

VIII. "Effects of Stress on Inductive Magnetism in Soft Iron."  
(Preliminary Notice.) By Prof. Sir WILLIAM THOMSON,  
F.R.S. Received June 10, 1875.

1. At the last ordinary meeting of the Royal Society (May 27), after fully describing experiments by which I had found certain remarkable effects of stress on inductive and retained magnetism in steel and soft iron, I briefly referred to seeming anomalies presented by soft iron which had much perplexed me since the 23rd of December. Differences presented by the different specimens of soft-iron wire which I tried complicated the question very much; but one of them, the softest of all, a wire specially made by Messrs. Richard Johnson and Nephew, of Manchester, for this investigation, through the kindness of Mr. William H. Johnson, gave a result standing clearly out from the general confusion, and pointing the way to further experiments, by which, within the fortnight which has intervened since my former communication, I have arrived at a complete explanation of all that had formerly seemed anomalous. These experiments have been performed in the Physical Laboratory of the University of Glasgow by Mr. Andrew Gray and Mr. Thomas Gray, according to instructions which, in my absence, I have sent them from day to day by post and telegraph.

2. The guiding result (described near the end of my former paper, and referred to in the last paragraph but one of the Abstract in Proceedings of the Royal Society for May 27) was, that the softest wire, tried with weights on and off repeatedly, after it had been magnetized in either direction by making the current, in the positive or negative direction, and stopping it, gave effects on the ballistic galvanometer which proved a shaking out of residual magnetism by the first two or three ons and offs, and a gradual settlement into a condition in which the effect of "on" was an *augmentation*, and the effect of "off" a diminution, of the inductive magnetization due to the vertical component of the earth's magnetizing force. When a fresh piece of the same wire was put into the apparatus and tested with weights on and off it gave this same effect. If the wire had been turned upper end down and tried again in the course of any of the experiments, still this same effect would have been shown. It seemed perfectly clear that in these experiments there was no other efficient dipolar quality of the apparatus by which the positive throw of the ballistic galvanometer could be given by putting on the weight, and the negative throw by taking it off, than the vertical component of the earth's magnetic force.

3. Yet I did not consider that I had *explained* the result by the terrestrial influence, because, for *all* the specimens of steel and soft iron, the effect of weights on had been uniformly to *diminish*, and of weights off to *augment* the magnetism when the magnetizing current was kept flowing. And I was, moreover, perplexed by the magnitude of the

result—the effect of weights on and off shown by the very soft iron wire, under only the feeble magnetizing influence of the earth, being many times (from three times to nine or ten times) as great as the effects which the same weights on and off produced in the same wires when under vastly greater magnetizing forces of the currents through the helix.

4. But by reducing the strength of the magnetizing current gradually, it was clear that the small positive effect of the “on” with the positive current flowing and the small negative effect with the negative current must be gradually brought to approximate more and more nearly to the large positive effect of the “on” when there is no current at all. Immediately after my former communication I therefore arranged to have experiments made with different measured strengths of current, feebler and feebler, until the law of the continuity thus pointed out should be ascertained; and so speedily arrived at the following astonishing conclusions:—

5. (1) When the magnetizing force does not exceed a certain critical value the alternate effects of *pull* and *relaxation* are respectively augmented and diminish the induced magnetization.

(2) When the magnetizing force exceeds the critical value the effects are—pull diminishes, relaxation augments, the induced magnetization.

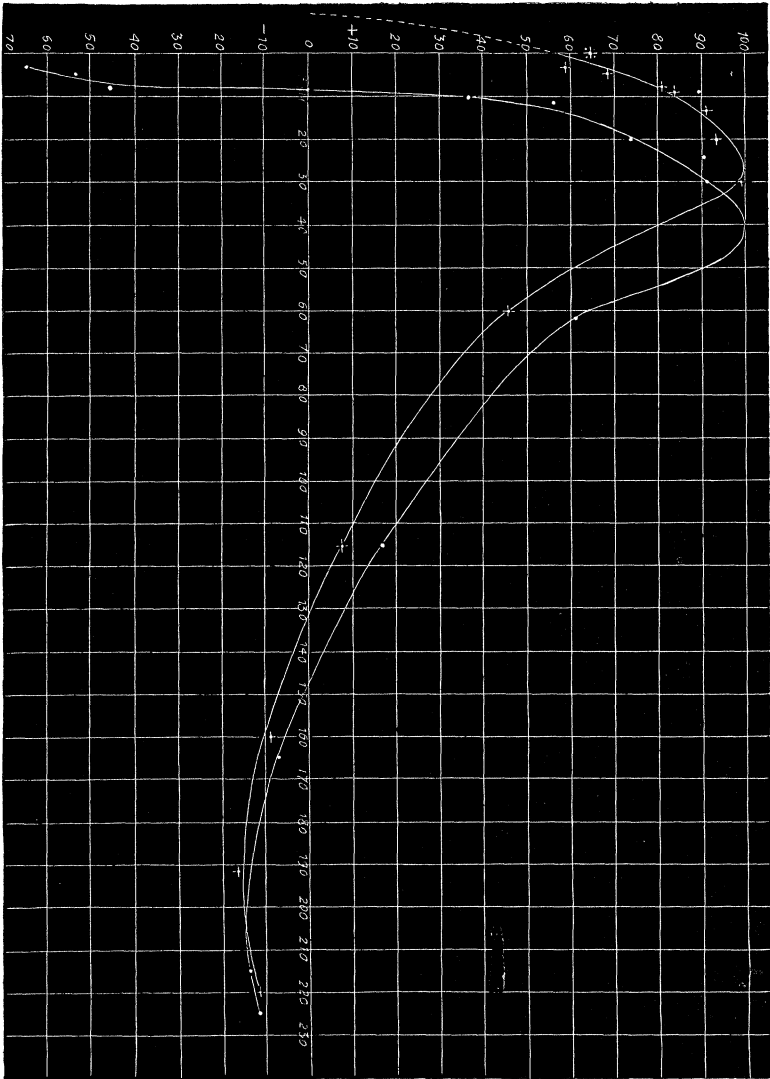
(3) The critical value of the magnetizing force for the annealed Johnson soft-iron wire, with 14 lbs. on and off, is about 17 or 18, if (for a moment) we take as unity the vertical component of the terrestrial magnetic force at Glasgow.

