"On the eve of our departure, we are being asked by our friends about our impression of war-time England. To this we say that we have been greatly impressed by the wonderful spirit of team-work of the people, by the way in which the human power and the material resources of the country have been mobilized to fight the enemy and by the steadfastness of your will to win. In particular, in the matter of organizing scientific research, in which we were specially interested, we were struck by the manner in which scientific talent throughout the country has been mobilized and researches in the different branches of science co-ordinated to produce the most fruitful result in the quickest possible time. We were also delighted to see that the industries directly responsible for the huge war productions have realized the importance of scientific research. We felt that without this collaboration between science and industry on one hand and the Government on the other, the successful prosecution of the War would have been an impossibility. We are sure that this new spirit of collaboration for the common cause will continue after the War and find its way to our country for constructive work.

"We are also being asked if our mission in Great Britain has been a success. Has it been worth the time and trouble that His Majesty's Government has spent on this visit of ours? To this we gratefully reply that we have seen and learnt whatever we wanted to see or learn. We have made contacts with the most distinguished men of science, industrialists and social workers of the country. Further, what to us has been of the utmost importance, we have had the fullest opportunity of studying the method of organizing scientific research for national needs to which I referred just now. We have visited many large-scale industries and have been taken round the most complicated manufacturing processes by the directors of the industries themselves. To us this has been a kind of a revelation. We now understand how much technical talent, large-scale organization and sense of team-work are necessary for efficient running of such industries. We hope to enlighten our countrymen on these matters when we return to India.

"One of our colleagues very aptly remarked that for the last seven weeks we were being put through an intensive course of adult education. So far as this aspect of the visit is concerned, we think it has been a success, because we hope we have not proved ourselves to be students who shirk work. Our object in coming to Britain, however, was not only to educate ourselves, but also at the same time to acquaint the people of Britain, by free and frank discussion and exchange of views, with our problems and needs. If by our visit we have, even in a small measure, been able to achieve this, we shall consider that our mission has been a complete success.

"The discoveries and inventions of science have annihilated space and time. We can now flash across space news which will go round the earth seven times in one second. We can cover distances in hours which formerly would have taken days. The world has in effect grown smaller. A result of this has been that the different nations of the world are being brought into closer and more intimate contact. In future, the different nations, big or small, will have to march together, whether they will or not. But this marching together will only be a source of strife and conflict if the different nations do not keep pace with each other. Nations which for some reason or other are left behind will be a drag on those moving forward and, by causing friction, will act as a brake on general progress. It is therefore the duty of the advanced nations, in their own interest, to see that none may be lagging behind, and to lend a helping hand to those who may unfortunately be so.

"I believe that it is the duty of every nation to strive for progress, as it is the endeavour of the plant to seek light. India has for a long time failed in this duty. It is no use discussing who has been responsible for this inaction. India is now striving for progress, and we are sure you will be ready to help us in our endeavour to seek light and freedom—freedom from want.

"In conclusion, I would thank, on behalf of my colleagues, all those who for the past seven weeks have been responsible for arranging our programmes, planning our visits and, in a hundred other ways, doing all that was necessary to make our visit as useful and as pleasant as possible. It is difficult to express adequately our gratitude to them for all they have done for us. The memory of this very pleasant visit, which has forged as it were a link of goodwill and fellowship between the scientific workers of your country and ours, will always be cherished by us. We shall be leaving the shores of Great Britain in the confident hope that India, just as she has been a partner of Great Britain in her struggles and tribulations in the dark days of war, will also be a partner of her prosperity in the days of peace in the near future."

OBITUARY

Sir Arthur Eddington, O.M., F.R.S.

THE death on November 22, at the age of sixty-one, of Sir Arthur Stanley Eddington is a great loss to science. In these days of specialization in science, it is given to few to have so wide a range of interests and to make contributions of outstanding merit in such diverse fields as he did. He combined to a unique degree an appreciation of the significance of new developments with great powers of mathematical analysis and keen physical intuition. A gifted expositor of the newest trends in physics, he was able to describe the most abstruse theories in clear and simple language; his name and writings were known throughout the world.

