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The Australian Physicist, November 1971

PHYSICIST

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School of Physics, University of New South Wales

8-11 February 1972

A conference on radiation damage in solids, sponsored by the Australian Institute of Physics, is to be held in Sydney, 8-11 February 1972.

Programme
Invited and contributed papers on:
(a) Theories of irradiation damage by neutrons and charged particles.
(b) Effect of damage on the mechanical properties of solids.
(c) Effect of damage on transport properties.
(d) Experimental techniques including diffraction, microscopy, and channeling.
Speakers from overseas will be attending.
Preliminary abstracts of contributed papers should be submitted by 30 November 1971.

Accommodation
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Registration
The conference fee will be $20.00 with concessional rates for students. This fee includes the conference dinner.

APPLICATION FORM

To be returned to: Dr C. J. Howard, Conference Secretary
Australian Atomic Energy Commission
Research Establishment,
Private Mail Bag, Sutherland, N.S.W. 2232,
by 30 November 1971.

Name: ......................................................
Address: ...................................................

I wish to attend the Radiation Damage Conference and enclose cheque/money order/postal note for the $2.00 conference deposit.

YES ☐  NO ☐

I intend to submit a paper and enclose title/abstract.

YES ☐  NO ☐

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The Editor-in-Chief,
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by 10th December, 1971.
1. Introduction

An underground observatory has been established in a mine at a location remote from both cultural and sealeveling effects. The prime, but by no means sole purpose, is to study solid-tidal phenomena in the southern hemisphere. Secondary interests are for research into and testing of instrumentation for tidal measurement and for other devices which require an extremely well controlled environment. The creation of a service facility is now mainly complete and a wide range of instruments are in various stages of development, procurement, and installation.

This paper provides an overall view of the project. A brief history of events to this time is given along with a statement of the aims of the observatory. Then follow descriptions of the topographical and geological features of the Hillgrove area where the underground facility exists. Brief outlines of the services and equipment already provided and the instruments to be used are given.

2. History and Events, 1887-1971

In the period 1877-1910, numerous shafts and drives were cut into the sides of the Hillgrove gorge, situated 50 km east of Armidale, New South Wales. These mines produced gold and antimony. The then boom town of 3000 inhabitants declined rapidly after this period and today only a few houses remain along with the many underground workings running in from the gorge. A survey of the Hillgrove gold fields was made by Andrews [1900] and this work proved most useful in locating mines for scientific work. A detailed history of mining in the New England area has recently been compiled by Catherine Balter [1971].

In 1966, a Department of Geophysics was created at the University of New England, Armidale [Green, 1967], with the first-named author as Head of the Department. A research programme was implemented to form the necessary facilities for studying earth tides. Various shafts in the New England area were visited. A decision was made late in 1969 to use an 800-m near-horizontal tunnel made by the early miners and known as the Main or Lower Cooney Drive.

At about this time the second author was completing a three-year research programme in England on methods and applications of high-resolution long-length metrology for industrial and geophysical purposes [Sydenham, 1969b]. One conclusion of this work was that long-length standard stability and calibration, geophysical strain, and surface geodetic length measurements could be advanced efficiently in a common underground facility where environment was well controlled [Sydenham, 1969b]. The opportunity to further this aim arose in 1970 when he accepted appointment at the University of New England. The creation of a serviced facility at Hillgrove was the main research task required of the position.

Late in 1970 a world antimony shortage occurred and mining operations resumed at Hillgrove. In December 1970, the mining operators decided to use the selected Lower Cooney tunnel to bore deeper in order to gain access to other probable sources of ore. This decision by the mining company prevented the development of the lower tunnel and forced a new selection to be made for the observatory. The upper drive, called the Upper Cooney tunnel was chosen where work could be carried out free of interruption. The upper drive was also found to be more suitable from a logistic point of view. In February 1971, the mining company was liquidated following a slump in antimony prices. As a consequence the Lower Cooney tunnel was not driven further and it has remained undisturbed. Power lines for the observatory were installed down the gorge by the New England Electricity Commission in May 1970.

The greatest problem with these tunnels was access, for no roads existed within 1.5 km of the Cooney tunnel entrances, which are situated at approximately 300 m down the 45° sloping gorge sides. The mining recession and a record wet season fortunately assisted the project, because materials became available from the liquidated mining company and an experienced bulldozer operator, together with his machine, were in need of work at the time.

By April 1971, a road was completed and work commenced on installation of a storage hut and toilet near the upper tunnel entrance. From that period until July 1971, available labour and materials have been concentrated on supplying the general requirements of the observatory.

3. Aims and Uses of The Facility

The properties and composition of the inner earth cannot be investigated by direct observation because of technological and economic limitations. However, much
can be and has already been found by the use of indirect measurement techniques such as seismic-wave propagation [Green, 1962], which has been the most fruitful technique.

However, the orbiting interrelation between the moon, sun, and earth produce well defined driving functions in which the gravitational potential at the earth’s surface varies systematically with dominant periods of approximately half a day, a day, and a month. The principal difficulty in using these driving functions to provide information about the earth’s interior has been a lack of suitably sensitive instrumentation.

Varying gravitational attraction causes the earth to change shape with time. Three main effects of this are measurable at a point or near the surface. The crust undergoes small length changes (solid-tidal strain), the centre of gravity of the earth moves resulting in variations of measured gravity (tidal gravity variation) and the deflected vertical-axis tilts (tidal tilt).

Earthquakes and the larger man-made explosions [Green, 1965] also produce shape changes by setting the earth into a damped oscillation in its various modes of natural vibration. The same three groups of measurement devices will detect these events provided they have adequate bandwidth (periods of minutes for microseisms to hours for natural vibration) and sufficient sensitivity. However, the random occurrence of earthquakes makes them less attractive as forcing functions for studies of the inner earth but they are used because there are no other suitable sources at the higher frequencies. As the frequency of occurrence of earthquakes rises sharply with reducing magnitude, the trend is toward the use of a greater number of locations for instruments (in order to raise the probability of being closer to an epicentre) and for use of more sensitive instruments, placed in quieter sites, which can detect smaller amplitude events.

