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Nobel Prize in Physics 1907

Albert Abraham Michelson

The Nobel Prize in Physics 1907 was awarded to Albert A. Michelson *"for his optical precision instruments and the spectroscopic and metrological investigations carried out with their aid"*.

RESEARCH INFORMATION:

The Royal Academy of Sciences has decided to award this year's Nobel Prize for Physics to Professor Albert A. Michelson of Chicago, for his optical precision instruments and the research which he has carried out with their help in the fields of precision metrology and spectroscopy.

With untiring eagerness and, it can truly be said, with brilliant results, work is forging ahead today in every field of research in the natural sciences, and new information of ever greater significance is accumulating every day in unprecedented profusion. This is especially true in the case of the exact sciences - astronomy and physics - in which fields we are now obtaining solutions to problems, the mere mention of which up till a short while ago had to be regarded as unreal as Utopia itself. The reason for this gratifying development may be found in improvements in the methods and means of making observations and experiments, and also in the increase in accuracy brought about by these improvements in the quantitative examination of observed phenomena.

Astronomy, the precision science par excellence, has not only thus acquired whole new branches, but has also undergone in its older parts a transformation of more far-reaching significance than anything since the time of Galileo; and as for physics, it has developed remarkably as a precision science, in such a way that we can justifiably claim that the majority of all the greatest discoveries in physics are very largely based on the high degree of accuracy which can now be obtained in measurements made during the study of physical phenomena. We can judge how high our standards in this respect have risen from the fact that, for example, as recently as the beginning of the last century an accuracy of two to three hundredths of a millimetre in a measurement of length would have been regarded as quite fantastic. Today, however, scientific research not only demands but achieves an accuracy from ten to a hundred times as great. From this it is obvious how fundamental is the importance which must be attached to every step in this direction, for it is the very root, the essential condition, of our penetration deeper into the laws of physics - our only way to new discoveries.

It is an advance of this kind which the Academy wishes to recognize with the Nobel Prize for Physics this year. Everyone is familiar with the significance and scope of the uses to which the telescope and the microscope can be put as measuring instruments in precision physics; but a limit to the efficiency of these instruments has been reached, a limit which cannot be exceeded appreciably, for both theoretical and practical reasons. Professor Michelson's brilliant adaptation of the laws of light interference has, however, perfected a group of measuring instruments, the so-called interferometers, based on those laws, which previously only had occasional uses, to such a degree that an increase in accuracy in measurement of from twenty to a hundred times what can be achieved with the best microscopes has been brought well within our grasp. This is due to the fact that, owing to the peculiar nature of the interference phenomena, the desired value - usually a length is measured - can be obtained in numbers of wavelengths of the type of light in use in the experiment directly from observation in the interferometer of the changes in the image, caused by interference. An accuracy of up to 1/50 of a wavelength - about 1/100,000 of a millimetre - can be achieved by this method. If we now remind ourselves that the quantities the measurement of which has been made possible by this increase in accuracy - that is, small distances and angles - are precisely those which it is most often necessary to determine in research in precision physics, then without further ado it becomes obvious how powerful an aid has been presented to the physicist in Michelson's interferometer - an invaluable aid, not only because of its efficiency, but also because of the multiplicity of its uses. To illustrate this latter point, it is enough to mention such achievements as, for example, measuring the heat expansion of solid bodies, investigating their elastic behaviour under stress and rotation, determining the margin of error of a micrometric screw, measuring the thickness of thin laminae of transparent solids or liquids, and obtaining the gravitational constant, mass, and average density of the Earth, using both ordinary and torsion balances. Among the more recent uses of the interferometer, by means of which small angle deviations can be recorded with an accuracy of minute fractions of a second, may be mentioned Wadsworth's galvanometric construction, with which can be measured electric currents of vanishingly small intensities with a hitherto unknown degree of accuracy. However, although these uses of the interferometer are important and interesting, nevertheless they are of relatively minor significance in comparison with the fundamental research done by Professor Michelson in the fields of metrology and spectroscopy with the help of these instruments and which, in view of its far-reaching significance for the whole of precision physics, surely deserves in itself to have been recognized with a Nobel Prize. In fact, metrology is concerned with nothing less than finding a method of being able to control the constancy of the international prototype metre, the basis of the whole metric system, so accurately that not only will every change, however small, which could possibly occur in it be accurately measured, but also if the prototype were entirely lost, it could nevertheless be reproduced so exactly that no microscope could ever reveal any divergence from the original prototype. The significance

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of this does not need any particular emphasis, but an outline, however brief, of the course of this research and its results would not be out of place here.

