196,000 — 82,000 = 114,000, the new region representing the increase in frequency number (oscillations per centimeter) of 312,000 — 196,000 = 116,000.

R. A. Millikan,
R. A. Sawyer
Ryerson Physical Laboratory,
University of Chicago,
Chicago, Ill.

THE PROBLEM OF THE BOY IN THE SWING

In the current issue of Science (p. 20), Professor A. T. Jones has given an excellent account of just how a boy works up in a swing. To solve a problem in physics qualitatively and experimentally and at the same time to keep the explanation clear and correct as Professor Jones has done is often much more difficult than to explain the same phenomenon quantitatively. Nevertheless, his last paragraph, dealing with the energy relations, aroused my curiosity to discover just what the equation is which connects the work done by the boy's muscles with the increased rotational energy of the swing.

What here follows is practically as old as Huygens and is well known, but may interest those who have read the note referred to.

If the distance of the center of gravity of the boy from the limb about which the swing rotates be denoted by r, his mass by m; and the angular speed of the swing by ω, then his angular momentum will be $mr^2\omega$. Suppose now that the boy who has hitherto been standing up in the swing proceeds to sit down upon his heels; then if his angular speed is to be maintained equal to that of a rigid pendulum (isochronous with the swing loaded with the standing boy and vibrating through the same amplitude) a torqe, L, must be introduced whose value, at each instant, is

$$L = \frac{d(mr^2\omega)}{dt} = 2mr\dot{r}\omega.$$

Or, if no such external torque be applied, then the boy's motion will be retarded, at each instant, by just this torque.

The tangential *force* which opposes the motion, as the boy moves away from the axis, will evidently be

$$F = \frac{L}{r} = 2m\dot{r}\omega,$$

a quantity which becomes zero whenever either the radial speed, $\dot{r}$, or the angular speed, ω vanishes. Except for very small angles of deviation, θ, this retarding force will be but a small fraction of the tangential component of the weight, $mg \sin \theta$, which is urging the loaded swing to its lowest point.

When the boy rises to a standing position, the sign of $\dot{r}$ changes and his motion, instead of being retarded, is accelerated. Here is where the kinetic energy of the pendulum is increased; and the amount of it, if ds be an element of length of the arc, will be

$$Fds = 2m\dot{r}\omega ds.$$

But since ω is much greater near the middle than near the end of the vibration, the boy will expend more energy in lifting himself at the bottom of the swing than he will gain in seating himself at the end of the swing; this quite aside from the fact that, at the lowest point, he works against the whole of gravity while at the maximum elongation only the radial component of his weight is effective.

To perform the actual integration of the above expression one would have to know—or assume—the rate at which the boy seats himself, *i. e.,* one would have to know $\dot{r}$ as a function of s.

The phenomenon is, of course, not necessarily associated with gravity. The same description would hold for a mass in radial motion along the spoke of an oscillating horizontal wheel—say, the balance wheel of a watch.

For the student of dynamics, the essential interest of the problem appears to lie in the general fact that, although a central force does not alter the angular momentum of a body about a perpendicular axis through the center, such a force will, unless balanced, affect the kinetic energy of the body. Any one who wishes to understand this fact will try for himself the simple pendulum experiment recommended by Professor Jones, no matter how vivid his boyhood recollection of the forward thrust which always accompanied his rising at the bottom of the swing.

Henry Crew

July 11, 1919

SCIENTIFIC BOOKS

The Evolution of the Earth and its Inhabitants. A series of Lectures Delivered before the Yale Chapter of the Sigma Xi during the Academic Year 1916–1917, by Joseph Barrell, Charles Schuchert, Lorande Loss Woodruff, Richard Swan Lull, Ellsworth Huntington. New Haven, Yale University Press. 1918.

This volume of essays prepared at the suggestion of Professor Lull, as president of the Yale Sigma Xi, is an interesting and unique addition to the literature of the subject. Each lecture is a separate essay, the preparation of which involved considerable time, thought and original work. The first lecture by Joseph Barrell, whose loss too early in life we all mourn, is entitled: "The Origin of the Earth." It was especially fitting that Professor Barrell should give this lecture since his work on the age of the earth had drawn him into close touch with the astronomical and mathematical work involved in the problem of the earth's origin. The lecture reviews the various attempts to explain the origin of the earth, giving chief attention to the planetesimal hypothesis. The phase of the work on which Professor Barrell's own work bears is to be found in his discussion of "The Origin of Ocean Basins," "The Reign of Surface Processes and Beginning of the Archean." He closes his lecture with the thought:

> It is not known how close they (oldest Archean rocks) stand in point of time to the formative processes whose description has been attempted. With these oldest rocks, the dimly known, heroic and mythical eon of the earth is closed and the first historic eon opens as the remote and long enduring division of geologic time.

Professor Schuchert's lecture "The Earth's Changing Surface and Climate during Geologic Time" reviews in part the lecture of Professor Barrell pointing out the climatic features involved and extending Barrell's observations into the known periods of geologic history. The fundamental factor in climate is atmosphere, and Professor Schuchert's discussion of the "Origin of the Atmosphere" opens the problems of "Climates of the Past" which he is able to discuss so well because of his extensive studies in paleontology and paleogeography.

The "Origin of the Earth's Waters," "Source of the Salts of the Ocean" and "Origin of the Sedimentary Strata" give the reader the most modern ideas of these fundamental aspects of geology and lead up to the discussion of the changes in surface features which the earth has experienced in its evolution from a primordial mass to the recent. The discussion is accompanied by maps and tables explaining in a graphic way the thoughts of the lecture. Professor Schuchert is inclined to the view that geologic time has endured about 800 million years, supporting the ideas of Matthew, Shapley and Barrell from other evidences.

Professor Woodruff in his lecture on "The Origin of Life" has attacked a much more difficult problem because of the great dearth of evidence or analogy. He has handled the difficult task cleverly in discussing, first the nature of protoplasm, the individuality of organisms, and by giving an interesting historical account of "The Theories of the Origin of Life" under the following titles: "Vitalism," "Cosmozoa Theory," "Pflüger's Theory," "Moore's Theory," "Allen's Theory," "Trolands Enzyme Theory," "Osborn's Theories." It is rather disappointing to have Huxley and Darwin close this lecture, since it would have been extremely pleasing to know what Woodruff himself thinks about the "Origin of Life," and his research work has certainly given him some idea on this interesting topic.

No one could speak with more knowledge of facts as to the "Pulse of Life" than Professor Lull in the fourth lecture.

> The stream of life flows so slowly that the imagination fails to grasp the immensity of time required for its passage, but like many another stream, it pulses as it flows. There are times of quickening, the expression points of evolution, and