TABLE I. Charge-independent potentials and corresponding effective ranges. The potential is $V=\infty$, for $r<r_c$, $V=-V_0e^{-r/r_s}/(r/r_s)^2$, for $r>r_c$.

r_s (10^{-13} cm)	r_c (10^{-13} cm)	V_0 (Mev)	$r_{0s}(n-p)$ (10^{-13} cm)	$r_{0s}(p-p)$ (10^{-13} cm)
2.60	0.014	3.50	2.33	2.60
2.70	0.007	3.07	2.35	2.65
2.80	0.000	2.70	2.37	2.70

minimum core radius which the program could handle. The method of integrating inwards has the advantage that only solutions corresponding to the experimental values of the scattering lengths are obtained, since the asymptotic solutions depend only on the scattering lengths. For a given pair V_0, r_s, the criteria for charge independence used were: (a) the same cutoff r_c should be obtained for both $n-p$ and $p-p$ and (b) the effective ranges should satisfy $1.9<r_{0s}(n-p)<2.9$, $2.54<r_{0s}\times(p-p)<2.74$ (units 10^{-13} cm). Runs were done for scattering lengths corresponding to the best experimental value and to the experimental limits in order to determine how closely the two values of r_c had to agree.

The values used for the scattering lengths were $a_s(n-p)=-23.69\pm0.06\times10^{-13}$ cm,[5] $a_s(p-p)=-7.68\pm0.04\times10^{-13}$ cm.[6] Calculations were made for the following attractive wells outside the core: (1) exponential,[7] (2) Yukawa, (3) Gaussian, (4) $f(x)=e^{-x}/x^2$. About 200 pairs of values V_0, r_s were used for each shape. Only e^{-x}/x^2 gave charge independence, and this for very small core radii. Three choices of parameters giving charge independence are given in Table I, together with the corresponding effective ranges.[8] Because of the small core radii involved, extrapolations were necessary, giving possible errors of 2 or 3 in the last digits of the numbers quoted.

We see that charge independence can be obtained with a static potential. Two features of this potential are of significance: (1) it has a strong singularity near the origin ($\sim1/r^2$) and (2) this infinity is cut off by a core of extremely small radius (zero core radius is consistent with charge independence). The potentials derived from pseudoscalar meson theory are even more singular; the Lévy potential,[1] for example, behaves as $1/r^3$ near the origin. Thus, this work seems to indicate that the meson potentials may yield charge independence, and it is planned to try some of these in the near future. We would also be glad to make the code available to check other potentials (with cores) which other workers may obtain.

* Holder of National Research Council of Canada Studentship, 1951–52; National Research Council of Canada Fellowship, 1952–53. This work is to be submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy at the University of Toronto.

[1] R. Jastrow, Phys. Rev. **81**, 165 (1951); M. M. Lévy, Phys. Rev. **88**, 725 (1952); A. Klein, Phys. Rev. **90**, 1101 (1953); Phys. Rev. **94**, 195 (1954); J. M. Blatt and M. H. Kalos, Phys. Rev. **92**, 1563 (1953).

[2] H. A. Bethe, Phys. Rev. **76**, 38 (1949); J. D. Jackson and J. M. Blatt, Revs. Modern Phys. **22**, 77 (1950).

[3] The code is actually more general and can handle potentials of the form $Af(r/a)+Bg(r/b)+Ch(r/c)$ with very slight modifications.

[4] H. A. Bethe, Phys. Rev. **82**, 60 (1951).

[5] G. Snow, Phys. Rev. **87**, 21 (1952).

[6] M. C. Yovits *et al.*, Phys. Rev. **85**, 540 (1952). The value of $a_s(p-p)$ was taken from their shape-independent fit; the error was assigned so as to include their results for other shapes.

[7] The $n-p$ equation can be solved explicitly for the exponential potential. This was used as a check on the program. The cutoffs agreed to 6 figures, the effective ranges to 5 figures.

[8] The results of E. M. Hafner *et al.*, Phys. Rev. **89**, 204 (1953), and an estimate of the shape parameters, P, suggest $r_{0s}(n-p)=2.21\pm0.25$ for these potentials.