I have already laid emphasis above on the facts that with the help of the interferometer measurements of small length can be made with an extraordinarily high degree of accuracy, and that they may be expressed using the wavelengths of any one type of light as a unit. Moreover, it is possible to measure in this way lengths up to 0.1 metre or more, in suitable conditions, without impairing the accuracy. Thus Michelson's research has first of all prepared the way for the measurement of the value of a standard length of 10 cm in wavelengths of a particular radiation in the cadmium spectrum. Proceeding from the value obtained in this way for the standard 10 cm, with a probable error of at the most ± 0,00004 mm, Michelson was able, likewise using the interferometer, to ascertain on that basis the length of the normal metre, ten times greater, and he obtained for this length a value of 1,553,164.03 wavelengths of this kind to the metre. The probable error in this measurement can in the least favourable conditions amount to only ± 0,00004 mm - that is, less than one wavelength - a value which is far too small to be detected directly by the microscope. Subsequently measurements were carried out in the International Bureau of Weights and Measures in Paris by different observers following an entirely different method, which showed that the error was in fact considerably smaller. These measurements actually give as a value for the length of the metre

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wavelengths of this kind - a result which differs from Michelson's figure by only 0. 1 wavelength, or 0,00006 mm. It is clear from this that Michelson's measurement of the length of the prototype metre must be accurate to within at least 0.0001 mm, and further, that this length can, by the use of his methods, be verified, or in the case of the loss of the prototype be reproduced, with the same degree of accuracy on every occasion. Finally, it also emerges from this that during the interval of 15 years which elapsed between the two series of measurements under discussion, no variation whatsoever from this figure had taken place in the prototype. The great care which had been taken in the execution and preservation of the prototype gave it at least the appearance of a high degree of constancy, but no more; it was only possible to obtain a real proof of its constancy when the metre could be compared with an absolute measure of length, independent of any physical element giving rise to it, the constancy of which under certain given conditions appeared to be guaranteed beyond a shadow of doubt. As far as our present knowledge goes, this is the case with wavelengths of light. It is to Michelson's eternal honour that by his classical research he has been the first to provide such proof.

From the value obtained in this way for the metre in wavelengths of one particular light radiation, it is now also possible to obtain, vice versa, figures for these wavelengths on an absolute scale of measurement, with a corresponding degree of accuracy. This accuracy is exceptionally high, and is in fact about fifty times greater than anything obtained by absolute methods in use up till now to determine wavelength. The conviction which had steadily been gaining ground for a long time past, that Rowland's wavelength system, otherwise quite accurate, which has been in use for the last twenty years as the exclusive basis of all spectroscopic research, is with respect to their absolute values subject to quite considerable errors, has thus received full confirmation; it has thus become apparent that a thoroughgoing reassessment of these values is necessary, using either Michelson's or some other similar interference method. And so we have reached the field of spectroscopy, in which it is clear that Michelson's interferometer is capable of an application no less significant than those which we have already considered. This is, however, not its only use. Considering the almost perfect clarity with which the majority of spectral lines appear in the emission spectra produced with the powerful diffraction-grating spectroscopes of our day, there were good grounds for regarding these radiated lines as simple and indivisible things; this is, however, not the case. Making use of his interferometer Michelson has in fact proved that they are, on the contrary, for the most part more or less complex groups of extremely closely packed lines, for the resolution of which the resolving power of even the strongest spectroscope proved utterly inadequate. The discovery of this internal structure of spectral lines to the more thorough investigation of which Michelson later contributed, in the form of the echelon grating invented by him, an even finer means of research than the interferometer, definitely belongs among the most important advances which the history of spectroscopy has ever been able to record, the more so as the nature and condition of the molecular structure of luminous bodies is extremely closely bound up with this structure of spectral lines. Here we are on the threshold of entirely new fields of research, over the unexplored expanses of which Michelson's experiments enable us to cast our first gaze, and his experiments can at the same time serve as a lead to those who are capable of carrying his work a stage further.

