LVIII. On the electrical resistance of vertically-suspended wires

Shelford Bidwell M.A. F.R.S.

To cite this article: Shelford Bidwell M.A. F.R.S. (1887) LVIII. On the electrical resistance of vertically-suspended wires , Philosophical Magazine Series 5, 23:145, 499-503, DOI: [10.1080/14786448708628044](https://doi.org/10.1080/14786448708628044)

To link to this article: <http://dx.doi.org/10.1080/14786448708628044>

Published online: 29 Apr 2009.

Submit your article to this journal [↗](#)

Article views: 3

View related articles [↗](#)

point we have a definite thing of known form which can be examined by a series of microscopes, and the point up to which it can be clearly seen observed for each.

I have thought it worth while to bring this subject forward in this very incomplete form, because there are already results of interest and there is so much prospect of more, that it is likely that Members may be glad to investigate some of the questions raised.

LVIII. *On the Electrical Resistance of Vertically-suspended Wires.* By SHELFORD BIDWELL, M.A., F.R.S.*

FROM the experiments to be described in this paper, it appears probable that the electrical resistance of vertically-suspended copper and iron wires alters to a small extent with the direction of the current traversing them. If the wire is of copper, the resistance is slightly greater when the current goes upwards than when it goes downwards; while, on the other hand, the resistance of an iron wire is apparently greater for downward than for upward currents†.

The arrangement employed for exhibiting this effect is shown in the annexed diagram. A wire, A B, of the material

* Communicated by the Physical Society: read March 12, 1887.

† Venturing to imitate the fanciful analogy used by Sir William Thomson, who, in discussing the thermoelectric effect now universally associated with his name, speaks of the "specific heat" of electricity, we may perhaps also speak of the "specific gravity" of electricity, and say that (like its specific heat) it is positive in copper and negative in iron.

to be tested is suspended at its middle point, P, from a support 10·5 metres above a metre-bridge, to the terminals, T T', of which the ends of the wire are connected. Another wire, C, is soldered at one end to P, and connected through the galvanometer, G, with the slider, S. A resistance of 100 ohms is inserted in each of the gaps, R R', and a commutator, K, is interposed between the two-cell battery, D, and the bridge.

With this arrangement, supposing that the two halves of the wire A B are of uniform sectional area and in the same physical condition, and that the various parts of the apparatus are in fair order and adjustment, there will be a balance when the slider is near the middle division of the scale. And if the resistances in the circuit are independent of the direction of the current, it is clear that the balance will be maintained notwithstanding that the commutator K be reversed. But this is found not to be the case.

A series of experiments was made with a copper wire ·4 millim. in diameter (No. 28 B.W.G.), and having a total resistance of 2·11 ohms. The commutator was first set so that the current through the wire passed up the portion B and down the portion A (*i. e.* in the direction B P A), and a balance was obtained by adjusting the slider. The commutator was then reversed and the current made to pass up A and down B. This at once destroyed the balance, and in order to restore it, it was necessary to move the slider several divisions towards the right. Assuming that the total resistance of the wire remains constant, this result may be explained by supposing that the reversal of the current is accompanied by increased resistance in the portion A, and diminished resistance in the portion B. Owing to its vertical suspension, the resistance of that portion of the wire in which the current travels upwards is greater than it would be if the wire were placed in a horizontal position, while the resistance of the portion in which the current travels downwards is less.

The experiment was repeated with an iron wire of larger size, its diameter being ·8 millim. (No. 22 B.W.G.). With this the effect of reversal was smaller; but it was well marked, and of the opposite nature to that observed in the former case.

