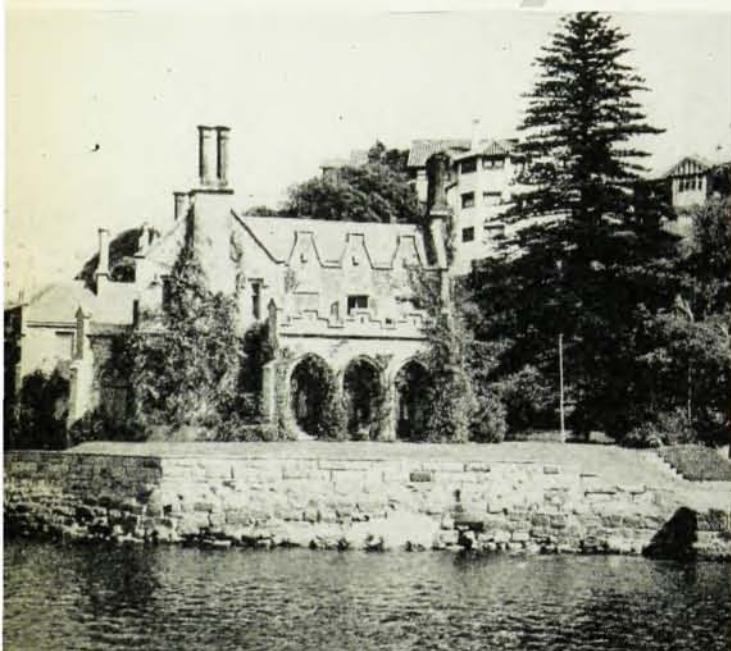




physics in

NORTHERN
TERRITORY



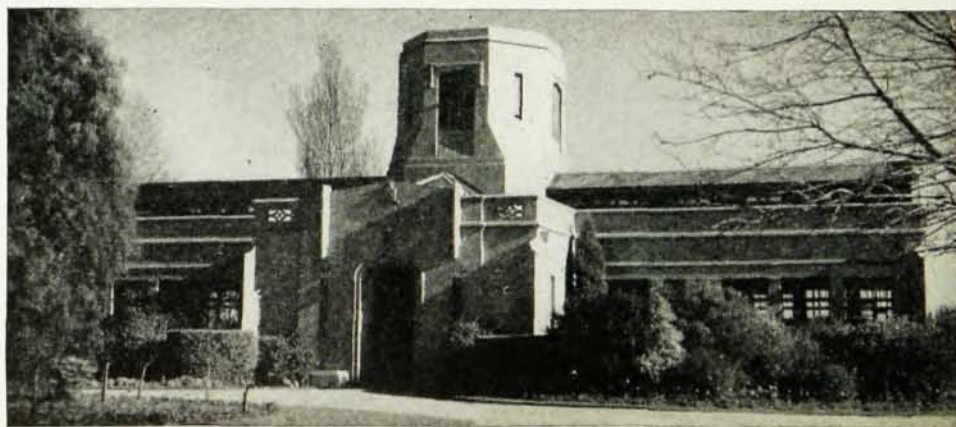
WESTERN
AUSTRALIA

PERTH

SOUTH
AUSTRALIA

ADELAIDE

MELB



Photographs shown include views of: Perth University in Western Australia (upper left); the New England University College at Armidale, New South Wales (upper right); Queens College Laboratory at Melbourne University (lower left); and the tower and entrance of Sydney University's main building (lower right).

AUSTRALIA

When Oliphant and Titterton and a few other physicists known to their colleagues in the U. S. went awaltzing with Matilda at the other end of the world they did not vanish into oblivion. Australian physics, as the following article shows, is concisely organized, well-supported, and in a state of vigorous growth.

By L. G. H. Huxley

Although the principles, methods, and terminology of a fundamental science, such as physics, should transcend geography, yet the branches of the science towards which a community chooses to direct its efforts may be expected to be influenced not only by geographical, but also by political and economic considerations.

