Mr. G. G. Henderson, M.A., D.Sc., LL.D., has been appointed to be Regius professor of chemistry in the University of Glasgow, in the room of the late Professor John Ferguson.

DISCUSSION AND CORRESPONDENCE

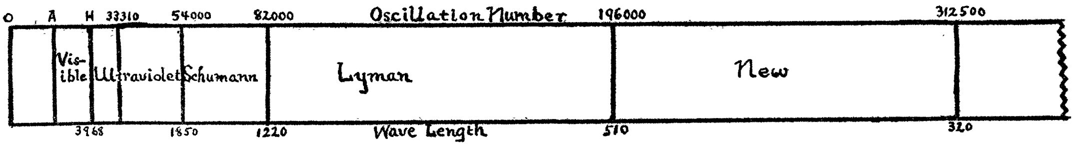
THREE FOURTHS OF AN OCTAVE FARTHER IN THE ULTRA-VIOLET

In the *Physical Review* for August, 1918, Vol. 12, p. 167, we made a preliminary report upon a new method of obtaining grating-spectra in vacuo devised by one of us in the expectation of extending the limits of the ultra-violet spectrum. This report was made because both of us were engaged in war activities, and could not then push further the very significant results which we had already obtained—results which brought to light some 30 new zinc lines, the shortest wave-length among which had a value of 928 Ångstroms.

There is every reason to believe, however, that every element except hydrogen will emit line spectra corresponding to waves of higher frequency than this, the limiting frequency for a given element pushing farther and farther into the ultra-violet, the higher the atomic weight of the element.[1] With a properly chosen source therefore, the limit to the observable ultra-violet spectrum ought to be set solely by the properties of the grating and by those of the medium through which the radiation passes. Heretofore, it has been set by the limitations of the source and the properties of the absorbing medium. We felt that we had removed these limitations entirely by working in a very high vacuum with a type of source altogether new in vacuum spectrometry, and one which enabled us to use enormous energies in the highest attainable vacuum. In our preliminary report we stated that we had "indications of zinc lines of shorter wave-length than 928Å though no positive proof as yet."

Immediately upon release from the service we had a new grating constructed so as to obtain the maximum possible brilliancy, and a new and very efficient diffusion pump, so as to eliminate altogether, if possible, the appearance of all glow discharges and enable very high potentials (up to several hundred thousand volts) to be used in producing our hot sparks in vacuo. We hoped thus to bring up the intensities of the very short lines. We also eliminated from the vacuum chamber certain gas evolving bodies like ebonite which had appeared to limit our exposure times by reducing the periods during which we could operate our hot sparks without giving rise to glow discharges, and which in addition had very injurious effects upon our grating.

As a result of these improvements we are now maintaining an exhaustion of about 10^{-4} mm. of mercury while the arc is running. We have thus brought to light a considerable number of new zinc lines below 928Å of such wave-lengths as to add up to date three fourths of an octave to the ultra-violet spectrum directly accessible to study with a grating spectrometer. We shall be in position at a very early date to publish a series of actual photographs, but in this preliminary report will content ourselves with stating that we have ten definite reproducible zinc lines below 500 Ångstroms the shortest having a wave-length of 320 Ångstroms. It is interesting to note by reference to the accompanying figure which is an extension of one given by Lyman[2] that this represents an extension in frequency of about four times that accomplished by Schumann, namely, 82,000 — 54,000 = 28,000, and a trifle more than that represents thus far in Lyman's work, namely,



[1] "The Electron, etc.," University of Chicago Press, 1917, p. 202.

[2] "The Spectroscopy of the Extreme Ultra-violet," Longman's, 1914, p. 105.

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.

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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