PHYSICAL REVIEW VOLUME 96, NUMBER 3 NOVEMBER 1, 1954

Proceedings of the American Physical Society

MINUTES OF THE 1954 SPRING MEETING OF THE OHIO SECTION AT OHIO UNIVERSITY, ATHENS, OHIO, APRIL 16 AND 17, 1954

THE regular spring meeting of the Ohio Section of the American Physical Society was held at Ohio University, Athens, Ohio, on Friday and Saturday, April 16 and 17, 1954. For Friday morning, no formal program was prepared save the showing of recently released educational films and time provided for viewing the exhibits of the High School projects prepared for the Junior Section of the Ohio Academy of Science. Approximately one-third of all the exhibits were related to the field of physics. Eight invited papers were presented having as the main theme the development of physics in the past century in the Northwest Territory. The subject was suggested by the Sesquicentennial of Ohio in 1953 and the present celebration of Ohio University which was the first college organized within the Territory; "Ohio University Celebrates its Sesquicentennial, 1804–1954," by John E. Edwards, Ohio University; "Remarks on the History of Astronomy in Cleveland," J. J. Nassau, Case Institute of Technology; "A New Analysis of the Interferometer Observations of Dayton C. Miller," by R. S. Shankland, S. W. McCuskey, and F. C. Leone, Case Institute of

Technology, (abstract included); "Physics in Industry," H. R. Nelson, Battelle Memorial Institute; "Ohio Machine Tools and Physical Science," M. E. Merchant, Cincinnati Milling Machine Tool Company; "The Past Half Century of Physics at University of Cincinnati," C. Harrison Dwight, University of Cincinnati; "Ohio's Contribution to Meteorology; Climatic Trends Since 1880," A. N. Dingle, The Ohio State University (abstract). The eighth invited paper was presented on Saturday morning, "Physics in American Universities: Its Growth and Influence," by Alpheus W. Smith, The Ohio State University.

This being the annual business meeting of the Ohio Section the following officers were chosen for the year 1954–1955: Chairman, William H. Gran, Miami University, Oxford, Ohio; Vice-Chairman, Richard N. Thayer, Lamp Development Laboratory, General Electric Company, Cleveland, Ohio; and Secretary-Treasurer, Leon E. Smith, Denison University, Granville, Ohio.

The nineteen contributed papers were presented in two sections so that the meeting could be completed by noon. There were three for which no abstracts appear: "Apparatus for Three Experiments Redesigned for General Physics," W. M. Pierce, Ohio University; "Undergraduate Research," J. W. McGrath, Kent State University; and "An Operational Definition of Inertial Mass Without the Use of Newton's Second Law of Motion," Thomas D. Phillips, Marietta College. The abstracts of the seventeen contributed papers and two invited papers follow.

LEON E. SMITH, *Secretary*,
The Ohio Section
American Physical Society
Granville, Ohio

Ohio's Contribution to Meteorology: Climatic Trends since 1880. A. N. DINGLE, *The Ohio State University*.—The temperature and precipitation records of selected stations in the United States are summarized graphically and presented. Study of the trend curves suggests a time-space continuity of prominent features of these curves from station to station. The synoptic study of the distribution of interdecadal changes of ten-year average precipitation values reveals some interesting indications of significant long term shifts of cyclonic activity and moist air currents. In the absence of casual relationships the secular changes of climate must be examined and explained statistically.

A New Analysis of the Interferometer Observations of Dayton C. Miller. R. S. SHANKLAND, S. W. MCCUSKEY, AND F. C. LEONE, *Case Institute of Technology*.—For nearly thirty years the results of the Michelson-Morley experiment obtained by Dayton C. Miller on Mount Wilson have stood at variance with all other trials of this experiment. As interest in Miller's results has continued to the present time, and since the original data sheets are available to the present writers, it has seemed appropriate that the observations be subjected to a new analysis by statistical methods. It is now concluded that the small periodic fringe displacements found by Miller are due in part to statistical fluctuations in the readings of the fringe positions in a very difficult experiment. The remaining systematic effects are so distributed in azimuth that it is concluded they are due to local physical causes, especially temperature effects. These were more troublesome at Mount Wilson than those encountered by other experimenters, including Miller himself in his work done at Case in Cleveland. As interpreted in the present study, Miller's extensive Mount Wilson researches are entirely consistent, within the accuracy of his readings, with a null result at all epochs throughout a year.

