"On the Modulus of Torsional Rigidity of Quartz Fibres and its Temperature Coefficient." By FRANK HORTON, D.Sc., B.A., St. John's College, Cambridge, late Mackinnon Student. Communicated by Professor J. J. THOMSON, F.R.S. Received December 15, 1904,—Read January 26, 1905.

[Abstract.]

The author recently had the honour of reading to the Society the results of some experiments in which a new method of timing by means of "coincidences"—a method devised by Professor Poynting—was applied to an investigation of the effects of changes of temperature on the modulus of torsional rigidity of metal wires. It seemed desirable to repeat similar experiments with quartz fibres, seeing that now they are almost universally employed as suspensions in torsion instruments where accuracy is required.

The fibres experimented on were prepared from different crystals of quartz, and care was taken in their manufacture so as as to obtain them free from air bubbles and of circular cross-section. The investigation was divided into three parts:

(1) The determination of the absolute value of the torsion modulus.

(2) The variation of the modulus over a range of temperature from 15° C. to 100° C.

(3) The variation of the modulus between 20° C. and 1000° C.

In the determination of the absolute value of the modulus, it is necessary to find the radius of the fibres used. The method adopted for this purpose consists of measuring the circumference of the fibre by rolling a small length of it between two fine glass capillary tubes and counting the number of revolutions it makes in travelling a distance of 5 mm. With practice, this method was made to give very good results; a fibre of diameter 0·001 cm. being measured to 0·01 per cent.

The results of experiments on six fibres gave numbers for the modulus of rigidity in very good agreement, showing that the rigidity of quartz is practically constant, and does not vary in different specimens as in the case of metal wires. The mean value obtained for the modulus of rigidity at 15° C. was

$$3 \cdot 001 \times 10^{11} \text{ dynes per sq. cm.}$$

The results showed that this value is independent of the longitudinal stress to which the fibres are subjected, so long as this is not greater than that which they are usually required to bear when used as suspensions in measuring instruments.

In the second part of the research, observations were made on several fibres at temperatures approximately 15° C., 35° C., 55° C., 75° C.,

and 100° C. In every case the modulus of rigidity was found to increase as a linear function of the temperature, but the values obtained for the temperature coefficient of the modulus were considerably different. The mean value was +0·0001235, but the experiments show that this is far from constant in different specimens of quartz, its variations being much greater than those of the modulus of rigidity itself. It was found that the fibres became slightly more rigid as time went on, the rate of increase of rigidity being greater at the higher temperatures. This is probably due to a gradual annealing of the fibre, the annealing consisting in an easing of the structure from contraction strains.

In addition to the determination of the periods of torsional vibration, observations of the logarithmic decrements of the amplitudes of the oscillations were taken at each temperature. Fibres were also made to vibrate in an atmosphere of hydrogen, and the logarithmic decrements were again observed. From the values thus found, and the known ratio of the viscosities of air and hydrogen, a measure of the internal friction of the fibre was obtained. It was found that the internal friction of the fibres was very small, only about 2·5 per cent. of the observed logarithmic decrement at 15° C. being due to that cause, and that it remained roughly constant when the temperature of the fibre was raised from 15° C. to 100° C.

A series of observations was taken to ascertain the manner in which the logarithmic decrement, and the torsional period varied with the amplitude of vibration, amplitudes between 14′ and 10° being used. It was found that both the logarithmic decrement and the torsional period remained constant within these limits. In this respect quartz differs from metal wires, in which it was found that both the internal friction and the period of torsional vibration increased with the amplitude of oscillation.

In the experiments between 20° C. and 1000° C. the fibres used were rather thick and were suspended inside a platinum tube which was heated electrically, and which could be maintained at any desired temperature. Observations were taken at intervals of about 50° C., and the temperature of the tube was obtained by means of a thermo-junction of wires of platinum and rhodo-platinum. It was found that the modulus of rigidity of the fibre increased with the temperature, at first as a linear function of it, but as the temperature rose the rate of increase gradually diminished, and a maximum rigidity was attained at about 880° C. After passing this point the rigidity decreased very rapidly with increase of temperature.

The internal viscosity of the fibres increased with the temperature at a rate which was at first small and constant, but after about 650° C. it became much more rapid. At 1060° C. the internal friction of the fibres was so great that the torsional vibrations were nearly dead-beat.