solar effects. A more recent review of the eleven-year period in those trees confirms its well-marked existence from before 1400 to the middle of the seventeenth century. Soon after 1700 it reappears, but not in complete form until the latter part of that century.

The test was then carried to the sequoias. It was found that the slow-growing sensitive upland trees were the ones which best displayed the solar cycle, and also that the interference by other cycles was such that the double period of about twenty-three years was a more satisfactory manner of tracing the changes of the solar period. When these conditions were allowed for, the same result was obtained as before from Arizona.

In 1922 or before, it was noticed that when the eleven-year cycle disappeared from the trees near 1700, two other cycles, one of ten or twenty years and the other of fourteen or twenty-eight years, became prominent in its place in the Arizona pines. Soon after it was noticed that the Vermont hemlocks show the same change at that time, and so also the sequoias of California. And then it was observed that these three basic cycles appear generally in the western trees; these are, first, eleven and one half or twenty-three years; second, ten or twenty years; and, third, fourteen or twenty-eight years. And these three cycles were recently confirmed in a study of 52,000 measures of rings in 305 trees scattered over ten western mountain states. And there is reason to think that all these cycles come from the sun, for at different times the sunspot cycle itself has changed to one or the other of them. For example, from 1748 to 1788 there were four complete cycles of ten years each; from 1788 to 1830, forty-two years, there were three complete cycles of about fourteen years each. It seems at least likely that these other two cycles, found in western trees with extraordinary persistence, are also of solar origin.

In the recent extensive study of cycles in the western yellow pine, it was noted that the moist coastal regions show the eleven-year cycle more generally than the drier interior sections or the Rocky Mountain area. This agrees with the result of ten years ago in which the wet-climate Scotch pines of North Europe, especially near the Baltic Sea, showed a direct single-crested sunspot cycle having a remarkable resemblance to the curve of sunspot numbers. Their growth gave the solar changes with an accuracy exceeding that of any trees of the southwestern area. Recent study confirms the further statement that this is a wet-climate phenomenon. But it is not yet clear just what causes this accuracy of record in the wet-climate trees. It seems probable that the wet-climate trees follow the sunspot cycle more closely than do the weather elements in which they live, and it is perhaps safe to repeat the suggestion made by the writer in 1922 that there may be some more direct line of cause and effect from the sun to these trees than we have taken into account, such, for example, as radiation (possibly of short wave length), that is especially favorable to trees growing generally under cloudy skies. In tree groups along the Atlantic coast of this continent, the eleven-year cycle is also prominent, but it has a phase displacement of two or three years.

The pages above give the probable forms which solar records take in tree growth. It was expected by the time of this writing to have a fairly complete historic study of solar variations, but the formal work along that line has had to be postponed for a time. In a general way it is safe to say that the sunspot cycle and its double and triple value are very general. The double value has persisted in Arizona for five hundred years and in some north European localities for the century and a half covered by our tree groups. The triple period, essentially Brückner's cycle, has operated in Arizona for the last two hundred years and in Norway for four hundred at least. A hundred-year cycle is very prominent throughout the three thousand years of sequoia record and also in the five hundred years of yellow pine. It is still uncertain whether the eleven-year cycle can be judged by the variations in its double value, which, from the absences of certain interfering periods, is more easily traced through long periods. But a very incomplete review of the sequoia record suggests that from 1300 B. C. to well after 1000 B. C. the eleven-year cycle was well developed; then it slowly decreased. From 300 B. C. on it was increasing and was very conspicuous during the first two centuries of our era. Then it decreased and from 400 to 650 A. D. was only occasionally evident. From 650 to 850 or 900 it seems fairly continuous. Then it appears only occasionally until about 1250, when it again becomes fairly continuous, except for the changes in the seventeenth century above noted.

Such then are the solar records so far translated from tree growth, whose complete understanding, it is believed, will give us extensive historical information of this sort in many different parts of the world.

