ELASTICITY OF WIRES[1]

THE experiments described in this paper form a continuation of experiments undertaken in connection with the work of the Committee of the British Association for commencing secular experiments on the elasticity of wires.

Long-continued application of stretching force increases to a very great extent the tensile strength of soft iron wire. Thus in experiments described to the British Association in 1879 (see Report of the Committee just referred to), a particular very soft iron wire was shown to have a breaking weight 10 p.c. higher if the weight necessary to break it is applied half a pound at a time per day, than it has if the breaking weight is applied half a pound at a time at intervals of say two minutes. It was found also that this wire, quickly broken, extends before breaking by as much as 25 p.c. of its original length; whereas if the application of the stress is very slow, the extension is not more than 5 or 6, or perhaps 8 p.c. Further experiments have been undertaken on this subject, and are still in progress.

Using a continuous arrangement for applying the stretching weight and employing some very soft iron wire which had been specially prepared, and which was used in former experiments, the greatest weight which could be rapidly put on the wire without breaking it was determined. It was found that with a weight of 41 lbs. gradually applied in $6\frac{1}{4}$ minutes the wire stretched by 24·4 p.c. of its original length, and broke 18 minutes after the weight was put on. With the same weight, 41 lbs., applied in $6\frac{3}{4}$ minutes, the wire stretched 22·1 p.c. and broke in 24 minutes. With 41 lbs., however, applied in $7\frac{1}{8}$ minutes, the wire stretched 18 p.c., and did not break. This weight, therefore, appeared to be just as much as the wire would bear with this method of applying the weight. Accordingly it was applied to a great number of wires for different lengths of time for the purpose of hardening them, and arrangements have been made for keeping a number of wires for very long times with this stretching force applied to them. The amount of extension produced by the application of the hardening stress was observed in each case.

After the hardening stress had been applied for a certain time the additional weight necessary to break the wire was determined, and also the additional elongation before breaking, which was in all cases almost insensible. The wires seemed permanently set in about forty minutes from the time when the hardening stress was applied. They did not alter in length till just before they broke, when they generally stretched 1 or 2 millimetres on a length of about 1,800 mm. The following table shows some of the results out of a great many that have already been obtained.

Length of wire used.	Hardening stress applied in pounds.	Time taken by continuous machine in applying the hardening stress in minutes.	Extension produced by application of hardening stress in p.c. of original length.	Duration of hardening stress in hours.	Total breaking weight after hardening.
150 cm.	41	$6\frac{1}{4}$	24·4	Broke with 41 lbs.	
,,	,,	$6\frac{3}{4}$	22·1		
,,	,,	$9\frac{1}{2}$	18·7	24	47·44
,,	,,	7	17·2	27	47·5
,,	,,	8	17·3	117	48·13
,,	,,	$7\frac{1}{8}$	18·1	790	52·31

Curves have also been obtained and were exhibited to the Section showing the extension with gradually applied weights both of a number of wires and of the different parts of the same wire; also curves showing the extension at different intervals of time from the beginning of an experiment in which the wire is running down under a weight sufficient to break it finally.

The author acknowledged the great assistance that he had received from Mr. A. C. Crawford and other students the in Physical Laboratory of the University of Glasgow.

Similar experiments are in progress on wires of copper and tin, and it is intended to test gold wire very soon, as it will probably give interesting results, and results very different from those given by soft iron wires.

[1] Strength and Elasticity of Soft Iron Wires. Abstract of a Paper read at the British Association, by J. T. Bottomley, M.A., F.R.S.E.

SPECTROSCOPIC NOTES, 1879-80.

DOUBLE *Reversal of Lines in Chromosphere Spectrum.*—The magnesium lines of the *b* group, and the two D-lines of sodium have been seen several times (first on June 5, 1880) *doubly-reversed* in the spectrum at the base of a prominence.

A bright line first appears in the centre of the widened dark lines; then this bright line grows wider and hazy at the edge, and a thin dark line appears in its centre, as shown in the figure. The phenomenon lasts usually from ten minutes to an hour. It is evidently the exact correlative of the double reversal of the bright sodium lines, observable in the flame of a Bunsen burner or alcohol lamp under certain circumstances when the quantity and temperature of the sodium vapour in the flame are greatly increased.

The H-lines in the Chromosphere and Sun-spot Spectra.—In 1872 I found the H- and K-lines to be reversed in the spectra of prominences and sun-spots, as observed at Sherman, 8000 feet above the sea. Until recently I have not been able to verify the observation, except for a moment during the eclipse of 1878. During the past summer, however, I have succeeded in seeing them again, and with suitable precautions as to shade-glass, adjustment of slit to true focal plane for these special rays, and exclusion of extraneous light, I have no further difficulty with the observation. The spectroscope employed has collimator and view-telescope each of $1\frac{1}{4}$ inches aperture, and about 13 inches focal length, and a speculum-metal Rutherfurd grating with 17,300 lines to the inch. A shade of cobalt-blue glass greatly aids the observation. The solar image is $1\frac{1}{4}$ inches in diameter.