Since this short account of physics in Australia is written for American readers, it is thought not to be a superfluity to preface it with a very brief review of some facts about the Commonwealth of Australia in order that the activities of Australian physicists may be seen in their geographical context.

Geographical Background

Australia, the world's largest island or smallest continent, according to taste, has an area of 2.975×10^6 square miles, which is nearly the same as that of the United States, but other geographical similarities are less marked than the differences. The central regions comprising one third of the whole are arid, another third has a modest annual rainfall of eight to fifteen inches, while in the remaining third lying mainly, but not exclusively, in the eastern coastal regions the rainfall is moderate to heavy.

The distribution of Australia's population of eight million is largely conditioned by this distribution of rainfall, being concentrated in the coastal regions and the southeastern corner of the continent. The political constitution of the Commonwealth resembles that of the United States in so far as there are States, six only in number, each with its own State Government, and a Federal Government with a Parliament comprising an Upper House (Senate) and a Lower House (Representatives). There is in addition the vast but sparsely populated region of the Northern Territory for which the Federal Government is directly responsible.

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QUEENSLAND



BRISBANE

NEW SOUTH WALES

ARMIDALE

SYDNEY

CANBERRA

VICTORIA

WESTERN AUSTRALIA

TASMANIA



Sydney, the state capital of New South Wales, is Australia's largest city. Sydney Harbour is shown in the center.



Each state capital is an important seaport and the largest city in its own state. Canberra, the Federal Capital, which corresponds to Washington, D. C., is, however, situated inland in a small area, Australian Commonwealth Territory (A. C. T.), ceded by New South Wales.

The position that Australia has achieved as the world's chief producer of wool, both in quantity and quality, together with the importance of its wheat and cattle production, leads to a common belief abroad that the Commonwealth is essentially a rural community; but it suffices merely to mention that the six capital cities alone account for about one half of the total population, in order to demonstrate the error of such an opinion. Moreover, the largest two cities, Sydney and Melbourne, have a combined population of nearly three millions.

The division of such a vast territory into so few states means that in most instances the state capitals are widely separated, even by American standards of distance. This separation is accentuated by the absence of railways across the interior. Thus Perth and Brisbane are at an effective separation of about three thousand miles; but even at the other extreme a journey of five hundred miles is required between the closest pair of capitals.

We now turn to our proper subject, "Physics in Australia", which for the purposes of this discussion it is convenient to divide into the two categories *Australian Universities and their Departments of Physics* and *Physics in Government Organisations*.

University Physics Departments

Since it is essentially correct to say that before 1930 research and instruction in advanced physics were almost entirely centred in the universities, it is not inappropriate to give a brief general description of these important institutions.

Each state of the Commonwealth possesses a university in its capital city, but despite their great geographical separation, the Australian State Universities form an essentially homogeneous group in both the type and the standard of instruction that they provide, as well as in the nature of their foundation. Although each was established by an act of its State Legislature in response to popular demands, none is a "State University" in the American sense, but rather a self-governing academic corporation on the general model of the universities of Great Britain. There are, in addition, two university colleges, one at Armidale, New South Wales, and one at Canberra, linked respectively with the Universities of Sydney and Melbourne. The dates of foundation of these universities are scattered sporadically over the last hundred years; thus we find, Sydney 1850, Melbourne 1853, Adelaide 1874, University of Tasmania 1890, University of Queensland 1909, University of Western Australia 1911, Canberra University College 1930, and New England University College, Armidale 1938.

Recently (1946), a university, of a character different from the State Universities, was founded by an Act of the Federal Parliament. This is the Australian National University at Canberra, whose activities will lie in the field of postgraduate research and study and not in undergraduate instruction. Research schools of the National University have already been established in the categories of medical research, physical sciences, social studies, and Pacific studies, subjects which are deemed to be of importance to Australia.

