

Radio Doppler

Meteor velocities have been measured using a continuous-wave radio Doppler method. This radio method is believed to be simpler, more economical, and more sensitive than the pulse techniques for meteor speed determination described in England by Hey and by Ellyett and Davies. A Doppler whistle is produced when radio energy reflected from the nose of an approaching meteor ion column is combined with signals reaching the receiver directly from the transmitter. The velocity of the meteor may be obtained from a recording of the pitch of this whistle as a function of time, and from a measurement of the range to the ion column when it becomes perpendicular to a line drawn to the observatory. Since the echo from the column in this broadside position is very strong, relatively low pulse power will suffice, and the range determination need not be highly accurate. Whistle-measuring requires only a thousand-watt continuous-wave transmitter, a standard radio receiver, and a magnetic tape recorder.

The velocity of the Perseid shower of July, 1948 was obtained in this way, giving a value (for selected meteors) of sixty-two and three-tenths kilometers per second with a standard deviation of one and six-tenths kilometers per second. This relative accuracy is somewhat better than that obtained by the radar methods.

A method of determining the height of selected shower meteor trails is also described. It was found that as the Perseid radiant rose, the average height at which the radio reflections took place fell from one hundred and twenty-five kilometers to something of the order of eighty-five kilometers.

It is concluded that the Doppler method of meteor speed determination is fully as accurate as radar pulse methods.

O.G.V.

Radio Doppler Investigation of Meteoric Heights and Velocities. By L. A. Manning, O. G. Villard, Jr. and A. M. Peterson. *J. App. Phys.* 20: 475, May, 1949.

The following summary of a letter to the editor from C. S. Shyman and D. D. Cherry appearing in the May 1, 1949 issue of the Physical Review, represents a sequel to the work reported in the paper summarized above.

It had been suggested that the accuracy of the continuous-wave Doppler meteor speed-measuring technique might be a function of radio frequency, because at the lower frequencies ion diffusion effects appear to be more frequently encountered. Thus, there is the possibility that the Doppler whistle might be more an indication of the rate of ion diffusion than of the speed of a moving meteor.

Simultaneous measurements were therefore made of the speed of the December, 1948 Geminid meteors at 30.66 and 12.86 megacycles. Velocities obtained at the two frequencies were in excellent agreement. It is con-

cluded that radio frequency does not affect the accuracy of the Doppler speed-measuring technique.

Self Hearing

For maximally useful hearing it is important that bone-conducted sounds—our own vocalizations and noises produced by chewing, swallowing, etc.—be minimized, while at the same time the ear remain maximally sensitive to airborne sounds. How, then, does the ear perform this dual function?

In order to investigate this question, we first studied lower animals, in which, as might be expected, we found simple mechanisms employed. For example, frogs produce loud sounds that subject the outer surface of the eardrum to intense pressures, but since these sound pressures can at the same time act on the inside of the drum by way of the very wide Eustachian tube, the net vibration is minimized. This makes it impossible for the frog to hear while he croaks, because his ear is sensitive to airborne sounds only when his mouth is closed.

In man, who is more highly developed and can hear while he is speaking, the mechanism is not nearly so simple. Measurements of the vibrations of the skull during vocalization show that the vertical vibrations are greater in amplitude than are the lateral ones. This is due to the fact that man is provided with two vocal cords that vibrate symmetrically: they both go out at the same time and then come in at the same time, so that the center of gravity does not move.

On the assumption that bone-conducted sounds should be minimal, we can explain the necessity for the joints between the three ossicles and for their peculiar shapes, especially the oval shape of the stapes footplate. The joints between the three ossicles damp out some of the bone-conducted vibrations, lateral as well as vertical. But it is the oval shape of the stapes footplate that is of prime importance in damping out the big vertical vibrations. For airborne sounds the stapes moves like a piston, back and forth in the oval window of the cochlea, with a maximal transmission of vibrations to the fluid in the cochlea. But for the bone-conducted sounds, whose vibrations are parallel to the plane of the footplate and at right angles to its long axis, the footplate rotates around this long axis, causing only slight movement of the fluid in the cochlea. Thus the amplitudes of the vibrations transmitted to the fluid in the cochlea are minimized.

The position of the middle ear in the skull is also of importance in minimizing bone-conducted sound. When we bend a rod, one side is compressed and the other is stretched, while in the middle there is neither compression nor stretching. In man the middle ear is located in the center of a thick petrous bone; when the bone vibrates, and the bony wall of the skull is bent, the middle ear is relatively unaffected.

The eardrum was investigated in order to find out whether it is adjusted for maximum sensitivity for airborne sounds. The membrane of the human eardrum is stiffened, first, by being cone-shaped, and second, by having one of the ossicles of the middle ear (malleus) attached to the drum from the middle to one edge. Ex-

periments showed that a stiffened membrane is much more sensitive than is a simple stretched membrane.