Due to the long periods of interest, instrumentation needs to have excellent low-frequency response (1 Hz downward to periods of years) so, unlike general electronic technology, it is the pseudo-zero frequency behaviour of devices which needs development. To date, insufficient tidal measurements have been made in the southern hemisphere due to the lack of a suitable observatory. The International Association of Geodesy (IAG) has repeatedly resolved in the last decade, that a southern member country provide such a facility in order that a broader knowledge be obtained of parameters such as density distribution and rheological properties for the earth. There is geodetic and tectonic evidence indicating that the southern hemisphere differs greatly from the northern in many ways.

The Cooney Observatory has been established primarily to determine many of the physical properties of the earth. It is intended to provide tidal measurement data as needed by Australian and international observers, and also a well equipped laboratory where standard and newly developed instruments may be tested and improved and intercalibrated so as to ensure that precise and accurate data is made available to those studying various theses on the inner earth.

4. Geographical and Geological Description

The Cooney tunnels are situated east of Armidale in the Hillgrove side of the Baker's Creek Gorge. Coordinates scaled from the NSW standard 2 in = 1 mile map are 30° 54’ 40’’ S; 151° 59’ 30’’ E. The direct distance to Armidale is 28 km and by the sealed road 50 km. East of Hillgrove lies the Tasman Sea at a distance of 140 km.

Baker's Creek Gorge cuts into the east side of the tableland area known as the New England Ranges. Hillgrove and the town Metz (which is situated on the opposite side of the gorge) are 990 m above sea level. Figure 1 shows the view looking toward Hillgrove side. The Upper Cooney Tunnel (which is now in operation) is 653 m above sea level. Lower Cooney Tunnel lies at 558 m above sea level with the creek being 11 m lower again. Referring to the illustration, they are placed in the lower right extremity of the photograph. These elevations are provisional: a new survey is being arranged by the Bureau of Mineral Resources, who are to have a third-order level established at the Upper Chambers in conjunction with their recently established gravity tie to the Australian gravity network.

Hillgrove is serviced by public telephone and a sealed road from Armidale. Only one shop and a post office exist; the nearest centre for commodities and accommodation being Armidale.

The gorge experiences 3500 points of rainfall per annum with the majority of this falling in heavy storms during the summer months of January and February. With the exception of this rain, the climate is mild.
being generally free from fierce winds and serious cloud cover. Like other areas in the Tablelands of New England, temperatures range from $-12^\circ$C minimum to around $38^\circ$C maximum. Light snow occasionally falls. Baker's Creek is for the most part a gentle waterway except when it fills with the January rains. At these times it is likely that a greater background noise level will be seen at the higher frequencies due to the movement of larger boulders.

The area is sparsely covered with Eucalyptus trees and low shrubbery. The precipitous sides of the gorge prevent agriculture and limit the wildlife. In Miocene times the mature sedimentary plains of Eastern Australia were uplifted from sea level producing the Great Divide. The New England Tableland forms part of this. Originally meandering water courses retained many of their mature aspects during this process showing all features of rejuvenation. The eastern drainage pattern features large gorges of which the Baker's Creek Gorge is typical.

The uplifted sediments were intruded by granites during Permain times and these have given rise to a system of mineralized sub-vertical veins. The sediments in the vicinity of the granites have been converted to low grade hornfelses of which spotted hornfels, slates, and metamorphosed silt-stones are typical. An extensive geological survey of the New England area has been published by the Department of Geology of the University of New England [Binns et al., 1967].

The Cooney tunnels are cut through the hornfelses and along a few of the fracture planes in the sedimentary rocks, where narrow mineralized reefs were suspected to exist. In the upper tunnel the cross drive is taken out along one such vein.

5. General Description of the Facility

The appropriate section of the NSW standard 2 in = 1 mile map has been redrawn in figure 2 to show the features of interest. An unpaved single width road has been cut around the face for a distance of approximately 4 km with grades never exceeding 1 in 7. This services the Upper Cooney Chambers. At present, no road exists to the mouth of the lower tunnel.

Open-wire power lines feed directly down the slope. The capacity is set at 10 kVA by the transformer used at present. The poles of this route also bear a six-pair shielded cable used for signal communication to the gorge top, where a two-way solid-state transceiver connects directly with the Geophysics Department on the University Campus at Armidale. In addition, a PMG telephone is soon to be installed. A vertical cross-section of the hill is shown in figure 3. Spur lines feed the Upper Chambers with power and communications. Power is terminated at the outside of the lower tunnel. To date

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the lower tunnel has not been used, but is available when need for it arises.

A plan view, figure 4, shows the upper tunnel and the surrounding area. The service road enters from the north and terminates at a turning area with a level ledge cut for parking, a site office, toilet, and stores. A steep road diminishing to a footpath feeds from here to the entrance. The extreme slope of the gorge and rock outcrop at this point prevented the road from being completed on available funds.

The mine consists of arch-shaped tunnels varying from 1.5 to 2.5 m wide and typically 2 to 3 m high. The main tunnel (driven around 1890) extends 190 m in and is straight. A cross-drive follows a vein cut around 1900. Here it is wider and somewhat taller with reasonably straight walls. The drive narrows half way along this and turns at roughly 90° for a further 20 m before going down into a deep shaft. Along the main drive are four niches which are just large enough to be turned into small rooms. Damp air at 15°C rises from the shaft and ventilates the tunnel with force. During the construction stage this was desirable but the air flow has been blocked for the use of the mine as an observatory. Hatches (0.9 x 0.9 m) have been bricked into a wall across the tunnel at various places to form chambers which are isolated to some degree from each other. The doors have airtight sealing incorporated. Doors are added as extra chambers are needed.

The first 26 m has been outfitted as workshops and domestic quarters for the observers and technicians. This area, shown in figure 5, provides bench space for processing and recording equipment and for service and developmental work. The domestic area provides a limited water supply and cooking appliances. This area is enclosed by normal size wooden doors and will be slightly heated (ambient temperature is normally 16°C) to reduce the humidity to a tolerable value. Space is available for several bunks.

Once an observatory such as this is operational it is undesirable to interrupt experiments, especially those
running for several months. For this reason, heavy-duty and duplicated power and light services have been provided.