Color Shifts Produced by Use of Polaroid Photographic Filters. ALEX KISHA, *Bowling Green State University*.—When a polaroid filter was used with a color film in taking a certain photograph, it was found that a shift in color had occurred in the blue-green region. The problem that presents itself here is that if the light coming from the subject is polarized and then enters the camera through a filter, the filter acts as an analyzer, the resulting intensity being dependent upon the angle between the axis of the polarizer and analyzer. The work is confined to analyzing various polaroid filters as to the effect of the angle of polarization on the transmission of monochromatic filters. The Beckman DU Spectrophotometer is used. The polarization angle indicated an influence upon the transmission for wavelengths of 400 to 825 mu. For wavelengths up to 650 mu at 90° angle, all light was absorbed. In the blue-green region, as the polarizing angle increased, the green was being eliminated more rapidly. For wavelengths below 350 mu there was no transmission. For wavelengths greater than 700 mu, there was a tendency for the percent transmission to converge at one point in the high red region, regardless of the angle.

Theory of Reflection and Transmission Measurements on Thin Metallic Films. THURSTON E. MANNING, *Oberlin College*.—The work of Matossi[1] on the intensities of reflected and transmitted beams of light incident on backed thin metallic films will be applied in a form suitable for the usual experimental work. In addition, a discussion of the polarization predicted in the reflected and transmitted beams on the basis of classical electromagnetic theory will be given.

[1] Matossi, J. Opt. Soc. Am. **39**, 928 (1949).

Optical Reflection and Transmission of Thin Aluminum Films. WILLIAM A GAREE, *Oberlin College*.—The results of measurements on the reflected and transmitted intensities of nearly monochromatic light (5140A) on glass backed films of aluminum will be reported. The measurements give the influence of the thickness of the metal film on the reflection and transmission. The results of limited experiments on the polarization of the reflected and transmitted beams will be given.

Laboratory Problems in Introductory Electricity and Optics. ALBERT B. STEWART, *Antioch College*.—In a twenty-week course in electricity and optics for science majors the students have been encouraged to work toward the solution of experimental problems, the answers to which cannot easily be found in texts or periodicals. Most students spend about half of their time on these original problems and half on the usual type of organized experiments. In grading their work, the quality of their approach, the completeness of their laboratory records and the care with which they evaluate the experimental uncertainties are emphasized over their success in solving the problems. Some of the advantages of this laboratory procedure seem to be: the problems capture the students' enthusiasm and call forth their best efforts; they provide an effective

way to learn how to treat experimental uncertainties; they help make the laboratory a stimulating place for both students and instructor. Two disadvantages, some students become overly discouraged by failure to solve a problem, and it is difficult to have equipment ready in advance without unduly influencing the students' approach. A few of the laboratory problems will be described.

A Simple Recording Microphotometer. ROBERT LIEFELD, *Kent State University.*—The design and construction of a simple but adequate microphotometer using apparatus commonly available will be discussed. The microphotometer is presently being used for measurement of x-ray M edge spectra.

Design and Behavior of Two Acoustic Lenses. JAMES V. SANDERS, *Kent State University.*—The design of a path delay lens and an obstacle array lens will be discussed. Experimental results on their behavior will be indicated. These lenses will be demonstrated after the session if time and facilities permit.