It is clear that in evolving the ear nature has utilized sound physical principles to improve communication. In terms of these principles it is possible to account for many peculiarities in the structure and arrangement of the parts of the middle ear.

G.V.B.

The Structure of the Middle Ear and the Hearing of One's Own Voice by Bone-Conduction. By Georg v. Békésy. *J. Acous. Soc. Am.* 21: 217, May, 1949.

The Proton's Magnetic Moment

The magnetic moment of the proton is one of the important physical properties of one of the fundamental particles of nature. A measurement of this property in terms of the magnetic moment of another fundamental particle, the electron, has been made by the application of molecular beam techniques. In essence the method involves a measurement at some fixed field of the frequency corresponding to a reorientation of the proton in the sodium hydroxide molecule and the frequencies of chosen lines in the hyperfine spectra of certain atoms. An application to the experimental data of our knowledge of the properties of atomic energy states and of the intrinsic magnetic moment of the electron yields the value of the proton moment in terms of the electron moment. Outside of the intrinsic importance of a knowledge of this important physical constant, the present result provides a scale in terms of which the magnetic moments of all other particles may be determined. Of equal importance is the use of the new result, in conjunction with other recent experimental results, in determining the values of two important physical constants, the fine structure constant and the specific charge of the electron.

P.K.

The Magnetic Moment of the Proton. By H. Taub and P. Kusch. *Phys. Rev.* 75: 1481, May 15, 1949.

Solar Radio Noise

Recent studies of solar radiation within the radio spectrum indicate that associated with sun spot activity there occur bursts of radiation whose intensity occasionally exceeds the normal radiation by a factor of several million. It has been previously suggested that these anomalous radiations are caused by oscillations of electron gas or plasma existing in the solar atmosphere. However, no detailed picture of the mechanism of excitation of the plasma has ever been given.

The solution of the problem now appears as a by-product of research in the field of electron tubes. A search for better methods of generation and amplification of microwave energy has led to the conception and a successful development at the Naval Research Laboratory of an entirely new method based on space charge wave amplification effects. The theory and experiment showed that if a stream of charged particles is injected into evacuated space occupied by another stream of particles there occurs a partial conversion of the kinetic energy of the particles into the energy of electromagnetic fields associated with periodic groupings of particles, or space-

charge waves. This mechanism of energy amplification was used successfully in special microwave tubes called "electron-wave tubes" in which energy amplification of over a million was obtained.

Intermingling streams of charged particles of different velocities emerging from sun spots, particularly during solar flares, constitute a medium which according to the space-charge wave theory tends to amplify small fluctuations. Thus the kinetic energy of solar particles can be partially converted into the energy of space-charge waves and eventually radiated. The theory of space-charge waves makes it possible to compute the intensity and the frequency at which maximum radiation will be observed if the number of particles emerging from the sun and their velocities are known. Estimates of these quantities are possible from measurements of variation of the magnetic field of the earth during magnetic storms since these storms are caused by solar corpuscles arriving upon the earth. Computed from such estimates the wavelength and the absolute intensity of this anomalous solar radiation is found to be in good agreement with observations.

A.V.H.

The Origin of Solar Radio Noise. By Andrew V. Haefl. *Phys. Rev.* 75: 1546, May 15, 1949.

Heavy Element Spectra

Because spectrochemical analysis has proved useful in establishing the purity of very small samples of the new heavy elements as they were produced in turn by the Plutonium Project, photographs of the spectra of these elements have accumulated. These plates have been measured and several hundred lines each have been listed for protoactinium, neptunium, plutonium, and americium. The wavelengths could be measured only roughly in a limited spectral region, but should be adequate for identification purposes. The heavy elements follow the pattern of the rare earths more closely than had been anticipated. While it had been recognized that the heavy elements form a second rare earth series, the analogy is not exact. It is now clear that there is an abrupt decrease in complexity of the heavy elements at americium, indicating that for this element the 5f shell is half-filled, by analogy with the simplicity of the europium spectrum among the rare earths. Hence the ground state of americium-I corresponds to europium. This similarity is being used as a guide in an attempt to make a term analysis of the americium spectrum.

M.F.

The Spectra of the Heavy Elements. By Frank S. Tomkins and Mark Fred. *J. Opt. Soc. Am.* 39: 357, May, 1949.

Eye Aberration

It has been recognized for many years that the human eye, like most simple lenses, is afflicted to a certain extent with spherical aberration. Accurate measurements of the aberration are remarkably few, however, and the methods employed in the past give a rather incomplete picture of the aberration, from which it is difficult to infer much about its effect on vision. New measurements were undertaken in the course of an investigation to determine whether spherical aberration or some other prop-