A SHORT HISTORY OF THE PHYSICS DEPARTMENT

DALHOUSIE UNIVERSITY

1838 - 1956

by

J. H. L. JOHNSTONE

Halifax, N.S.
March, 1971

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ACKNOWLEDGEMENTS

My grateful acknowledgements are to Miss Evelyn Campbell, Librarian of the Nova Scotia Research Foundation, for obtaining information about Professors J. J. Mackenzie and J. G. MacGregor; and to Miss S. J. Fullerton, Chief Science Services Library, Dalhousie University, for a list of Dr. A. S. Mackenzie's publications.

Mrs. Martin King has very kindly let me make use of a scrapbook with many items having to do with the career of her father, Dr. A. S. Mackenzie;

I wish to thank Mrs. G. H. Henderson for details concerning the life of her late husband; and Mrs. H. L. Bronson for similar information about Dr. H. L. Bronson;

I am indebted to Miss Grace Tratt, chief of special collections, the Killam Memorial Library, for making available Patterson's History of Dalhousie University and also the History of Dalhousie University written by the late Dr. D. C. Harvey;

Miss Helen Reynolds, formerly Dean of Women at McGill University, and Dr. J. E. Blanchard, President of the Nova Scotia Research Foundation, have kindly read the typed script and made valuable suggestions about it;

My secretary, Mrs. Deborah Cummings, has typed nearly the whole manuscript and retyped it many times with unfailing care;

Finally, I must acknowledge my debt to my wife for the valuable advice and assistance she has given to me in preparing this short history.

THE EARLY DAYS
1838 - 1877

Dalhousie University came into being as the result of an Act of the Legislature in 1818. The cornerstone of the first building was laid in 1820 but the structure was not completed until 1828. It did not assume the functions of a university, however, until 1838 when Dr. Thomas McCulloch, of Pictou Academy, finally achieved his ambition of presiding over a degree-granting institution. In his short time as President, McCulloch established traditions of excellence which put their imprint on the university he directed. He strongly supported the claims of mathematics and natural philosophy as "subjects best fitted for the understanding of nature and society."

In addition to Dr. McCulloch, the first professors were the Rev. Alexander Romans and the Rev. James MacKintosh. The latter was the first professor of Natural Philosophy, and so can be considered the first Professor of Physics. McCulloch could well have taken the class in Natural Philosophy, as he had been the professor of that subject at Pictou Academy and he was a firm believer in the importance of Natural Philosophy in any educational system. He went so far as to write:- "If Dalhousie College acquires usefulness and eminence, it will not be by an imitation of Oxford, but as an institution of science and practical intelligence."

MacKintosh, a native of the north of Scotland, came to Prince Edward Island as minister of St. James Church, Charlottetown. In 1830 he came to Halifax and taught in the high school before his appointment to Dalhousie. Paterson writes in his history of Dalhousie that MacKintosh, a minister of the Church of Scotland, "was not a man of that high standard needed to build a university. The social life of Halifax was already telling on him, inducing or strengthening those habits which not long after led to his deposition from the Ministry." So, the first professor, a clergyman, who taught Physics at Dalhousie apparently left it under a cloud.

The college did not have a library then and the only scientific equipment available for teaching had to be borrowed from the Mechanics Institute. It also appears that all was not peaceful in the college as Patterson states that Romans and MacKintosh had a good deal of trouble with "their boys".

McCulloch died in 1843 and the college came on difficult times. Thomas McCulloch, a son of the President took MacKintosh's classes when the latter resigned in 1843. At this time there were 16 students in attendance, 11 of them taking Natural Philosophy. The next year the attendance

dropped to ten with only two taking Natural Philosophy. Physics was becoming unpopular! In 1847 it is recorded that there were no professors and no students, and in 1848 the College became a high school under Thomas McCulloch, its Headmaster. A little later the building was used in turn as a pastry cook's shop, a Mechanics Institute, a brewer's vault and a sub-post office!

At about this time the United Empire Loyalists who had settled in Liverpool, N. S., decided they should have a College there, and in 1851 an institution was opened which was called Gorham's College in honour of its chief benefactor. In 1853 the College building was destroyed by fire. A few years later what was left of the College joined Dalhousie and the President of Gorham, the Rev. Tompkins, M.A. (London) came to Halifax and taught Natural Philosophy for a year.

A reorganization of Dalhousie took place in 1863 sponsored by Joseph Howe and William Young (later Sir William) on principles proposed by Dawson, then principal of McGill and on April 29 of that year an Act of the Legislature incorporated Dalhousie as a university. Funds were sufficient to provide for a professorial staff of six. It was said that they were the equal, or superior, to any in Upper Canada.

In 1863 the course in Natural Philosphy was given by Thomas McCulloch. When he died in 1865, this subject was taught to fourth year students by the Principal, the Very Rev. James Ross, D.D., one of the best students of the older McCulloch. Charles MacDonald, M.A., Professor of Mathematics, gave the class in Mathematical Physics to third year students. The text books used in these courses were Lardner's "Handbook" and Galbraith and Houghton's "Mechanics".

Between 1873 and 1876 Honours courses were introduced and during this period five degrees with honours were awarded including two in mathematics and physics. Dalhousie was making its reputation and proving its worth.

The teaching of Natural Philosophy continued with little change until the term 1876-1877 when J. G. MacGregor, M.A., was appointed lecturer in this subject. MacGregor gave the classes in Experimental Physics and Mathematical Physics, and MacDonald gave a class in Hydrostatics, Optics and Astronomy.

In 1878 money became available to establish the first chair in physics as such in Canada. Previous to this time physics was called Natural Philosophy. The chair was offered to a Dalhousie graduate, Dr. J. J. Mackenzie, who had just completed post graduate study in Germany.

J. J. MACKENZIE
1878 - 1879

The first holder of the new Chair, Dr. John James Mackenzie, was born at Green Hill, Pictou County, in 1847. After attending school there and at Pictou Academy, he entered Dalhousie University and graduated with a B.A. in 1869. During the three following years he taught mathematics and physics at Pictou Academy. He then returned to Dalhousie and received the degree of M.A. in 1873.

Mackenzie crossed the Atlantic in the autumn of 1873 accompanied by two other Pictonians, Herbert Bayne and Archibald Purves, together with J. G. MacGregor, whose father was a Pictonian. They were probably among the first Nova Scotians to take post graduate work in Europe. He joined the University of Leipsig for three years working with Professor Hankel and Professor Weidemann, and received the degree of Ph.D. with great distinction in 1876 for a dissertation which contained an account of his investigation upon "The Absorption of Gases in Saline Solutions". He then proceeded to

the University of Berlin and carried out original investigations under Helmholtz and Kirchhoff.

Before leaving Berlin he applied for the Chair of Physics which had been established at Dalhousie. He was highly recommended by Helmholtz and Weidemann*. The former wrote: "Mr. Mackenzie has carried out a number of fine and difficult experiments on the matter of the electromotive force induced by magnetism in insulators...Mr. Mackenzie has been found to be quite capable of accomplishing such difficult problems...He has been able to acquire a very clear understanding of his experiments...Therefore, I look upon this young man as one on whom great hopes can be placed...I also consider him to be absolutely ready to step forth as a teacher of physics as he knows how to analyze his thoughts clearly and correctly." Professor Weidemann says, "Mr. J. J. Mackenzie has attended my lectures on inorganic and physical chemistry and has worked in my laboratory...He executed original research on the absorption of carbonic acid by means of salt solutions. The results are given in Mr. Mackenzie's thesis, by means of which he passed successfully examinations at this University, the degree of Doctor of Philosophy was bestowed on him with honourable mention...I do not doubt that based on scientific knowledge and achievement, he would completely fill the professorship of Physics at your university."

Mackenzie also had glowing testimonials from the Trustees of Pictou Academy and from the Rev. James Ross, Principal of Dalhousie.

These recommendations and the fact that Mackenzie was a Dalhousian were enough to persuade the Board of Governors to appoint him Professor of Physics in 1878. The records indicate that in addition to giving lectures and doing research, he was active in community affairs, giving a series of popular lectures in 1878 and enthusiastically promoting the Technical Institute.

He held his Dalhousie professorship for a very short time, meeting a sad death in 1879, the result of inhaling fumes from the old-fashioned wet electric batteries. He was buried at Durham, close to his old home, Green Hill.