Eddington was born on December 28, 1882, at Kendal, Westmorland, of a Quaker family, his father being the headmaster of the Friends' School at Kendal. In 1902 he entered Trinity College, Cambridge, after having carried all before him at Owens College, Manchester. In the Mathematical Tripos of 1904 he was Senior Wrangler and in the following year was placed in the first division of the first class of Part II of the Tripos. In 1907 he was Smith's Prizeman and was elected to a fellowship at Trinity College.

In 1906 Eddington was selected by Sir William Christie, the Astronomer Royal, to fill the vacancy in the post of chief assistant at the Royal Observatory, Greenwich, caused by the appointment of F. W. Dyson as Astronomer Royal for Scotland. At Greenwich, he obtained experience in observational astronomy and a familiarity with its problems which were to stand him in good stead. Though his interests were primarily in theoretical investigations, he was able to appraise the value of observations and to test theoretical conclusions by means of the data provided by observation. He discussed the observations made with the Airy reflex zenith tube and when, as the result of this discussion, it was decided to discontinue these observations and to employ the Cookson floating zenith telescope, loaned by the Cambridge Observatory, for the determination of the variation of latitude and of the constant of aberration, he planned the programme of observation with this instrument.

But Eddington's main interest at this time was in stellar motions. Kapteyn had but recently announced his discovery of the two star-streams. A rapid increase in knowledge of the proper-motions and radial velocities of the stars was taking place. Eddington used the new material, discussed it thoroughly, and confirmed and amplified Kapteyn's conclusions. In 1914 his "Stellar Motions and the Structure of the Universe" was published. This work contained an account of his own researches, but this was made subservient to the wider aim of giving an account of the many recent discoveries in sidereal astronomy and co-ordinating them to present, so far as was possible at the time, a coherent description of the stellar universe. In each of the main fields in which Eddington worked, he followed the same plan of publishing a connected account of the new advances, incorporating the work of others; students and investigators of these fields are greatly indebted to him for the valuable assistance which was thus provided for them.

In 1913 he was elected to the Plumian professorship of astronomy at Cambridge, which had become vacant through the death of Sir George Darwin; and the next year, after the death of Sir Robert Ball, he was appointed director of the Cambridge Observatory. In 1916 he took up the study of the radiative equilibrium of the stars. Schwarzschild had developed in 1906 the theory of the radiative equilibrium of a star's atmosphere, but did not apply the theory to the interior of a star. Eddington found that the extension of the formulæ to the interior of a star was not difficult. The theory was thought at first to be applicable only to the diffuse giant stars; it was considered that in the interiors of the dwarf stars, with their much greater mean densities, there would be an appreciable departure from perfect gas laws. The theory indicated that the bolometric magnitude of a gaseous star is independent of its stage of evolution and depends only on its mass. But in 1924, as the outcome of a careful discussion of all the reliable determinations of stellar masses, he found that the formulæ of the theory predicted correctly the absolute magnitudes of all ordinary stars, regardless of whether they were giants or dwarfs.

This discovery of the correlation between the masses and the luminosities of the stars was a result of outstanding importance. It showed that dense stars, such as the sun, obeyed the laws of a perfect gas; it also necessitated a complete revision of the then accepted views of stellar evolution. The two branches of the familiar Russell-Hertzsprung diagram must either represent loci of equilibrium points or, if there was evolution along them, it must be accompanied by appreciable loss of mass. The white-dwarf stars did not satisfy the mass-luminosity relationship; Eddington came to the revolutionary conclusion that the mean density of 53,000 of the companion of Sirius was not absurd and should be accepted; he pointed out that, if this density were correct, there should be an Einstein shift of its spectral lines of about 20 km. per sec., which was shortly afterwards confirmed by Adams at Mount Wilson. Eddington also investigated the problem of the Cepheid variable stars, on the hypothesis that their light variations were caused by periodic pulsations, and was able to account for the period-luminosity relationship obeyed by these stars, which had been found by Miss Leavitt at Harvard from the study of Cepheid variables in the Magellanic Clouds. In 1926 Eddington gave a connected account of these investigations in "The Internal Constitution of the Stars", while "Stars and Atoms" (1927) gave a fascinating and graphic description of the new results in a form intelligible to the general reader.

