balance. However the well-defined chemical properties of both ThX and UrX are not in accordance with the view that the actual amounts involved are of this extreme order of minuteness. On the other hand, the existence of radioactive elements at all in the earth's crust is an *à priori* argument against the magnitude of the change being anything but small.

Radioactivity as a new property of matter capable of exact quantitative determination thus possesses an interest apart from the peculiar properties and powers which the radiations themselves exhibit. Mme. Curie, who isolated from pitchblende a new substance, radium, which possessed distinct chemical properties and spectroscopic lines, used the property as a means of chemical analysis. An exact parallel is to be found in Bunsen's discovery and separation of cæsium and rubidium by means of the spectroscope.

The present results show that radioactivity can also be used to follow *chemical changes occurring in matter*. The properties of matter that fulfil the necessary conditions for the study of chemical change without disturbance to the reacting system are few in number. It seems not unreasonable to hope, in the light of the foregoing results, that radioactivity, being such a property, affords the means of obtaining information of the processes occurring within the chemical atom, in the same way as the rotation of the plane of polarization and other physical properties have been used in chemistry for the investigation of the course of molecular change.

Macdonald Physics Building,
Macdonald Chemistry and Mining Building,
McGill University, Montreal.

XLII. *On a Remarkable Case of Uneven Distribution of Light in a Diffraction Grating Spectrum.* By R. W. Wood, *Professor of Experimental Physics, Johns Hopkins University**.

It is a well-known fact that in the spectra formed by a diffraction-grating the light is unevenly distributed, that is the total light in any one spectrum will not recombine to form white light.

I have been examining a most remarkable grating recently ruled on one of the Rowland dividing-engines in which this uneven distribution is carried to a degree almost incomprehensible. If the spectra of an incandescent lamp are viewed directly in the grating without any other optical appliance, at certain angles of incidence perfectly sharp monochromatic

* Communicated by the Physical Society: read June 20, 1902.

images of the filament appear in different parts of the first order spectra. Sometimes these images are nearly black, and sometimes they are far brighter than the rest of the spectrum. On mounting the grating on the table of a spectrometer I was astounded to find that under certain conditions the drop from maximum illumination to minimum, a drop certainly of from 10 to 1, occurred within a range of wave-lengths not greater than the distance between the sodium lines. *In other words, this grating at a certain angle of incidence will show one of the D lines, and not the other.*

Setting the grating at nearly normal incidence, a bright narrow line appeared in the yellow, and a slightly broader dark line showed up in the green. On decreasing the angle of incidence these lines approached one another, one travelling up the spectrum, the other down. At an incidence angle of a few minutes they came in contact presenting an appearance very similar to one of the shaded lines in the spectrum of a Nova. On decreasing the angle of incidence to zero, the lines fused producing uniform illumination at the spot.

When the light is incident on the opposite side of the normal from the spectrum we find the red and orange extremely brilliant up to a certain wave-length, where the intensity suddenly drops almost to zero, the fall occurring, as I have said, within a range not greater than the distance between the D lines. A change of wave-length of 1/1000 is then sufficient to cause the illumination in the spectrum to change from a maximum to a minimum.

The theory of the diffraction-grating, as it stands at the present time, appeared to me to be wholly inadequate to explain this most extraordinary distribution of light, and I accordingly endeavoured to find out if possible the necessary modifications which must be introduced.