Until comparatively recently the most serious handicap experienced by physicists in Australia was that of isolation, not only from physicists in other Australian universities but also from Great Britain and America. There is a story on record that one of Melbourne's more distinguished physicists had the fortitude in 1897 to decline having himself considered for a Fellowship of the Royal Society on the grounds that the *Proceed-*

ings and *Transactions* of this Society were available in Melbourne and he was "unaware of any other advantage which Fellowship would bring". A further handicap was the fact that until comparatively recently Australia's secondary industries were poorly developed; consequently it was necessary to import many ordinary types of physical apparatus. In recent years both these handicaps have been to a large extent removed by the development of efficient internal and overseas air services, and by the rapid growth, especially during the second World War, of secondary industries.

In spite of these early handicaps some honoured names are to be found in the annals of Australian physics; for instance, Horace Lamb was the first professor of mathematics and W. H. Bragg the first professor of physics at the University of Adelaide. The latter in fact performed his first experiments on x-rays and his famous experiments on the ranges of alpha-particles here. His son, W. L. Bragg, the present head of the Cavendish Laboratory, received his early education in mathematics and physics in Australia. The physicist William Sutherland, whose formula for the dependence of the viscosity of a gas upon temperature is a commonplace of kinetic theory, was first a student and later a lecturer at the University of Melbourne. The late Professor T. H. Laby, known to generations of physicists throughout the British Commonwealth through "Kaye and Laby's Tables of Physical Constants", did much for experimental physics in Australia by his precise determinations of Joule's constant, the thermal conductivities of gas (Laby and E. O. Hercus), the electronic charge by Millikan's method, and his work in x-ray diffraction. He occupied the chair of physics at Melbourne University with distinction for many years. The work of such men has had a persisting influence on the scientific community in this country. The standard of training given in physics in Australian Universities is high and the many Australians who seek postgraduate experience in Great Britain find little difficulty in adjusting themselves to the academic standards in British Universities. Among Australian physicists who have distinguished themselves abroad we mention M. L. Oliphant and G. E. M. Jauncey (late Professor of Physics, Washington University, St. Louis) both of whom received their undergraduate training in physics at Adelaide under my predecessor, Sir Kerr Grant. Distinguished graduates of the University of Melbourne were H. S. W. Massey at University College, London, and the late J. K. Roberts, author of a well-known treatise on heat and thermodynamics. Dr. F. P. Bowden, a leading authority at Cambridge, on the physics of friction, is a graduate of the University of Tasmania.

The universities also play an important role in determining the standard of physics taught in the many excellent secondary schools and technical colleges in this country, through public examinations and the standards required for entrance to the universities.

Australian universities are financed through annual grants made to them by their respective State Governments, but as the Federal Government is the chief

taxing authority the grants ultimately come from it. The Federal Government also makes a direct grant to each university which is a definite proportion (one fourth) of the State grant provided the latter does not fall below a specified amount. Some universities also possess private endowments, but none is sufficient to provide income for more than a small fraction of its total needs.

Each university determines through its governing bodies how the grants are spent with no intervention by either the State or the Federal Government. Thus each university determines what proportion of its income is to be spent on scientific research and on research in physics in particular.

There is no general scheme for financing research in universities by means of government contracts for particular projects, such as obtains in the United States, although the Commonwealth Scientific and Industrial Research Organisation (CSIRO, see below) finances some projects in universities, as, for instance, research on nuclear physics at the University of Melbourne.

As some readers may be interested in more specific information about extant research in physics in Australian universities it is hoped that the following brief epitome, while in no sense exhaustive, may to some extent meet their wishes.

Physics Research in the State Universities

The University of Sydney. The chief research activities in recent years have been those of V. A. Bailey, Professor of Experimental Physics, and his pupils. Bailey is well known for his experimental and theoretical work in the subjects of "Motions of electrons in gases; attachment of electrons to molecules; the theory of normal and gyro-radio wave interaction (ionospheric cross-modulation) oscillations in ionised gases and miscellaneous contributions to mathematics." Further subjects of research at Sydney are: gas discharges, photoelectricity, nuclear research (R. E. B. Makinson); optics (G. A. Harle).

Research on semiconductors and electrical computers is done in the department of electrical engineering (D. Myers and R. E. Aitchison).

