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XVIII. *On the Production of Sudden Changes in the Torsion of a Wire by Change of Temperature.* By R. H. M. BOSANQUET, *St. John's College, Oxford**.

[Plates VI. & VII.]

THE wire which forms the subject of the following observations is the finest platinum wire which can be procured; its diameter is about $\cdot 001$ inch, and the length of the piece used was about 3 feet 6 inches. It originally formed the suspension of a galvanometer having a pair of nearly astatic needles about 7 inches long. The steel needles could be replaced by brass ones for the purpose of examining the properties of the suspension.

During the summer no disturbances worth attention were noticed; but in the winter, when the use of the stove occasioned rapid changes of temperature, disturbances became evident. The brass needles were employed throughout the present investigation.

The tables and diagrams which follow, except the last, all refer to one and the same state of the wire, the suspended weight not having been lifted during their progress. The lifting of the weight entirely changes the condition of the wire so far as these phenomena are concerned. The last table and diagram exhibit a subsequent state in which the phenomena are less distinct and in reversed direction.

The angular position of the needles was read on a scale of degrees attached to the circular glass shade surrounding them. This position, which we may call the elongation, is the abscissa of the diagrams. The temperature was measured by a very sensitive thermometer with a long spiral bulb, hung up alongside of the wire. The temperature in degrees Fahrenheit forms the ordinate of the diagrams.

The principal effects are as follows:—The elongation varies between the limits of about 21° and 85° . Rising temperature drives it up to about 85° , where it remains while the temperature continues to rise. Falling temperature drives it down to about 21° , where it remains while the temperature continues to fall. The change of elongation is usually complete or nearly so by the time that the reversed change of temperature amounts to from 2° to 5° .

If the change of temperature is reversed as soon as the elongation reaches either of its limits, the line of the diagram returns along its original course: see diagram, April 27th.

* Communicated by the Physical Society: read May 14, 1887.

(The zigzags in the middle of this diagram arise from the rapid movement setting the needles in vibration.)

If the change of temperature is pushed in each direction after the limiting elongation is attained, we obtain a cycle of events which can be most simply represented by a parallelogram or series of parallelograms, such as the following:—

Here the vertical lines represent the limits of elongation, the one corresponding to rising temperature, the other to falling temperature. On reversal of the direction of change of temperature such lines as the sloping lines are described. The inclination of these is nearly constant, and they may lie at any height between the lines of limiting elongation.

The above figure is a typical representation of the character of the principal effect; but the lines are never really straight, and there are subsidiary effects, which, however, in the present case are small compared with that above described.

The tables and figures at the end of this paper explain themselves.

There was some difficulty in obtaining that part of the curve which corresponds to the lower horizontal line of the *Phil. Mag.* S. 5. Vol. 24. No. 147. August 1887. M

typical parallelogram, as the corresponding change of temperature usually took place in the small hours of the morning. The diagram May 4th-5th shows a case in which this part of the curve was obtained. This exhibits a subsidiary effect, which consists of a tendency to increase the elongation * in the neighbourhood of the lower limit when the temperature is constant. Another very clear case of this effect will be found on the diagram for April 28th. My impression is that conditions of wire are common in which this effect is considerably developed. In such cases changes of temperature give rise to excursions, after which there is a more or less rapid return to a mean position.

The observations and diagrams hitherto referred to deal with changes in the angular position of a body hanging from the wire at rest. Observations were also made of the periods of vibration, for the purpose of ascertaining what changes took place in the torsional rigidity of the wire. The results of these observations are as follows :—

Periods of vibration.

Mean period.		Mean elongation.	Number of observed periods.
m.	s.		
4	45	89.2	4
4	53	88.5	4
4	41	85.4	13
5	0	84.6	4
5	39	83.7	4
6	3	77.0	4
5	52	72.1	12
6	33	57.9	4
4	23	54.6	2
5	33	46.4	4
5	16	37.0	2
3	56	35.0	8
3	4	32.3	2
2	29	28.6	2
2	40	27.5	4

It appears from these numbers that the period of vibration is least when the elongation is in the neighbourhood of the lower limit, increases rapidly as the limit is departed from up to a maximum value, and diminishes again slightly as the upper limit is approached and attained; that is to say, the torsion force has

a maximum at the lower limit of elongation;

a minimum between the limits;

and an increase up to the upper limit.