J. GORDON MacGREGOR
1879 - 1901

Dr. Mackenzie was succeeded by his friend, J. Gordon MacGregor, who was born in Halifax on 31 March 1852 where his father, the Rev. Peter G. MacGregor was minister of the Poplar Grove Presbyterian Church. His grandfather was Dr. James MacGregor, the famous Pictou County clergyman.

His early education was obtained in Halifax at the Academy on Gerrish Street, and then Dalhousie, from which he graduated in 1871 with a B.A. degree, and an M.A. in 1874. It is interesting to note that he took classics in every year of his course, and did not commence to study Physics until his third year, when he took one course and then another in his fourth year. He achieved 1st class standing in every one of the 19 classes of his B.A. course, and won 13 scholarships and prizes. He was also one of the founders of the Dalhousie Gazette.

In 1874 he was awarded one of the famous Gilchrist scholarships, the holders of which are expected to study for a London University degree. In the matriculation examination in London he ranked "higher than 600 of the 630 candidates, who came from India, Australia, Canada and Great Britain". It is interesting to note that he prepared himself for his London B.Sc. degree by studying at the University of Edinburgh in Tait's laboratory. In 1875 he attended the University of Leipzig for a time and then returned to London and received the degree of D.Sc. in 1876. He then came back to Halifax and lectured in Natural Philosophy at Dalhousie for the 1877-1878 term, before returning to England to become Physics Master at Clifton College, Bristol. At this time he had a severe breakdown in health and was ill for several months.

MacGregor's return to his alma mater was made possible by the munificent benefactions of George Munro, a Pictonian who had gained wealth in New York. Munro began his Dalhousie benefactions in 1879 by endowing a chair at $2,000 per year which was called the George Munro Chair of Physics.

During the next twenty-two years at Dalhousie MacGregor's researches made him and the University widely known. In this period he published some fifty papers and memoirs, a truly astonishing record. At the same time he took an active part in the administration of the college and was recognized as an inspiring teacher and a leading exponent of the merits of science. He preached the need of facilities for technical training. If there had been no MacGregor, President Mackenzie said that he doubted if Nova Scotia would have had the Nova Scotia Technical College. He was a strong fighter for university consolidation and wrote a pamphlet on the subject. He took a prominent part in forming the Royal Society of Canada and made many contributions to its transactions.

His researches ranged over a wide field, but the important ones were mainly concerned with the electrical conductivity of liquids. He also published papers on "The absorption of radiant heat by gases", Thermo-electricity, the Variation with temperature of the electrical resistance

of alloys and on viscosity. Papers on the foundations of Dynamics were expressed in his book, "Kinematics and Dynamics", which the writer of this history studied for distinction work in Physics I at Dalhousie. Most of his scientific papers were published during his time at Dalhousie. He had little time for research at Edinburgh because of administrative duties.

MacGregor was elected Fellow of the Royal Society of London primarily for the papers he published during the Dalhousie period. At that time he was the only physics professor in Canada who had been elected, and he was the first of three Dalhousie graduates in Physics to become Fellows of this distinguished Society. It was undoubtedly because of his status as a physicist that Dalhousie was granted the privilege of nominating candidated for the 1851 Exhibition Scholarships.

When Tait died in 1901, MacGregor was the successful applicant for the Chair of Natural Philosophy at Edinburgh. The Physics laboratory was said to be nothing more than a museum of lecture room apparatus when he took up the appointment. With his usual enthusiasm he soon established a well-equipped laboratory, then collected money from his friends to establish a chair of mathematical physics as a memorial to Tait. As was to be expected, he took an active

part in the affairs of the university and in the activities of the Royal Society of Edinburgh.

MacGregor was a first-rate teacher, loved by his students, a man with many friends who will long cherish the memory of his personality. Whatever he undertook he pursued with untiring industry. He was unsparing of himself, and the result was that he was never robust in health. Early in life he had suffered a serious breakdown, and continued to suffer from a heart condition. Great as his achievements were, his ill-health must have limited them. He died suddenly at Edinburgh on 21 May 1913 at the age of 61.

The Dalhousie Gazette, in a special edition, published in 1913 shortly after MacGregor's death, gives a full account of his life, with tributes from the Senate of Dalhousie University, "The Scotsman", an Edinburgh Colleague's estimate, and many others. It includes interesting analects from his lectures, which throw a light on MacGregor's thinking. In a lecture on The Conditions of Scientific Progress he says, "I hold Physics to be next to Literature, the best of all subjects of study as a means to a general education." In another Calculus Dodging and other Educational Sins, he said, "Calculus Dodgers are a most respectable body of men. The most artful dodger of them all is Clerk Maxwell, whose book on the theory of heat...has obtained wide popularity...

In Optics, Glazebrook takes the same course, and to men of small mathematical equipment throws a flood of light on a region that was cloudy and dark before...May we not rank even Newton himself a dodger, though he had no Calculus to dodge?"

In A Short Statement of the Advantages of University Consolidation, he says, "We can put our young men on an equal footing with those of the Upper Canadian Provinces only through the establishment of a well-equipped University, and such a University can be established only by a policy of consolidation."

STEPHEN M. DIXON
1901 - 1903

Stephen M. Dixon, M.A. (Dublin) A.M.I.C.E., succeeded MacGregor as Munro Professor of Physics and lecturer in applied mechanics. Seven classes were then offered by the department:- Junior Physics, Senior Physics, Mathematical Physics, Advanced Experimental Physics, Junior Practical Physics, Senior Practical Physics and Advanced Practical Physics.

The Faculty of Pure and Applied Science came into being at this time and Engineering Classes started in 1901.

The first degree in Mining Engineering was awarded in September, 1904, and the first degree in Civil Engineering in 1907, and the last degree in Engineering was awarded in 1909.

Dixon, who had Engineering training, was probably chosen as Professor of Physics because the University at that time was embarked on Engineering courses. The records indicate that he resigned as Professor of Physics in 1903 to become professor of Civil Engineering. From 1903 to 1905 the classes in Physics were given by T. C. Hebb, B.A. Dalhousie (1900) and M.A. (1901), who later became Professor of Physics at the University of British Columbia.

A. S. MACKENZIE
Head of Department 1905 - 1910
President 1911 - 1931

Dr. A. Stanley Mackenzie, who later became President of the University was made George Munro Professor of Physics in 1905.

He was born on 28 September 1865 in Pictou, the fourth son of George A. Mackenzie and Catherine Fogo. Some time between 1876 and 1880 the family moved to New Glasgow and by 1881 had settled in Dartmouth. In 1881 he entered

Dalhousie from the New Glasgow High School and the Halifax Academy with a Munro bursary, which he continued to hold throughout his course. Like MacGregor he took classes in Latin Greek, Logic and Chemistry as well as in Mathematics and Physics. Throughout his courses he achieved 1st class standing in nearly all his classes, and graduated in 1885 with honours in mathematics and physics and was winner of the Sir William Young Gold Medal.

The records show that he participated actively in athletics during his time at Dalhousie. While in his third year his name appears as taking part in eight of eighteen events in the first Grand Assault-at-Arms by the students of Dalhousie held in the Academy of Music on 29 February 1884.

As was usually the case of young men living in Dartmouth at this time, he was an active canoeist. Not long after graduating, while on a canoe expedition to Windsor via the Dartmouth Lakes and the Shubenacadie River, the canoe holding him, his brother, George, and a friend, F. L. Harvey, upset when close to Windsor and Harvey was drowned. The newspaper accounts at the time indicate that Stanley and George Mackenzie narrowly escaped drowning and were very lucky to be alive.

He spent the next two years teaching science in Yarmouth Academy and returned to Dalhousie to be tutor in Physics and Mathematics from 1887 to 1889, working under Professors Charles MacDonald and J. Gordon MacGregor.

In 1889 he entered Johns Hopkins University with a scholarship to do graduate work in physics. This graduate school was the outstanding research institution in the United States at that time and students came to it from all parts of the world. He was very fortunate in being able to work under the direction of that great, if somewhat difficult genius, Henry A. Rowland. It was Rowland, on the witness stand in an important lawsuit, who, when asked by an attorney, "Who is the greatest physicist in America?" replied simply, "I am." When a colleague twitted him on his lack of modesty, he replied indignantly, "But I was on my oath." Mackenzie was one of Rowland's favourite pupils, which is a tribute to his qualities as a man and his skill as a scientist. His first doctoral research was on a problem in spectroscopy. One day when Mackenzie was working with one of Rowland's prized diffraction gratings and had nearly finished the experimental work for his thesis, Rowland came into the room and unfortunately bumped the grating stand; the grating fell to the floor and broke in several pieces (one of them was given later to the Physics Department at Dalhousie by

Mackenzie, and should still be there). As this was the only grating available for Mackenzie to get the required data for his thesis, he had to give this work up and start anew on an investigation of the laws of gravitation involving crystalline solids. This was carried out with an apparatus somewhat like that used by the great Cavendish. His thesis was so highly regarded that he was chosen later to edit the classical memoirs of Newton, Cavendish and others on gravitation.