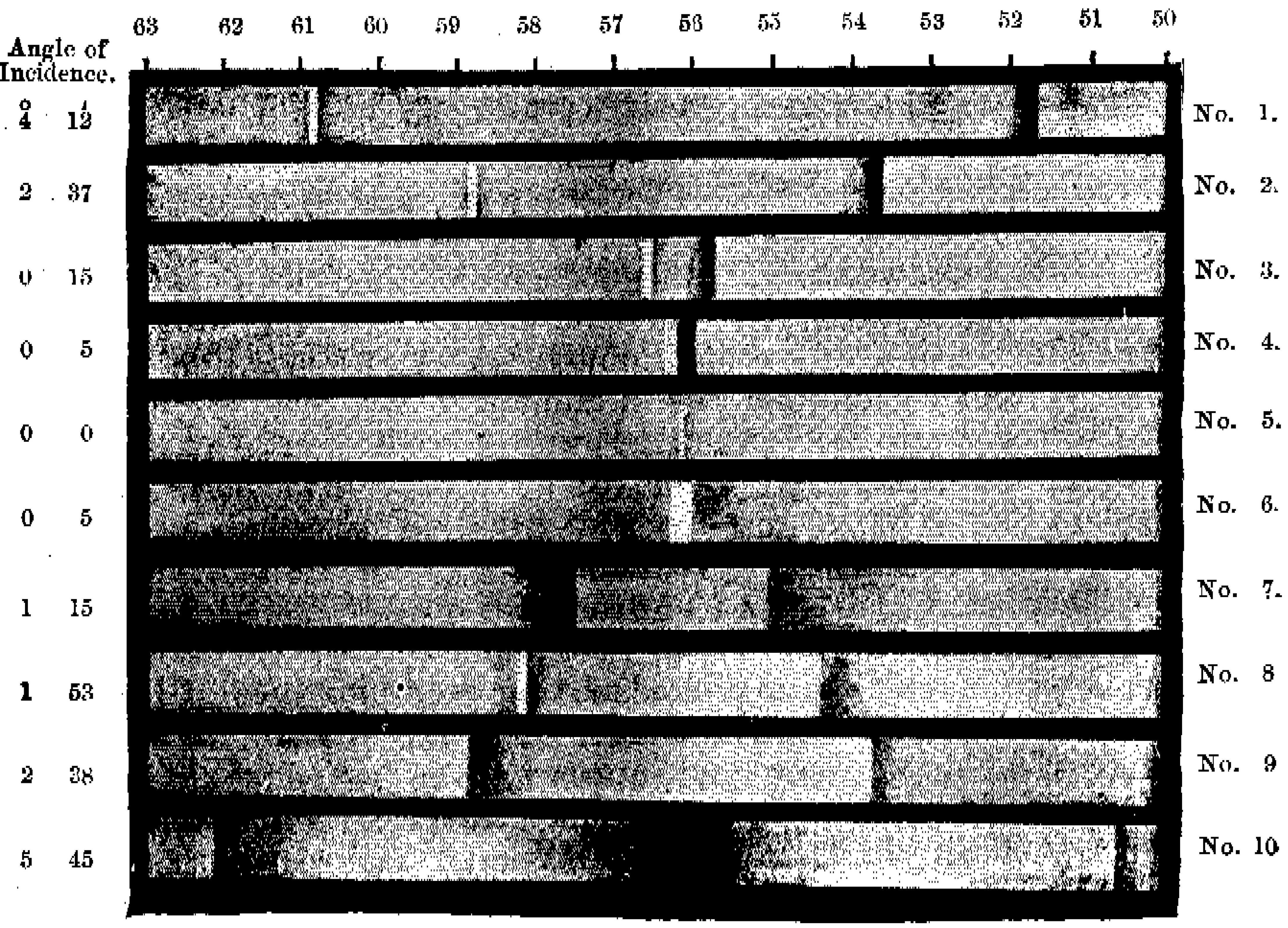
The ordinary theory shows that under certain conditions (square groove and normal incidence for example) the directly reflected light, or central image, may have certain wave-lengths wholly absent and appear strongly coloured in consequence. Coloured central images have been studied experimentally by Quincke, and Rayleigh has treated them theoretically for transmission-gratings, and Rowland for gratings acting by reflexion.

In studying the colours of these central images I have found that when the plane of polarization is parallel to the groove the colour is quite different from what it is when the plane is at right angles to the groove. The polarizing power of gratings has been experimentally investigated by Wien and Rubens, but to the best of my knowledge their experiments were confined to wire gratings, and dealt merely with the amount of light directly transmitted under the two conditions. So far as I know, polarization has never been introduced into the theory of gratings.

