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HARWELL EXPERIMENT TO MEASURE THE GRAVITATIONAL RED SHIFT

ONE of the results which follows from Einstein's general theory of relativity concerns the frequency of emission of light—or other electromagnetic radiations—by atoms situated in different gravitational fields. According to the theory a characteristic radiation involving two atomic energy states should have a lower frequency when the radiating atom is, for example, on the sun than when it is on the earth. It may be looked upon that the radiated photon ($h\nu$), in escaping from the greater gravitational forces of the sun, loses more energy than it does on the earth, where the gravitational force is comparatively weak, and thus appears to have a lower frequency or a longer wavelength. This gravitational red shift amounts to $\Delta\lambda/\lambda = 2\cdot12 \times 10^{-6}$ for the sun, where the gravity is 27·6 times as great as it is on the earth. For the dense white star, the companion of Sirius, the shift is about 30 times as great.

The difficulties involved in the astronomical methods of testing the predictions of the theory are well known. During the last two years methods have been devised to test the theory by "red shift" experiments carried out on the earth itself, say, between two fixed points at different gravitational potential. In such a trial it is obvious that because of the extremely small magnitude of the shift, nothing but an experiment of extraordinary precision and sensitivity may be expected to yield any fruitful result. The ingenious method suggested by Pound and Rebka of Harvard University is based on the recently discovered Mössbauer effect concerning the resonance absorption of gamma rays by atomic nuclei (see p. 85). As pointed out in that article any characteristic gamma radiation from a radioactive nucleus does not emerge with the indefinitely precise frequency, determined by the two discrete energy states, but for reasons connected with the nature of the nucleus, the radiation is rather spread over a range of frequencies, thus giving the gamma line a certain spectral width. One of the chief reasons for this 'smearing' of frequency is the recoil of the emitting nuclei. Mössbauer has shown that in crystalline solids there is a finite probability for the gamma rays to transfer momentum to all the nuclei of the crystal as a coherent whole instead of to the individual nucleus. In other words since the recoiling mass has considerably increased, the velocity of recoil, and hence the energy loss from the photons, is also correspondingly reduced. Thus such photons will emerge with practically no change in frequency. If now these gamma rays are made to pass through a second crystal of the same material they will be absorbed due to the nuclear resonance phenomenon. It has been shown that the condition for the resonance absorption is so critical that even an extremely small change in energy, as for example by the movement of the source towards or away from the absorber, destroys the resonance absorption.*

Experiments to detect the red shift, based on the above principle, have been undertaken at Harwell, at Harvard and also in the Manchester University. The principle of the Harwell experiment is to compare the frequency of the gamma rays emitted by the radioactive iron isotope Fe^{57} at a certain height above the ground, with the same frequency at ground level. Because of the difference of height, and therefore of gravitational energy, atoms above the ground ought to emit at a higher frequency than those on the ground. Though the amount of red shift is proportional to the difference in height between the two sources, calculations show that the accuracy with which the red shift can be measured in the Harwell experiment is more or less independent of the distance. So a length of vertical and evacuated water pipe 12·5 metres long and 15 cm. in diameter is mounted inside a water-tower at Harwell, and the comparison of frequencies is carried out in that.

The gamma ray source Fe^{57}, which is itself produced by the radioactive decay of Co^{57}, is placed at the top end of the water pipe. At the bottom of the pipe is a thin foil of the same material which acts as the absorber. Radiation not absorbed is transmitted through and is detected by means of suitable amplifiers and recording device.

If there be no gravitational effect on the radiation, the frequency (as well as its range width) from the emitting nuclei being exactly identical with that of the absorbing nuclei, there will be, theoretically speaking, complete absorption and the detector will indicate no transmission energy. Due to the gravitational red shift, however, the gamma line from the source will be shifted bodily to a slightly higher frequency and only the overlapping range of frequencies in their "natural widths" will be absorbed. There would thus be a small range which would not in any circumstances be absorbed in the iron (Fe^{57}) foil at the bottom.

To make measurements possible the source at the top is made to vibrate through a small distance 50 times a second, so that during half of each vibration the red shift is cancelled out by the source's Doppler speed. There will be an asymmetry in the transmission and by comparing the transmission through the foil every hundredth of a second, the transmission thus modulated can be amplified and it will be possible to detect the asymmetry due to the gravitational red shift.

*Pound and Rebka have shown that the movement of the Fe^{57} source at the rate of 0·017 cm /s. reduces the absorption by a half. In the familiar analogy of the Doppler effect in sound, this is equivalent to detecting the frequency change of the whistle of a railway engine moving at the rate of one-eighth of an inch per year!

SYMPOSIUM ON SOLID STATE PHYSICS AND THE CONFERENCE OF THE PHYSICAL RESEARCH COMMITTEE (C.S.I.R.)

A SYMPOSIUM on Solid State Physics was organized by the Physics Department, Indian Institute of Science, Bangalore, during the Golden Jubilee year to take place along with the annual Conference of the Physical Research Committee of the Council of Scientific and Industrial Research. They were held on February 1-3, 1960, and were attended by over 130 delegates from the different laboratories of India. More than 100 papers were presented. Dr. S. Bhagavantam, Director, Indian Institute of Science, inaugurated the Conference. This was followed by a lecture on "Geomagnetism of the Upper Atmosphere" by Prof. K. R. Ramanathan, of the Physical Research Laboratory, Ahmedabad.

The technical sessions on the opening day were devoted to the Spectroscopic study of solids, Neutron scattering and the structure of the solid state, and Defects in solids. Prof. R. S. Krishnan (Bangalore) gave an account of the important results obtained during the past few years in the Physics Department of the Institute by the use of the Rasetti technique in regard to the Raman spectra of crystals and Brillouin scattering. A noteworthy feature of this resume was the verification of the recent measurements of the photoelastic constants of diamond by Poindexter from Brillouin scattering studies. Prof. R. S. Krishnan's talk was followed by presentation of papers on Raman Effect, Infra-Red Spectra and Microwave Spectra. In the