The open-wire power line and signal cable are terminated inside the external security door. Power is distributed using thermal-trip overload circuit breakers. The main power run is 7/0.64 cable to keep the voltage drop to a minimum of 10 V or so at the inner chamber. This circuit has power outlets provided as needed for fluorescent lighting at key positions, and for general equipment. A second cable (7/0.29) is to provide power for priority circuits such as those involved in experiments. The third cable, also 7/0.29 in size, has festoon lamps fitted in all chambers to provide an illumination level which avoids the need for hand carried lights. The six-pair signal cable also passes through all chambers, its purpose is to take high-level signals from instruments to recorders and the data sending terminal in the observers' chamber.

As the rock was found to be extremely hard, all cables, power points, and lights are suspended by a steel bearer cable running along the top of the wall. The domestic area has its own service. As photographic recording will be used by some of the installed equipment, an area has been reserved for a limited amount of processing of films. The on-site water supply is at present very limited and has to be transported to the site.

The chambering shown has been developed to suit known immediate plans. It is comparatively simple to alter walls as needed. In places of intensive work the entire walls are painted with white enamel to increase the light level and provide a cleaner environment. A typical area is shown in figure 5. At present, the relative humidity is near to 100 per cent., but with the exception of a few isolated places, there is no obvious surface water or water seepage. The floor has a layer of crushed rock on the bedrock.

It is interesting to consider the scientific value of the observatory to date. The road cut mainly by a mining company, cost at least $40 000 and the cost today of boring the upper tunnels would be $20 000. Materials for fitting out amount to $3000 and expended labour to date amounts to 3500 man hours which would have cost some $10 000. The power line cost $5000. This totals $78 000. Fortunately, the University and science had to bear only a small proportion of this cost. From inquiries already made by Australian and overseas interests, it is expected that instruments with a value of at least $70 000 will be installed in the next few years. Instruments costing $20 000 are to be placed this year.

6. Instruments

The instruments to be installed will be decided on the extent of finances and the source providing the assistance or interest. The main emphasis for the Department's resources is on strain instruments as tilt and gravity instruments are expected from external sources. As the secular stability of strain meters is of vital importance [Sydenham, 1971] a programme is under way to provide a stable, relatively massive, test base which is controlled in length by thermal methods. The original base is modelled on a previous construction and with minor improvements should realize 1 part in $10^8$ stability as a starting point to alternative bases. The thermally controlled base will also act as a strainmeter standard bar.

To date, three tensioned invar-wire strain meters [Sydenham, 1969c] have been prepared. These will be used to verify the behaviour of the two components of a laser interferometer strainmeter provided by an Australian Research Grants Committee grant and to verify the performance of a novel temperature and pressure compensated quartz rod strain gauge being constructed as an Honours Student team project. It will also be possible to investigate the behaviour of various developments in the wire strain meters. Strain meters must resolve strains of $10^{-10}$ and use typically 10-m rock intervals as gauge lengths.

The Bureau of Mineral Resources, who are working in co-operation, now have underway a programme to install two Verbaandert–Melchior horizontal pendulums as part of the Bureau's responsibility for gravity and geodetic datum values. This task involves the cutting of a 0.4 by 0.4 by 0.8 m niche into the rock wall without the use of explosives. These pendulums measure minute changes in tilt and have a resolution limit of around $10^{-9}$ seconds of arc. If resources permit, it is hoped to duplicate tilt measurements with a hanging pendulum device such as developed by Muirhead [1971] at the Australian National University or by mercury reservoir devices such as that developed at Queensland University [Stacey et al., 1969].

The most expensive instruments needed are tidal-gravity recording gravimeters. Correspondence is underway to place a gravimeter, made available by an overseas group, in the observatory.

Many of these instruments require corrections due to changing environmental parameters such as temperature, pressure, and to a lesser extent, humidity. Recording transducers are under development to measure these and produce a continuous record. An electrical recording microbarograph is being negotiated. Conventional Beckmann thermometers, sling psychrometers, and a mercury Fortin barometer have been provisioned to act as on-site substandards.

One niche has been prepared as a non-magnetic room where alkali-vapour magnetometers will be used to study magneto-telluric effects. The AV magnetometers that are in operation have been totally constructed within the University as a PhD research project [Clack and Stanley, 1971]. Timing is to be provided by an IBM observatory pendulum clock with time checks made with reference to standard radio transmissions.

It will not always be desirable for researchers to visit the Observatory. To this end a multiplexer is under construction which will switch the signals from up to eight instruments onto a common f.m. carrier system which will be received at the new Geophysics building now also under construction. (In the interim period on-site records will be made.) This data will be transmitted in digital code and, when received, it will be serialized ready for processing on the Department's
IBM 1620 computer or on the University's central computer. A room has been provided in the new building as a computer centre for this operation.

Another instrument related to, but not installed in, the Cooney Observatory is a trailer strain station that will be used to investigate the strain homogeneity around the tableland area. This station will be able to operate unattended for periods of up to a week in places remote from roads and power.

Few of the abovementioned instruments are installed as yet due to the need to complete all major works, but by the end of 1971 most of these projects will be operational.

7. Future Expansion

One feature of this observatory will be its concentration of instruments which will at least duplicate most measurements by different types of device. Already there have been promising inquiries from northern observatories who are considering placing gravimeters, magnetometers, and ultra-long-period inertial seismometers.

There is adequate space and service capability for small devices but the need to use strain intervals of hundreds of metres may arise. If this does happen the lower Cooney drive (800 m long) and various other drives in the gorge of lengths to 150 m can be used, provided funds are made available to fit them out.

The 1972 research grant applications allow for a vertical-component laser strain meter, to be fitted in the shaft of the Upper Chambers, and a mercury cistern tilt meter for study of the stability of the various kinds of mounting methods to the rock. Further, but limited, funds will be available to develop improved thermally controlled rod systems and to investigate improvements to stabilize the laser source.

Naturally, the authors would like to hear from those interested in the present or future aims of the observatory.