Electric Field in an Oscillating Discharge.* R. E. WARNER, G. E. OWEN, AND A. B. STEWART, *Antioch College.*—The time average electric field strength in an argon dc glow discharge with spontaneous oscillations has been studied by measuring the potential difference between two plane probes 1.1 cm apart placed in the positive column at fixed distances from the cathodes. With a discharge current of 17 ma, a pressure of 12.4 mm of Hg, an external series resistance of 30 000 ohms, and cylindrical iron electrodes (anode moveable) the oscillations were stable with a frequency of 2700–2940 cps over the range of electrode separations studied (10 to 30 cm). The electric field between the probes varied between 2.3 and 7.5 volts/cm as the electrode separation was changed, repeating approximately its variation with each 4 cm increase in length of the discharge. An abrupt change of 2–4 volts/cm coincided with the creation of an additional wavelength of the positive striations in the positive column. From the probe data a curve of the time average potential difference as a function of distance from the anode has been constructed for the positive column. The voltage across the tube increases linearly with increasing separation.

* Supported by the Frederick Gardner Cottrell Fund of the Research Corporation.

Cloud-Chamber Program at Kent State University.* A. A. SILVIDI AND J. GLENN MAXWELL, *Kent State University.*—Since the advent of continuous cloud chambers, several qualitative uses of the instrument have been reported[1–3]. The Kent State program is investigating the quantitative features of this instrument by obtaining a beta spectrum and comparing it with the spectrum obtained by other instruments. Construction details of the chamber will be presented; field characteristics of the magnetic coils will be discussed; and preliminary photographs of beta tracks taken with and without magnetic field will be shown.

* Research supported by National Science Foundation.
[1] A. Langsdorf, Rev. Sci. Instr. **10**, 91 (1939).
[2] E. W. Cowan, Rev. Sci. Instr. **21**, 991 (1950).
[3] T. S. Needels and C. E. Nielsen, Rev. Sci. Instr. **21**, 976 (1950).

Neutron Slowing Down Time.* C. E. FOREMAN AND M. F. CROUCH, *Case Institute of Technology.*—A study is in progress of the slowing down time of fast neutrons produced in the reaction $He^4+Be^9\rightarrow C^{12*}+n$ and detected by a BF_3 counter in a paraffin moderator. The photon emitted by the excited C^{12} nucleus signals the time of production of the neutron. Measurements are made of the time delay between production of the neutrons and their capture in the BF_3 proportional counter. 7200 events were recorded with delays less than 25 microseconds, and an integral distribution of delay times was plotted. This curve, after correcting for accidental coincidences and for the effect of competing capture processes, was found to reach a constant slope at 9.6 microseconds, which was taken to indicate that virtually all neutrons were thermalized by this time. Assuming a roughly symmetrical distribution of slowing down times, this gives a mean slowing down time of about 5 microseconds. The curve was observed to rise almost immediately with a slop not much less than the final constant value, indicating that the greater distance traveled per microsecond by the faster neutrons offsets, to a large extent, the $1/v$ law detector response.

* Work supported by the U. S. Atomic Energy Commission.

Theory of the Photodisintegration of Li^6, I.* E. F. CAROME, *Case Institute of Technology.*—As part of a general program of investigating gamma-ray processes in light nuclei, calculations of cross sections for the photodisintegration of Li^6 from threshold to about 30 Mev have been made on the basis of two assumed nuclear models. The present investigation is based on a deuteron-alpha particle model for the ground state of Li^6. The neutron and proton are described by plane waves in the final state and the alpha particle is assumed unchanged throughout the process. Utilizing approximate wave functions for the initial and final states of the system it has been possible to obtain expressions for the electric and magnetic dipole contributions to the $Li^6(\gamma,np)He^4$ reaction. Because three particles emerge in the final state the expressions for the differential cross section are rather complex and numerical integrations were necessary to obtain the total cross section. The result of these calculations will be presented. The reaction $Li^6(\gamma,d)He^4$ has also been investigated. It is easily demonstrated that this reaction does not occur in the dipole approximation. Calculations of the electric quadrupole contribution to the cross section indicate that it is quite small consistent with recent experimental results.[1,2]

* Work supported by U. S. Atomic Energy Commission.
[1] E. W. Titterton and T. A. Brinkley, Proc. Phys. Soc. London **A65**, 1052 (1952).
[2] P. Jensen and K. Gis, Z. Naturforsch. **8a**, 137 (1953).