The Professor of Applied Mathematics, K. E. Bullen, has contributed fundamental theoretical work to geophysics, seismology, and the constitution of the planets.

At the University College of New England, Armidale (J. M. Sommerville is head of the physics department), research is done on gaseous discharges and the ionosphere.

The University of Melbourne. The department of physics (L. H. Martin) is at present the chief centre of research in nuclear physics and cosmic rays in Australia, and an active group (Professor Martin, C. B. Mohr, J. C. Bower, V. D. Hopper) does experimental and theoretical work in these fields with financial assistance from CSIRO.

Work has also been done in recent years on precise determinations of the electronic charge by the method

of the falling drop (V. D. Hopper). The Professor of Mathematics, T. M. Cherry, has achieved distinguished theoretical work on fluid dynamics.

The University of Adelaide. The research activity of the department of physics (L. G. H. Huxley) lies in the fields of motions of very slow electrons in gases (R. W. Compton and D. Sutton), the ionosphere (W. G. Elford, G. J. Aitchison, and D. Robertson), and vacuum physics. A school of research in biophysics is being developed under the direction of S. G. Tomlin and a modern electron microscope will soon be installed.

Research is also being done on surface tension and the spreading of liquids by R. S. Burdon, who is the author of a monograph on this subject.

A new chair of mathematical physics has been filled by H. S. Green, a former pupil and colleague of Max Born.

The University of Tasmania. Under the direction of A. L. McAulay an active school of biophysics has been developed in which mutations and problems of growth are studied. Other work is done in cosmic rays (G. Fenton) and geometrical optics (F. D. Cruickshank). Theoretical work in relativity and thermodynamics is also done (H. Buchdahl). J. C. Jaeger of the department of mathematics has done much to spread the use of the Laplace Transformation throughout the British Commonwealth by his books on this subject. He has a wide interest in general theoretical physics.

The University of Queensland. The research interests lie in the fields of medical physics, the ionosphere (H. C. Webster), and semiconductors (A. L. Reimann). Dr. Reimann is the author of a well-known treatise on thermionics.

The University of Western Australia. The research activities in physics include investigations on atmospheric ozone, cosmic rays, vacuum physics and ionospheric research (A. D. Ross); x-ray crystal analysis and optical pyrometry (J. Shearer); and cosmic noise (S. E. Williams). The Professor of Mathematics, C. E. Weatherburn, is widely known to physicists through his treatises on vector analysis, differential geometry, and mathematical statistics.

Technical University. The Government of New South Wales has recently established a Technical University in Sydney which, however, is not a self-governing corporation in the sense of the State Universities described in the preceding paragraphs. The physics department is directed by N. F. Astbury.

The National University. This recently founded University at Canberra has already been described. The Director of the School of Physical Sciences is M. L. Oliphant, who will develop an important centre of nuclear research. Professor Oliphant is already in residence at Canberra and is gathering a team of research workers among whom is E. W. Titterton, who will arrive soon to fill a Professorship in Nuclear Physics. The existence of a strong research centre of this character will serve to stimulate physicists throughout Australia.

Physics in Government Organisations

CSIRO. The Commonwealth Scientific and Industrial Research Organisation is responsible for the major portion of research in pure and applied science in Australia. Between the years 1926 and 1949 it was known as the Council for Scientific and Industrial Research (CSIR) and was directed by a somewhat large Council of which Sir David Rivett was Chairman, and the late Dr. A. E. V. Richardson Chief Executive Officer. On the retirement of Sir David Rivett in 1949 a change in the directorate was made and by the Science and Industry Research Act of May 1949 the "Council" became the "Organisation" under the direction of an Executive of five members, three of whom are full-time. The Chairman of the Executive is Dr. I. Clunies-Ross (a former professor of veterinary science at Sydney) and the Chief Executive Officer is Dr. F. W. G. White (a former professor of physics in New Zealand). "The powers and functions of the Organisation," to quote its first annual report, "are similar to those of the Council and include the initiation and carrying out of research in connection with, or for the promotion of, primary and secondary industries in the Commonwealth or any Territory of the Commonwealth, or in connection with any matter referred to the Organisation by the Minister; the training of research workers; the making of grants in aid of pure scientific research; the testing and standardization of scientific apparatus and instruments, and the carrying out of scientific investigations connected with standardization; the collection and dissemination of information relating to scientific and technical matters; the publication of scientific and technical reports and periodicals; and acting as a means of liaison with other countries in matters of scientific research."