It occurred to me that polarization might prove to be the key to the explanation of the very singular behaviour of the grating of which I am writing. Experiment proved this to be the case, for it was found that *the singular anomalies were exhibited only when the direction of vibration (electric vector) was at right angles to the ruling.* On turning the nicol through a right angle all trace of the bright and dark bands disappeared. The bands are naturally much more conspicuous when polarized light is employed.

We will now examine in some detail the appearance of the spectrum at different angles of incidence. In fig. 1 we

Fig. 1.



have the appearance of the spectrum for ten different angles of incidence. The position of the dark and light bands in the spectrum was determined by employing sunlight, and using the Fraunhofer lines as reference-marks. The wave-lengths are indicated at the top of the figure, and the angles of incidence at the left. Beginning with No. 1, we have the

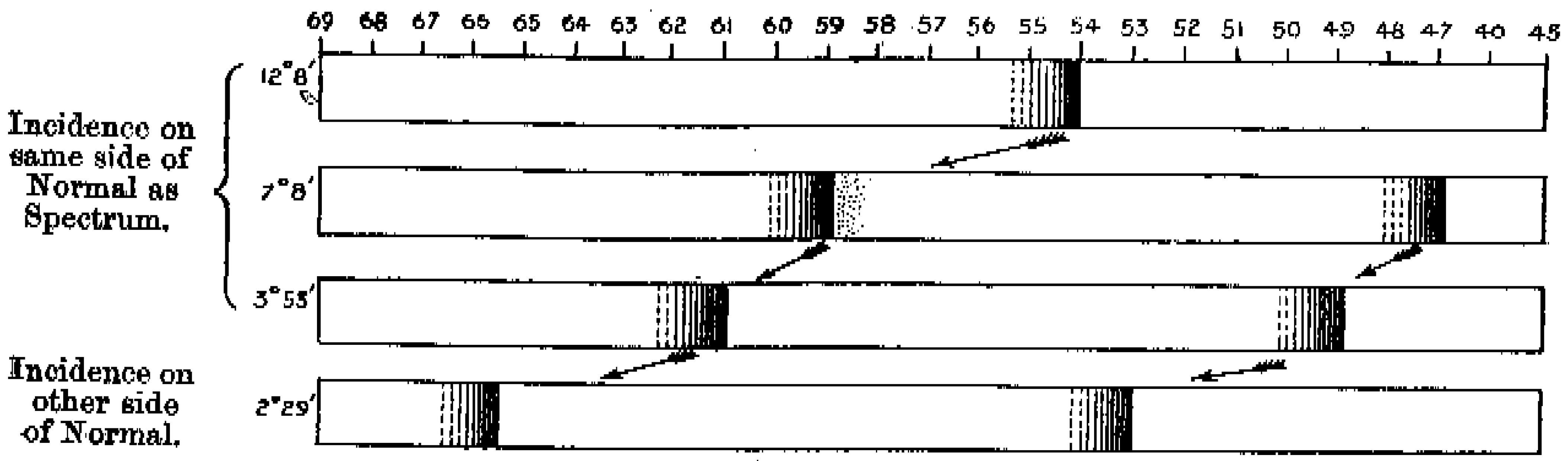
light incident at an angle of 4° 12′ on the same side of the normal as the spectrum. A bright line not much wider than the distance between the D lines appears at wave-length 609, and a dark band at 517: the latter is sharp and black on one side and shades off gradually on the other. On decreasing the angle of incidence to 2° 37′ the bands approach, occupying the positions shown in No. 2.

Numbers 3 and 4 show two subsequent positions, and it will be noticed that the rate of progress along the normal spectrum is the same for each. In No. 4 we have the appearance which I have likened to the line in the spectrum of a Nova.