Before receiving the degree of Ph.D. in 1894 he was appointed lecturer in physics at Bryn Mawr. He was an Assistant Professor from 1893 to 1897 and in 1898 he became a full professor. During his stay at Bryn Mawr he published papers on the vibrations of rods, the propagation of heat and in the field of spectroscopy.

As the new discoveries such as the electron, X-rays and radio activity were being made at the turn of the century, Dr. Mackenzie turned his attention to them, and before coming to Dalhousie in 1905 as George Munro Professor of Physics, he spent a sabbatical year at the Cavendish Laboratory with Sir J. J. Thompson and there he made the first measurements of the velocity and mass of the alpha particles from radium. During his stay at Cambridge he so impressed those who worked in the Cavendish that a decade later, when

Dr. G. H. Henderson, newly arrived at the Cavendish, was asked whence he came and replied, "Dalhousie", the immediate response from several people was, "Why, that is where Dr. Mackenzie came from!"

His first problem on returning to Dalhousie was to build up and equip his laboratory. This he did with characteristic vigour and with the financial assistance of some of his Halifax friends. During this period he continued measurements of the velocity of alpha particles which he had started at the Cavendish--and under conditions which might well intimidate the physicists of today.

Dr. Mackenzie was an outstanding teacher. He always impressed his youthful, but critical, audience with his commanding presence. The writer was one of the students who was so impressed by the way that Mackenzie opened up the delights of physics that he decided to become a physicist rather than an engineer. His students were enthralled by his brilliant expositions and by his artistry with chalk and blackboard. His bi-weekly conferences with individual students were memorable. They were quickly put at ease and came away inspired to do better things. His class record book is as easily read now as on the day it was written. It shows, for instance, that in 1908-09 he lectured to 81 students in

five separate classes and supervised laboratory work as well. There was little time left for research, but even so, if one passed his laboratory windows late at night, the lights were often burning.

In all he did he was painstaking and thorough. Shoddy work of every kind he abhorred, and woe betide the careless or lazy student. Not only did he teach physics, but his hand was felt in everything that pertained to the good of the College.

Dr. Mackenzie during his professorship was assisted at different times by three demonstrators:- A. J. Barnes, B.Sc. (1906) for the period 1906-08; W. Stewart Lindsay, B.A. (1906) afterwards Dean of Medicine, University of Saskatchewan, for the session 1908-09; and Dr. T. C. Mackay (B.A. 1893) from 1909-1910.

His departure from Halifax to take the Chair of Physics at the Stevens Institute occasioned expressions of deep regret. The "Herald" and "The Echo" referred to Dr. Mackenzie as one of the brilliant graduates of Dalhousie. The Dalhousie Gazette said that his appointment to Dalhousie brought prestige to the University in scientific circles, that he was ideal head of the Physics Department and that his loss would be severely felt by the College. Before he

left, his Dalhousie friends, fellow members of the Halifax Club and the Halifax Golf Club gave a dinner in his honour on 31 August 1910. On this occasion a "Lament for Mackenzie" to the tune of "Lochaber No More" was sung. Three of the five verses indicate the esteem and affection in which Mackenzie was held and need no excuse to be repeated in this story. They are:

> In the teaching of Physics, Mackenzie's a dab,
> But now he must part from the College and Lab
> Where he cheerfully tinkered, nor thought it a bore--
> Alas, he'll return to Dalhousie no more!
>
> Farewell to Mackenzie--farewell to the Prof
> Who can mingle in Physics and fishing and golf
> With a drop of the liquid that betters the score,
> And we hope he'll return to our City once more.
>
> When we foozle and drive, put and play thro' the green,
> We'll "stay with" St. John at the Hole called Nineteen,
> We will all miss Mackenzie, our hearts will be sore--
> And we hope he'll return to the Golf Club once more!

What greater tribute could be paid by the friends of A.S.M.!

Dr. Mackenzie was at the Stevens Institute but a year when he returned to Dalhousie to become its President, the ninth distinguished Pictonian to become a college head. He was singularly well equipped for such duties. He well knew the problems facing Dalhousie and the spirit of the constituency which he had to serve. He had academic experience in three universities and had been associated with undergraduates, graduate students and teachers. He had been

associated with outstanding teachers of unusual ability and promise and with many of them he had formed life-long friendships, not only in Canada, but the United States, England and Germany.

Dalhousians and Mackenzie's many friends were delighted when they knew he was returning to Halifax. The daily press again paid high tribute to him. He threw himself into the work of building up the University, and soon had the support of those who knew him so well in Halifax. Under his inspiration a financial campaign was undertaken. With the new money the Studley property was purchased and six fine buildings were erected, the first one being the Science Building (now the Chemistry Building) which was used for the first time in September, 1915. In 1911, the Nova Scotia College of Pharmacy began its existence under the sheltering wings of Dalhousie. He was responsible for the College taking over the old Halifax Medical College in 1912 and making it into the Faculty of Medicine with financial aid from the Carnegie and Rockefeller Foundation. Following this the Law School and the Dental School were made faculties of the university in fact as well as in name. Then a Department of Commerce was organized.

He followed his old teacher MacGregor in being a fluent and persistent advocate of university federation,

without which he felt that true educational progress in Nova Scotia would be seriously impeded in the future. Without doubt he was largely responsible for having the Carnagie Corporation undertake a study of the situation and report on it. It was a great disappointment to him that all that came of their recommendations was that King's College alone associated itself with Dalhousie.

On his appointment as President he did his best to keep in touch with physics and for two years gave a class in spectroscopy until the pressure of presidential duties caused him to give up this activity with reluctance.

On numerous occasions he represented the University at home and abroad with distinction to himself and honour to Dalhousie and he gave unstintingly of his service outside the University. He often talked of the place of the university in the life of the Canadian people, and stressed "that the university's finest function is to teach the art of living".

Dr. Mackenzie played a prominent part in the formation of the National Research Council of Canada and was one of the founding members. He was asked to succeed Dr. A. B. MacCallum as president of the council in 1920, but fortunately for Dalhousie he refused the offer. He served the Council well from 1916 until his death in 1938. He was

particularly interested in the administration of scholarship awards. Thistle, in his book, "The Inner Ring", the early history of the National Research Council, indicates the strength and wisdom embodied in Dr. A. Stanley Mackenzie by citing "his ability to control and put to good use the powerful egotistical engine that was J. C. MacLennan" (who was Professor of Physics at the University of Toronto at that time). Mackenzie is also referred to in one account as being certainly "the most reasonable member of Council", but even so, he could not help stating in one of his letters that senators "are a lot of blathering idiots".

After twenty-six years of distinguished service to the University, which included five years as Professor of Physics, the Board of Governors reluctantly accepted the resignation of Dr. Mackenzie, which became effective when a successor, Dr. Carleton Stanley, was appointed in 1931.

In 1935 when the Government of Nova Scotia decided to set up an Economic Council to act in an advisory capacity on matters pertaining to the industrial development of the Province, Dr. Mackenzie consented to act as Chairman of this group of nine outstanding business and professional men, representative of various interests in the Province.

He continued to be Chairman until his death. This Council was the forerunner of the Nova Scotia Research Foundation.

He was prominent in the affairs of the National Conference of Canadian Universities all through his time as President of Dalhousie University.

Arthur Stanley Mackenzie died in Halifax on 3 October 1938, seven years after he had resigned from the University he had done so much to develop. He is buried in Indianapolis beside his wife, the former Miss Taylor. Mrs. Martin King, his only daughter, resides in Halifax.

The late President Walter Murray in his eulogy aptly writes:- "A phrase applied to President Eliot of Harvard might well be applied to Dr. Mackenzie--'He was a kingly man--kingly in presence, outlook, and leadership, kingly in courage and conception of public duty, kingly in his sense of responsibility for his university and all associated with it, kingly in his reserve and detachment from all mean and petty things of life'."