In the spectrum of the chromosphere, H and K are both *always* reversed. I have never failed to see them both when circumstances were such that *h*, the nearest of the hydrogen lines, could be seen.

Furthermore, H, in the chromosphere spectrum, is *always double*: that is, a fine bright line always accompanies the principal line, about one division of Ångström's scale below. The principal line seems to be exactly central in the wide dark shade, the other is well within the nebulosity. K on the other hand shows no signs of duplicity.

In the spectrum of a sun-spot H and K are also, both of them, generally, though not always, reversed; and the reversal is not confined to the spot, but covers often an area many times larger in its neighbourhood.

In the spot spectrum, however, H has never yet been seen double. The companion line of H is therefore probably due to some other substance than that which produces H and K; a substance prominent in the chromosphere, but not specially so in the neighbourhood of spots. In view of the recent observations of Vogel, Draper, and Huggins, it is natural to think that hydrogen is probably the element concerned. If so, it may be expected that H will be found doubled in the spectrum of a spot which reverses the hydrogen line *h*. I have not yet been able to test it in this way, as *h* is rarely seen reversed, though C and F occur pretty frequently.

[*Note.*—An observation made since my paper was written leads me to modify this opinion, that the companion of H is due to hydrogen, and satisfies me that in all probability both H and K must themselves be hydrogen-lines. At 11 A.M. on October 7, a bright horn appeared on the S.E. limb of the sun. When first seen it was about 3′ or 4′ in elevation, but it rapidly stretched up, and before noon reached a measured altitude of over 13′ (350,000 miles +) above the sun's limb. It faded away and disappeared about 12.30. It was brightest about 11.30 with an altitude of about 8′ and at this time both H and K were distinctly, and for them, brilliantly reversed in it clear to the summit. H was not double in it to any notable elevation, though the companion of H was visible at the base of the prominence. The H- and K-lines also showed evidence of violent cyclonic action, just as C did. *h* was only faintly visible in the prominence; F and the line near G were of course strong. But no other lines, either of sodium, magnesium, or anything else, could be traced more than a very few seconds of arc above the sun's limb. I am not able to say how long the H-lines continued visible, or to what elevation they extended afterwards, as I returned to the C-line to watch the termination of the eruption. If I remember rightly, this eruption reached a higher elevation than any before observed. There was (and is to-day) nothing on the sun's limb visible with the telescope which would account for it.—Princeton, October 8.]

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Examination of Lines in the Solar Spectrum which are given in the Maps as common to Two or more Substances.—For this purpose a spectroscope of high dispersion has been constructed by combining the grating mentioned above, which has about 4 square inches of ruled surface, with a collimator and observing telescope each of 3 inches aperture and about 42 inches focal length, using magnifying powers ranging from 50 to 200. The apparatus is arranged upon a wooden frame-work, and when in use is strapped to the tube of the 12-feet equatorial of our observatory, so that it is kept by the driving-clock directed to the sun. An image of the sun is formed on the slit by an achromatic object-glass of 3 inches aperture, in order to increase the light and to avoid the widening of the lines due to the sun's rotation. A large prism of about 20° angle was sometimes placed in front of this object-glass (between it and the sun) to separate the colours before reaching the slit; and in examining the darker portions of the spectrum a concave cylindrical lens was sometimes used next the eye, like a shade glass, to reduce the apparent width of the spectrum and thus increase its brightness.

The grating is an admirable one, on the whole the best I have ever seen. But I have been greatly surprised at its excessive sensitiveness to distortion by pressure or inequalities of temperature. Although the plate is fully ⅝ of an inch thick, and only 3½ inches square, an abnormal pressure of less than a single ounce at one corner will materially modify its behaviour, and a quarter of a pound destroys the definition entirely. In fact the plate is not naturally exactly flat, and to get its best performance it is necessary to crowd a little wedge gently under one corner. When it is in good humour and condition, however, the performance is admirable; one could wish for nothing better, unless for a little more light in the violet portions of the spectrum.

With this instrument I have examined the 70 lines given on Ångström's map as common to two or more substances. Of the 70 lines, 56 are distinctly double or triple; 7 appear to be single; and as to the remaining 7, I am uncertain; in most cases, because I was unable to identify the lines satisfactorily on account of their falling upon spaces thickly covered with groups of fine lines, none of which are specially prominent.

As a general rule the double lines are pretty close, the distance being less than that of the components of the 1474 line. Generally also the components are unequal in width or darkness, or both, though in perhaps a quarter of the cases they are alike in appearance. The doubtful lines are the following, designated by their wave length on Angström's map: 5489·2, 5425·0, 5396·1, 5265·8, 4271·5, 4253·9 and 4226·8. I strongly suspect 5396·1 and 5265·8 (which present no difficulty in identification) of being double, but could never fairly split either of them, and therefore leave them among the doubtfuls.

