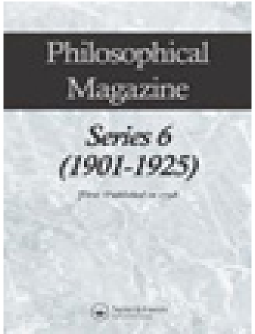

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LV. *Unsymmetrical Diffraction-bands due to a Rectangular Aperture.* By C. V. RAMAN, *Demonstrator in Physics at The Presidency College, Madras**.

WHEN a pencil of monochromatic light coming from a slit in the focal plane of a collimating lens falls upon the object-glass of a telescope in front of which a narrow rectangular aperture is placed with its sides parallel to the luminous slit of the collimator, the diffraction-pattern seen in the focal plane of the telescope consists of a series of bright and dark bands symmetrically arranged on either side of the geometrical image of the slit, provided that the light falls normally upon the aperture. If, on the contrary, the aperture is held inclined to the incident pencil—its sides being still parallel to the slit—the diffraction-pattern is *not* necessarily symmetrical. The symmetry is not, however, *sensibly* departed from, unless the incidence be very oblique. The case in which this unsymmetrical pattern was first seen is this: place a prism on the table of a spectrometer and observe the image formed by the light reflected at very oblique incidence from one of the faces of the prism. With a prism of face-width 4·5 cms. and an incidence of 85°, the diffraction-pattern seen in the field is sensibly symmetrical, and the minima of illumination equidistant from one another. If the incidence is greater than 87°, this is no longer true. The bands are wider on one side of the pattern than on the other, those on the side towards the direct image of the slit being broader. This asymmetry increases greatly as the angle of incidence approaches 90°, and at the same time the number of bands on one side of the pattern—the side where they are broader—becomes smaller and smaller till at last they disappear altogether.

The facts can be explained quite easily. Let a be the width of the face of the prism and λ the wave-length of the light, and $\frac{\pi}{2}-\theta$ the angle of incidence. Then, in any direction making an angle $\frac{\pi}{2}-\phi$ with the normal to the face of the prism, there is no illumination provided

$$a(\cos\theta-\cos\phi)=\pm n\lambda, \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where n is any whole number.

If $n=0$, $\theta=\phi$, and we have the position of the light

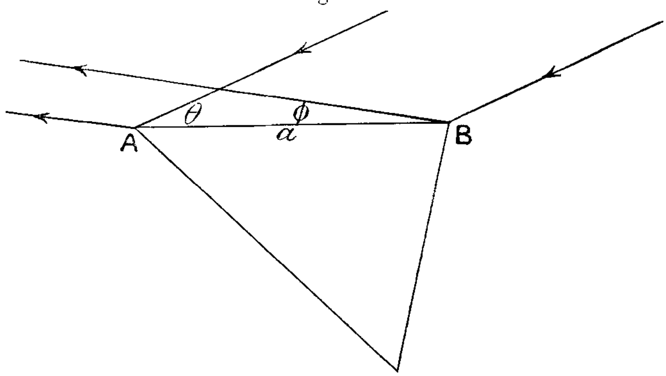
* Communicated by the Author.

reflected according to the usual law. If θ is not small,

$$2a \sin\frac{\theta+\phi}{2}\sin\frac{\phi-\theta}{2} = \pm n\lambda$$

$$\phi-\theta = \pm\frac{n\lambda}{a\sin\theta}; \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Fig. 1.



and the diffraction-pattern is identical with that produced by the effective aperture of the prism-face, and is symmetrical. If θ is small, (2) is no longer true, and a reference to the Tables shows that if the angle is small, for equal increments of its cosine, the increments of the angle are large and by no means equal. This shows that the bands are fairly broad, and that the minima are not at equal angular distances from one another.

I give this example worked out from the following data :—

$$a=3 \text{ cms.} \quad \lambda=7000 \text{ A.U.} \quad \theta=1^\circ\ 9'.$$

Angular Distance from

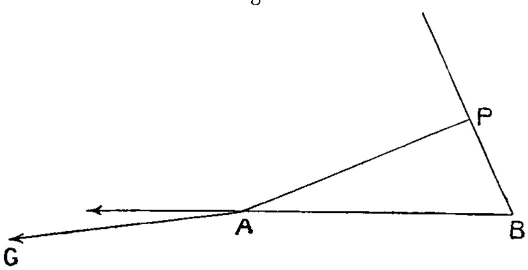
The 4th minimum to the 3rd	202″
3rd „ to the 2nd	212″
2nd „ to the 1st	223″
1st „ to the central band ...	233″
Central band to the 1st minimum	247″
1st minimum to the 2nd	266″
2nd „ to the 3rd	287″
3rd „ to the 4th	311″

Further, the smallest value of ϕ admissible is zero. There is therefore a limit to the number of bands possible on one side of the pattern. There can be one or two or more, the number being the greatest integer in

$$\frac{a(1-\cos\theta)}{\lambda}.$$

This fact can be put in another way. If AB be the face of the prism and BP the incident wave-front, the limit to the

Fig. 2.



diffraction-pattern is set by the direction BA, for points on the surface AB obviously cannot send out wavelets in the direction AG.