In 1926 Eddington gave the Bakerian Lecture of the Royal Society, taking as his subject "Diffuse Matter in Interstellar Space"; this was an important contribution to the understanding of the nature of the interstellar clouds. He found that ionization and capture form the main process of interchange between radiant energy and atomic kinetic energy in diffuse gas, and that this tended to raise the temperature to the level of the effective temperatures of stars, independently of the dilution of radiation. He modified the usual equilibrium formulæ for the amount of ionization to apply to matter in a field of evenly diluted radiation. The relative abundance of sodium to calcium was found to be very much greater than on the earth; the tremendous preponderance of hydrogen over all other elements was not realized at that time, and Struve later showed that the discordance was much reduced when it was assumed that hydrogen supplied the overwhelming majority of the free electrons. Eddington concluded that the stationary sodium and calcium lines in the spectra of early-type stars were produced by absorption by the interstellar cloud; but found that the dimming of distant stars by interstellar gas could not be accounted for unless it was assumed that these contained non-gaseous (meteoric) matter. This conclusion has since been amply confirmed.

Concurrently with these investigations, Eddington had also been occupied with the theory of generalized relativity. The War of 1914–18 had disrupted scientific intercourse, and Einstein's important papers were generally unknown in Great Britain. Eddington had received a copy from the Dutch astronomer, de Sitter, in 1917; he immediately accepted the new theory, perceiving its great importance. His "Report on the Relativity Theory of Gravitation", prepared for the Physical Society in 1918, provided the first account of the new theory in the English language and did valuable service in bringing the theory to the notice of British men of science. Many were converted to it; but many others, because of its revolutionary conceptions and the employment in its mathematical development of the tensor calculus, with which physicists and applied mathematicians were not generally familiar, were inclined to suspend judgment. The theory had accounted for the unexplained motion of the perihelion of Mercury, but further observational confirmation was needed to convince the sceptics. Sir Frank Dyson found that the total eclipse of the sun on May 29, 1919, would provide a particularly favourable opportunity for testing Einstein's prediction of the amount of the deflexion of rays of light by the sun. It was decided to proceed with the necessary preparations at Greenwich for two expeditions, to Brazil and the Island of Principe, though the state of the War at the time gave little hope that it would be possible for the expeditions to set out. But the end of the War came in time, and Davidson and Crommelin from Greenwich went to Brazil, while Eddington and Cottingham went to Principe. Both expeditions made successful observations, and the results obtained supported Einstein's prediction of the amount of the deflexion, and did much to secure general acceptance of the theory. In "Space, Time and Gravitation" (1920) Eddington gave a non-mathematical account of the theory, to which he prefixed the very appropriate quotation from "Paradise Lost":

Perhaps to move
His laughter at their quaint opinions wide
Hereafter, when they come to model heaven
And calculate the stars: how they will wield
The mighty frame: how build, unbuild, contrive
To save appearance.

About this time there appeared a spate of popular accounts of the theory, but none could compare with Eddington's masterly presentation. In 1923 he followed this with "The Mathematical Theory of Relativity", which included an account of his own important contribution—a generalization of Weyl's theory of the electromagnetic and gravitational fields, based on the notion of parallel displacement. He emphasized that there must be woven into the structure of the world a standard of length making possible the comparison of lengths at different points in space-time.