Auxiliary Condition in Generalized Quantum Electrodynamics.* GEORGE R. PITMAN, JR., *University of Cincinnati.*—In Podolsky's generalized electrodynamics[1] one obtains the wave equation of the form $(1-a^2\Box)\Box A_\mu(x)=0$ from the generalized Maxwell-Lorentz equations if one assumes either of the following auxiliary conditions:

$$(1-a^2\Box)A_{\mu,\mu}(x)=0;\quad A_{\mu,\mu}(x)=0.$$

Defining the ordinary and extraordinary potentials, respectivly, as $\mathring{A}_\mu(x)=(1-a^2\Box)A_\mu(x)$ and $\bar{A}_\mu(x)=a^2\Box A_\mu(x)$ so that $A_\mu(x)=\mathring{A}_\mu(x)+\bar{A}_\mu(x)$, the first of these conditions demands the vanishing of only the four divergence of the ordinary field potentials whereas the second demands the vanishing to the divergence of both the ordinary and extraordinary potentials. The energy eigenvalues of the extraordinary field are:

$$\bar{H}=-c\hbar\bar{k}_0(\bar{n}_1+\bar{n}_2+\bar{n}_3-\bar{n}_0).$$

Imposing the second condition demands that $\bar{n}_0\leq\bar{n}_1+\bar{n}_2+\bar{n}_3$ which means that the energy of this field will be negative definite whereas the use of the first condition imposes no restriction on the relative magnitude of the occupation numbers and the energy may be positive. The author is indebted to Professor Boris Podolsky for his help and guidance during the course of this investigation.

* Because of printing limitations, a bar has been substituted for the author's tilde over A, H, n, and k in this abstract.
[1] B. Podolsky, Phys. Rev. **62**, 68 (1942); B. Podolsky and P. Schewd, Rev. Modern Phys. **20**, 40 (1948).

Theory of the Photodisintegration of Li^6, II.* G. F. BING, *Case Institute of Technology.*—The present investigation assumes a Li^6 ground-state model consisting of an alpha particle

with orbital neutron and proton. Using this model calculations of the cross sections for the reactions $Li^6(\gamma,n)Li^5$ and $Li^6(\gamma,p)\times He^5$ have been made. It is assumed that the residual Li^5 or He^5 nucleus may be treated as stable for purposes of this calculation. The contributions of the electric and magnetic dipole matrix elements to the cross sections have been calculated using suitable approximate wave functions for initial and final states. The alpha particle is assumed unchanged in the energy range of interest, that is from threshold to about 30 Mev. It is hoped that comparison of experimental results with the predictions based on the deuteron-alpha model and the present model will yield some information about the actual Li^6 ground state.

* Work supported by U. S. Atomic Energy Commission.

Half-Life Determinations of Radium-223 and Thorium-227. G. R. HAGEE, M. L. CURTIS, AND G. R. GROVE, *Mound Laboratory,* Monsanto Chemical Company.*—Half-life values for radium-223 and thorium-227 have been determined by analyzing data obtained from samples of each element by alpha counting in a proportional counter over a period of 116 days. The samples contained small amounts of other members of the actinium chain. The growth and decay equation of the principal activity and its daughters plus contaminants was derived in terms of the decay constants of radium-223 and thorium-227 and the amounts of each activity present. The decay constants and the disintegration rates of the activities were each set equal to an approximate value plus a correction term. Taylor's expansion was applied to the general equation to yield an expression which was linear in the correction terms. A least-squares treatment was used to derive the correction terms most representative of the data. The half-life values obtained from these analyses were 18.169 ± 0.084 days for thorium-227 and 11.685 ± 0.056 days for radium-223.

* Operated under U. S. Atomic Energy Commission contract.

