me that a few details, mainly constructive, might prove of interest. It was suggested by Mr. Preece, in consequence of a statement made by me in a paper on "Measurement in the Medical Application of Electricity," read before the Society of Telegraph Engineers. This statement was to the effect that some difficulty still existed in the trustworthy estimation of induction currents of medium strength, such as are habitually used for physiological and therapeutical purposes. The French International Commission had only imperfectly remedied the deficiency by recommending the universal adoption of a particular pattern of induction coil made by a single German firm, and arbitrarily graduated to a "sledge" apparatus. Mr. Preece thought that a dynamometer, which may be regarded as a galvanometer of which the moving magnet is replaced by a suspended coil introduced into the circuit, would answer the purpose; since the deflection of the coil is in one uniform direction, although the currents traversing the circuit are alternate. This very practical hint seemed to offer a prospect of obtaining accuracy in a department of science in which it is much needed. But on examining existing dynamometers I found only Weber's original instrument, which, in spite of its immense value, is fitted only for a well-appointed laboratory, and another, made by Messrs. Siemens for the measurement of very intense electric light currents, which erred on the opposite side of deficient delicacy. The dynamometer of Messrs. Siemens, shown at the French International Exhibition, by means of which the alternating currents of telephones were demonstrated, was probably in the same category, though neither I, nor the president of the Physical Society could obtain any exact details of its internal arrangements.

An electrodynamic balance, described in the *Annalen der Physik* in 1881 by Helmholtz, comes somewhat closer to the requirements of the case, but this, like that of Weber, is a delicate apparatus, difficult of transportation. It might, however, prove excellent as a means of calibrating a less perfect and absolute, but more handy instrument, such as that I was in search of.

Another form of dynamometer had been incidentally named to me by Mr. Ayrton, of his invention, in which the moving coil is replaced by a piece of soft iron which becomes magnetic during the passage of the current. Of this also further details were wanting.

I therefore attempted to make one for myself by the usual method of suspending a coil of wire from two silk fibres within a fixed coil, bringing its two ends to mercury contacts at the lower part, and joining all up in one circuit. Two defects at once appeared. 1. The coil of copper wire was far too heavy to move with the small currents at my disposal; and when it did swing, it continued to oscillate slowly for an unlimited time, giving no satisfactory reading. 2. The mercury contacts caused so much friction as absolutely to stop all motion whatever.

It was therefore obvious that (1) a light coil, and (2) a sensitive bifilar suspension were needed. Both of these must have a fairly high electrical conductivity. The second of these desiderata may be dismissed first. I found at the gold lace shops bobbins of silver-gilt wire, in which the gold is drawn over the silver in manufacture; not merely plated on. These two combined have a diameter of $\frac{1}{500}$ of an inch; which is exactly that of the finest platinum wire commercially made. But whereas the resistance of 1 metre of the latter is 62·2 ohms, that of the former is only 9·8 ohms. An induction shock from Dubois-Reymond's apparatus passed through a metre of this wire has such strength, that I do not wish to try it again, nor should I venture to administer it to an invalid.

It occurred to me that (1) the light coil might be obtained by using fine aluminium wire covered with silk. Messrs. Johnson and Matthey, with their usual courtesy, drew this for me specially, to a diameter of 1-100th of an inch, or even less,[1] and Mr. Rickards, of Derby, completed the operation.

By winding this on a mandril, tying the ring thus obtained with silk threads, and immersing in photographic amber varnish, which I find much less dense, and as good an insulator as Shellac, I obtain a coil composed entirely of metal and silk, which is at once rigid, light, and conductive. One of these, of 1·25 inches internal diamater, not of very fine wire, contains forty-two turns of wire in five layers, its length thus being over four yards. It weighs 6·25 grammes, less than 100 grains, its resistance is about half an ohm.

On suspending this light coil from two threads of the silver-gold wire named above, I found its deflections considerable, and easily measured, even with moderate currents. It could easily be made "dead-beat." The bifilar couple was varied by giving the suspending points a sliding motion to and from each other. By also fashioning the suspensions in the form of light vertical springs, the two threads were kept at an approximately equal tension.