8. Acknowledgements

The Australian Research Grants Committee, The University of New England, New England Antimony Mines NL, Carpentaria Exploration Co. Pty Ltd, and Esso Standard Oil (Australia) Ltd have each contributed to the financial cost of creating this facility. Enthusiastic assistance by F. C. Ludbey, Senior Technician and students D. P. Blair, K. E. Le Brocq, A. R. Limbert, B. W. McKnight, B. C. Preston, and J. M. Stanley of the Department of Geophysics is acknowledged with gratitude.

I. G. Mathias provided the geological description of Hillgrove.

9. References


THE CALENDAR

December

14 Irrigation—An Australian Myth, Sydney Uni. (NSW-AIP, Annual Dinner); Dr B. R. Davidson, Dept of Agricultural Economics, Sydney Uni.

January, 1972

24-28 Astronomy and Geophysics, ANU Summer School; (ACT-AIP and Astronomical Society; see AP, July 1971).

Late Notices

February

8-11 Radiation Damage Conference, Uni. of NSW (NSW-AIP; see AP, May 1971).

14-17 Fourth AINSE Nuclear Physics Conference, Sydney Uni.

14-17 Third Australian Conference on Electron Microscopy, Canberra (AAS).

14-18 Magnesium, Phase Transitions, Advanced Materials; Monash Uni. Summer School (VIC-AIP; see AP, July 1971).


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AN AUDIO-TUTORIAL PROJECT IN PHYSICS

J. R. Hanscomb and P. S. Arbib
School of Physics and Tertiary Education Research Centre,
University of New South Wales

The lecture method remains the traditional method of imparting information in the universities despite technological advances. Thus although in recent years, closed-circuit television has been used to extend the lecture method to larger classes, this has not resulted in any significantly new approach to teaching.

Lectures can perform several functions other than the transmission of information and they can be an enjoyable experience for both the lecturer and the student. It may be questioned, however, whether they make best use of the students timetabled hours and whether they provide an environment in which the student becomes involved to the extent that he learns the material presented.

Many students approach lectures with the attitude that they must take down all that the lecturer says and thereby obtain a good set of notes which, they hope, will enable them to study the material at some later time. When lectures follow one another in rapid succession and when they are devoted to a variety of topics, it is doubtful if the student mentally retains or understands much of what has been presented, particularly when he is not required to question or otherwise to take an active part in the programme. It may be that if the number of lectures were reduced and designed deliberately to stimulate, to provide an overview of a topic, or to clarify difficult points, the lecture would have much more meaning for the student.

Merely reducing the number of lectures and relying on a good textbook is not in itself sufficient, however. The majority of students need to be guided in their study. A teaching programme is required which will maintain student interest, which will be flexible enough to enable each student to proceed at his own pace, and which affords and indeed, requires him to adopt an active attitude towards study.

One recent innovation in teaching which seeks to provide, in an individual way, instruction to large numbers of students is the audio-tutorial method devised by Postlethwait [1964] at Purdue University for the teaching of biology. The method is in use in a number of Universities in the USA and, in this country, has been adapted by Brewer [1970] for the teaching of botany.

The audio-tutorial method does away with lectures almost entirely and provides a set of integrated learning experiences in which the student is led to take an active role. The method involves the use of an individual study booth (carrel) equipped with tape recorder, headphones, tapes, and relevant visual material. The lecturer’s voice, recorded on tape, is used to programme the students activity and to lead him at his own pace to understanding. In addition, the student attends tutorials and occasional large group sessions.

In this paper a project is described in which the authors (with the assistance of Mr. J. R. Shepanski in discussing and preparing the study guides and tapes) have adapted the audio-tutorial method to the teaching of physics. Financial assistance was provided by way of a grant received from the Australian Vice-Chancellors Committee.

Study Booth Method in Relativity

The topic chosen for the project was a five-week section on relativity comprising part of the Modern Physics course for second year science at the lower level. Students find considerable interest in this topic but do not, in general, maintain the continuous effort required to appreciate fully the concepts involved. Students frequently arrive at tutorials remembering very little of what they have written down in lectures and generally are not at that level of comprehension required for intelligent discussion or appreciation of the points raised. Admittedly student performance is good in the final examination, which occurs many weeks later, but at the expense of private-study time. The questions set in this examination seek to test for satisfactory performance in the whole subject of Modern Physics rather than seeking a detailed understanding of any particular topic.

The specific aim of the project was to develop in the student a deeper understanding of the subject and increased ability to apply its concepts than it has proved possible to obtain in the same length of time by the conventional lecture method. If this could be done then the time which the student spends at the university would be more profitably employed, private study time would not need to be so heavily devoted to understanding lecture material and tutorial sessions would be more beneficial.

Ten study booths each equipped with a cassette recorder and headphones were provided. In place of twelve lectures and three whole-class tutorials the student studied in individual carrels for nine one-hour sessions and received three tutorials given in half-class groups and three tutorials given in full-class groups. Since the number of students (50) exceeded the number of booths the normal timetable could not be adhered to. Instead students booked a study booth for two one-hour periods per week at times, between 9 a.m. and 5 p.m., convenient to them.

A surprising degree of flexibility existed and no student resistance to the re-organization of their timetables was encountered. In addition to the rostered time the student could, if he wished, return to the booths at any other time that he found one unoccupied, for purposes of revision or further study. No member of staff
was in attendance during any of the sessions. No equipment damage or theft occurred.

The student was required to study one 60-minute cassette tape per week. On entering the booth the student placed the tape in the machine, adjusted the headphones, and opened the printed study guide (supplied to each student) at the appropriate place. The study guide is structured to follow the tape presentation and to direct student attention to all relevant diagrams, mathematical expressions, etc.

An Active Role

If the tape commentary was merely a lecture to be given without interruption, there would be little point in adopting the carrel approach. The real task for the lecturer is to provide the material on the tape and to structure the guide in such a way that the student is called upon to take an active role. Much remains to be learnt as to the best way of achieving this aim. Our approach has been to divide the topic into small sections, to discuss each of these on the tape, and to pose, either during the discussion or following it, a number of questions for the student in order to test his comprehension or to apply what he has studied. After each question is posed there follows a brief musical interlude. The student then usually switches off the recorder, considers the question (which is also printed in the guide), enters his answer in the appropriate place, and then switches on again to receive the answer. If he has not understood the material covered and has thus answered the question incorrectly, he replays the appropriate section of the tape.