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THE SIGNIFICANCE AND SCOPE OF THE IDEA OF FREQUENCY IN PHYSICS[1]

IT has long been recognized that exponential (periodic) solutions of certain partial differential equations are essentially necessary when such equa-

[1] Paper presented at the Philadelphia meeting of the American Physical Society.

tions are applied to bounded systems, whereas the use of periodic solutions of such equations (of the familiar wave equation, for example) for extended media is largely a matter of convenience. We do, as a matter of fact, have periodic or quasi-periodic waves in extended media so that to this extent the use of periodic solutions of the wave equations in extended media is justifiable; and the important phenomena of interference and diffraction and the phenomena of dispersion settle to steady states, which are observable and amenable to calculation, only for steadily maintained periodic waves or for an utterly disordered but steadily maintained wave-aggregate like white light.

That we do have periodic or quasi-periodic waves is due to the periodic or quasi-periodic character of the disturbance in the bounded and nearly closed system or systems in which the waves originate. *Periodicity seems always to be associated with the motion of bounded and nearly closed systems.* Aside from translatory motion, the steady state motion of a bounded system must be singly or multiply periodic. Water waves seem to be the only exception to the general rule that periodicity or quasi-periodicity always originates in a bounded system. Water waves are formed by the wind, a wind of a certain velocity tends to produce waves of a certain velocity and therefore of a certain wave-length and frequency because the velocity of water waves is a function of the wave-length.

The wide-spread notion that wave motion is essentially periodic is wholly erroneous; the general solution of the simple wave equation

$$\frac{d^2y}{dt^2} = v^2 \frac{d^2y}{dx^2}$$

is wholly devoid of the element of periodicity.

Before the advent of the Bohr theory it was quite generally recognized that periodicity was a very restricted thing, as explained above, and that complete periodicity, which is always assumed in the treatment of interference and diffraction, was an ideal, not a fact; but the Bohr relation $W = h\nu$ raised the idea of frequency to an exalted position which puzzled us all, and the Bohr theory was leading us all to the acceptance of frequency as one of the most fundamental of unitary (non-resolvable) ideas of physics! Indeed, we do have very much more sharply defined frequencies in light than in any other branch of physics; a pendulum may vibrate a hundred times before its amplitude is greatly reduced, but the electron in a hydrogen atom would, according to classical electrodynamics, make an enormous number of revolutions before its energy would be greatly reduced.

There had come to be an excessive emphasis on the notion of frequency before the advent of the Bohr theory, excessive because it was non-critical, and the Bohr theory brought in the idea of frequency in a way that made a critical examination of the idea impossible; the idea of frequency as it appears in the Bohr theory must be accepted as an "absolute" or not at all, and to the critical student of physics there is no such thing as an "absolute."

The excessive (non-critical) emphasis on the notion of frequency before the advent of the Bohr theory can be seen in nearly every treatise on wave motion. Many years ago I came upon the following: "To prove that a phenomenon is due to wave motion it is sufficient to show, first, that it is periodic and, second, that it is propagated at a finite velocity"—instantly the Gatling gun came into my mind; the effect of the Gatling gun is periodic and it travels at a finite velocity! Periodicity is not an essential property of wave motion; and every one who is familiar with the terms wave-velocity and group-velocity and especially every one who understands, with Heaviside, that wave motion when not too highly idealized always partakes more or less of the characteristics of diffusion, knows that wave motion is not necessarily characterized by a velocity!

In connection with our statement that periodicity of waves always originates in a bounded and nearly closed system (usually the emitting system but possibly the reacting receiving system; thus the sharply defined frequencies of the various parts of the spectrum of white light are properly assignable to the action of the prism, they do not exist as such in the light before it passes through the prism) it is of interest to recall Helmholtz's comments on the question of the physical justification of the resolution of a periodic sound into Fourier components. Helmholtz says that the Fourier resolution is justified because of the sharply defined maximum of response of a harmonically oscillatory receiver when the frequency of the free oscillations of the receiver coincides with the frequency of any one of the Fourier components of the impinging sound.