In No. 5 the incidence is normal and the lines have fused and disappeared. This is not merely an approximation, for I have found that if the grating be turned until the spectrum has this appearance, the light reflected back through the collimator passes through the slit. This furnishes us with a new method for adjusting *a* grating for normal incidence. On passing this position a narrow bright line appears which broadens into a very sharply defined rectangle, appearing, as is shown in No. 6, at an incidence angle of 5′ on the opposite side of the normal from the spectrum. This rectangle broadens as the angle of incidence increases, its edges becoming heavily shaded, as is shown in No. 7, where we have essentially two dark bands retreating from each other at equal rates as the angle of incidence increases. There is nothing especially peculiar about the one which is journeying towards the violet end of the spectrum, but the other behaves in a most singular manner, which could only be fully illustrated by a kinematograph-view of its changes. In No. 7 we find it very sharp and black on the right-hand edge, shading off towards the red end of the spectrum. As it moves along, a shadow appears on its right-hand side, the two shadows being separated, however, by a narrow bright region; the right-hand shadow increases in depth, while the left-hand one clears up, until the band becomes symmetrical, a narrow bright line with a shadow on each side, as is shown in No. 8. On increasing the angle of incidence still further, the inverse of this operation takes place, until in No. 9 the shadow has transferred its position to the right, and appears with a sharp black edge as before only reversed in position. This process of turning inside out of the shadow marks the beginning of another curious event, for, as the reversed shadow travels along towards the red with increasing angle of incidence, an exceedingly black symmetrical band splits off from it and travels down the spectrum in the opposite direction, arriving at the position shown in No. 10, at an incidence angle of 5° 45′. This band is much wider than the others and seems to be absolutely black at the centre, even with a fairly wide slit.

This represents the cycle when the grating is in air. If a piece of plane-parallel glass is cemented to the front of the grating with cedar oil the cycle is quite different. In this case we have a pair of unsymmetrical shaded bands which move in the same direction as the angle of incidence is changed. In fig. 2 I have given the appearance and position

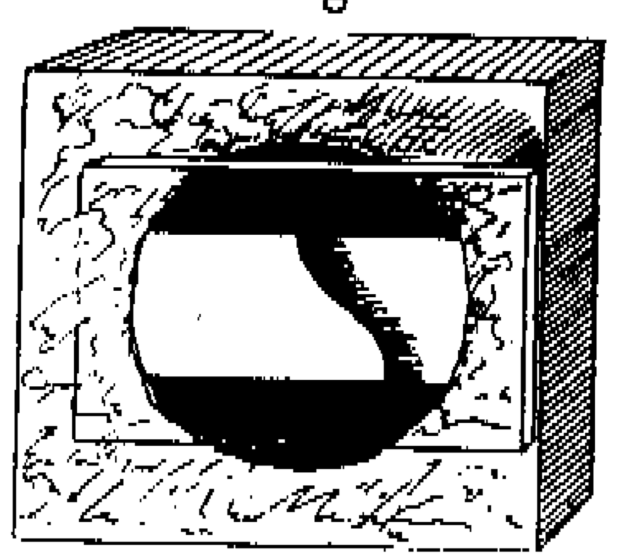
Fig. 2.



of these bands for three different angles of incidence. It will be observed that they remain distinct on passing through the position of perpendicular incidence.

It is impossible to identify these bands with those observed with the grating in air, since the jump in the refractive index of the medium in which the grating is immersed is too great. To determine the effect of increasing the refractive index of the medium on the position of a given band I fastened a plate of glass in front of the grating at a distance of about 0·3 mm. from the ruled surface. Water was introduced between the two, and glycerine applied to the lower edge. The denser fluid gradually diffused up into the water, and I observed the dark bands sharply curved, on looking at the spectrum directly in the grating without the aid of a telescope, the shift being towards the red, as the refractive index increased. The appearance of one of the bands is shown in fig. 3. It will be observed that the shift is in the same direction as when a resonator is immersed in a medium of high dielectric constant, and though there may be no connexion between the two phenomena, it seems perhaps worth while to mention it as there may be something akin to resonance in the action of this grating.

Fig. 3.



It is useless to attempt to fully explain the very complicated sequence of events which I have outlined, until some working hypothesis is established which will explain some one of them, and it appears to me that the first thing to do is to make some assumption which will explain the very remarkable fact that a change of wave-length of one part in a thousand is sufficient to change the illumination from a maximum to a minimum.