H. L. BRONSON

Head of Department 1910 - 1956

Dr. Howard Logan Bronson, B.A., Ph.D., LL.D., F.R.S.C., who became the fifth holder of the Munro Chair, was born in Washington, Conn., in 1878, the son of Walter W. and Helen Logan Bronson. He received his early education at the Gunnery School in his home town before entering Yale from which university he graduated in 1900. He was appointed Instructor in Physics at Lehigh University and stayed there a year, returning to Yale as an assistant in Physics, at the same time working towards his Ph.D. degree which he received in 1904. He was at Yale in the days of the famous J. Williard Gibbs, then professor of mathematical physics and he took classes from him. Later on he was attracted to McGill by the presence there of the famous Rutherford, later Lord Rutherford. The four years he spent at McGill were happy ones.

Dr. Bronson arrived at McGill in 1904 and immediately began doing research in radioactivity and at the same time demonstrated in Physics. He was soon advanced to lecturer and then Assistant Professor. His first experimental work with Rutherford led to a paper on the "Distribution of the active deposit of Radium in an Electric field". He devised a unique high resistance known as the Bronson resistance

which depended on the ionization produced by the alpha and beta particles emitted from a small quantity of radium. He also made accurate observations of the half lives of some of the radioactive elements and developed a scheme for measuring ionization currents.

When Bronson heard that Mackenzie had resigned to go to Stevens, he applied for the Munro Chair and was accepted. The Department in 1911 was a small one consisting of Dr. Bronson and one demonstrator and it offered in that year seven classes in physics which included 19 hours of laboratory work. In addition to this heavy teaching load, he also supervised the research of his first graduate student, who happens to be the writer of this history.

The writer remembers him in those early days as being a first-rate teacher, but not an eloquent lecturer. He never actually lectured; he just talked and asked questions from time to time and expected his students to interrupt him and ask questions any time they wished. He was a firm believer in the open text book examinations, when memorization by itself was of little value.

To him physics was not something one could learn by reading or listening to lectures alone; one had to experience it by making measurements. He believed that the best teaching of physics is done in the laboratory where he

dealt with each student individually. This kind of teaching produced a number of well-trained physicists large in proportion to the size of the university.

Bronson's first demonstrator was Harold S. Davis, who had just completed a B.Sc. degree with high honours in chemistry. He gave a class in medical physics and supervised the laboratory work of the first-year students at the same time. He left Dalhousie after winning an 1851 Exhibition Research Scholarship and went to Harvard for his Ph.D. Subsequently he had a distinguished career as a Research Officer with Standard Oil of New Jersey and then with the American Cyanamid Company.

His second demonstrator and MacGregor Fellow was the writer of this history, who supervised first-year laboratory classes and lectured to engineering students for the period 1912-14 when he, too, won an 1851 Exhibition Science Research Scholarship and proceeded to Yale University. Johnstone, in turn, was succeeded as demonstrator by G. H. Henderson, who also won an 1851 Scholarship. In 1916 Miss Merle Colpitt, now Mrs. H. L. Bronson, became demonstrator in physics.

During this period, 1912-15, Bronson was actively engaged in planning the physics part of the new Science

and Engineering Building, the first to be erected on the recently purchased Studley property. It is interesting to note that the other planners involved were the late C. D. Howe, President Mackenzie and Professor E. MacKay. Bronson moved his department to the new building in 1915 when help was hard to get. The War years imposed a great burden on the University professors as every young and able-bodied member of the staff enlisted and those that remained had to do "two men's work". The explosion of 1917 did much damage to the Science Building which had to be repaired in the depths of winter under the direction of Dr. Bronson. He often told of his experiences in trying to keep the snow and rain out of a building that had no glass left in any of the windows. At this time the closing of the University for the duration of the War was seriously considered.

After the War, the writer, who had obtained his Ph. D. at Yale before serving in France and Salonika with the Canadian Army, returned to Dalhousie as instructor in Physics at a salary of $1200 per annum. When King's became affiliated with Dalhousie it was part of the arrangement that it must support a professorship in mathematical physics, and so the late Dr. G. H. Henderson became the Professor in this subject in 1925. Bronson, not long after this date, had two full professors in the department, Johnstone, who was the O. E. Smith Professor, and Henderson, the Professor of Mathematical Physics.

The period from 1925 to 1940 was a very active one. Henderson and Bronson, in particular, were highly productive in their research efforts; Bronson in the field of specific heats of metals and Henderson in the study of pleochroic haloes and Johnstone worked on the dielectric constants of crystals.

The Department was seriously affected again by War in September, 1939, when it soon became evident that members of the Department would become involved in warfare. In February of 1940 Henderson and Johnstone were drawn into Naval Research and their activities are described elsewhere. They were on a half-time basis with the University until 1942 when they left the Department to devote full time to their Naval activities. Before doing so they were successful in persuading Dr. C. J. Mackenzie, the President of the National Research Council, to release Dr. W. J. Archibald, then in the Division of Pure Physics, to come to the assistance of Dr. Bronson (in 1942) who had been carrying far more than his share of the teaching load of the Department and at the same time supervising a pre-Radar training course. It can be said that had it not been for the war, Dalhousie might not have been fortunate enough to attract Dr. Archibald, one who has played a prominent part in the affairs of Dalhousie. He has served as Head of the Department of Physics and then Dean of Arts and Science and he is the A. C. Fales Professor of Theoretical Physics at the present time.

Dr. Bronson was responsible for the production of a number of physicists large in proportion to the size of the university, and who subsequently entered graduate schools in Canada, the United States and England for further training and who now occupy or have occupied prominent positions in universities and in industry. Two of them are fellows of the Royal Society of London and a number are fellows of the Royal Society of Canada. To mention but a few:- the late Dr. G. H. Henderson, F.R.S.; Dr. George Lawrence, F.R.S.C. now retired from being President of Atomic Energy of Canada Limited: the late Dr. G. O. Langstroth, at one time Head of the Physics Department, University of Alberta, and later Superintendent of the Naval Research Establishment, Halifax; W. H. MacCurdy, physicist with the Westinghouse Company in Pittsburg; Dr. J. L. Nickerson; Dr. Sydney Bateson, physicist with DuPlate Glass Co.; Dr. L. G. Turnbull of the National Research Council; Professor W. J. Archibald, F.R.S.C; Professor G. B. Crawford of Mount Allison University; Dr. V. D. Crawford, now Vice-President of the Georgia Institute of Technology; Dr. S. M. Dockerty; Dr. J. B. French, Professor of Theoretical Physics at Rochester; J. R. Longard and Oscar Sandoz, now of the Defence Research Board; the late Dr. Lloyd Elliott, F.R.S.C., director of the Physics Division of Chalk River Laboratory of A.E.C. of Canada; Professor A. J. C. Wilson, F.R.S. Head of the Physics Department of the University of Cardiff; the late Dr. Carl Kenty, physicist with General Electric Company Limited Research Laboratory in Cleveland; Dr. Wendell Hewson, Professor of Meteorology at the University of Michigan; Dr. Alex MacDonald, formerly

associate professor at Dalhousie and now a private consultant in Palo Alto; Dr. G. C. McCormick, National Research Council; Dr. Alex Stewart, F.R.S.C., now Chairman of the Department of Physics at Queens; Dr. J. E. Blanchard, F.R.S.C., President of the Nova Scotia Research Foundation; Miss Helen Reynolds, formerly Warden of Royal Victoria College and Dean of Women at McGill.

Dr. Bronson was far from being a one-sided scientist. His sage advice was often sought by his colleagues and by the Administration. He started the Student Christian Movement at Dalhousie University. The study groups which he conducted, almost until his death, became famous in university circles. He was a keen tennis player, golfer and curler in his younger days. He greatly enjoyed trout fishing in the lakes about Halifax and was an amateur gardener of first rank. He was interested in all matters that affected the welfare of the community and was a former member of the Halifax School Board.

Above all, he will be remembered by his students for his effective teaching of physics and the keen interest he displayed in their welfare. He set high standards for himself and demanded them of his students.

Dr. Bronson retired as George Munro Professor and Head of the Department in 1945, when he was succeeded by

Dr. J. H. L. Johnstone. Shortly after this, Dalhousie University awarded him the Honourary Degree of LL.D. Although he gave up active physics at that time, he continued to maintain an enthusiastic interest in the affairs of the Physics Department and of the university he had served so well.

After a long illness he died at his home in Halifax 7 March 1968 at the age of 90 years and is survived by his wife, Merle Colpitt Bronson.

G. H. HENDERSON
Professor 1924 - 1949

During Dr. Bronson's period at Dalhousie he had associated with him as professors the two oldest of his former students, J. H. L. Johnstone and G. H. Henderson.