In order to implement these terms of reference the Organisation has established a number of Divisions (sixteen major establishments which may be subdivided into Sections) and independent Sections dealing with special subjects but of less scope and magnitude than the Division. A simple list of the names of the Divisions and independent Sections will serve to indicate the range and importance of the Organisation's activities.

Divisions.

Plant Industry (headquarters and laboratories at Canberra; field stations in Queensland, New South Wales, Northern Territory, and Western Australia).

Entomology (headquarters at Canberra; field stations in Victoria and New South Wales).

Animal Health and Production (headquarters and laboratories in Melbourne; laboratories in Sydney and Queensland; field stations in New South Wales, Queensland, and Victoria).

Biochemistry and General Nutrition (main laboratory in Adelaide; field stations in South Australia).

Soils (laboratory in Adelaide).

Forest Products (Melbourne).

Food Preservation and Transport (headquarters and laboratories in Sydney; laboratories in Brisbane and New South Wales).

Fisheries (laboratories in New South Wales; exploration section at Perth; field stations at Brisbane, Thursday Island, and Hobart).

The National Standards Laboratory comprising the 3 Divisions: Metrology, Physics, Electrotechnology.

Radiophysics (at Sydney).

Industrial Chemistry (headquarters and main laboratories in Melbourne).

Tribophysics (Melbourne).

Building Research (Melbourne).

Independent Sections.

Irrigation Research Station (Murray River Irrigation Areas); Radio Research Board (headquarters and laboratory in Sydney); Flax Research (Melbourne); Ore Dressing Investigations (Melbourne and Kalgoorlie, W. A.); Mineragraphic Investigations (Melbourne); Mathematical Statistics (Adelaide); Dairy Research (Melbourne); Meteorological Physics (Melbourne); Coal Research (Sydney); Wild Life Survey (Canberra); Mathematical Instruments (Sydney); and Wool Textile Research Laboratories (headquarters in Melbourne, units in Sydney and Geelong, Victoria).

There are in addition the following regional laboratories concerned with problems of particular districts: the Regional Pastoral Laboratory (Deniliquin with associated Falkiner Memorial Field Station); the Regional Pastoral Laboratory (Armidale, N. S. W., and field station "Chiswick"); the Tasmanian Regional Laboratory (Hobart); the Western Australian Regional Laboratory (Perth); and the Plant and Soils Laboratory (Brisbane).

It appears from this list that, although the greater part of the Organisation's activities are concerned with the Plant and Animal industries which contribute so greatly to Australia's prosperity, research in physical subjects is not overlooked. In fact physicists are more actively engaged than the list might suggest since their services are of importance in Divisions where physics is not mentioned in the title, such as, for instance, those of Soils (Adelaide), and of Industrial Chemistry (Fisherman's Bend, Melbourne, where techniques of electron diffraction and microscopy are highly developed). It is clearly impracticable to review in detail all the activities of physicists in the Organisation; consequently all that will be attempted is a brief synopsis of the work of some of those groups where the aim would seem to be addition of knowledge or direct assistance to physics, rather than the use of physics in an ancillary rôle, important as the latter is. We choose to consider therefore:

The Radio Research Board

This Board, under the Chairmanship of Sir John Madsen, has, during the last twenty years, carried out extensive investigations on the ionosphere. The work

of the Board's two senior officers, D. F. Martyn and G. H. Munro, is well known abroad. Dr. Martyn has done important work on the physics of the atmosphere (Martyn's theorem; temperature-height dependence; winds and tides in the upper atmosphere; solar noise radiations). Dr. Munro's recent work is concerned with observations of travelling disturbances which he discovered in the F-region.