Aluminium appears to offer great advantages for employment in such functions as these. It is said in Watt's "Dictionary," that "the electric conducting power of aluminium is eight times as great as that of iron, and about equal to that of silver," where probably the comparison is intended to be made with equal weights, and not volumes. But even if it were lower, it would be abundantly sufficient for the purpose named, as the currents are of high tension, and as the resistance need not be materially less than that of the suspending wires given above. Its specific heat is very great, so that moderate changes of temperature affect it but little. This property might render it valuable for the fabrication of resistance coils.

It was stated at the meeting that this metal had been tried by Messrs. Siemens, but given up in consequence of the failure of connection in the ends of the aluminium wire. This difficulty I have not found, probably in consequence of the high tension, and also from the fact that the contacts are between gold and aluminium, both stable substances. In any case the difficulty could be overcome by making a gripping contact with a light clamp, such as is already used in watchwork. Nor can Messrs. Siemens' unsuccessful attempt for other purposes be, I think, considered as a distinct anticipation of this. The mechanical advantage of such a light coil in diminishing moment of inertia, and in reducing the force of the bifilar couple, can hardly be denied on theoretical grounds, and is, indeed, borne out by experiment. W. H. STONE

MATHEMATICS AT THE JOHNS HOPKINS UNIVERSITY

FROM time to time we receive copies of the *University Circular*. From two now before us, we make a few extracts, which will serve to show what this young but promising University has done (or attempted to do) in the session 1881-82. The students have been thirty-two in number; of these, twenty followed advanced and University courses, and twelve pursued collegiate courses.

Supreme over the department presides Prof. Sylvester, F.R.S., who, besides editing the *American Journal of Mathematics* and reading papers at the Mathematical Seminary (similar in its character to our own London Mathematical Society), has delivered two courses of lectures—one on the Theory of Numbers (and in especial on an extension of Tchebycheff's theory concerning Prime Numbers), the other on a new theory of universal multiple algebra.

This session on the invitation of the Trustees, Prof. Cayley was called in as *amicus curiæ*, and arrived at

[1] The finest wire has not yet been measured in the microscope; it passes through the smallest hole of the B.W.G., No. 80.

Baltimore in December last. At the January meeting of the Seminary, he read a paper "On Two Cases of the Quadric Transformation between two Planes," and has subsequently read other papers, and been a contributor to the *Journal*. But the result of his visit has been the delivery of "a systematic and highly original course of lectures upon Algebraical Geometry, in connection with the Abelian and Theta Functions."

These lectures, we hope, will be given, in book form, to a more extended audience. Besides the ordinary class lectures, given by the able staff of assistant professors, some of whom are well known to mathematicians here, short courses of lectures have been delivered by Mr. C. S. Peirce (who has recently annotated and published in the *American Journal* his father's fine work on "Linear Associative Algebra"), on the Logic of Relatives, by Dr. Story; on the Clebsch-Gordan invariantive theory; and by Dr. Craig, on the Construction and Direction of a Riemann's surface (how these two last courses recall to our minds a departed master.)

Leibnitz somewhere says "Les mathématiques sont l'honneur de l'esprit humain;" if this be so, then the University has done well in assigning so great a part of its time and resources to the study of the higher branches of this department of knowledge. But indeed Johns Hopkins is a true university, for it is catholic in its sympathies, and enfolds in its wide embrace all branches of culture and learning.

In No. 13 is an abstract of a lecture before the students by Dr. James Bryce, M.P., on our English universities.

R. T.

KŒNIG'S EXPERIMENTS IN ACOUSTICS

I.