Some questions are asked which require no written response, others require the student to draw a diagram or to work out a numerical problem. In addition, from time to time, the student is required to write down the statement of some basic law or definition or to summarize a section of the tape discussion. The guide, on completion by the student, constitutes a comprehensive set of notes which he can retain and refer to.

To enhance interest, the tape commentary was presented in the form of a dialogue. The change of voices provided a natural way of reinforcing central ideas and for presenting the topic from alternative viewpoints.

Group Sessions

Tutorials are considered an essential part of the teaching method. These were arranged such that in any one week the student spent two one-hour periods in the booths and attended a one-hour tutorial related to the topics covered in the previous week's tape.

A number of problems are included in the study guide at the end of each tape programme. These are attempted by the student in his own time and prior to the tutorial relating to that tape. At the tutorial session these problems are discussed in addition to individual difficulties relating to the tape content.

A marked improvement was noted in student attitudes and comprehension at these tutorial sessions. The active feature of the study method ensures that students are much better prepared to benefit from these sessions. The personal contact provided is essential and benefits both the lecturer and the student. It also retains the best feature of the lecture method. Since the method allowed the number of tutorials to be doubled and since these were more beneficial, effective lecturer-student contact was in fact increased even though lecture contact had been deleted.

Evaluation

We present here some aspects of the evaluation of this project. A fuller discussion appears elsewhere [Arbib and Hanscomb, 1971].

The experimental group consisted of 50 science students. For comparative purposes, 120 electrical engineering students enrolled in the same course were also studied. This control group received the traditional method of instruction. It could not, however, be considered strictly as a control group, since both groups were not taken by the same lecturer.

Both groups were given questionnaires prior to the commencement of the course and at the end of the course. These were designed to determine student attitude towards physics generally and relativity in particular, time demands, student favourability to the teaching method, suggested improvements, etc. The experimental group were also asked detailed additional questions about the audio-visual method at the end of each carrel session. Students rated 18 items on a five-point scale covering such variables as amount of replay necessary, difficulties experienced, etc.

At the end of the Relativity course all students were given the same one-hour test on Relativity. This test was not compulsory but the majority of students sat for it. All students sat for the compulsory end-of-course examination on Modern Physics, which was held some seven weeks later and which included one main question on Relativity.
2. Synchronization of clocks and simultaneity

(a) Describe here how two clocks A and B may be synchronized by means of light signals emitted from the midpoint O of the segment AB.

\[ \begin{align*}
A & \quad \quad O \quad \quad B \\
\end{align*} \]

(b) Einstein's definition of simultaneity:

4. Applications of the Lorentz Equations

Questions:
(i) Suppose the \( S' \) frame is moving with a speed \( v = \frac{3}{5}c \) with respect to the \( S \) frame, determine the value of \( \gamma \).

\[ \gamma = \]

(ii) Suppose that at \( t = 0 \) in the system \( S \) an event occurs at \( x = 40 \). Use the Lorentz equations to determine the position of this event as seen from the system \( S' \).

\[ x' = \]

(iii) Determine the time when this event is seen to occur from the system \( S' \).

\[ t' = \]

(iv) What is the meaning of the negative sign?

(c) Relativity of simultaneity:

Statement:

(ii) Choose a simple example to illustrate the relativity of simultaneity, e.g., a train passing a platform and describe it here.

\[ \begin{align*}
&\quad v \\
&\quad \quad 0 \\
&\quad A \quad \quad \quad \quad B \\
\end{align*} \]

Figure 3.3

Question: Observers in \( S \) state that at \( t = 0 \) (when \( O \) and \( O' \) are coincident and the clocks there read \( t = t' = 0 \)) that all clocks lying in the \( x' \) plane passing through \( x = L \) read the same time. Will the \( S' \) observers agree?

Answer:

Justification:

The average total mark (marked out of 70) was 42.6 for the experimental group and 28.6 for the control group. The distribution for the two groups also clearly indicated the differential performance. Whereas approximately half of the control group lay between the marks of 10 and 30, only 5 per cent. of the experimental group did so. This difference in performance is not due to differences in ability of the two groups, since their average performance in Physics I and in the Higher School Certificate is very similar.

Whilst the performance of the experimental group in the Relativity test was greatly superior to that of the control group, their performance in the end-of-session examination was as good as, but no better than, the performance of the control. The pass rate in each group for the Relativity question was 70 per cent.

On the basis of the Relativity test and the tutorial sessions, it seems reasonable to conclude that the carrel method is an efficient one and is very effective in encouraging students to make better use of their time at the university and to learn the subject as it is presented rather than at some later stage. In attempting to understand the different performances obtained in the Relativity test and in the final examination, the following points can be made.

(i) The test was not compulsory. It is likely that the experimental group was more motivated than the control
group. The experimental group were not however, volunteers—they were required to take the carrel method.

(ii) In the period intervening between the test and the compulsory final examination it is probable that the control group, by individual study, had mitigated some of the effects of the differential treatments. Also it is possible that the experimental group, in view of their intensive study and good performance in the test, directed their attention to those other topics requiring study and thereby suffered some learning loss in Relativity.

(iii) The Relativity test was designed specifically to test in depth the student's grasp of this topic. The final examination, on the other hand, consisted of Relativity and the remaining two-thirds of the Modern Physics course, and was designed to test for satisfactory overall performance. As previously stated, results from past years have shown good performance in this final examination.

(b) Student Reaction.

Students' reactions to the audio-study method were obtained from discussions with students, student evaluation of individual tapes, and from a questionnaire. The reaction was extremely favourable, and would point to a general satisfaction with this method of teaching.

Most striking is the fact that when asked 'Would you like to see the use of study booths extended to other areas of the teaching of physics?' two-thirds of the students answered yes. Students do not, however, wish to see study booths completely replacing lectures (89 per cent. of students favoured either one lecture with two study booth sessions or two lectures with one study booth session). Only 5 per cent. of students wished to see no study-booth sessions.

Students overwhelmingly (86 per cent.) feel that the use of study booths is the best teaching method for enabling them to work at their own pace and to study in depth the subject matter. Tutorials are regarded as essential to the method. This reinforces our previously held conviction that, while lectures can be severely restricted (perhaps to an inspirational or a review lecture), it is essential that the audio-study method involve integration of tutorials with study in the booths.