I am most decidedly inclined towards the highly restricted idea of frequency of the pre-Bohr days and it pleases me greatly to observe that the new "wave mechanics" of Schrödinger is bringing us back to the older point of view. The Schrödinger mechanics is based on a generalized wave equation, and Schrödinger limits himself to exponential (periodic) solutions because he is primarily interested in the motion of bounded and nearly closed systems such as electrons, and atoms, and molecules. Thus the idea of frequency in the new "wave mechanics" is

exactly on a par with the idea of frequency which existed in the pre-Bohr days.

Perhaps the boldest step which has been made in the development of the new "wave-mechanics" is de Broglie's quantization of the total energy (including mass energy) of the electron. It is allowable, perhaps, to think of the electron as a bounded system, and as a very nearly closed system. If the energy of the electron is to be thought of as due to motion within the electron, this motion must be periodic because a steady state of motion in a bounded system (except for purely translatory motion) must be periodic. Of course the motion might involve a number of distinct periods, as in the transverse vibration of a steel bar, for example, but one's first guess would be one frequency ν and therefore the total energy of the electron would be placed equal to $h\nu$.

The quantization of the motion of a bounded closed system seems to me to be more reasonable than the quantization of a detached portion of light energy whose frequency *was* fixed by the system which emitted the light.

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SCIENTIFIC EVENTS

THE NEW HARVARD COLLEGE OBSERVATORY IN SOUTH AFRICA

A CONTRACT has been let by the Harvard College Observatory for the construction of a 60-inch reflecting telescope to be mounted at a new southern astronomical station to be located somewhere in the Union of South Africa. The exact site has not yet been chosen, but a location near Bloemfontein, capital of the Orange Free State, is being seriously considered.

The new telescope, to be the largest in the southern hemisphere, will be constructed by J. W. Fecker, at Pittsburgh, Pennsylvania. It will have an aperture of a little over 60 inches and a focal length of 27 feet. It will be used for photographic, photometric and spectrographic work on stars and nebulae, and for study of the Magellanic clouds and the large southern clusters.

Two photographic refractors and three photographic telescopes, now at the Boyden station at Arequipa, Peru, will be moved to the new site in South Africa where they will be placed on mountings now being made in this country.

The transfer of the station from Peru to South Africa is being supervised by Dr. John S. Paraskevopoulos, superintendent of the Arequipa station. The new station is expected to be the largest in the southern hemisphere. Photographs will be shipped regularly to the Harvard Observatory at Cambridge for study and filing in the photographic collection there.

The new telescope has been made possible by gifts to the Harvard Observatory by the Rockefeller International Education Board and by Harvard University.

A MEDICAL CENTER FOR WASHINGTON, D. C.

PLANS for the establishment in Washington of an extensive medical center have been launched by the executive heads of the Garfield Memorial Hospital, the George Washington University and the Washington Home for Foundlings.

The basis of the agreement is the fact that the experience of many other cities has demonstrated the value of the establishment of great medical centers in which close and lasting associations have been formed between the work of theoretical medical instruction and the practical instruction afforded by the facilities for clinical teaching found in hospitals and dispensaries.

The plan contemplates that the Washington Home for Foundlings shall build upon the grounds of the Garfield Memorial Hospital a hospital for the care and treatment of cancer and cancer research laboratories, under the provisions of the Warwick bequest. This building will be known as "The Helen L. and Mary E. Warwick Memorial."

The George Washington University Medical School will erect a new medical school building in the vicinity of Garfield Memorial Hospital. Ultimately the work now being done in the George Washington University Hospital will be transferred to the Garfield Memorial Hospital, but the work of the George Washington University Hospital will be maintained until, in the judgment of the trustees of the university, it is practicable to sell the hospital and medical school property upon favorable terms and conditions.

Upon discontinuance of the university hospital, the university medical faculty and hospital staffs will be organized in a manner to carry on the clinical and laboratory work in the Garfield Hospital and the Cancer Hospital under conditions most favorable to high grade hospital service and medical education as well.

Those who are parties to the agreement wish to emphasize the fact that there will be no change in the activity of any of the institutions until such time as the actual changes in buildings are brought about, and that the support given to the various institutions will be continued with the added incentive that all will now be contributing to an important project along the most efficient and modern lines.