II. "On the Increase in Resistance to the Passage of an Electric Current produced on Wires by Stretching." By HERBERT TOMLINSON, B.A., Demonstrator of Natural Philosophy, King's College, London. Communicated by Prof. W. G. ADAMS, F.R.S. Received November 14, 1876.

(Abstract.)

The object of this inquiry was

(1) To determine the relation between increased resistance to the passage of an electric current and stretching force.

(2) To ascertain how much of the increased resistance in each case is produced by mere increase of length and diminution of section of the stretched wire.

In order to determine the increase of resistance from stretching, the wires were each divided into two parts, about 14 ft. in length; one end of each part was fastened to a stout hook firmly fixed into a block of wood. These two hooks were about 8 inches apart, and the block of wood in which they were fixed was securely fastened across two uprights placed resting against a wall of the room, so that the weights, which were attached to the other ends of the wires, might swing clear of the table. The two parts of the wire were joined at the top, about 2 inches below each hook, by a small piece of copper wire, which was securely soldered on to each part of the wire so as to connect them. Towards the lower extremities of the two parts, about 5 inches above the points of attachment of the weights, two copper wires of small resistance were soldered so as to connect the wires with a Wheatstone-bridge arrangement. The increase of resistance was measured by means of a sliding scale of platinum wire divided into millimetre divisions, each equal to ·00166 ohm. As the object was to obtain the temporary, and not the permanent, increase of resistance, which permanent increase was found more or less with all the wires, weights slightly heavier than those intended to be used were first put on and then taken off. Afterwards the wire was balanced as nearly as possible by German-silver wire without the sliding scale, and then very exactly with the sliding scale, which was connected with one of two resistance-coils of 100 ohms each, which formed the other two sides of the bridge. The weights used were then carefully put on to the wires, and the increase of resistance measured by means of the sliding scale; the weights were next taken off again, and the sliding scale used for balancing once more. If there was any slight difference, as sometimes occurred, between the readings of the sliding scale before the weights were put on and after they were taken off, the mean of the two readings was taken. In order to secure still greater accuracy, as many as eight or ten trials were frequently made with each particular weight, and the mean of all the trials taken. In this manner

4 pianoforte steel wires, 1 wire of commercial steel, 3 iron wires, and 4 brass wires were examined with several different weights. The wires taken were of various sections, and it was found that in each case the increase of resistance was "exactly proportional to the stretching force," the stretching not being carried beyond the limit of elasticity of each wire. The resistance of a cubic centimetre of each wire was then determined, also the increase of resistance which a cubic centimetre of each wire would experience when stretched by a force of 1 gramme in the same direction as the passage of the current was calculated from the observations made. The former values varied from

$1574{\cdot}8 \times 10^{-8}$ to $1882{\cdot}4 \times 10^{-8}$ in the case of steel, from
$1200{\cdot}8 \times 10^{-8}$ to $1291{\cdot}0 \times 10^{-8}$ in the case of iron, and from
$656{\cdot}7 \times 10^{-8}$ to $782{\cdot}2 \times 10^{-8}$ in the case of brass;

the latter values varied from

2982×10^{-17} to 3511×10^{-17} in the case of steel, from
2557×10^{-17} to 2712×10^{-17} in the case of iron, and from
1565×10^{-17} to 1843×10^{-17} in the case of brass,

the numbers in each case representing so many ohms.

On dividing the latter values by the former, it was found that the increase per unit of resistance for a stretching force of 1 gramme on a cubic centimetre of each wire was nearly the same for wires of the same material, but differed with wires of different materials. The mean increase per unit of resistance was

for the steel wires $1875{\cdot}5 \times 10^{-12}$,
for the iron ,, $2132{\cdot}2 \times 10^{-12}$,
and for the brass ,, $2244{\cdot}9 \times 10^{-12}$,

the greatest departure from the mean value being

for the steel less than 2·7 per cent.,
for the iron about 3·0 per cent.,
and for the brass about 8·5 per cent.

The temporary increase of length which a cubic centimetre of each wire would experience on being stretched with a force of 1 gramme was then calculated from observations which had been made in the usual manner with the cathetometer; this increase of length was found to vary

in the case of 3 steel wires from 5082×10^{-13} to 5665×10^{-13},
in the case of the iron wires from 4896×10^{-13} to 5938×10^{-13},
and in the case of 1 brass wire was 10120×10^{-13}.

On dividing the increase per unit of resistance for a stretching force

of 1 gramme on a centimetre of the material by the increase of length produced by the stretching force, so as to obtain the increase per unit of resistance when the wires are stretched 1 centimetre, a mean value of 3·525 was obtained for the steel wires, 3·951 for the iron wires, and 2·203 for the brass wires—thus showing that, though the increase per unit of resistance for a given stretching force is greater in brass than in iron or steel, the increase per unit of resistance for a given lengthening of the wire is much greater both in iron and steel than in brass.

The torsional rigidity of the wires was next ascertained by the method of vibrations, several trials being made with different lengths of each wire; the results for different lengths of the same wire agreed very closely indeed.

From the values of torsional rigidity and the increase of length, the diminution of section was calculated for a cubic centimetre of each wire when stretched with a force of 1 gramme, assuming the wire to be isotropic. Next the increase of resistance which would result from mere lengthening of each wire and diminution of section was determined, and it was ascertained that, on subtracting this latter value from the total observed increase of resistance, there was a considerable residue in the case of the steel and iron wire, also a residue not so great in the brass. This residual increase of resistance probably arises from increased space in the line of flow of the current between the particles of the wire produced by the stretching force.

The conclusions to be drawn from the experiments are :—

1. That the temporary increase per cent. of resistance of a wire when stretched in the same direction as the line of flow of the current is exactly proportional to the stretching force.

2. That the increase per cent. of resistance, when a cube of each material is stretched by the same weight, is greater in iron than in steel wire, and greater in brass than in iron; also that the increase is nearly the same for different specimens of the same material.

3. That the increase per cent., when a cube of each material is stretched to the same extent, is much greater in iron and steel than in brass.

4. That there is a residual increase in each case over and above that which would follow from mere increase of length and diminution of section; that this residual increase is much greater in iron and steel than in brass, and greater in iron than in steel.