There is also an Ionospheric Prediction Service (A. L. Green) which issues monthly forecasts of global conditions of transmission. This service is associated with the Commonwealth Observatory, Canberra.

The Radio Research Board also gives financial aid to some State Universities for ionospheric research.

Division of Radio Physics

The Division's laboratory and headquarters are sited on the grounds of the University of Sydney and its work is directed by E. G. Bowen, who, it may be of interest to recall, first took a magnetron from Britain to the United States in 1940 with the Tizard Commission and later acted as a liaison officer for the British Ministry of Aircraft Production at the Radiation Laboratory of MIT until 1943. Second in the Division to Dr. Bowen is Dr. J. L. Pawsey. The Division's chief work lies in the following fields:

1. **Radio Astronomy.** Many original and pioneering contributions to the study of radio-frequency radiations from the sun, the galaxy, and radio stars have been made in recent years by the Division's scientists.

This work is well known and of great scientific interest.

2. **Radio Meteorology.** This title covers investigations of the scattering and reflection of microwaves by rain drops, ice particles, and snowflakes, in order that quantitative information can be obtained from other investigations on the natural and artificial formation of rain. Such work, on the physical properties of clouds and the artificial stimulation of rainfall by "seeding", is, as may well be imagined, of great interest in a country in which large areas suffer from inadequate rainfall.

3. **Radio Aids to Navigation.** Significant advances in techniques have been made and these are especially important in an "air-minded" country.

4. **Mathematical Physics.** An electronic computer has been developed to satisfy the needs of the Division.

The National Standards Laboratory

This comprises a group of the three Divisions, Physics, Electrotechnology, and Metrology, all associated in one large and well-equipped building. The National Standards Laboratory, which was founded in 1938, is also placed in the grounds of the University of Sydney. It is in effect, but on a more modest scale, analogous to the Bureau of Standards or The National Physical Lab-

oratory. One of its functions is to maintain standards of measurement which will in due course, when an act, already passed, is promulgated, be the only legal standards of measurement in the Commonwealth. Other functions are those of testing and calibration. These activities are undertaken to meet the requirements of: the Weights and Measures administrations of the various States; Government and semi-Government authorities, for purposes outside the Weights and Measures Acts; and industry and scientific research, for precision measurements generally.

The fields of activity are shared among the three Divisions as follows:

Physics. Chief: G. H. Briggs (a former professor of physics at Sydney). Heat (maintenance of International Temperature Scale); light (candle-power, luminous flux, illumination, colour measurement); viscosity; the primary electrical standards of resistance and voltage.

Metrology. (Chief: N. A. Esserman.) Length, mass, time, and the physical quantities directly derived from these (area, volume, force, pressure).

Electrotechnology. (Chief: F. J. Lehany.) The maintenance of standards both for direct and alternating current over a range in practical use, of resistance and voltage (other than primary standards), inductance, power, frequency, magnetic quantities.

The three Divisions engage in research on matters related to the maintenance of standards and precision measurement and also in fundamental physics.

It is hoped that these examples will serve to indicate the type of activity in physics that is sponsored by CSIRO. The Organisation is responsible to the Federal Minister for National Development (Rt. Hon. R. G. Casey).

The Commonwealth Observatory

Australia with its frequent clear skies can offer many an ideal site to the astronomer. Such a site is that of the Commonwealth Observatory on the top of Mount Stromlo, twelve miles from the Federal Capital, Canberra, a city in which industrial development is forbidden.

Under the direction of R. v. d. R. Woolley, the Commonwealth Astronomer, and senior members of his staff (C. W. Allen and A. R. Hogg), much observational and theoretical work has been done in the following fields: the solar corona, the ionosphere, solar and galactic noise, observations of double stars, cosmic rays, and magnetic storms and solar activity. At present the most important work in progress is an investigation of monochromatic magnitudes and stellar colours.

The following additions to the Observatory's equipment will be made in the near future:

(1) A 74-inch reflecting telescope from the firm of Grubb and Parsons in Great Britain (1953).