(4) The maximum positive effect of the pull on the inductive magnetism is obtained when the magnetizing force is about 4.

(5) The positive effect of the pull when the magnetizing force is 3 is about eight or nine times the amount of the negative effect when the magnetizing force is 25.

6. The actual results of the experiments which proved these conclusions are exhibited graphically in the accompanying diagram. The horizontal scale (abscissas) shows the numbers of divisions of the scale of the steady-current galvanometer (called for brevity the “battery-galvanometer”) used to measure the strengths of the current through the helix. The scale of ordinates shows the numbers of divisions of the scale of the ballistic galvanometer by which the sudden changes of the magnetism of the wire produced by 14 lbs. “on” and 14 lbs. “off” were measured. The ordinates are drawn in the positive direction when the effect of “on” is to increase and of “off” to diminish the magnetism. The simple round spots show the results of observations with currents in the direction called negative (being those which gave negative deflections of the battery-galvanometer). The spots in the centre of signs (+) show results obtained with currents in the direction called positive. The star (\*) at the position 64 on the line of ordinates through the zero of abscissas

shows the mean effect of many ons and offs with no current flowing—that is to say, when the sole magnetizing force is the vertical component



of the earth's magnetic force. The curves are drawn as smoothly as may be by hand, one of them to pass as nearly as it can (without intolerable roughness) through all the crossed (plus) dots and the star at 64, the other through all the plain dots. The latter curve cuts the line of abscissas at 8, this being the result (telegraphed to me this evening) of special

experiments made to-day for the purpose of finding accurately the amount of the negative current which, by neutralizing the vertical force of the earth or the wire, gives an accurate zero effect for the "off" and "on." The dotted prolongation of the curve through the plus's, to cut the line of abscissas on its negative side, is ideal, and is inserted to illustrate the relation of this curve to the other. By the two curves cutting the line of abscissas at +8 and -8, we see that 8 is the strength of the current, measured on the scale of the battery-galvanometer, which gives a magnetic force in the axis of the helix equal to the vertical component of the terrestrial magnetic force.

7. Next a series of experiments to test the inductive effects of repeatedly making the current always in one direction, and stopping it, with the weight of 14 lbs. always on, and again with the weight off, and this with various degrees of current, feebler than those used in the earlier experiments. The results with all the different intensities of magnetizing force thus applied were the same in kind as that which I found on the 23rd of December, operating with a much stronger magnetizing force on the first soft-iron wire tried; that is to say (contrarily to what I had found in the steel wires), *the change of magnetization produced by repeated applications and annullings of the magnetizing force of the helix was greater with the weight off than on.*

[*Note on Diagram, added July 2, 1875.*—A continuation of the experiments with higher and higher magnetizing powers, since the communication of this paper, disproves the negative minimum indicated by the curves on the diagram, and proves an asymptotic approach to a value approximately -12, of ordinates, for infinitely great positive values of the abscissas.]

*Presents received, May 13, 1875.*

#### Transactions.

Christiania :—Kgl. Norske Universitet. Om Skuringsmærker, glacierformationen, terrasser og strandlinier samt om grundfjeldets og sparagmitfjeldets mægtighed i Norge, af T. Kjerulf. 2. 4to. 1873. Jættegryder og gamle strandlinier i fast klippe, af S. A. Sexe. 4to. 1874. Norges Flora, af M. N. Blytt. 3 parts. 8vo. 1861-74. Enumeratio Insectorum Norvegorum, auctore H. Siebke. fasc. 1. 8vo. 1874. Die ägyptischen Denkmäler in St. Petersburg, Helsingfors, Upsala, und Copenhagen, von J. Lieblein. 8vo. 1873. Grundtrækkene i den ældste Norske Proces, af Ebbe Hertzberg. 8vo. 1874. Postala Sögur, udgivne C. R. Unger. 8vo. 1874. Oðða Testamenta. 8vo. 1874. Oanedubme Dr. Erik Pontopiddan Cilgitusast samas jorgali J. A. Friis. 8vo. 1873. Forhandlinger i Videnskabs-Selskabet in Christiania. Aar 1873. Hefte 2. 8vo.