Half-Lives of Al^{25} and Al^{26}.* D. W. GREEN, J. C. HARRIS, AND J. N. COOPER, *Ohio State University.*—The half-lives of Al^{25} and Al^{26} have been determined by a method previously reported.[1] The Al^{25} was produced by exciting the $Mg^{24}(p,\gamma)Al^{25}$ reaction with 825-kev protons from a Van de Graaff generator in targets of isotopic Mg^{24}, which was obtained from Carbide and Carbon Chemicals Corporation, Oak Ridge, Tennessee. The value measured for Al^{25} was 7.20 seconds, which is in good agreement with the 7.3 seconds reported by Bradner and Gow.[2] The half-life of Al^{26} was measured both at the 563- and the 720-kev resonances in the $Mg^{25}(p,\gamma)Al^{26}$ reaction. The values obtained were 6.47 and 6.40 seconds, respectively, which agree well with the 6.3 seconds of Bradner and Gow[2] and with the 6.5 seconds found by Katz and Cameron.[3]

* Supported in part by the U. S. Atomic Energy Commission through a contract with The Ohio State University Research Foundation.
[1] Green, Harris, and Cooper, Phys. Rev. **90**, 1132 (1953).
[2] H. Bradner and J. D. Gow, Phys. Rev. **74**, 1559 (1948).
[3] L. Katz and A. G. W. Cameron, Phys. Rev. **84**, 1115 (1951).

X-Ray Absorption in a Curved Crystal at the Bragg Angle. ROBERT G. SAUER AND JOHN E. EDWARDS, *Ohio University.*—Primary extinction generally decreases the transmitted x-ray beam intensity when Laue type diffraction occurs in a single crystal. However, Borrmann[1] and others[2] have observed an increase in the transmitted intensity in "thick" crystals at the Bragg angle. An attempt has been made to observe this absorption anomaly in a curved crystal. A double Gauchois type spectrograph was used, the first crystal serving as a monochromator with the speciman crystal placed back of the focal circle. Thus, only x-rays from a very small point on the target were diffracted from the specimen crystal giving sharp lines slightly greater than the natural width. Characteristic lines and the transmitted beams were photographed with a 0.2-mm quartz crystal for wavelengths ranging from 0.469 A to 2.289 A. A 0.81-mm quartz crystal and a 0.56-mm mica crystal were used with 1.54 A lines. A pronounced decrease in intensity of the transmitted beam was observed in every case. The "deficiency" lines were nearly the same width as the diffracted lines.

[1] G. Borrmann, Physik. Z. **42**, 157 (1941).
[2] N. Campbell. J. Appl. Phys. **22**, 1139 (1951); R. L. Rogosa and G. Schwarz, Phys. Rev. **87**, 995 (1952).

Collective Model in the Analysis of Gamma Rays. D. N. KUNDU, *The Ohio State University.*—Nuclear gamma energies are studied from a combined point of view of the independent particle model and the collective model. The former provides the broad pattern of the nuclear energy states on which is superimposed additional states arising from the collective motion of the nucleons within the nucleus. The Coulomb excitation data, whenever available, have been utilized to identify rotational lines near the ground state. The success and also the limitations of the models are examined, among others, with Se^{75}, Lu^{176}, Hf^{181}, Au^{195}, and Hg^{197}, as examples. The gamma rays of Np^{238} have been used to illustrate the possibility of rotational levels associated with the ground state and also the particle-excited state of Pu^{238}. Some tentative decay schemes involving the collective model will be suggested.

MINUTES OF THE 1954 JUNE MEETING HELD AT MINNEAPOLIS, MINNESOTA, JUNE 28–30, 1954

(Corresponding to *Bulletin of the American Physical Society*, Volume 29, No. 5)

THE 1954 June meeting of the American Physical Society was held at Minneapolis on Monday, Tuesday, and Wednesday, June 28, 29, and 30. The unusual choice of days of the week was dictated by the fact that a total eclipse of the sun occurred at 5:07 A.M. on June 30, although preliminary announcements of the meeting stated that the local committee had kindly arranged for the eclipse as an added attraction to the meeting. Be that as it may, the local committee certainly provided ideal weather for the eclipse. After several hot and high-humidity days, interspersed with thunderstorms, the sun rose on Wednesday in a clear and cloudless sky, which remained that way during the entire duration of the eclipse. But within an hour after the eclipse the sky was again half covered with clouds. The great bulk of our members saw the eclipse, as well as the "Skyhook" balloon launching, from the Old University airport, under perfect seeing conditions. A very few were so fortunate as to see it from one of the two special planes provided by the airplane companies.

The American Association of Physics Teachers held concurrent sessions with the American Physical