(2) A 48-inch telescope in Melbourne is to be remodelled as a Schmidt telescope, with objective prism (not earlier than 1953).

The Commonwealth Observatory is affording facilities to other institutions as follows:

(1) Yale and Columbia Universities propose to move their 26-inch ($f = 400$ inches) refractor from South Africa to Mount Stromlo late in 1951. The Yale-Columbia Southern Station on Mount Stromlo will be under the charge of an officer appointed by and responsible to these Universities.

(2) The University of Uppsala has accepted an invitation to establish a Southern Station on Mount Stromlo.

The chief instrument will be a Schmidt telescope, under construction in Sweden, which will not be completed before 1952.

The Commonwealth Observatory, if not so already, will soon become the most important Observatory in the Southern hemisphere. The Observatory is responsible to the Federal Minister of the Interior (Hon. P. A. McBride).

Other Government Research Stations

The Magnetic Observatory at Watheroo in Western Australia, which was established and formerly maintained by the Carnegie Institution of Washington, is now the responsibility of the Federal Government.

In Melbourne there is the Commonwealth X-Ray and Radium Laboratory in which are maintained standards of x-ray dosage and radioactive sources. This laboratory is directed by C. E. Eddy.

Many physicists are employed in defence research. The Federal Government maintains research on defence and aeronautics. Well-equipped laboratories are located at Maribyrnong, Victoria, and there is a large organisation, The Long Range Weapons Establishment at Salisbury, near Adelaide.

The Department for External Affairs maintains ionospheric and meteorological stations on the subantarctic Macquarie and Heard Islands.

Numbers of Physicists

It must be stressed that what has preceded by no means exhausts the modes of employment of physicists in Australia. Physicists here, as elsewhere, serve the community in industry, in the post and telegraph services, as teachers in schools and colleges of technology, as radiologists, as meteorologists, and geophysicists, but it is not possible to do justice to all these activities in a brief account. A recent survey has shown that there are 625 physicists employed in industry, universities, government laboratories and in other occupations.

The present output from the universities is about two hundred graduates per annum with physics as a major subject, of whom somewhat less than fifty percent become professional physicists. These numbers will probably appear small to American readers, but it should be recalled that Australia's total population is only eight millions.

At present the only association which provides lec-

One of the towers of the Commonwealth Observatory on Mt. Stromlo. The Observatory, located twelve miles from Canberra, has a sun telescope, a 30-inch reflector, and a 48-inch reflector from Melbourne Observatory, now being installed. A 74-inch telescope is now being built in England for the Mt. Stromlo Observatory. Official Australian Photos courtesy Australian News & Information Bureau.



tures and meetings devoted only to physics is the Australian Branch of the British Institute of Physics. It would not cause general surprise, however, if some Australian association of physicists were founded in the very near future. Physicists publish locally in *The Australian Journal of Scientific Research A* and in *The Australian Journal of Applied Science*, but the chief media of publication are the scientific journals of Great Britain.

It is hoped that this somewhat inadequate sketch of physics in Australia will serve to stimulate the interest of readers of *Physics Today* in this energetic and self-reliant community of the Southern Pacific. The destinies of Australia and of the United States have not been so distinctly separate as might at first be thought, for it was the loss of the American colonies that led the British Government to proceed seriously with the settle-

ment of Australia. The year 1788 saw both the arrival of Captain Phillip's "First Fleet" in New South Wales and the ratification of the new American constitution; moreover the lessons of the second world war are too recent to require stressing.

The sense of isolation in this country has been greatly diminished since the war by the visits from Britain and elsewhere of a large number of persons distinguished in politics, the arts, and the sciences, and there is every reason to believe that such contacts with the outside world will continue.

For instance, it is a source of satisfaction to Australian radio physicists that a meeting of the Union Radio Scientifique Internationale (URSI) is to be held in 1952 in Australia for the first time, and it is hoped that some American physicists may be able to take this opportunity of paying us a visit. They will be most welcome.