The latter was born in St. Augustine, Florida, on 8 December 1892, the only son of John Alexander and Margaret Henderson of Pictou. His parents died shortly after they had returned to Pictou in 1895, where he was brought up by his grandparents. He attended Pictou Academy from 1906 to 1910 and each year he was the top man in his class, winning all the distinctions and medals that were offered. He acquired a great liking for physics when attending the academy. He told me that this was due chiefly to the inspiration he received from one of his teachers, the late Dr. W. P. Fraser, who later became Professor of Zoology at the University of Saskatchewan.

In 1910 Henderson entered Dalhousie with a bursary and in 1914 he received the degrees of B.A. and B.Sc. His thesis for the honours course in physics, "The Distribution of the active deposit of Thorium in an electric field" was published in 1914 in the Transactions of the Nova Scotia Institute of Science. On graduation he was awarded the

MacGregor Fellowship and appointed Demonstrator in Physics. In 1916 he received the degree of M.Sc. for his thesis on "The Distribution of the active Deposit of Radium in an Electric Field".

The First World War was then on and Henderson was keen to take an active part in it, so, when he had completed his course at Dalhousie, he applied for a commission and received one as a lieutenant in the Canadian Engineers. Much to his disgust, however, he had to serve in the forts at the entrance to Halifax Harbour. Despite repeated attempts to join his friend, Johnstone, who was then serving in France with the Royal Engineers, he was turned down for overseas service because of his eyesight.

The formation of the National Research Council of Canada was being actively discussed at this time and a decision was finally made to organize it in 1916. One of the first and best things the Council did was to set up a system of bursaries and scholarships to assist in the production of young scientists. George Henderson received one of the first of these scholarships and with its help proceeded to McGill to do research under the direction of the able mathematical physicist, Professor L. V. King. While there he published two papers in the Physical Review of 1920 on the "thermal conductivity of gases" and received his second M.Sc. in that year.

As was usual for a high honours graduate in physics from Dalhousie in those days, he won an 1851 Science Research Scholarship, but because of the War, he could not hold it until 1919, when he proceeded to the famous Cavendish Laboratory at Cambridge, where he spent three happy years. During this period he was very productive in research, publishing six important papers and he was awarded the degree of Doctor of Philosophy in 1922. While at Cambridge he became great friends with three fellow research students, who later became famous:- J. Chadwick (later Sir James Chadwick), the discoverer of the neutron, Kapitza, who later returned to Russia to become one of the outstanding engineer-scientists of that country and J. Cockcroft (later Sir John Cockcroft), who later became one of the chief science administrators of the United Kingdom.

In the summer of 1922 he accepted an offer to become an assistant professor of physics at the University of Saskatchewan. He enjoyed his time in Saskatoon except for the winter, which he said lasted from September to May! So when the Professorship of Mathematical Physics was established at King's in 1924, it was with joy that he accepted the offer to come back to Halifax and become a colleague of his former Professor, Dr. Bronson.

In 1929 he married Miss Ruth Wallace Ross, the daughter of the Honourable Senator W. B. Ross, then leader of the Conservative Party in the Senate of Canada. At their home on Morris Street they developed a fine art collection and also a fine flower garden. Every summer they spent some time at Petite Riviere where Henderson enjoyed salmon fishing in that delightful little river. In Halifax and Petite Riviere their two daughters grew up--Nancy, the elder, who is now a professor of zoology in the University of Calgary, and Margaret, now the wife of Commander Crickard, R.C.N.

Henderson was a first-class lecturer, clear and to the point in all he said. He was an excellent experimenter and a source of inspiration to everyone of his many research students. During his second Dalhousie period he published seventeen papers ranging from such subjects as "The capture and loss of alpha particles when passing through matter" to "A Mayflower from the Halifax Region". The most important ones were the eight on the study of "pleochroic haloes". This work led to a method for determining the age of the minerals in which the haloes were found. He achieved an international reputation for his halo research and was elected a Fellow of the Royal Society of London in 1942, the second Dalhousian to receive this honour.

In addition to his intense research activity during his early years at Dalhousie, he found time to provide advice and assistance to the Radiology Department of the Victoria General Hospital, then directed by his friend, the late Dr. S. R. Johnston. He developed a neat and compact method for purifying and making available for use, radium emanation or radon, a gas produced in very small quantities from the element radium. The small gold "seeds" filled with radon were then available for insertion in the cancer tissue by the surgeons. The compact equipment he designed and developed found quite a wide use in hospitals. Shortly after World War II began, he reluctantly gave up his halo research and with patriotic zeal devoted his great talents to the many problems involved in mine and antisubmarine warfare in association with his life-long friend, the writer of this history. These activities are described more fully in the section dealing with the contributions of the Physics Department to the War effort. During the latter period of the War he not only superintended the Naval Research Establishment but also became Staff Officer, Operational Research, North West Atlantic, under Rear Admiral Murray in Halifax. When the War ended he remained with the Naval Research Establishment as its Chief Superintendent on a part-time basis until the establishment was rebuilt to a healthy peacetime state. He was made an Officer of the Order of the British Empire in 1943 for his war service.

In 1946 he became a member of the Honourary Council of Scientific and Industrial Research (N.R.C.) and played an active part in its affairs until his death.

He supported the Nova Scotia Institute of Science throughout his active years and was its President from 1936-38.

He was always interested in the affairs of Pictou Academy and served on its Educational Foundation for a number of years. He left a tenth of his estate to "establish and maintain a historical museum dedicated to the pioneers of Pictou County."

He was a member of the editorial Board of the Dalhousie Review and made several contributions to it; one a celebrated article on "Mayfly Fishing"; another "The Cambridge Eclipse Expedition" (1932) and the last one an article on "Graduate Schools for Canadian Universities". As is evident from these articles, he was an ardent fisherman, trout fishing at first and then salmon fishing, at which he became very expert.

He was active in the formation of the Nova Scotia Research Foundation 1946 and served as a member of the Board until his death.

He was greatly interested in art and gathered one of the finest private collections of paintings in Nova Scotia - mostly done by Canadians such as Maurice and Tom Thomson.

Not only did he look after the affairs of the Naval Research Establishment after the War, but he also was very active at Dalhousie in supervising the research work of his students. At the June meeting of the Royal Society in 1949, seven of them presented papers on a wide variety of subjects.

It had been evident for some time that his health was failing due in large measure to his strenous wartime activity. Not long after attending the learned Society meetings at Halifax in June, and participating in the symposium on oceanography, he left by train on a salmon fishing trip to one of the rivers in New Brunswick, but he died enroute of a heart attack on 19 June 1949.

He was buried in the Haliburton Cemetery, Pictou, N. S. On the day of his funeral the flags on all ships and establishments of the Atlantic Command of the Royal Canadian Navy were at half-mast, an unusual tribute from the Navy to a civilian.

J. H. L. JOHNSTONE

Instructor 1912-14 and 1919-20
Assistant & Associate Professor 1920-1922
Professor 1922-1960
Head of Department 1945-1957
Dean of Graduate Studies 1949-1956

J. H. L. Johnstone was born in Pictou, N. S., on 27 April 1891, the son of George Elliott Johnstone and Jane Lavinia Johnstone. His primary education was obtained at the old Pictou Academy in Pictou.

After four years at Pictou Academy he achieved the highest standing in the Province in the examinations of Grade XII in 1908, taking both the classical and scientific side with a total of 28 examinations all written in one week.

With the award of a bursary of $50 Johnstone entered Dalhousie College and registered for engineering. At that time President Forrest was also the registrar from whom Johnstone received four dollars change from Dr. Forrest's back pocket after registering for six classes. In the following year he changed from Engineering to the Honours Physics course, chiefly because of the inspiration received from the teaching of Dr. A. S. Mackenzie in Physics I. This, in spite of the fact that he was taking his engineering classes from the late C. D. Howe, who was also a first-rate teacher.

He completed his B.Sc. Honours course under the direction of Dr. Bronson and graduated in 1912 with High Honours in Physics and the University medal. He was then appointed demonstrator in Physics, and at the same time worked towards his M.Sc. degree which he received in 1914 for a thesis on the "electrical conductivity of ice", and which was published in the transactions of the Nova Scotia Institute of Science. As the winner of an 1851 scholarship he was not permitted to hold it in the United Kingdom as the war had just begun, but was allowed to hold it at Yale.