Measurements were made on the diffraction-pattern by means of a micrometer, in order to test the theory. The measurements given below were made at an incidence where the asymmetry was not very marked yet sufficient to be easily seen.

$a=4{\cdot}57$ cms. $\lambda=6500$ A.U. $\theta=1^\circ\ 24'\ 55''$.

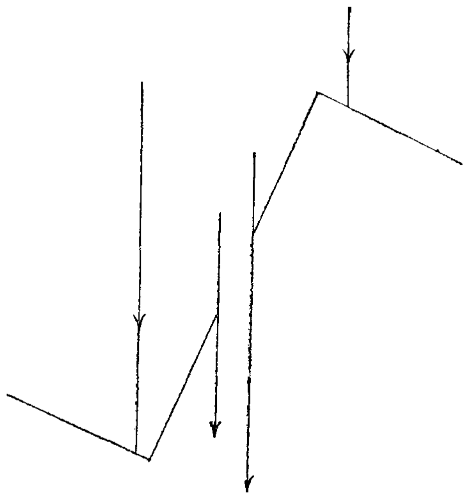
Angular Distance from	Observed.	Calculated.
The 5th minimum to the 4th	110″	108″
4th „ to the 3rd	105″	110″
3rd „ to the 2nd	111″	113″
2nd „ to the 1st	118″	115″
1st minimum on one side to the 1st on the other	234″	237″
1st „ to the 2nd	125″	123″
2nd „ to the 3rd	127″	126″
3rd „ to the 4th	132″	130″
4th „ to the 5th	132″	134″

For the same angle of incidence and with approximately homogeneous light of mean wave-length 7100, the observed width of the central band was $261''\pm2''$, the calculated value being $260''$. Theory and observation agree as to the number of bands on one side of the pattern, if it is not more than six or seven.

The facts described above suggest that by holding a fairly wide rectangular aperture very obliquely in the pencil of light, we should get an identical system of diffraction-fringes.

This was verified by experiment. An aperture 2 cms. wide was cut in a thin sheet of zinc, which was then bent into the shape

Fig. 3.



shown (fig. 3). The side-vanes served to cut off the light from the other portions of the collimator and to support the sheet on the table of the spectrometer. It was found that the diffraction-bands were sensibly symmetrical when the incidence was moderate, and asymmetrical when it approached 90°. The minima in this case are of course given by the usual equation

$$a(\cos\theta-\cos\phi)=\pm n\lambda.$$

The angle θ could not be measured; only the relative positions of the bands could be determined. The table gives some measurements.

$a=2$ cms. $\lambda=6500$ A.U. θ unknown.

From	
The 2nd minimum to the 1st	306″
1st ,, to the central band	322″
Central band to the 1st	364″
1st minimum to the 2nd	422″

The intensity of illumination at any point of the diffraction-pattern is given by the expression

$$\mathrm{I}\,\frac{\sin^2\dfrac{\pi a}{\lambda}(\cos\theta-\cos\phi)}{\left\{\dfrac{\pi a}{\lambda}(\cos\theta-\cos\phi)\right\}^2}.$$

It is perhaps worth noting that Bridge's Theorems do not hold for this unsymmetrical system ; *i. e.*, the scale as well as the relative distribution of the maxima and minima in the unsymmetrical pattern is altered by altering the width of the face of the prism or the wave-length of the light, the incidence being constant. If, however, the ratio $\frac{a}{\lambda}$ is kept unchanged, the diffraction-pattern is not altered.

The experiments and observations recorded in this note were made at the Presidency College Physical Laboratory.

LVI. *Remarks on Professor Jeans' Article "On the Thermodynamical Theory of Radiation."* *By* L. B. Tuckerman, Jr.

IN the July number of this Magazine*, Professor Jeans has a short article on the "Thermodynamical Theory of Radiation," in which he draws conclusions which do not seem to me to be justified. He says: "Since, however, σT^4 is to be the amount of energy per unit volume, the physical dimensions of σ are known.

"The thermodynamical argument by which, in this first theory, the formula σT^4 is reached, is concerned only with phenomena taking place in the æther. Thus we should naturally expect that it would be possible to evaluate σ in terms of quantities which measure the properties of the æther."

That, however, is not the case, as the dimensions of σ are dependent also on the dimensions of T, a quantity which is and can be defined only in terms of the properties of matter, and in fact in terms of properties which are common to all matter.

If, then, the second method mentioned by Professor Jeans gives us a valid relation between σ and e (the charge of an electron) which enables us to evaluate e in terms of σ and *vice versa*, this relation does not in the least invalidate the derivation by means of the "Thermodynamical Theory of Radiation," but merely adds another universal constant to those already thermodynamically deduced.

The apparent paradox obtained by assuming an "ideal" matter, with electrons bearing the charge $\frac{1}{2}e$, is therefore no more and no less fatal an objection to the thermodynamics of radiation, than the paradox obtained by assuming an "ideal" fluid for which Clapeyron's formula does not hold, is to the thermodynamics of ordinary matter.

Berlin, Physikalisches Institut,
July 30, 1906.

* Phil. Mag. 1906, vol. xii. no. 67, pp. 57-60.