We know that this can take place if we are dealing with interference with a large difference of path. Hamy's "extincteur"* is a piece of apparatus which illustrates this better than anything with which I am familiar. It occurred to me that possibly the anomalies were to be referred in some way to the interference between disturbances coming from widely separated lines, though I had no very definite idea as to just how it could produce any of the anomalies, or how it was to be connected with the polarization effect. It seemed worth while, however, to investigate the matter, and I accordingly covered the grating with a thin sheet of black paper, leaving exposed only a strip about 0·3 mm. wide along one edge. By bringing the eye close up to this small strip the spectrum could be distinctly seen, but the sharpness of the dark bands seemed to be undiminished. As there were only about 200 lines acting there could not have been any very considerable difference of path between even the extreme rays. In consequence of this I am compelled to refer the matter to the form of the groove. The important fact which must be taken into account in any endeavour to explain the action of the grating is, that the anomalies only occur when the electric vector lies across the ridge. We can speculate about the action of the narrow ridges on the light waves, assuming, perhaps, something of the nature of resonance taking place across the ridge, or we can seek for the explanation in the behaviour of the transverse vibrations in between the ridges, but in any case we are confronted with the difficulty of explaining the tremendous change in the intensity of the illumination with the exceedingly small change of wave-length.

The study of this grating has been limited to the two or three days immediately preceding the closing of the laboratory for the summer, consequently I have been unable to give a very exhaustive account of its behaviour under other conditions, or secure any very satisfactory photographs of the peculiar spectra. The few photographs which I have taken and which are reproduced, were made on some old orthochromatic plates, without any especial appliances, the plates

* M. Hamy, *Compt. Rend.* cxxv. p. 1092 (1897).

being applied to the end of the spectrometer tube, while the slit was illuminated with a Nernst lamp, which makes the best source of light possible when a continuous spectrum is required. The photographs are interesting as showing the sharpness of the bright and dark bands in the spectrum. I am of the opinion that a study of the colours of the central image with polarized light in the case of this grating may throw some further light on the problem, which is one of the most interesting that I have ever met with.

Baltimore, June 2nd, 1902.

XLIII. *On the Measurement of Young's Modulus.* By W. Cassie, *M.A., Professor of Physics in the Royal Holloway College* *.

