The belief, which Sir Frederic seems to approve, that thinking is "tied up with the solution of problems" may be seriously questioned. It does not appear to be necessary for Sir Frederic's proposals and it is a pity that he has not criticized it. The cliché—so often met in the American text-books—that "thinking is problem-solving" overlooks the fundamental portion of our thinking which has to do with the detection or identification of problems. The very word 'problem' is hard to pin down to any useful meaning, and in much of our thinking we are groping to find out *what* needs to be done rather than *how* it needs to be done.

Whenever we consider experiments in psychology, we should see them in perspective and recognize that there are other methods just as important. Without in any way diminishing the value of Sir Frederic's suggestions about thought and skill, we have to bear in mind that most illuminating insights into thinking have come from men gifted with an intuitive understanding of their own mental life, from novelists and poets like Proust and Keats, as well as from men of science and mathematicians like Helmholtz, Poincaré, Graham Wallas and Hadamard. Above all, we are indebted to Freud for a far-reaching conception of thought which is at once biological in character and based on profound clinical observation. The scope of the psychology of thought must cover the developmental sequence of mental growth, pathological thought, as well as comparative studies in different cultures. In these spheres, it is vital to supplement experiment with other methods of inquiry. Sir Frederic's proposed experiments are drawn from his interest in skill. A full programme of experimental inquiry into thinking must be founded upon a deep understanding of the characteristic features of thought during the period of development, of non-conscious thought structures, of the psychopathology of thought and of social and cultural influences on thinking. JOHN COHEN

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A NEW ÆTHER-DRIFT EXPERIMENT

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THE special theory of relativity is so well established by indirect evidence that the significance of the original æther-drift experiments has decreased, and the experimental discrepancies in the results obtained have caused few misgivings. Such discrepancies should, however, be examined if further developments in experimental technique enable new and possibly more precise methods to be employed.

The possibility of performing an experiment similar to that of Michelson and Morley but using short radio waves in place of light waves has been discussed in several letters in *Nature*[1–4], and the experiment outlined in one of these[2] has now been completed at the National Physical Laboratory.

A cylindrical cavity resonator of length 16·866 cm. and diameter 8·075 cm. was used to control the frequency of an oscillator at approximately 9,200 Mc./s. The resonator was mounted with its axis horizontal and was rotated continuously in a horizontal plane at a rate of about one turn per minute, the frequency of the oscillator being measured by comparison with a quartz standard at intervals of 45° during the rotation.

The theory of the method may be described in the following way in order to bring out the points of similarity to the optical method. The cavity resonates when its length is a whole number of half-wave-lengths and the resonant frequency is given by:

$$f = \frac{v}{\lambda} = \frac{nv}{2l}$$

where v is the phase velocity, λ the wave-length, l the length of the resonator and n the number of half-wave-lengths. In this condition the time taken for the phase of the wave to travel to and fro between the end faces of the resonator is $1/f$. If now because of the earth's orbital motion a relative velocity q be postulated between the resonator walls and the medium of propagation within it, then just as in the optical case, this time becomes:

$$t_1 = \frac{2l}{nv}\left(1 + \frac{q^2}{v^2}\right)$$

when the axis of the resonator is in line with the orbital motion, and:

$$t_2 = \frac{2l}{nv}\left(1 + \frac{1}{2}\frac{q^2}{v^2}\right)$$

when it is at right angles to it. The resonant frequency and therefore the frequency of the controlled oscillator should thus vary by a fractional amount of $q^2/2v^2$ on rotation, there being two minima and two maxima for a complete rotation of 360°.

In the optical experiment, interference fringes are formed between two beams of light which have followed paths at right angles to each other. On rotation of the interferometer through 90°, the positions of the paths are interchanged and the difference in transit time is reversed, giving a fractional change of q^2/v^2 which is observed as a fringe displacement. Another difference from the present experiment is that whereas the phase velocity of the light waves is very nearly equal to the free space value c, it is greater than c for the radio waves and depends on the diameter of the cylinder in which the waves are travelling. The calculated frequency-change is accordingly only 3 parts in 10^9 for the resonator and frequency employed if the earth's orbital velocity is taken as 30 km./s., while the corresponding fractional time change in the optical method is 1 part in 10^8.

The results obtained are summarized in Table 1, which gives the average of each set of observations reduced to a convenient form by a correction for linear drift and the subtraction of a constant term.

