Change of Frequency of a Light Wave by the Variation of its Optical Path

THE time t' at which B receives the wave sent from A at time t is related to t by

$$t' = t + \frac{\Sigma\mu l}{c},$$

where c/μ is the velocity of the wave in a medium of refractive index μ and length l through which the wave travels.

Therefore,

$$dt' = dt + \frac{d}{dt}\left(\frac{\Sigma\mu l}{c}\right)dt,$$

or the frequency,

$$\nu' = \frac{\nu_0 dt}{dt'} = \frac{\nu_0}{1 + \frac{d}{dt}\left(\frac{\Sigma\mu l}{c}\right)} \doteq \nu_0\left(1 - \frac{d}{dt}\frac{\Sigma\mu l}{c}\right), \quad (1)$$

where ν_0 is the original frequency.

The change of frequency can be obtained either through the rate of change of μ or through the rate of change of l. The latter is identical with the Doppler effect if $\mu = 1$. Thus, in any interference experiment of light, the motion of interference fringes by changing the optical path of one of the two interference beams is equivalent to light-beats. The changes of frequency of the diffracted and the directly transmitted light by a progressive ultra-sonic wave might be better understood by considering relation (1).

Relation (1), when applied to material waves, gives interesting confirmation of the relation $E = h\nu$.

Careful considerations show that relation (1) represents only one kind of change of energy of photons, this being of the work done against a force due to the rate of changing linear momentum of photons. The general principle of the change of frequency of a wave should be expressed as:

$$\nu' - \nu_0 = -\frac{1}{2\pi}\frac{d\Phi}{dt}, \quad . \quad . \quad . \quad (2)$$

where $\frac{d\Phi}{dt}$ is the rate of change of the phase of the wave.

By applying this general principle, another important case of the change of frequency of the light wave, namely, the change of frequency due to the rotation of a doubly refractive medium through which the light passes, can be explained. On resolving analytically the emergent waves into circularly polarized components and examining the variation of phase in each component, the changes of frequency are readily shown to be 0, $-2N$ and $+2N$, N being the number of rotations per second. The relative amounts of light having these respective frequency changes depend on the length of light-path in the medium, the state of polarization of the incident light and the angles which the axis of rotation makes with the optical axis and the direction of the incident light. This case represents the second kind of change of energy of photons, and relates to work done against a torque exerted on the medium by the turned-over photons as defined by Atkinson[1].

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[1] Atkinson, *Phys. Rev.*, **47**, 623 (1935).

Seismic Sea-Wave of November 27, 1945

THE Chief Meteorological Officer, Royal Air Force, East Africa, has reported an interesting tidal irregularity observed by Captain A. Sauvage, port officer at Port Victoria, Mahé, Seychelles, on November 28, 1945, at about 10 a.m. local time. It appears that while the normal water-level corresponding with the state of tide at this time was 1·5 in., the level observed at 9 hr. 47 min. a.m. was 12 in. The water then rose to 18 in. at 9 hr. 52 min., dropped to 0 at 10 hr. 5 min. and rose again to 14·5 in. at 10 hr. 13 min. a.m.

This tidal irregularity was almost certainly associated with the major earthquake which occurred some hours earlier in the Arabian Sea[1]. The seismograph records at Kew Observatory, Richmond, showed the first pulse for this earthquake on November 27, 1945, at 22 hr. 6 min. 22 sec. G.M.T., the maximum phase at 22 hr. 40 min. 45 sec. (ground movement at Richmond nearly 2 mm.), and the end at 2 hr. 30 min. on November 28. The analysis of the Kew Observatory records gave a distance of about 6,100 km., and the combination of the results from other seismological stations determined the epicentre as at lat. 25° N. and long. 62·2° E., with a time of origin at 21 hr. 57 min. 0 sec. G.M.T. This is 7 hr. 55 min. before the first peak (5 hr. 52 min. G.M.T.) of the 'tidal wave' was observed at the Seychelles.

As the distance of Mahé from the epicentre is 3,300 km., this gives an average speed v of the sea-wave of about 116 m./sec. and from this we can calculate the average depth H of ocean traversed to be about 1·3 km. If the peak of the tidal wave observed at 10 hr. 13 min. is taken as representing the second crest of the seismic sea-wave, the time interval of 21 min. between the two crests leads to a wave-length for this wave of $L = 146$ km.

Those values of v, H and L are substantially smaller than the values deduced from other recorded cases of seismic sea-waves. Gutenberg[2] gives four cases where $v = 169$–208 m./sec., and refers to $L = 150$–500 km. as typical wave-lengths.