The readings obtained in the two series of experiments are given in the following Table :—

Copper Wire.			
Number of experiment.	Scale-readings.		Difference.
	Current direct.	Current reversed.	
1.	569	633	-64
2.	567	637	-70
3.	595	651	-56
Mean difference -63.3			
Iron Wire.			
1.	780	770	+10
2.	760	748	+12
3.	759	748	+11
Mean difference +11			

I believe these effects are associated with certain thermo-electric phenomena discovered by Sir William Thomson. In his famous Bakerian lecture, published in the Philosophical Transactions for 1856, he showed that if a stretched copper wire is connected with an unstretched wire of the same metal and the junction heated, a thermoelectric current will flow from the stretched to the unstretched wire through the hot junction; while, if the wires are of iron, the direction of the current will be from unstretched to stretched. It follows, therefore, from the laws of the Peltier effect, that if a battery-current is caused to flow from a stretched to an unstretched wire, heat will be absorbed at the junction when the metal is copper, and will be developed at the junction when the metal is iron: and if the direction of the current is reversed the thermal effects will also be reversed.

Now a vertically suspended wire is unequally stretched by its own weight, the stress gradually increasing from zero at the lowest point to a maximum at the highest. Any small element of the wire is more stretched than a similar element immediately below it, and less stretched than a neighbouring

element just above it. Thus a current of electricity, in passing from the lowest to the highest point of such a wire, is always flowing from relatively unstretched to relatively stretched portions. If, then, the wire were of copper, heat would be evolved throughout its whole length; the temperature of the wire would rise, and its resistance would consequently be increased. With a current flowing from top to bottom, the temperature of the wire would fall and its resistance diminish. So also an iron wire would be cooled and have its resistance lowered by an upward current, while a downward current would heat it and increase its resistance. The changes of resistance are thus, as I believe, proximately due to changes of temperature.

The resistance of the bridge-wire used in my experiments was $\cdot 244$ ohm, and, as already mentioned, an additional resistance of 100 ohms was placed in each of the gaps adjoining the bridge-wire. Denoting the resistance of the half A of the suspended wire by a , and that of B by b , we have, from the first experiment with the copper wire (the result of which agrees closely with the mean):—

For direct current,

$$\frac{a}{b} = \frac{100^w + \cdot 569 \times \cdot 244^w}{100^w + \cdot 431 \times \cdot 244^w} \\ = \frac{100139}{100105}$$

Also

$$a + b = 2 \cdot 11^w.$$

Hence

$$a = 1 \cdot 0551792^w *, \\ b = 1 \cdot 0548208^w.$$

For reversed current,

$$\frac{a}{b} = \frac{100^w + \cdot 633 \times \cdot 244^w}{100^w + \cdot 367 \times \cdot 244^w} \\ = \frac{100154}{100090}.$$

* Of course the resistances are not really measured to the high degree of accuracy suggested by these figures; but any small error of excess or defect would be approximately the same for the two values of a (with direct and reversed currents) and would not materially affect their difference, to which alone importance is attached.

And, as before,

$$a + b = 2.11^{\circ}.$$

Hence

$$a = 1.0553372^{\circ} *,$$

$$b = 1.0546628^{\circ}.$$

When therefore the current was reversed, the value of a was increased by

$$\begin{aligned} & 1.0553372 - 1.0551792 \text{ ohm} \\ & = .000158 \text{ ohm.} \end{aligned}$$

This is equivalent to about 16 thousandths per cent.

Assuming that a change of temperature of 1° C. produces an alteration of .4 per cent. in the resistance, it follows that the temperature of the copper wire was $\frac{1}{25}$ degree C. higher with an upward than with a downward current.

The current traversing the wire was not measured, but it was probably about 1 ampere.

It will be seen from the figures in the Table that the changes which occurred in the resistance of the iron wire were considerably smaller than those observed in the case of copper. This was unexpected, since the thermoelectric effects are, I believe, somewhat greater with iron. But the apparent anomaly is obviously to be accounted for, at least in part, by the higher specific resistance of iron. With the same electromotive force the current per unit of sectional area would be six or seven times greater in copper than in iron, and the Peltier effect is proportional to the current. To render the results in the two cases strictly comparable, other less important differences, such as those of specific heat and radiating-power, would have to be taken into account.

If a convenient opportunity offered it would be satisfactory to repeat the experiments with much longer wires, such as might be suspended in the shaft of a coal-pit or in a shot-tower. The effects hitherto observed are so small that they might possibly be due to accidental causes, and I publish this account of them with some diffidence.

* See note in preceding page.