As seen by students, a principal advantage of the method is that it enables them to play back parts of the tape which they did not understand. Almost half of the students cite this as the main advantage, 27 per cent. see it as the second most important advantage, and only 8 per cent. do not consider it an advantage at all.

Students also report disadvantages with the method as it has been applied here. Thus 34 per cent. indicate as the main disadvantage the inability to ask questions at the time that they come to mind. The fact that students do wish to ask questions indicates, however, that the method encourages active response. With extension of the method to larger student numbers, it would be desirable and economical to have a staff member in attendance. Allled to this is the disadvantage mentioned by about half the students that, in order to have their problems solved, replay is not enough. There is a need to have the matter explained in a different way. Another disadvantage that students have experienced relates to the lack of visual content. About 40 per cent. of the students considered that there were insufficient visual aids and that this led at times to inattention. This is to some extent peculiar to the subject matter of relativity. While the visual aspects should certainly be improved, we are not convinced that this necessarily implies that synchronized lantern slides or film loops in conjunction with the tape recorder are more effective than duplicated sheets, photographs, and other illustrative items.

Further Aspects

The fact that students perform so much better than the control when tested for understanding and application immediately after study, that they perform at least as well as the control after a period of seven weeks when private study of both groups would have intervened, and that students are favourable to the method, lead to the conclusion that the carrel method is both feasible and viable.

In our application of the method, we have eliminated all formal lectures in the topic without any increase in total timetabled hours and have been able to double the number of tutorials. It seems important to us to stress that, while there are many learning aids which can be offered to students as optional extras to their timetabled hours, the real challenge is to make better use of their existing hours. The student already spends a large proportion of his time in attending lectures.

A further experiment will shortly be conducted with a group of Physics I students. It is planned here to teach the topic Heat by replacing 9 one hour lecture periods by 4 one hour carrel sessions and 4 one hour tutorials. The method adopted will be essentially the same as that used with relativity but the visual content will, it is hoped, be increased.

We do not advocate the blanket application of the audio-tutorial method nor the complete elimination of the traditional lecture method. The employment of a variety of teaching methods would seem to be a desirable aim. Formal lectures, however, whether delivered through the live lecturer or through television should not continue to be the only 'work horse' for imparting instruction. If these are restricted in number and deliberately designed to stimulate and to provide an overview of a topic then they could be more worthwhile.

One final point concerns economy. It may be argued that the carrel method is not practical with large classes of 1000 to 2000 students. We would point out that a tape recorder and headphones can be purchased for less than $60. Mass produced booths could be constructed for approximately $40 each. Hence the total cost should not exceed $100 per carrel. With 10 booths and the flexible roster system, which we were able to employ, fifty students were easily accommodated and, given the existing student timetabled hours in all courses, over 100 students could be catered for with two individual one hour sessions per week. It is unlikely
that more than 300 booths would ever be required in order to cater for 2000 students. In the USA considerably less booths have been used by extending their availability beyond daylight hours and also into the weekend.

With 300 booths at $100 each the initial cost would be $30 000. While this figure seems large, it is in fact insignificant compared with the cost of television installations and the cost of providing large tiered lecture halls.

References

**INSTITUTE AFFAIRS**

**RECOGNITION OF AUSTRALIAN QUALIFICATIONS IN BRITAIN**

A letter from Mr B. H. Thomas, Grad.AIP, was published in the August issue of *The Australian Physicist* drawing attention to certain difficulties he had experienced in obtaining recognition of his Australian qualifications in Britain.

This letter was considered by the Executive at a recent meeting and the opportunity was also taken to discuss the matter with Dr L. Cohen, Secretary of The (British) Institute of Physics, during his recent visit to Australia. Dr Cohen explained that governmental and semi-governmental authorities in Britain set their own standards of acceptability for tertiary qualifications and problems of equivalence arise for British as well as for overseas qualifications. Precisely the same situation obtains in Australia, of course, where employers decide for themselves the relative merits of various tertiary qualifications. However in Australia eligibility for Grad.AIP is a generally recognized standard.

With regard to similar recognition of Grad.AIP in Britain it must be recognized that there is no formal agreement between the Australian Institute of Physics and The (British) Institute of Physics regarding the equivalence of similar grades.

Whilst the Executive was sympathetic in its consideration of the difficulties encountered by Mr Thomas, no easy solution is evident. The obvious course of action in such cases should be to contact the British Institute for advice and Dr Cohen said that if such approaches were made directly to him he would ensure that every possible assistance was given to members of the Australian Institute of Physics.

It is worth stressing that strong ties exist between the two Institutes and members can be assured that the British Institute is genuinely interested in helping Australian physicists in Britain.

R. D. B. Fraser
Honorary Registrar

**THE REGISTER**

**Changes in Membership from 13 August 1971 to 24 September 1971**

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POSTGRADUATE TRAINING

LA TROBE UNIVERSITY

School of Physical Sciences

There are two research divisions of physics at La Trobe University.

Division of Electron Physics, Prof. D. E. Davies

Research interests: ionization phenomena in pure gases with particular reference to a study of the plasma/surface interface; work function studies of metallic surfaces; electron mobility measurements.

Photoelectron spectroscopy of energy-band structures of solids using Alkx and helium resonance radiations. Topics include: instrument development, angular distributions of photoelectrons emitted from gold, structural disorder changes in alloys, transition-metal oxides, and electron mean free paths in thin metal films.

Secondary electron emission at low energies; electron collision phenomena in solids. Both spherical retarding-grid and 127° cylindrical monochromator and analyser techniques are in use, together with theoretical work.

Electron spin resonance and nuclear magnetic resonance studies, including investigations of magnetic impurities in metals, with particular reference to Kondo systems, and ferromagnetic resonance studies of whiskers and platelets.

Laser interferometry of solid surfaces. The study of scattering of photons by surface waves. Excitation of atoms and ions by photons.

Division of Space Physics, Prof. K. D. Cole

Research interests include: theory of ionosphere and magnetosphere of the earth; interrelation of variations of the interplanetary magnetic field and the geomagnetic field; field aligned currents in the magnetosphere.