The observations for the period are necessarily complicated

* *I. e.* to return from the lower limit towards the mean position.

by the changes in the position of rest, and they are not of great accuracy or consistency; but there can be no doubt that the course of the values is as above described.

It only remains to suggest what may be possible in the way of explanation of these phenomena. It appears to me that the only way of throwing any light on them is to imagine a mechanism capable of producing angular changes similar to those in question under the influence of changes of temperature.

A B are materials differently expandable by heat, capable of shifting, but with difficulty, through the clamp which binds them together.

Suppose C to be free between D and E; then any change of temperature will cause C to shift its position between D and E, and the pinion F will be turned round by the racks between which it lies. As soon as C comes up either against D or E the rotation of F is stopped, and the bars are compelled to shift in the clamp, if there is further change of temperature.

This arrangement exactly reproduces the typical changes observed in the present experiments. It is intended to serve the purpose of a formula.

The suggestion which we obtain from the above mechanism is that of loose contact between the parts involved, in this case probably between the molecules of the metal. As these peculiarities appear to originate in the extension of the wire by the suspended weight, it is possible that a partial separation of the molecules involving loose contact may arise out of this extension.

In any such case the molecules would bed against each other at the opposite parts of the loose contact, under the conditions which would give rise to either of the limiting elongations in the above experiments. The whole framework would be much stiffer when the loose contacts were thus bedded together than when they were free. In this way it would be possible to account for the increased values of the

torsion force at the limiting elongations, and its lesser values in the intermediate region.

It would be easy to imagine several types of framework with loose contacts which would be capable of realizing the phenomena; but at present evidence in support of any particular arrangement would be wanting.

Observations of Temperature and Elongation.

Time.	April 25th.		April 26th.		April 27th.		April 28th.		April 29th.		April 30th.	
	Temp.	Elonga- tion.	Temp.	Elonga- tion.	Temp.	Elonga- tion.	Temp.	Elonga- tion.	Temp.	Elonga- tion.	Temp.	Elonga- tion.
9 A.M.	46.8	81.5	45.7	77.0	46.3	75.5	48.8	75.0	50.0	65.7	47.2	81.5
9.15	47.8	84.0	46.0	77.0	47.5	79.2	49.5	77.0	50.4	71.3	49.0	82.0
9.30	48.0	78.0	46.7	78.5	48.1	80.2	50.5	80.0	51.0	75.0	49.8	82.0
9.45	48.2	79.0	47.2	78.5	49.2	81.0	51.7	80.5	51.5	77.5	50.3	81.5
10.0	48.7	78.4	49.0	79.0	50.9	81.0	55.0	80.5	51.7	78.3	54.0	82.5
10.15	49.0	79.0	48.7	79.2	54.0	81.0	60.6	80.0	52.1	79.5	58.0	83.3
10.30	49.8	78.3	50.3	79.8	57.3	81.8	63.8	83.5	53.8	80.5	62.0	84.0
10.45	50.5	78.0	49.5	79.2	60.2	81.2	67.5	84.0	58.4	79.5	66.2	81.5
11.0	51.0	78.3	49.7	78.8	62.5	81.3	70.6	81.6	63.5	78.3	71.5	82.0
11.15	51.4	78.3	49.5	79.2	63.3	82.2	72.4	81.2	68.3	80.2	74.1	80.8
11.30	51.6	78.3	49.6	79.2	65.2	82.5	73.3	81.2	69.6	80.5	76.2	81.0
11.45	51.6	78.8	49.7	79.4	66.5	83.0	73.5	81.5	70.0	81.5	76.2	81.2
12.0	51.8	78.8	50.2	79.5	68.9	83.0	72.8	81.5	69.8	81.5	77.0	82.7
12.15	52.4	79.0	50.3	79.7	69.4	82.3	72.4	82.5	69.6	81.5	76.3	82.5
12.30	53.8	78.5	...	...	69.0	82.3	72.0	82.0	69.5	82.5	75.0	82.3
12.45	54.0	78.7	50.2	79.3	69.2	82.5	71.6	82.0	69.0	82.0	65.0	78.5
1 P.M.	54.0	78.7	50.5	79.8	68.6	82.0	71.3	82.5	68.8	82.0	78.0	64.6
2.0	54.2	79.2	49.7	78.0	76.5	85.0	70.7	83.0	66.8	82.0		
2.15	54.2	79.2	49.7	78.3	77.0	83.5	70.4	83.0	66.2	82.2		
2.30	54.4	79.0	49.6	78.0	77.7	83.5	70.0	82.5	66.0	83.0		
2.45	54.4	79.0	49.8	78.5	78.7	84.5	69.2	82.5	63.2	76.0		
3.0	54.5	78.8	50.6	80.2	80.3	84.5	68.6	84.0	61.4	50.5		
3.15	54.5	78.8	51.4	82.0	82.4	84.5	68.4	83.0	60.7	37.0		
3.30	54.7	78.8	53.4	82.0	84.3	84.0	68.1	79.8	59.9	29.6		
3.45	55.0	78.5	57.6	82.3	84.4	84.0	67.6	83.5	59.6	29.5	59.3	32.0
4.0	55.0	77.7	60.3	83.0	84.6	84.0	67.0	77.5	59.0	27.5		
4.15	54.5	77.0	61.2	83.0	72.4	77.0	66.2	68.5	56.1	22.5		
4.30	54.5	76.7	62.0	84.0	70.0	65.0	65.5	61.0	55.5	22.5		
4.45	54.3	77.5	63.1	84.0	68.0	33.0	64.8	47.7	55.2	22.5		
5.0	54.3	77.5	64.2	83.3	66.6	26.3	64.3	40.0	54.6	22.0		
5.15	...	...	...	...	...	...	63.7	34.5				
5.30	55.3	85.0	64.0	83.2	64.0	22.5	63.3	30.4	53.6	23.0		
5.45	55.5	88.0	62.6	83.2	66.0	27.0	61.4	24.3	53.6	22.0		
6.0	55.2	82.0	62.6	82.3	68.5	36.7	60.1	22.0	54.8	22.5		
6.15	55.0	76.0	61.2	82.3	68.3	36.8	59.0	21.0	52.8	20.8	56.5	25.5
6.30	55.0	71.3	60.7	82.2	69.5	60.0	59.6	21.8	51.8	21.7		
6.45	54.4	60.5	60.1	82.4	70.7	70.0	59.1	21.3	51.3	21.5		
7.0	53.7	50.3	59.5	82.0	74.5	85.0	56.0	21.3	50.7	22.0		
7.15	53.0	40.3	59.0	80.0	76.1	85.0	54.8	21.0	50.0	20.8		
7.30	52.5	33.0	58.7	79.2	76.5	84.3	54.6	21.0	49.2	22.5		
7.45	52.2	29.5	58.1	78.5	76.0	83.5	54.6	21.5	49.0	21.0		
8.0	52.0	27.0	57.8	75.0	75.7	82.0	54.6	21.5	48.7	21.0		