The Chairman of the Department of Physics at Yale was then Professor Bumstead, who was regarded as one of the outstanding physicists of the United States. He was also a delightful person; regarded highly by all who knew him. (Incidentally a great friend of Dr. A. S. Mackenzie.) Leigh Page had just been appointed to the staff and was beginning his brilliant career as a theoretical physicist.

Johnstone received his Ph.D. in absentia in 1916 for research in the field of radioactivity under the direction of Professor B. B. Boltwood who was one of the leaders at this time in the beginnings of nuclear physics. As a result of this two papers were published:- "The relative activity of Radium and Uranium with which it is in

equilibrium" and "On the variation of the 'emanating power' of certain uranium minerals with temperature and a new secondary Radium Emanation Standard".

In the early part of 1916, Johnstone felt that he must soon become involved in the War in an active way, and as a result of a letter to the Member of Parliament for Pictou, N.S., who wrote the Hon. R. L. Borden, then Prime Minister, who wrote to the Chief of the General Staff, Johnstone received a letter from the Director General of Engineer services offering him a commission and asking him to report for training as an engineer officer in Ottawa on May 15, 1916! It is of interest to note that military men and politicians of that time were uncertain about what physicists did, so they bracketed them with engineers!

After the usual training, Johnstone proceeded to England and became adjutant of A Company, the Canada Engineer Training Department. Suddenly out of the blue a signal came ordering him to proceed to France and report to the Sound Ranging School which was then directed by Major W. L. Bragg, now Sir Lawrence Bragg. Professor Bumstead of Yale, of his own volition, had written to Sir Ernest Rutherford evidently to the effect that physicists were wasted as engineers. Apparently Rutherford wrote the War Office, and

so Johnstone found himself a "sound ranger". In a short time he was sent to the Vimy front to join L Section and then to the Passchendale area with Q Section. After difficult times in the Ypres salient, Q Section was taken out of the line to refit, and early in January was on its way to Salonika, not as Q Section, but for security reasons as "Johnstone's Party", and the unit was known in the British Army by this name until the end of the war. Before the war ended Johnstone was mentioned in despatches and awarded the M.B.E. (Mil. Div.).

Not long after his return to Halifax in 1919 he applied for a position with his old Department at Dalhousie and was appointed Instructor in Physics. In the summer of 1921, and again in 1929, he was fortunate to be employed with the Research Laboratory of the General Electric Company Schenectady to work under Dr. Irving Langmuir who was then at the peak of his career.

In 1920 he became an assistant professor; in 1921 an associate professor and the O. E. Smith Professor in 1922. When Dr. Bronson retired in 1945 he became George Munro Professor and Head of the Department, which position he kept until 1957 when he was succeeded by Dr. W. J. Archibald.

In 1932 Johnstone and his colleague, Henderson, were asked to join the University of Cambridge Eclipse Expedition at Magog, Quebec. They spent nearly a month assisting a number of outstanding British astrophysicists in setting up the spectrometers and interferometers to be used to learn more about the sun. Unfortunately, clouds covered the sun on the great day and all the effort was in vain, but firm friendships were formed. Dr. Henderson gives an excellent account of this expedition in the Dalhousie Review of that year.

During his time at Dalhousie he was actively interested in the Nova Scotia Institute of Science, serving as its President from 1932-34.

In 1945 he married Janet Scott MacDonald, the daughter of the late James A. MacDonald, K. C. and his wife Sarah Gray MacDonald.

He was a member of the Fisheries Research Board from 1946-1955; the Defence Research Board 1947-1950; and a member of the National Research Council from 1949-1951, from 1952-1955 and from 1955-1958.

In association with Dr. Henderson he was active in advocating the provision of facilities for graduate work at Dalhousie University. In 1949 he became the first Dean of the Faculty of Graduate Studies which position he held until 1956. Previous to this period he was successively secretary of the Faculty of Arts and Science, joint registrar of the University and secretary of the Senate.

Since 1949 he has served as a member of the Board of Governors of the Nova Scotia Research Foundation and since 1961 he has been employed by this organization as a consultant.

After retiring as Head of the Department in 1957 Johnstone became head of the team responsible for the design of the interior of the new building being built for the departments of Physics, Geology and Engineering, with funds provided by the late Sir James Dunn.

Not only was he concerned with the design of the interior, but at the request of the Chancellor of the University the late C. D. Howe, became responsible for the overall supervision of the construction of the building as Chairman of the Building Committee. On the occasion of the official opening of the building, he was awarded the Honourary Degree of LL.D. by his old university.

During the 1945-57 period, Johnstone was appointed an official Canadian delegate to various conferences: the British Empire Scientific Conference in London in 1946; the Defence Research Conference in London, 1946; the U.S. Navy Operational Research Conference in Washington in 1948; the International Union of Pure and Applied Physics in 1954; and the Low Temperature Physics Conference in Leyden in 1958.

In the period 1946-56 additional resources became available to increase the staff of the Physics Department.

Dr. E. W. Guptill, later Head of the Department, joined it in 1947; Dr. C. K. Hoyt, now a Professor in the Department, was appointed to the staff in 1955; Dr. Stephens-Nensham was added in 1948; Dr. Alex MacDonald, now a consultant physicist in Palo Alto, Calfornia, became an Assistant Professor in 1949; Dr. J. E. Blanchard, now President of the Nova Scotia Research Foundation, first joined the department as lecturer in 1949 and later became Professor of Geophysics; and Dr. Alex Stewart, now Head of the Department of Physics of Queen's University, joined the department in 1952.

Dr. Henderson, an ardent fisherman, became friends with another fisherman, the late Dr. A. C. Fales. As a result of the friendship, Dr. Fales became interested in the Physics Department, and on his death in 1954 left the greater part of his estate to endow a chair in Theoretical Physics and also the Fales visiting professorship. Dr. W. J. Archibald has been the holder of this Chair since 1955. The first Fales visiting professorship was held during 1956 by Dr. Gerhard Hertzburg, C. C., F. R. S.

During this period Professor Guptill and his students carried on experiments with sound waves of very high frequency, particularly the study of the behaviour of these waves in liquids. Dr. MacDonald was concerned with the

electrical conduction in gases at high frequencies and the voltage required for breakdown. A little later Dr. Guptill set up a first-rate laboratory for work in the field of low temperature physics. Dr. Blanchard measured the carbon 14 content of various materials in order to determine their age. Dr. Archibald carried on studies in theoretical physics particularly in quantum mechanics and the nature of the meson. Dr. A. T. Stewart published several papers on the scattering of neutrons and on the field of positron annihilation.

Appendix I lists the majority of the papers published by the members of the department from 1911 to 1956.

THE PHYSICS DEPARTMENT LABORATORIES

From 1838 to 1877 the teaching of Physics was carried on in the Dalhousie College of the Grand Parade (where now the City Hall stands). In 1887 the foundation stone for the red brick building on Carleton Street, later named after President Forrest, was laid. MacGregor was the first Professor to use the quarters designed in the south end of the second floor of the building. These are small when looked upon today - one large room, the main laboratory where the first and second year laboratory classes were conducted, a second smaller room for the advanced laboratory classes, a lecture room which held about 75, a battery room, a small research room, and an office for the Professor. This space was all that was available for the Department until it moved to the new Science Building at Studley in 1916. The Studley quarters seemed large then compared to those vacated, but ten years later the Department was cramped for space.

In 1960, the new Sir James Dunn Building was opened for use. Eleven years later, space for research and teaching is no longer adequate!

THE WAR RECORD OF THE DEPARTMENT OF PHYSICS, NAVAL RESEARCH

The early advent of the German magnetic mine, involving the necessity of immediate counter measures, led the Royal Canadian Navy at Halifax to call in scientific aid.

On the afternoon of 21 February 1940 the late Captain (afterwards Vice-Admiral) H. E. Reid, then Commanding Officer Atlantic Coast, asked Johnstone and Henderson to come to the Dockyard. He explained the situation and asked for their help in combating the magnetic mine. They agreed eagerly and so the Naval Research Establishment, now known as D.R.E.A. was born. The information available to protect ships from magnetic mines was very scanty at that time in Halifax. It was obvious to any physicist, however, that a degree of protection could be obtained by a coil of wire around the perimeter of the ship, energized by an electric current.

It was clear that apart from the engineering of the coils, a method for measuring the magnetic field under the ship was needed. Each ship would have to be tailor fitted. The magnitude of the task of dealing with thousands of ships was enormous. There was no information available about the kind of measuring instrument needed for the purpose.

The Dalhousie physicists went to work and the first model of a magnetometer was used to test a ship on the 20 March 1940 and it worked!