Winds in the upper atmosphere induced by heating in the auroral zones; photometric studies of the aurora; relationship of ionospheric absorption to the auroral electrojet.

Quantum mechanics, statistical mechanics; theory of liquids; theory of rarefied gases; a simple model for liquid of molecules with internal degrees of freedom; collision broadening of polyatomic gases; quark models; relativity; critical analysis of current algebras in particle physics.

Ionospheric studies using radio and optical techniques; phase height of the E and F regions; E region distortions due to tidally induced electric currents; optical emission from the ionosphere in midlatitudes; total electron content of the ionosphere (studies at Macquarie Island).

The Division of Space Physics has a 34 acre field station off-campus as well as roof-top facilities from the Physics building on campus. It has a collaborative programme of research with Lockheed Palo Alto Research Laboratories, California, and encourages joint effort with other overseas research groups.

Prospective students should write to the Head of the Division in which they are interested, c/o School of Physical Sciences, Bundoora, Victoria, 3083.

UNIVERSITY OF QUEENSLAND

Physics Department

The Department offers opportunities for postgraduate studies in each of the fields described below.

Ionospheric Physics

Experimental and theoretical research is carried out on the formation and movement of ionospheric irregularities. Other interests include ionospheric disturbances, electric currents in the ionosphere, and the formation of ionospheric layers.

Solid-Earth Geophysics

Experimental and theoretical work on earth stress and strain has resulted in the development of a number of novel techniques. An active programme of research into rock magnetism is also in progress.

Microwave Spectroscopy

Spectrometers have been constructed for the accurate measurement of the widths, shifts, and shapes of microwave spectral lines of gases at low pressures. Measurements have also been made on mixtures of gases and at pressures up to 700 atmosphere, and this work is being extended into the liquid regime.

Astrophysics

A group of theoreticians is concerned with the formation of spectral lines in the surface layers of stars. The studies are being undertaken with a view of determining the physical properties of these surface layers.

Geomagnetic Micropulsations and Magnetospheric Theory

Routine collection of micropulsation data has been in operation for some years, and the processing has been almost fully automated. Detailed analysis of the frequency spectra of the pulsations has enabled deductions to be made about the structure of the magnetosphere.

Thermal Neutron and X-ray- Diffraction Physics

Interests, generally, are in aspects of scattering by crystalline solids. Specifically, solids in regions very close to phase transformations are being investigated as well as the relationships between large-scale elastic properties and atomic-scale forces.

Radiation Damage in $\alpha$ and $\beta$ Tin

Research has just started on the effects of charged-particle irradiation of $\alpha$-phase (semiconductor) and $\beta$-phase (metal) tin. The experimental work is done at Lucas Heights.

Biological Physics

A high-powered monochromator is being constructed to investigate the spectral response of biological actions. This is being done in conjunction with the Pathology Department.
NOTES AND NEWS

Conferences

The following conferences are being organized by Groups of the Institute of Physics, London. A conference on Laser Interactions with Matter is to be held on 20 January 1972 at the IEE, London and a conference on Phase Analysis is to be held at the University of Hull on 5–7 April 1972. The Sixth Thin Films Conference on Interfacial and Surface Phenomena will be held in York on 10–13 April 1972. An International Conference on Point Defects and their Aggregates in Metals is to be held at the University of Sussex from 18–20 September 1972.

Applications of Physics in Industry

Commencing in November, the University of New South Wales will offer four radio lectures over Radio University VL2UV and one seminar over Television University VITU on the application of physics in industry. The principal lecturer will be Professor John S. Blakemore, who will explore the advantages to industry of having applied physicists supporting industrial activity from research and development to sales and service. He will discuss the motivations and satisfactions of an applied physicist and the ways in which his contributions are complementary to those of engineers.

Details of enrolment, broadcasts and a tape correspondence service can be obtained from the Division of Postgraduate Extension Studies.

Errata

In the article on ‘Magnetic Resonance Studies of Atomic Motions’ in the September issue of the Australian Physicist, the expressions on pages 127, 128 containing h should be divided by 4π² and in the equation for 1/T₁ on page 129 the ‘−’ within the brackets should be replaced by ‘+’.

Aid for Academic Refugees

The World Federation of Scientific Workers has advised its members and affiliated organizations of the plight of many university staff and school-teachers who have left East Pakistan and sought refuge in India. It has been suggested that fellowships might be provided to offer temporary work for these displaced academics.

The staff of Macquarie University have undertaken to provide one such fellowship. Further information can be obtained from Professor H. Feith, Department of Political Science, Monash University, Clayton, Vic.

BOOK REVIEWS


Reviewed by H. S. Green, University of Adelaide.

This book represents the proceedings of the Batheva Seminar, held at the Technion (Haifa, Israel) in the summer of 1968. Many of the participants come from the United States, Britain, and European countries, and there are over twenty contributors to this volume, many of them well known for their contributions to low-temperature physics. The restriction of the subject matter of the Seminar to superfluid phenomena has resulted in as much cohesion as can be expected in a volume made up of diverse contributions, and some, but not all of the contributors, have resisted the temptation to publicize their own research achievements. The result is a fairly readable review of the subject in fairly recent perspective.

Some of the excitement of the original discoveries that liquid helium II and the superconductors have remarkable and anomalous fluid behaviour has evaporated in the last two decades, especially since some sort of understanding of the phenomena has been achieved. But, for those who are recent arrivals in this part of the scientific world, Reif, in the opening contribution, does well in recreating the experience of the early settlers. The rest of the book is divided into two parts, of which the first has pedagogical objectives, and is mostly the work of Israeli contributors. As might be expected the emphasis is here on theoretical development, and this should be useful to anyone who wishes for a concise, up-to-date exposition. The second part is also mostly theoretical in emphasis, but opens with a good review (again by Reif) of experimental results. After this the visitors to Israel give accounts of topics on which they are authorities. There is perhaps more on liquid helium than on superconductors, but both are well covered.

I believe that this book will have a more enduring value than most of its kind, and is worthy of acquisition.