IN the volume mentioned below[1] Dr. Kœnig has collected the valuable series of researches in experimental acoustics that have been published by him chiefly in the *Annalen* of Poggendorff and of Wiedemann during the past twenty years. Many of these researches are well known in England, having attained to "classic" importance, and their main results are to be found embodied in all the best text-books of acoustics. Other researches of more recent date are yet known only to the few, but will doubtless win their way to general knowledge before long. The most novel points in the book are the late researches of its author with the ingenious instrument known as the wave-siren. This invention Dr. Kœnig has applied to support his views upon the origin of the beats of imperfect consonances, and also to investigate the influence of differences of phase upon the quality of tones. The general nature of the wave-siren has already been explained in the pages of NATURE, but in the sequel we will attempt to describe fully its most recent forms, as applied in the last investigation. In addition to these deeply interesting matters of recent research, there is a mine of wealth contained in the volume. The first chapter deals with the application of the graphic method in acoustics; an equally interesting chapter on manometric flames and their applications occur a little further on. Dr. Kœnig's researches on the standard tuning-fork or "*diapason normal*" are too well known to need comment. The reader will find the whole series of papers collected in Chapter XIII. He will also find notices of an adjustible tuning-fork capable of giving a variety of tones, of a curious tuning-fork clock, of new stethoscopes, of instruments for producing continuous beats audible to a large company of persons, together with researches on the phase of vibration of two associated telephones, on the fixed notes charcteristic of the different vowel sounds, and on several other matters of great importance. He must not, indeed, expect to find deep mathematical insight nor folios of analytical equations. But he will find a perspicuous and fascinating record of experiments planned with rare ingenuity, carried out with honesty, patience, and consummate skill, by the man whose exceptional abilities as experimentalist and constructor have done more than those of any other physicist to make the science of experimental acoustics what it is to day.

In the present article we shall refer in some detail to Dr. Kœnig's researches on the influence of phase upon the quality of sound.

It has long been an accepted doctrine of acoustics that every continuous sound possesses three recognizable characteristics, viz., *pitch*, *intensity* and *quality*, and that these three characteristics depend respectively upon the frequency, the amplitude, and the degree of complexity of the sonorous vibrations. The third of these characteristics, the *quality* of a sound, has also been denominated "*timbre*" or "*clang-tint*" by those who affect Gallic or Teutonic proclivities in scientific nomenclature. Everyone now knows that, by whatever name this third characteristic is called, it constitutes the almost indefinable yet perfectly recognizable difference which exists between a note as played on one musical instrument and the same note as played upon another. The notes may be the same in pitch and in intensity, but there is a residual difference in quality that the dullest ear cannot mistake.

It was by one of the finest pieces of scientific research by Germany's greatest living physicist, that the true cause of this mysterious "quality" was established. Helmholtz's great work on *The Sensations of Tone* takes for its basis the fact that with every fundamental "tone" or perfectly simple sound there co-exists a whole series of "partial tones," which together with the fundamental make up the mass of sound that we usually call a "note." All our musical instruments yield us complex sounds in which every fundamental is accompanied by a variety of upper partial tones (sometimes called by mistranslation "overtones"; and also, by a far more serious mistake, "harmonics), the number of such upper partials and their relative intensity being a consequence of the conditions of vibration in the instrument. Hence instruments having different kinds of vibrating parts—strings in one, reeds in another, columns of air in another—will emit tones that vary in number and intensity of accompanying partial tones; and the ear taking the mass of complex vibration as a whole will pronounce that there is a difference *in quality*. Helmholtz's theory, in short, asserts that the quality of a tone depends on the following points: firstly, whether there were any upper partials present; secondly, what those upper partials were; thirdly, what their relative intensity toward one another and toward the fundamental note might be. Thus, for example, the thin quality of the notes of wide, stopped organ-pipes, which contrasts both with the full rich quality of the pianoforte notes, and with the harsh, strident, irrepressible notes of the harmonium, becomes intelligible when it is rendered plain that in the first case there is an almost complete absence of upper partials, that in the second the partials, though numerous, are loud only for such partial tones as are concordant with the fundamental, while in the third discordant partials, loud and shrill mingle with the fundamental.

But there is a negative proviso in Helmholtz's theory of a very important kind, namely, that differences in quality of tone depend "*in no respect on the differences in phase under which these partial tones enter into composition*."[1]

This negative law, which Helmholtz has sought to confirm by various experimental proofs, is a consequence of the hypothesis that the ear unconsciously analyzes complex sounds into their simple elements—the partial tones—each simple (partial) tone actuating a separate part of the nerve-structures of the ear. Before Helm-

[1] "Quelques Expériences d'Acoustique." Par Rudolf Kœnig. (Paris: R. Kœnig, 27, Quai d'Anjou, 1882.)

[1] *Helmholtz.* Sensations of Tone (Ellis's Translation) p. 186.