In the last column is given the amplitude of the second harmonic periodic term as determined by harmonic analysis. The figures in the last line are obtained by averaging the observations for every rotation and not by averaging the mean figures given above. The averaging is permissible because the

Table 1. Variation of Frequency with Rotation of the Cavity Resonator
Date of measurement, December 3–15, 1954. Unit, 1 c./s. (1·09 parts in 10^{10})

No. of rotations	Deviation of resonator frequency from the reference value at orientation								Amplitude of 2nd harmonic term
	0°	45°	90°	135°	180°	225°	270°	315°	
12	9·1	41·8	59·7	60·9	36·1	0·8	−16·5	−22·2	0·55
7	1·2	22·2	45·6	37·7	18·8	10·0	− 6·3	−12·6	2·5
12	2·5	32·3	57·8	43·5	24·2	− 6·3	−30·4	−24·9	0·8
22	9·6	18·0	19·6	13·6	9·7	4·6	− 5·7	− 0·8	1·2
15	6·7	47·2	67·8	49·4	20·4	−31·0	−42·4	−22·4	1·4
22	6·5	33·5	47·8	42·6	9·0	−28·9	−38·5	−27·0	1·6
14	5·8	36·2	52·6	42·0	7·8	−25·0	−40·6	−30·4	0·2
14	−1·6	3·7	4·6	6·8	2·9	− 3·0	− 6·2	− 5·7	0·4
Total 118	0·9	23·3	36·9	29·3	9·4	−15·5	−27·4	−20·9	0·1

Table 2. Variation of Frequency with Rotation of the Cavity Resonator, Individual Observations
Unit, 1 c./s. (1·09 parts in 10^{10})

No. of rotation	Deviation of resonator frequency from the reference value at orientation							
	0°	45°	90°	135°	180°	225°	270°	315°
1	− 19·0	10·5	17·0	18·5	13·0	6·5	0	− 25·5
2	5·5	28·6	11·7	− 0·2	4·0	− 9·9	− 23·8	− 11·2
3	5·0	10·5	6·0	1·5	− 3·0	− 7·5	− 12·0	− 6·5
4	− 19·0	− 6·7	13·6	29·8	18·0	8·3	4·5	− 27·2
5	5·0	5·0	− 5·0	− 10·0	− 15·0	0	5·0	10·0
6	5·5	4·5	3·5	2·5	− 1·5	− 9·5	− 5·5	3·5
7	− 3·0	0·1	3·2	21·3	− 0·6	− 7·4	− 4·3	− 1·2
8	− 1·0	− 3·5	4·0	− 4·5	− 6·0	− 3·5	− 1·0	− 3·5
9	− 10·0	− 10·0	− 5·0	0	10·0	15·0	5·0	0
10	− 5·0	− 8·1	3·8	0·7	7·6	4·4	1·3	− 1·8
11	− 1·0	7·1	5·2	8·3	11·4	− 0·4	− 12·3	− 14·2
12	− 5·0	5·6	11·2	11·8	17·1	− 6·8	− 20·2	− 15·6
13	18·0	− 0·1	− 16·2	3·7	0·5	− 7·6	− 10·8	1·1
14	2·0	8·9	10·8	12·7	− 15·5	− 23·6	− 11·8	12·0
Average	− 1·6	3·7	4·6	6·8	2·9	− 3·0	− 6·2	− 5·7

observations were all made at about the same time of day. It will be noticed that there is a much larger periodic variation, having one maximum and one minimum per rotation. This was found to be due to a tilt of the turntable and was difficult to remove for reasons explained later. It was least in the last set of measurements, and the individual observations for this set (again corrected for linear drift) are given in Table 2 to illustrate the precision of measurement achieved.

The experiment was performed with existing apparatus and was completed within a few weeks of its assembly. Some of the practical difficulties that were met could probably have been overcome by the construction of special equipment, but others were of a more fundamental nature.

The cavity resonator was made of invar to secure the low temperature coefficient required in its original application[5], and preliminary tests were therefore made to determine the effect of magnetostriction on the oscillator frequency. The changes of frequency observed on applying magnetic field-strengths between 1 and 10 gauss suggested that the earth's field would produce a periodic change with rotation of about $\pm 2 \times 10^{-11}$, and this could account for the second harmonic term in the results given in Tables 1 and 2.

The turntable, which was adapted from the base of a fatigue testing machine by Messrs. H. L. Cox and N. B. Owen, carried the whole apparatus, including the resonator, the oscillator control circuits and the frequency standard, weighing altogether approximately 5 cwt. It was mounted on rollers and driven through a reduction gear by an electric motor; and a certain amount of gear vibration and non-uniform acceleration was detected. The effect of the vibration was reduced by mounting the oscillator on sponge rubber, but this accentuated the effect due to a tilt of the turntable to which reference has already been made.

The principal practical difficulty was, however, the adjustment of the oscillator to have the necessary small band-width and stability. Under the conditions accepted for observations, the band-width was such that a single comparison of frequencies in terms of the standard could be made with a precision of $\pm$ 1 part in 10^{10}; but when the apparatus was rotating, this condition was not maintained for very long. If the stability of the oscillator could be increased, it might be worth while repeating the experiment with an improved turntable and with the magnetostriction effect eliminated by screening or by using a cavity resonator of different material.

It may be of interest to recall the most recent optical results. In the precise determination made by Joos[6], the interference fringes were measured by a microphotometer and it was concluded that there was a null result to $\pm$ 0·001 fringe or 0·3 per cent of the expected displacement. Miller[7], however, who carried out the most extended measurements, was critical of this result and afterwards published a paper in which he persisted in his view that there is a definite effect of about 8 per cent of that anticipated. The present experiment suggests that Miller's conclusions cannot be accepted; the effect, if any, is shown to be not more than one-tenth of that reported by him, which must probably be ascribed to some systematic error[8].

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