Kourganoff’s Basic Methods in Transfer Problems (1952) is well known as a standard text in transport problems. The present book is an elementary, but taxing, construction of the physical concepts involved in transport processes. The discussion is extensive,
involved, but relatively non-mathematical and would serve as an introduction to more advanced works. The other novel feature of the book is the parallel consideration of the neutron and phonon (optical and astrophysical) transport problems. This is illuminating and assists with the physical interpretation. However, the notation becomes so involved that eight pages are required to list all quantities. The printing type made it difficult to distinguish vectors from scalar quantities.

The major part of the book is concerned with elucidation of the quantities involved, namely particle density, flux, intensity, and current and in showing that the principle of transport theory has been justified by the experimental verification of its consequences. Long appendices deal with the critical size of homogenous slab, elastic scattering of neutrons, and phonon-transition probabilities. A series of searching problems are provided with answers. Neutron-diffusion theory is then developed further and the problem of boundary conditions is considered. Finally, radiation pressure is considered and applied to stellar structure.

The book would make a suitable basis for an undergraduate lecture course. Students are likely to find it difficult, but rewarding.


Reviewed by I. D. Johnson, School of Physics, University of Sydney.

Everyone who has taught—and most of those who have studied—quantum mechanics during the past ten years, will doubtless have used on innumerable occasions the books of worked examples collected by Gol’dman and Krivchenkov (1961) and by Kogan and Galitsky (1963). Since there are so very few problems which can actually be solved by beginner students without a prohibitive amount of algebra, these books were in their way a complete cover of the subject. However since their publication there has been a marked trend for quantum mechanics to be taught to students at earlier stages of their careers, and subjects which just ten years ago were considered far too advanced are now being taught to undergraduates.

The publication of this present volume is therefore very timely. Although it is nowhere stated that it is in any way connected with the two previously mentioned volumes, it seems on casual inspection to be a direct expansion of Kogan and Galitsky in particular. The early chapters cover the same material, use the same examples, and even have the same diagrams in their worked solutions. Perhaps this merely reflects the fact already mentioned, that there are not many suitable problems that can be presented, and there is really only one best way of doing each.

However, it is the material included in sections on pictures and representations, second quantization, and relativistic quantum mechanics which is especially welcome. In these subjects, workable problems have up till now been even more difficult to come by; and worked solutions, against which the student could test his understanding, virtually non-existent.

The layout of the book incidentally, is a decided advance. Each chapter is divided into three parts: a short description of the relevant theory and all necessary formulas; a list of problems to be done; and then worked solutions. It is this self-containedness which makes the book so easy to use—as opposed to one which has all the questions in the front of the book and all the answers in the back. Perhaps the publishers might like to issue each chapter in separate (and hopefully, cheap) binding. This would seem to me to be a worthwhile undertaking, because this book will obviously be a must for all students of quantum mechanics, especially at fourth-year level; and, at the above price it is hardly within everyone’s grasp.


Reviewed by B. H. J. McKellar, School of Physics, University of Sydney.

Each of these books is based on lectures by A. Martin, ‘Scattering Theory’ on lectures given in 1969 and ‘Analyticity Properties’ on lectures given in 1967-68. The ‘Scattering Theory’ is the later book and was moreover available to the public much earlier. It is photoprinted from typescript, but most workers in the field would be willing to put up with this to achieve rapid publication.

The material in each is very similar, but ‘Scattering Theory’ reflects the greater mathematical sophistication of the audience to which it was delivered. The work described is the attempt (largely by Martin and his collaborators) to determine, from axiomatic field theory and elastic unitarity, the analyticity domain of the scattering amplitude. The programme which has been carried to the point where the analyticity domain conjectured by Mandelstam has almost been proved for π→π scattering, but Martin has provided a counter example to show that the Mandelstam representation cannot be proved without a new ingredient. However, along the way one obtains a great many results regarding bounds on the scattering amplitude, including the Froissart bound in the form \( \sigma < \frac{\pi r^2}{\log S/S_c^2} \) where \( r_c \) is the pion Compton wave length.

Workers in this field will want to own one of these books. Libraries should save their money, especially as ‘Analyticity Properties’ is a direct reprint of the lectures by Martin, published by Gordon and Breach in ‘Elementary Particle Physics and Scattering Theory’, reviewed elsewhere in this journal.
FINAL NOTICE

Australian Institute of Physics
(Victorian Branch)

SUMMER SCHOOL

The 1972 Summer School will be held in the Physics Department, Monash University from Monday, 14th February to Friday, 18th February, 1972 and will have three concurrent courses with at least six common lectures.

I Magnetism and its applications.
II Phase transitions.
III Advanced materials.

Accommodation is available at a University Hall of residence or a motel if required.

Application forms are available from the Convenor

Professor H. C. Bolton,
Department of Physics,
Monash University,
CLAYTON, VIC. 3168.

CSIRO
RESEARCH SCIENTIST
Division of Physics

Field: FLUID STATE PHYSICS

General: The Division, which forms part of the National Standards Laboratory, is responsible for standards of measurement of uncertainty, temperature and optical radiation, and pursues experimental programmes in the physics of solids, especially at low temperatures, solar physics, molecular collisions and airglow. A wide range of measurement facilities is maintained, and the work is supported by instruments, electronic and optical workshops.

Duties: To undertake research in the physics of the fluid state and high fluid pressures. The appointee will spend the major part of his time on basic experimental work in fluid-state physics, working with pressures of up to 14 kilobars, but will also participate in the standards work and in activities in technical physics with applications in industry.

Qualifications: Applicants should have a Ph.D. degree, and considerable research experience in some branch of the physics of the fluid state or in an allied field, supported by satisfactory evidence of research ability. They should have an aptitude for precise work, and preferably some experience of experimentation at high fluid pressures.

Salary: Depending upon qualifications and experience, within the ranges of Research Scientist or Senior Research Scientist, $7,484-$11,517 p.a. Appointment at a higher classification could be considered for an applicant with a considerable reputation in this field.

Conditions: The appointment will be for three years in the first instance.

Applications, quoting reference number 770/435, and stating full personal and professional details, together with the names of at least two referees, should reach:

The Chief,
Division of Physics, CSIRO,
University Grounds,
City Road,
CHIPPENDALE, N.S.W. 2008

by 10th December, 1971.
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