At about this time arrangements were made to have Johnstone and Henderson become members of the National Research Council staff; to have joint responsibility for the conduct of Naval Research at Halifax. Not long after this Dr. Henderson went to England and returned early in July with detailed information regarding the latest methods of dealing with these problems.

Meanwhile, in Halifax, many ships were being treated by the magnetometer designed by Henderson and Johnstone. Additional members of the staff were recruited from students at Dalhousie and at other universities, who had specialized in Physics or mathematics or chemistry.

As the summer drew on, 50 United States destroyers turned over to Britain were tested by the magnetometer at Halifax. Not long after this an open range for calibrating ships was established and used for the first time on the 13th of November 1940, the first range outside the British Isles open for business. Later ranges were installed by us at Sydney, Quebec and in the main Halifax channel. Hundreds of ships of all kinds, including battleships, destroyers,

passenger liners, freighters and corvettes were dealt with at the Atlantic ports of Canada under the supervision of N.R.C., Halifax, N.S.

The requirements for magnetic mine sweeping called for a switching system capable of handling thousands of amperes actuated regularly to a precision of a fraction of a second. England was too pressed to provide us with such equipment so it had to be put together in Halifax. Fortunately, the Halifax group was able to enlist the services of the National Research Council of Ottawa who were responsible for the design of an excellent mine sweep. Had this not been done by Canadian initiative, our ports would have remained unprotected for many months.

Early in 1941 it was clear that another type of influence mine, the acoustic, would have to be contended with. The problems involved were of the same general nature as in the case of the magnetic mine. First one had to measure the acoustic output of ships, then one had to design a noise maker for sweeping these mines.

With the aid of equipment designed by Dr. G. S. Field of the National Research Council, Ottawa, the Halifax group was able to measure the acoustic output of any type of ship on the acoustic range at Halifax. Later on when the

problem of the German acoustic torpedo arose the knowledge and experience gained in this program enabled adequate counter measures to be developed.

At the same time efforts were turned to the development of methods for acoustic mine sweeping. The most notable result was the development of a noise maker and also a decoy for acoustic torpedoes, each of simple design worked out in Halifax and finally adopted by both the U.S. and Canadian Navies.

The development of acoustic mine sweeping methods by the group at Halifax enabled the coast to be protected at a much earlier date than if reliance had to be placed on other organizations. When the approaches to Halifax and St. John's, Newfoundland, were mined by the enemy in 1943, the clearance of these fields was completed quickly with little loss to shipping.

In the early days of the war a great part of the experimental work was done in the laboratory of the Physics Department at Dalhousie where a small, but excellent, machine shop or instrument shop was available.

In addition to the projects mentioned, a large number of other problems were handled by the staff at Halifax. Scientific advice was given to Naval officers who brought their problems to the group.

By the middle of 1942 Henderson and Johnstone obtained leave of absence from Dalhousie until the end of the War, and joined the staff of the National Research Council. The Naval Research staff at Halifax had grown to about 30, nearly all of whom were young physicists and engineers recently graduated from Canadian universities, the majority of them, however, came from Dalhousie. The university should indeed be proud of the devoted service rendered Canada in wartime by these young physicists and mathematicians, nearly all of whom have since reached positions of prominence in their fields.

Not long afterwards it was deemed wise that these scientists be commissioned in the Navy. One of the reasons was that the local draft board was pushing to have them conscripted into the Army! Another was that often they had to go to sea and for their own protection it was desirable to have them in uniform, and finally, as temporary Civil Servants they had little chance of promotion and increases in pay while their friends in uniform working beside them were getting more pay and would receive benefits at the end of the war. So, in the early part of 1943 all the personnel were commissioned in the R.C.N.V.R. A little later on in January, 1944, the official connection with the National Research Council ended and the scientific work at Halifax was carried on by H.M.C. Naval Research Establishment and Doctors

Henderson and Johnstone became joint superintendents of the organization.

Throughout the early part of 1943 the pressure to have either Dr. Henderson or Dr. Johnstone take an active part in scientific affairs at Naval Headquarters at Ottawa and also in Washington became great. It was evident also for some time that the R.C.N. should make use of what was then a new approach to the application of science to warfare, viz. Operational Research. On 1 July 1943 Dr. Johnstone left Halifax reluctantly for Naval Service Headquarters in Ottawa to take up the position of Director of Operational Research and become a member of the Naval Staff.

The months of July and August were spent by Henderson and Johnstone visiting the United States Navy Operations Staff and the Admiralty in London to acquire familiarity with operational research techniques. At the Admiralty, Professor P. M. S. Blackett, now Lord Blackett, who was primarily responsible for the development of Operational Research, placed his organization at our disposal and its help was invaluable. In addition numerous visits were made to the operational commands of the Royal Navy in various parts of the United Kingdom. In Washington, Dr. Philip Morse, who directed operational research for the 10th Fleet, took the two Canadians into his confidence and gave them invaluable assistance until the end of the war.

On his return to Canada, Johnstone was able to recruit several outstanding physicists to staff the Division of Operational Research at Ottawa, while Dr. Henderson, as Superintendent of the Naval Research Establishment became, in addition, Operational Research Staff Officer at Halifax on the staff of Rear-Admiral Murray, C-in-C Northwest Atlantic.

The work of the group was chiefly concerned with anti-U boat warfare. It was continuously necessary to anticipate the introduction of new technical developments of the enemy and to forestall them by counter-measures planned in advance. During the period 1 August 1943 to 1 August 1945 reports and memoranda on a wide variety of subjects were prepared, circulated and discussed with the Naval operational authorities.

In order to be effective in the field of Operational Research, it was essential that the scientists be taken into the full confidence of the Naval operational authorities. This was happily the case at Headquarters and at Atlantic Command at Halifax. D.O.R.'s close contact with the Naval Staff at Ottawa, and Dr. Henderson's close relations with C-in-C, North West Atlantic in Halifax, left nothing to be desired in the way of co-operation.

The following words of Sir Francis Drake, noticed by Dr. Henderson on the wall of an office of the Admiralty during the war are to the point:

> "I must have the gentlemen to haul and draw with the mariners and the mariners with the gentlemen; Let us show ourselves to be all of one company."

These sentiments express well the spirit of cooperation between the Canadian Navy and the scientists.

Dr. Henderson was honoured for his war services by the award of Officer of the Order of the British Empire (O.B.E.), and Dr. Johnstone was made an Officer of the Order of the British Empire (O.B.E.) (Mil. Div.).

OTHER WARTIME ACTIVITIES OF THE DEPARTMENT

The Physics Department made two other significant contributions to the war effort:- Under the leadership of Dr. Bronson it gave pre-radar training in basic Physics to a selected group of young Canadians, and under the direction of Doctors Henderson and Johnstone it initiated and organized a School for the Training of Instrument Makers (mechanics highly trained to do precision work) urgently needed by industry and by laboratories carrying on war research.

Radar had been developed not long before the War, and it soon became apparent that England was in need of young officers who could supervise its use on land and on the sea. Canadian Universities agreed without hesitation to provide the necessary courses in electricity and in wave propagation preliminary to the more advanced training in Radar which was provided in England. A large number of young Canadians with this basic training were sent to the United Kingdom and most of them were given commissions in the armed services and served with distinction throughout the War. The Dalhousie Physics Department played a prominent part in this important activity.

When mentioning radar it is fitting to note that the slotted array antennas in common use today are the result

of an invention of Dr. E. W. Guptill, now a Professor in the Department, and Professor W. H. Watson, who were working for the National Research Council at McGill University in 1942 and 1943. This invention resulted in a much higher resolution radar, which contributed to the successes of the allied air forces operating over Europe. An adaption of this device is in use today in television transmitting antennas and it also assists in the control of guided missiles.

In the early days of the War it became apparent to those who were involved in the design and production of prototypes of the equipment and apparatus being developed that the country lacked highly trained mechanics who were capable of doing high-precision work needed in the making of sensitive instruments of various kinds.

The Physics Department at that time had in its employ a highly skilled instrument maker, Mr. A. V. Brody. The small instrument shop in the old Science Building was enlarged by taking over the ladies' waiting room, additional equipment obtained, and a course was commenced for several apprentices. It was soon found that the demand was great for the products of this little school and it became apparent it must be expanded. This was done and funds were provided by the Federal Department of Labour in association with the Nova Scotia Technical College. Additional machine tools were

obtained and Brody moved his establishment to larger quarters in the basement of the old Law School, where instrument makers were trained until the end of the War. All of these instrument makers were eagerly sought by Canadian industry engaged in the War effort. Brody made a fine contribution to the War effort, not only by producing these instrument makers, but also by his contribution to the design and the making of many devices required by the Naval Research Establishment in its early days.

