tically eliminated by making the observations on a bright, clear day at a high-level station, and the self-illumination of the sky under the same conditions is very small in respect of wave-lengths near the extreme red end of the spectrum. The residual effect of self-illumination in these circumstances may be computed with sufficient accuracy by the method used by L. V. King (Phil. Trans. Roy. Soc., A, vol. 212, 1913), the uncertainties due to the neglect of the curvature of the earth and other simplifying assumptions in the calculation being then of little importance.

In order to obtain material for testing these ideas I made observations on the forenoon of December 4 last from the summit of Mount Dodabetta, in the Nilgiris (8750 ft. above sea-level), the sky at the time appearing beautifully clear, free from cirrus clouds, and almost completely black when seen through a deep red filter. The weaker component of polarisation was found to have 13 per cent. of the intensity of the stronger component. Diffuse illumination of the sky is capable of explaining only a part of this, a weaker component of about 8 per cent. intensity being indicated by the calculations. The residual 5 per cent. must therefore be ascribed to molecular anisotropy, and this is in agreement with the laboratory determinations of Rayleigh.

Observations on the molecular scattering of light in liquids made by the writer also show an imperfect polarisation attributable to anisotropy. Experiments in the same direction on the atomic scattering of light in crystals are being made, and an attempt is also in progress to discover the existence of an effect indicated by Sir J. J. Thomson's theory (Phil. Mag., October, 1920), namely, the dependence of the results on the frequency of the scattered radiation.

C. V. RAMAN.

210 Bowbazaar Street, Calcutta, December 19.

The Resonance Theory of Hearing.

MAY I reply to Dr. Perrett's letter (NATURE, December 29 last), in which he makes the objection to the resonance hypothesis that it does not explain how we perceive when there are two tones of the same pitch sounding simultaneously?

It seems to me that Dr. Perrett has made two slight errors:—

(1) There must be, he writes, one result, unique and without alternative, when the tracing of the combined wave-form of any two notes of the same frequency is submitted to Fourier analysis.

But surely this cannot be true; for example, if in one case the two tones are 256 vibrations per sec. from an oboe and a flute simultaneously sounded, the relative amplitudes of the overtones found by Fourier analysis would be quite different from those found for the same tone sounded simultaneously on a violin and a cornet. Not only would the amplitudes of the overtones differ in the two cases relatively to the fundamentals, but they would differ also relatively to one another.

(2) Dr. Perrett proceeds: "If the ear acts as a kind of practical Fourier's theorem, it can perceive only one fundamental tone. But we invariably judge of the pitch of a note by its fundamental tone. If, then, we hear at the same time two notes of pitch n , the ear must be able to perceive also at the same time two fundamental tones of frequency n —that is to say, it must be able to perform an analysis which is not in accordance with Fourier's theorem."

Surely Dr. Perrett has omitted in the above reasoning to take into account the existence of beats, overtones, and phases. If these did not exist, and if

the ear could still tell whether one or more than one instrument were contributing to a tone, then the resonance theory would have met with a serious difficulty. But overtones do exist, and they are known to differ for different instruments, also for one instrument in different circumstances, e.g. the human voice when sounding various vowels. The resonance theory, in that it explains the perception of overtones, even when their intensity compared with the fundamental is small, also explains how we can tell whether two different instruments are contributing to a tone or one only. But there are other clues; for besides that given by overtones, which in accordance with the resonance hypothesis the ear might make use of, viz. (a) if there were beats, due to the two instruments not being exactly in tune, the observer might infer that two were sounding, and not one; (b) if the sound-waves from one instrument reached the observer's right ear a little earlier (or later) than they reached his left, whereas those from the other instrument had different time relationships, he might infer that there were two sources of sound, from the observation that the two sources did not occupy the same position relative to his own plane of symmetry; and (c) if the sounds from the two instruments did not begin and end together the observer might get information from this also. All these possible methods of observation are compatible with the resonance theory, and therefore it is quite unnecessary to assume that the ear must be able to perform an analysis which is not in accordance with Fourier's theorem. It seems to me, therefore, that Dr. Perrett's objection must fail on all the above grounds.

May I take this opportunity of describing a fresh piece of evidence in favour of the resonance theory? Helmholtz showed, from physical considerations, that the coefficient of "sharpness of tuning" should be inversely proportional to the "persistence" coefficient in the case of resonators responding to tones of different pitch. This relationship does not postulate any special form of resonator, but appears to be a general rule equally as applicable to an electrical oscillating circuit as to a stretched string. If, then, it could be shown that the ear obeys this rule, it would be presumably very strong evidence indeed for the existence of resonators in the cochlea. The following table, calculated from observations by Mayer (published in *Amer. Journ. Sci.*, January, 1894), shows that the necessary evidence exists:—

A	B	C	B x C
Mean tone in vibs. per sec.	Per cent. difference of tone required to stop dissonance (tuning factor)	No. of vibrations performed during a subliminal silent interval (persistence factor)	Tuning factor multiplied by persistence factor.
128	12.70	1.78	22.6
256	10.00	2.06	20.6
320	9.45	2.19	20.8
384	9.07	2.18	19.8
512	8.45	2.37	20.0
640	8.15	2.54	20.7
760	7.82	2.68	21.0
1024	7.22	3.01	21.7

Since multiplying tuning factor by persistence factor gives values nearly constant for different resonators (the average error is less than 3 per cent.), as shown in the last column in the above table, the tuning coefficient must be very nearly inversely proportional to the persistence coefficient. That is, the ear behaves quantitatively as it ought to do if it contained resonators.

I find a correction is necessary in my letter to NATURE of January 5. "Tide production" on line 20 should read "tide prediction."

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