Now the estimate from eight approximately equidistant soundings gives the actual depth of ocean traversed as about 3·5 km., and, reversing the procedure, this leads to a speed of the seismic sea-wave of 187 m./sec. With this speed the wave would travel the 3,300 km. to the Seychelles in 4 hr. 53 min., so that on this basis of reckoning the first wave should have arrived at 2 hr. 50 min. G.M.T. (6 hr. 50 min. local time) on November 28. The first tidal observation was made at 9 hr. 47 min. local time, but it was then noted that tidal-levels were well above their normal value, suggesting that an earlier wave may indeed have arrived by that time.

Using the 21-min. interval between the two observed crests and the 9-cm. decrease in amplitude, we may conclude that the first observed crest was the eighth in the train, and that the first crest arrived with an amplitude of about 0·7 m. above normal. This agrees well with the order of magnitude given by Gutenberg[3] for large seismic waves in the open sea. Both the velocity (187 m./sec.) and the corresponding wave-length (236 km.) are also well within the range of values quoted above for similar phenomena.

Remembering that about 100,000 seismic disturbances are experienced every year, it is of interest to add that the earthquake which caused this tidal wave was among the twelve most violent shocks experienced in the past forty years[4]. It was of the same order of magnitude as the earthquake which destroyed San Francisco on April 18, 1906. The same communication by Rothé directs attention to the fact that E. Suess in 1883 postulated a large sea-wave originating in about the same region as the earthquake of November 28, 1945, as being responsible for the Deluge. This notion was sceptically received, because there was no observational evidence of any seismic sea-waves ever having occurred in this region.

We are indebted to the Director of the Meteorological Office for permission to communicate this note.

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[1] *Nature*, **156**, 712 (1945).
[2] "Handb. d. Geophysik", **4**, 668 (1932).
[3] *l.c.*, p. 667.
[4] Rothé, J. P., *C.R. Acad. Sci. Paris*, **222**, 301 (1946).

Japanese Men of Science in Malaya during Japanese Occupation

THE circumstances of the publication of C. F. Symington's "Foresters' Manual of Dipterocarps", recently reviewed in *Nature*[1], are known to very few persons, but they are interesting enough to be recorded in detail. The Manual was issued from Raffles' Museum, Singapore (Syonan Hakubutukan), towards the end of 1943 and was on sale solely for *bona fide* men of science. At that time, the Japanese Military Administration and the Syonan (Singapore) Municipality were endeavouring harder than ever to stamp out all traces of the British, even their language. That the Manual was published, and that there was a stock of some 280 copies for the British in September 1945, we owe to the far-sightedness, influence and discretion of a few Japanese men of science.

The acting director at Raffles' Museum in 1942 was Prof. Hidezo Tanakadate, of Tohoku Imperial University, Sendai. He obtained the temporary release of Mr. H. E. Desch, of the Malayan Forestry Service, from the Changi Military Camp and, at the end of June, took Mr. Desch to Kuala Lumpur, where he found the galley-proof of the Manual. It was decided to publish the work (500 copies) on the ground that it would be more likely to survive the War in that way than as a single galley-proof, for the whereabouts of Mr. Symington and his manuscript were unknown. The cost of printing was met personally by Prof. Tanakadate and by Marquis Yositika Tokugawa, who acted as president of the Museum and Library. It was insisted by Prof. Tanakadate that the book should conform exactly with the previous series of *Malayan Forest Records*, of which it is No. 16, so that it should stand the test of time, as a scientific work, regardless of hostilities and racial prejudice. He therefore added a brief preface, as a single page of romanized Japanese, and he issued the Manual from the Museum to give it official standing and to prevent pilfering of the stock by what he called 'common people'.

The proofs were read mainly by Mr. Desch, even after his return to the Military Camp in January 1943. The Japanese officers who succeeded Prof. Tanakadate, namely, Prof. Kwan Koriba and Dr. Y. Haneda, took the proofs personally to the camp and fetched them again on correction. As the printing was continued by the Caxton Press in Kuala Lumpur, great care had to be taken in sending the proofs from Singapore, for there was a very strict censorship and the post was unreliable. Japanese staff officers travelling to and fro carried them personally, while duplicates were kept at the Singapore Botanic Gardens. The co-operation of military officers was possible only because they were known personally to the professors as students or colleagues.

Similar action was taken by Dr. Koga, the director of the Tokyo Zoological Gardens, in publishing M. W. F. Tweedie's "Poisonous Animals of Malaya", which was rescued from the broken and looted premises of the Methodist Publishing House in Singapore. A large remainder is also at Raffles' Museum.

In the interest of science, one must distinguish carefully between the 'Japanese' of popular conception and the Japanese men of science, who in Malaya, at least, endeavoured to serve science with impartiality.

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[1] *Nature*, **157**, 671 (1946).