Time.	May 2nd.		May 3rd.		May 4th.		May 5th.		May 7th.		May 9th.	
	Temp.	Elonga- tion.	Temp.	Elonga- tion.	Temp.	Elonga- tion.	Temp.	Elonga- tion.	Temp.	Elonga- tion.	Temp.	Elonga- tion.
9 A.M.	46.2	75.5	51.7	83.0	56.0	36.5	58.0	83.0	50.0	122.5	57.4	102.5
9.15	46.5	77.5	...	...	...	...	55.3	69.0	50.2	122.0	58.7	98.0
9.30	46.7	78.5	...	...	54.1	23.5	55.0	59.0	50.5	119.8	59.2	96.8
9.45	47.0	78.5	...	...	53.8	23.2	54.9	55.5	51.8	115.0	60.5	95.0
10.0	47.6	80.0	...	...	53.5	23.0	...	...	52.3	106.0	61.5	92.0
10.15	48.2	80.5	...	...	53.3	23.5	...	...	53.5	101.0	64.3	84.5
10.30	49.3	81.0	...	...	53.0	23.5	...	...	56.8	90.0	70.0	83.0
10.45	50.4	80.5	65.3	87.5	52.8	23.5	...	...	...	...	72.7	81.5
11.0	51.5	81.0	68.0	87.0	52.8	24.0	...	...	...	...	76.2	81.8
11.15	...	...	69.0	85.0	52.6	24.5	...	...	69.8	78.5	78.8	80.8
11.30	57.5	85.0	70.2	86.0	52.7	26.0	...	...	71.5	80.7	80.2	80.0
11.45	...	...	70.4	85.0	52.7	29.0	...	...	73.5	79.0	82.0	80.0
12.0	62.5	82.0	...	...	52.7	30.5	...	...	65.1	82.5	82.0	80.3
12.15	...	...	...	...	53.0	30.0	...	...	63.3	87.5	81.7	80.5
12.30	67.0	83.5	...	...	52.7	30.0	...	...	61.5	94.5	81.5	81.0
12.45	67.2	82.0	...	...	52.6	29.0	...	...	60.7	96.5	81.2	81.5
1 P.M.	68.0	82.0	...	...	52.8	33.5	...	...	61.2	98.5	81.0	82.5
2.0	69.2	83.7	69.7	86.0	52.6	38.5	...	...	...	...	79.3	92.0
2.15	60.8	79.0	...	...	52.6	39.5	...	...	...	...	69.2	117.5
2.30	60.2	76.5	...	...	52.7	40.5	...	...	...	...	68.2	124.5
2.45	57.8	70.0	...	...	52.2	39.5	...	...	...	...	67.4	123.0
3.0	...	...	...	...	52.2	41.0	...	...	...	...	67.3	123.0
3.15	57.5	59.0	...	...	...	...	...	...	...	...	67.0	123.0
3.30	58.4	60.5	...	...	...	...	...	...	...	...	66.0	122.8
3.45	...	...	...	...	51.8	34.5	...	...	...	...	65.1	122.8
4.0	60.3	86.0	...	...	...	...	...	...	...	...	65.0	123.0
4.15	...	...	...	...	...	...	...	...	...	...	65.0	123.0
4.30	58.5	69.0	...	...	51.0	34.5	...	...	...	...	65.5	123.5
4.45	...	...	...	...	...	...	...	...	...	...	64.5	123.0
5.0	57.5	45.0	62.5	40.0	50.8	36.0	...	...	...	...	65.0	123.0
5.15	...	...	...	...	...	...	...	...	...	...	...	...
5.30	56.0	33.0	61.5	30.0	50.7	40.0	...	...	...	...	64.3	123.0
5.45	...	...	...	...	...	...	...	...	...	...	64.3	123.0
6.0	53.6	26.0	...	...	50.5	41.5	...	...	...	...	65.0	123.0
6.15	...	...	...	...	...	...	...	...	...	...	63.5	123.0
6.30	52.5	22.7	...	...	50.5	42.5	...	...	...	...	63.5	123.0
6.45	...	...	...	...	...	...	...	...	59.7	121.5	63.0	123.0
7.0	51.8	22.0	59.0	23.0	50.8	43.5	...	...	...	...	62.8	123.0