Much of Eddington's later work was concerned with the development of the cosmological aspects of relativity theory and with the unification of quantum theory and relativity theory. Observations had shown that the external galaxies were receding from our own galaxy and from each other with speeds proportional to their mutual distances apart. This gave rise to the conception of the expansion of the universe. The small popular book "The Expanding Universe" (1933) gave an account of the phenomena to be expected in a finite expanding spherical universe, of the type first suggested by Einstein and later developed by the Abbé Lemaître. Eddington sought to find relations between the radius of curvature of space, the recession-velocity constant of the external galaxies, the number of particles (or the mean density of matter) in the universe and the physical constants, such as the ratio of the mass of the proton to that of the electron, the ratio of the gravitational to the electric force between a proton and an electron, the fine-structure constant and the velocity of light. The connexion between the constant of gravitation and Planck's constant was obtained by treating an Einstein universe first by relativity theory and then by wave-mechanics applied to the system of particles forming that universe. The mathematical account of the theory was given in "The Relativity Theory of Protons and Electrons" (1936) and was revised and completed in his lectures before the Dublin Institute for Advanced Studies, entitled "The Combination of Relativity Theory and Quantum Theory" (1943). These researches, to which Eddington gave much time and thought, have not yet carried general conviction, though the agreement between observed constants and the values found by pure reasoning are extraordinarily close. The extremely abstruse and complex nature of the investigations, which few can claim to have thoroughly understood, is no doubt responsible in some measure, but the purely deductive nature of the theory is an important contributory factor. Eddington wrote that:

"An intelligence, unacquainted with our universe, but acquainted with the system of thought by which the human mind interprets to itself the content of its sensory experience, should be able to attain all the knowledge of physics that we have attained by experiment. He would not deduce the particular events and objects of our experience, but he would deduce the generalizations we have based on them. For example, he would infer the existence and properties of radium, but not the dimensions of the Earth".

This is a philosophy of science that does not command general acceptance to-day. Nevertheless, it may well be that generations yet to come will regard Eddington's recent work as one of the most important and significant advances in science.

In "The Nature of the Physical World" (1928) being the Gifford Lectures for 1927, and "New Pathways in Science" (1935), being the Messenger Lectures at Cornell for 1934, Eddington dealt with the new developments in science—the theory of relativity, quantum theory, the principle of indeterminacy, the expansion of the universe, etc.—and with their effect on philosophical thought. Both books were essentially concerned with the question: What kind of knowledge does science give us? He showed that in dealing with the universe, science is confined to investigating its structure; it can tell us nothing of the nature of that which possesses that structure. It was not so much the particular form that scientific theories have now taken that is important, for they may in time give way to some fuller realization of the world, as the movement of thought behind them changes. Whatever changes may come, it will never be possible to go back to the old outlook. Eddington was a master of the English language, and these lucid expositions did more than any other books to make the intelligent layman aware of the new trends in science and of their philosophical implications.

Eddington was elected a fellow of the Royal Society in 1914 and was awarded its Royal Medal in 1928. He was president of the Royal Astronomical Society during 1921–23, and foreign secretary from 1933, and was awarded its Gold Medal in 1924. He was awarded the Bruce Gold Medal of the Astronomical Society of the Pacific in 1924. He was president of the Physical Society during 1930–32. He received honorary doctorates from twelve universities, and was honorary member, foreign member or foreign associate of many learned societies in Europe and America. He was created a Knight Bachelor in 1930 and received the Order of Merit in 1938. He was elected president of the International Astronomical Union at its last General Assembly in 1938. He was a great ambassador of science, who travelled and lectured widely.

Many in Great Britain mourn the passing of a friend and colleague while still in the zenith of his intellectual powers; their sense of loss will be shared by many others in all parts of the world, who have admired from afar his achievements and have received instruction and stimulus from his writings.

H. SPENCER JONES.

THROUGHOUT his career as an astronomer, Sir Arthur Eddington's connexion with the Royal Astronomical Society, both formal and scientific, was close and intimate. He was elected a fellow in 1906, was president during 1921–23 (a period of office which included the celebration of the centenary of the Society), received its Gold Medal in 1924, and