Those which show no signs of doubling, so far as could be seen, were: 6121·2, 6064·5, 5019·4, 4585·3, 4578·3, 4249·8, and 4237·5.

In respect to the lines 5019·4, 4585·3 and 4237·5 it is quite possible there may be some mistake as to the coincidence, since in his *tables* Thalén gives neither of them as due to iron. An accidental strengthening of the dotted line, which, on the map, leads up from the symbol of the element concerned, through the iron spectrum, would account for the matter, by making the line appear on the map as belonging to iron also.

As the facts stand, therefore, it is obvious that arguments which have been based upon the coincidence of lines in the spectra of different elements lose much of their force; it appears likely that the coincidences are in all cases only near approximations. At the same time this is certainly not yet demonstrated. The complete investigation of the matter requires that the bright line spectra of the metals in question should be confronted with each other and with the solar spectrum under enormous dispersive power, in order that we may be able to determine which of the components of each double line belongs to one, and which to the other element. If in this research it should be found that *both* of the components of a double line were represented in the spectra of two different metals, and the suspicion of impurity were excluded, we should then indeed have a most powerful argument in favour of some identity of material or architecture in the molecules of the two substances involved.

Distortion of Solar Prominences by a Diffraction Spectroscope.—Generally, in such an instrument, the forms seen through the opened slit are either disproportionately extended, or compressed along the line of dispersion. The reason is this: if the slit be illuminated by monochromatic light, the image of the slit, formed on each side of the simple reflected image in the focus of the view-telescope (which is supposed to have the same focal length as the collimator), will have the same width as the slit itself only in one special case, not usually realised with a reflecting grating.

If the angle, between the normal to the grating and the view-telescope, is *less* than that between the normal and the collimator, the slit-image will be *narrower* than the slit, and a prominence seen through it will be *compressed* in the plane of dispersion. If the relation of the angles be reversed, then of course the distortion will also be reversed, and we shall have extension instead of compression.

The mathematical theory is very simple. Suppose the collimator and telescope to be fixed at a constant angle, as in the now usual arrangement.

Let angle between telescope and collimator $= \alpha$.
Angle between telescope and normal to grating $= \tau$.
Then angle between collimator and normal $= \kappa = \alpha - \tau$.
Also, let space between adjacent lines of grating $= s$.
And the order of spectrum observed $= n$.

Then, by principles of spectrum formation, we have

$$\lambda = \frac{s}{n}\left\{\sin\tau - \sin\kappa\right\},$$

λ being the wave-length of the ray which is in the centre of the field of view:

whence $$\sin\tau = \frac{n\lambda}{s} + \sin\kappa.$$

Differentiating, we have at once

$$d\tau = \frac{\cos\kappa}{\cos\tau}d\kappa, \text{ or } \frac{\cos(\alpha-\tau)}{\cos\tau}d\kappa;$$

which reduces to, $d\tau = (\cos\alpha + \sin\alpha\tan\tau)\,d\kappa$. Distortion can only disappear in cases when this coefficient of $d\kappa$ reduces to unity. Special cases—

1. If $\tau = \kappa$ there is no distortion—but also no dispersion: it is the case of simple reflection.
2. If $\kappa = 0$, the grating being kept normal to the collimator, then $d\tau = \sec\alpha\,d\kappa$.
3. If $\tau = 0$, the grating being kept normal to the telescope (which in this case must be movable), then $d\tau = \cos\alpha\,d\kappa$.
4. If $\alpha = 90°$, $d\tau = \tan\tau\,d\kappa$.
5. If $\alpha = 0$, $d\tau = d\kappa$, and there is no distortion.

This is possible only by using the same tube and object-glass both for collimator and view-telescope, the grating being slightly inclined at right angles to the plane of dispersion. The principal difficulty in this form of instrument lies in the diffuse light reflected by the surfaces of the object-glass. It is hoped that this may be nearly obviated by a special construction of the lens which will throw the reflected light outside of the eyepiece. An instrument on this plan is being made for Prof. Brackett by the Clarks, for use in the physical laboratory at Princeton, and is now nearly completed.

Princeton, September 27, 1880 C. A. YOUNG

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

DR. J. E. HARRIS (D.Sc. Lond.) has been appointed to the vacant Professorship of Natural Philosophy at Trinity College, London.

FROM the new Calendar of the University College of Wales we learn that the present number of students is fifty-seven. We see there are classes for most of the branches of science, only unfortunately they are all taught by one professor, which, to say the least, must be rather hard on him. We hope the college will soon be able to have separate teachers, at any rate for the physical and biological sciences.

THE new University Library at Halle has just been opened. It is built entirely on the French system, and special precautions have been taken with regard to fire. It now numbers some 200,000 volumes, but there is room for half a million. The cost of the building amounts to 400,000 marks (20,000*l.*).

SCIENTIFIC SERIALS

THE *American Naturalist* for December, 1880, contains:—D. Cope, on the extinct cats of America.—F. V. Hayden, Twin

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