is applied to the liquid is called a Kerr cell. Effectively, then, this arrangement of a Kerr cell between the two Nicol prisms is a light shutter, because it allows light to pass when the electric field is applied and extinguishes or stops the light when the electric field is removed from the Kerr cell. The time required for this Kerr effect to take place or to vanish after the electric field is applied or removed in a liquid is very short; for example, in carbon disulfide it is probably less than a billionth of a second.

It is this property of the Kerr cell light shutter of responding almost instantaneously to electrical control that makes it, in its variously modified forms, of great value in studying short-time phenomena as well as in immediate practical applications. It has been used in many researches, including studies of the electric spark and other discharges; studies of the time element in fluorescence; studies of the time required for light to eject electrons from a photosensitive metal, or in other words the time required for the photoelectric effect to take place; and even for measuring the velocity of light. Among its practical uses is its application to television.

Time does not permit a discussion of the many other beautiful methods, such as the electric or Lichtenberg figures, cathode ray oscillograph, or Wilson cloud chamber, any of which can record events that happen in times much shorter than a millionth of a second. However, in closing, it may be of interest again briefly to call your attention to the difficulty of conceiving of such short times as a millionth of a second. For example, an automobile running a mile a minute would move about a thousandth of an inch in this time, while a fast airplane could travel less than one tenth of an inch. Yet difficult as it is to imagine, we now have at our command several different methods of recording events that happen in considerably less than a hundred-millionth of a second; or, in other words, we now have methods of measuring a millionth of a second with as much precision as we can measure a minute with the best stop-watch or ten minutes with an ordinary watch.

SLEEP

By Dr. S. W. RANSON

PROFESSOR OF NEUROLOGY AND DIRECTOR OF THE INSTITUTE OF NEUROLOGY, NORTHWESTERN UNIVERSITY

WHY do you spend about eight hours a day or one third of your time in sleep when there are so many interesting things to do for which you can find no time? The obvious answer that unless one gets adequate rest one soon becomes