After May 5th the wire was readjusted, and the subsequent readings refer to an altered condition of the wire.

Supplementary Observations.

Date.	Time.	Temp.	Elongation.
April 25.....	9.30 P.M.	49.0	24.5
„ 25.....	10.0	48.5	23.0
„ 26.....	10.45	50.8	22.5
„ 27.....	9.20	63.7	23.0
„ 28.....	10.20	54.5	25.0
„ 29.....	9.20	50.0	24.5
„ 29.....	11.0	48.6	25.5
„ 30.....	11.20	45.8	23.5
May 4.....	10.0	48.6	40.0
„ 4.....	11.0	56.8	86.0
„ 5.....	11.0	51.8	118.0
„ 6.....	7.45	51.0	124.0
„ 6.....	9.20	52.5	124.5
„ 8.....	9.15	59.0	124.0
„ 10.....	8.50 A.M.	54.7	143.5

XIX. On the Value of “ γ ” for a Perfect Gas.

By CHARLES V. BURTON, *B.Sc. (Lond.)*.*

THE ratio, γ , between the two elasticities or the two specific heats has been measured, in the case of gases, by various experimental methods. Some of these methods are based on the assumption that the gas in question may be considered approximately perfect.

The object of the following investigation is to show that γ has the same value ($\frac{5}{3}$) for all perfect gases, and can be calculated for this hypothetical class of bodies from purely theoretical considerations.

Let us take a certain portion of perfect gas whose volume is v , pressure p , and molecular kinetic energy W . The isothermal elasticity of the gas under these conditions,

$$E_t = p.$$

Now, in order to find the isentropic elasticity, let the gas be compressed adiabatically until its volume is diminished by dv , the volume after compression being $v_1 = v - dv$; and the pressure being at the same time increased to $p_1 = p + dp$.

* Communicated by the Author.