In addition to the more or less complicated structure which owing to the peculiar internal nature of luminous bodies is found in spectral lines, it is also possible to split them under the influence of a magnetic force into several more or less closely packed components. A few years ago this Academy was in a position to reward with the Nobel Prize the first exhaustive research, carried out by Professor Zeeman, into this phenomenon, which is extremely important to the science of physics. By using a powerful spectroscope, it is of course possible to examine this phenomenon in its general aspects; as a rule, however, the details are so subtle and so difficult to make out that the resolving power of that instrument is just not adequate for a full investigation. In this case the interferometer - or still better the echelon grating - may be used to advantage, as Michelson has shown. There can remain no shadow of doubt that through this instrument it will be possible to facilitate substantially research into the Zeeman effect.

I have only been able to give here a brief account of the numerous important problems whose solution has been brought so much nearer by the powerful aid to research, with its unprecedented degree of accuracy, which we have received in Michelson's optical precision instruments. This account would certainly seem incomplete if no mention were made of those applications which these instruments have already found, and will surely go on finding, in the field of astronomy, which are almost as important as those in the field of physics. Among these belong the series of measurements of the diameters of the satellites of Jupiter, which have been carried out partly by Michelson

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himself in the Lick observatory, and partly with the interferometer by Hamy in Paris - a series within which there is substantially closer agreement than it has been possible to achieve with normal micrometric observations through the biggest refracting telescopes of the present day. Similarly, there can be no doubt whatsoever that it will be possible to obtain considerably more reliable figures in measuring the small planets between Mars end Jupiter than those which have been obtained by the photometric method of observation, which up till now has been the only one available, but which is extremely unreliable. The interferometer method can likewise be of some importance in the investigation of close double and multiple stars, and in this way we may cease to regard as utterly hopeless the problem, which has long been abandoned as completely insoluble, of finding by measurement true values for the diameters of at least the brighter stars. Thus astronomy has once again received from physics in the interferometer - as earlier in the spectroscope - a new aid to research which seems particularly suited to tackling problems whose solution was formerly impossible, as there were no, or at the most inadequate, instruments available.

The aforegoing will suffice, not only to explain to those who are not themselves closely involved in these problems the comprehensive and fundamental nature of Michelson's research in one of the most difficult fields of precision physics, but also to demonstrate how fully justified is the decision of this Academy to reward it with the Nobel Prize in Physics.

The following words were spoken to Professor A.A. Michelson, by Professor the Count K.A.H. Mörner, President of the Royal Swedish Academy of Sciences, during a private ceremony in the premises of the Academy.

Professor Michelson. The Swedish Academy of Sciences has awarded you this year the Nobel Prize in Physics in recognition of the methods which you have discovered for insuring exactness in measurements, and also of the investigations in spectrology which you have carried out in connection therewith.

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Your interferometer has rendered it possible to obtain a non-material standard of length, possessed of a degree of accuracy never hitherto attained. By its means we are enabled to ensure that the prototype of the metre has remained unaltered in length, and to restore it with absolute infallibility, supposing it were to get lost.

Your contributions to spectrology embrace methods for the determination of the length of waves in a more exact manner than those hitherto known.

Furthermore, you have discovered the important fact that the lines in the spectra, which had been regarded as perfectly distinct, are really in most cases groups of lines. You have also afforded us the means of closely investigating this phenomenon, both in its spontaneous occurrence and when it is produced by magnetic influence, as in Zeeman's interesting experiments.

Astronomy has also derived great advantage, and will do so yet more in the future, from your method of measurements.

In bestowing the Nobel Prize in Physics upon you the Academy of Sciences desires to signalize as worthy of especial honour the eminently successful researches you have carried out. The results you have attained are excellent in themselves and are calculated to pave the way for the future advancement of science.

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