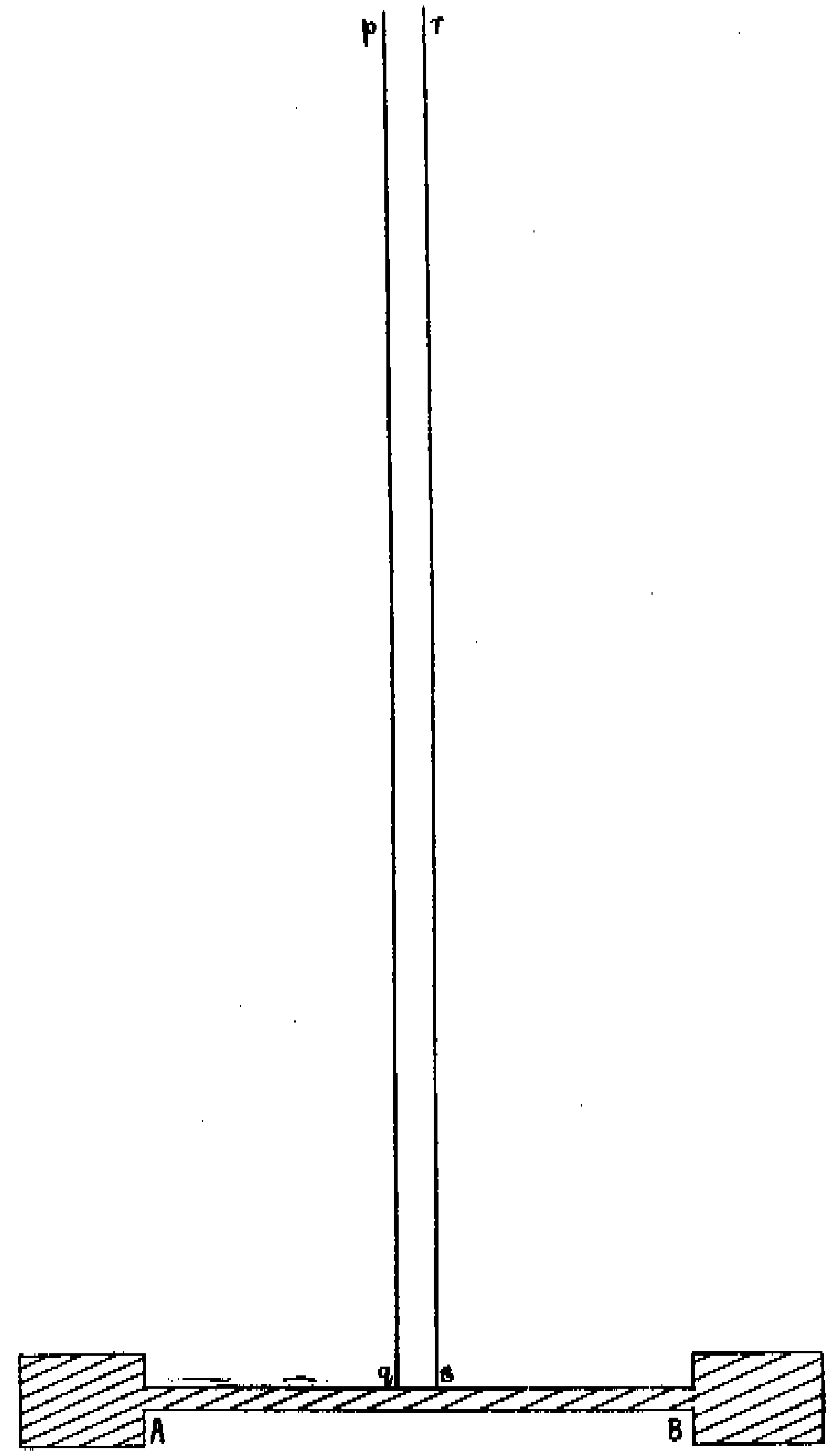
A reliable oscillation method of measuring the stretch modulus ought to have advantages in accuracy and convenience which would give it some practical value. A method depending upon the oscillations of a spiral spring has been given by Prof. L. R. Wilberforce *, and a simplification of that method depending upon flexural vibrations of a straight piece of wire has been given by Mr. G. F. C. Searle †. The apparatus described in the present paper yields an oscillation method which is fairly simple, and it has the additional advantage that without any change of the apparatus a statical measurement of the stretch modulus can also be easily made.

If a horizontal bar AB, fig. 1 (hereafter called the needle), is symmetrically supported by two equal parallel wires *pq*, *rs* it may be made to execute a small oscillation in the plane of the paper about an axis passing through the middle point of *qs* perpendicular to the plane of the paper. This oscillation is accompanied by alternate extension and contraction of the supporting wires, so that the resistance to stretching of these wires controls the oscillation and determines its period. The period of the oscillation for a given pair of wires may be made of any convenient length by altering the moment of inertia of the needle. Some of the dimensions of the apparatus can be eliminated by observing other modes of oscillation of the system, so that in its simplest form the experiment gives an expression for the stretch modulus involving only four periods and the weight of the needle, qnantities which can be measured with ease and accuracy.

* Communicated by the Physical Society: read November 22, 1901.
† Phil. Mag. Oct. 1894. ‡ Ibid. Feb. 1900.

In the statical method a small weight is hung on the needle at a measured distance from the centre. This produces

Fig. 1.



a known difference between the tensions in the wires, and the consequent difference in extension can be measured on a scale by a beam of light reflected from a small mirror attached to the needle. By hanging the mall weight at various distances a series of measurements can be made.

I. First Oscillation Method.

The Needle.—The vibrating needle AB may be conveniently made of a straight bar or tube with a heavy cylinder fixed at each end of the bar by set screws. If these cylinders are hollow, and each made with four set screws placed as shown