PAPERS PUBLISHED BY THE LATE DR. J. G. MACGREGOR

Scientific And Educational Publications

In Dynamics

"An Elementary Treatise on Kinematics and Dynamics". Crown 8vo, pp. xvi + 512, 1888. Macmillan & Co., London and New York.

"On the Elementary Treatment of the Propagation of Longitudinal Waves". Trans. N.S. Inst. Sci., vol. 7, pp. 88-92, 1888.

"The Fundamental Hypotheses of Abstract Dynamics". Trans. Roy. Soc. Canada, vol. 10, sec. 3, pp. 3-21, 1892. (Also Science, N.Y., Aug. 5th, 1892.)

"On the Graphical Treatment of the Inertia of the Connecting Rod". Trans. N.S. Inst. Sci., vol. 8, pp. 193-202, 1892.

"Contact Action and the Conservation of Energy". Philosophical Magazine, London, vol. 35, pp. 134-142, 1893.

"On the Hypotheses of Dynamics". Phil. Mag., vol. 36, pp. 233-264, 1893.

"On the Definition of Work Done". Trans. N.S. Inst. Sci., vol. 8, pp. 460-464, 1895.

"On the Hypotheses of Abstract Dynamics". Trans. Roy. Soc. Can., ser. 2, vol. 1, sec. 3, pp. 85-95, 1895-6.

"The Hypotheses of Abstract Dynamics and the Question of the Number of the Elastic Constants". Phil. Mag., vol. 42, pp. 240-245, 1896.

On The Mechanical Properties Of Solutions

"Notes on the Volumes of Solutions (in conjunction with J. A. Ewing)". Report British Association, 1877, pp. 40-41.

"On A Test of Ewing and MacGregor's Method of Measuring The Resistance of Electrolytes". Trans. Roy. Soc. Can., vol. 8, sec. 3, pp. 49-56, 1890.

"On the Calculation of the Conductivity of Mixtures of Electrolytes". Trans. N.S. Inst. Sci., vol. 9, pp. 101-119, 1895-6; and Phil. Mag., vol. 41, pp. 276-287, 1896.

"On the Calculation of the Conductivity of Electrolytes". Trans. Roy. Soc. Can., ser. 2, vol. 2, sec. 3, pp. 65-82, 1896-7.

"On the Calculation of the Conductivity of Aqueous Solutions containing Two Electrolytes with no Common Ion (in conjunction with E. H. Archibald). Phil. Mag., vol. 45, pp. 153-159, 1898.

"On the Calculability of the Results of Electrolysis in Solutions containing Two Electrolytes with One Ion in Common". Trans. Roy. Soc. Can., ser. 2, vol. 4, sec. 3, pp. 117-148, 1898-9; and Physical Review, vol. 8, pp. 129-141, 1899.

On Relations Between Electrical And Other Properties Of Solutions

"On the Relation of the Physical Properties of Aqueous Solutions to their State of Ionization". Trans. N.S. Inst. Sci., vol. 9, pp. 219-245, 1896-7; and Phil. Mag., vol. 43, pp. 46-55, and 99-109, 1897.

"On a Diagram of Freezing-point Depressions for Electrolytes". Trans. N.S. Inst. Sci., vol. 10, pp. 211-235, 1899-1900; and Phil. Mag., vol. 50, pp. 505-519, 1900.

In Light

"Note on Peculiar Aurorae". Trans. N.S. Inst. Sci., vol. 6, pp. 100-101, 1886.

"On the Variation, with Temperature and Concentration, of the Absorption Spectra of Aqueous Solutions of Salts". Trans. Roy. Soc. Can., vol. 9, sec. 3, pp. 27-41, 1891.

In Thermo-Electricity

"On the Thermo-Electrical Properties of Cobalt" (in conjunction with C. G. Knott and C. M. Smith). Proc. Roy. Soc. Edin., vol. 9, pp. 421-424, 1876-7.

"On the Thermo-Electrical Properties of Charcoal and certain Alloys, with a Supplementary Thermo-Electric Diagram" (in conjunction with C. G. Knott). Trans. Roy. Soc. Edin., vol. 28, pp. 321-343, 1879.

In Electricity

"The Electrical Conductivity of certain Saline Solutions, with a Note on the Density" (in conjunction with J. A. Ewing). Trans. Roy. Soc. Edin., vol. 27, pp. 51-70, 1873.

"Note on the Conductivity of Saline Solutions". Proc. Roy. Soc. Edin., vol. 8, pp. 545-559, 1874-5.

"On the Electrical Conductivity of Stretched Silver Wires". Proc. Roy. Soc. Edin., vol. 9, pp. 79-85, 1875-6.

"On the Electrical Conductivity of Nickel" (in conjunction with C. M. Smith). Proc. Roy. Soc. Edin., vol. 9, pp. 120-123, 1875-6.

"On the Variation, with Temperature, of the Electrical Resistance of Wires of certain Alloys" (in conjunction with C. G. Knott). Trans. Roy. Soc. Edin., vol. 29, pp. 599-608, 1879-80.

"On the Measurement of the Resistance of Electrolytes by means of Wheatstone's Bridge". Trans. Roy. Soc. Can., vol. 1, sec. 3, pp. 21-25, 1882.

"Experiments showing the Electro-motive Force of Polarization to be Independent of the Potential Difference of the Electrodes". Trans. Roy. Soc. Can., vol. 1, sec. 3, pp. 49-54, 1883.

"On the Resistance to the Passage of the Electric Current between Amalgamated Zinc Electrodes and Zinc Sulphate Solution". Trans. N.S. Inst. Sci., vol. 6, pp. 47-53, 1883.

"On the Density of Weak Aqueous Solutions of certain Salts". Trans. Roy. Soc. Can., vol. 3, sec. 3, pp. 15-19, 1885.

"On the Relative Bulk of certain Aqueous Solutions and their Constituent Water". Trans. N.S. Inst. Sci., vol. 6, pp. 261-264, 1886.

"On the Variation of the Density with the Concentration of Weak Aqueous Solutions of certain Salts". Trans. Roy. Soc. Can., vol. 7, sec. 3, pp. 23-31, 1889.

"On the Relative Bulk of Aqueous Solutions of certain Hydroxides and their Constituent Water". Trans. N.S. Inst. Sci., vol. 7, pp. 368-376, 1889-90.

"On the Density of Weak Aqueous Solutions of certain Sulphates". Trans. Roy. Soc. Can., vol. 8, sec. 3, pp. 19-38, 1890, and vol. 9, sec. 3, pp. 15-17, 1891.

In Heat

"On the Absorption of Low Radiant Heat by Gaseous Bodies". Proc. Roy. Soc. Edin., vol. 12, pp. 24-45, 1882-3.

"On the Density and Thermal Expansion of Copper Sulphate Solutions". Trans. Roy. Soc. Can., vol. 2, sec. 3, pp. 69-76, 1884.

"Note on Temperatures of Maximum Density". Trans. N.S. Inst. Sci., vol. 6, pp. 226-227, 1886.

"On the Measurement of Temperature and Time". Trans. N.S. Inst. Sci., vol. 7, pp. 20-23, 1886-7.

"On Carnot's Cycle in Thermodynamics". Trans. N.S. Inst. Sci., vol. 7. pp. 227-230, 1888-89.

"A Table of Cubical Expansions". Trans. Roy. Soc. Can., vol. 6, sec. 3, pp. 3-16, 1888.

"On a Noteworthy Case of the Occurrence of Ice in the form of Non-crystaline Columns". Trans. N.S. Inst. Sci., vol. 7, pp. 377-380, 1889-90.

"Lecture Experiments illustrating Optical and other Properties of Saline Solutions". Trans. N.S. Inst. Sci., vol. 8, pp. 71-76, 1890-91; and Chemical News, London, vol. 62, p. 223, 1890.

In Chemical Physics

"On the Determination of the State of Ionization in Dilute Aqueous Solutions, containing Two Electrolytes". Reports British Association, 1897, pp. 581-582, and 1898, p. 803-804.

"On the Conductivity Method of Studying Moderately Dilute Solutions of Double Salts" (in conjunction with E. H. Archibald). Phil. Mag., vol. 46, pp. 509-519, 1898.

"On Finding the Ionization of Complex Solutions of Given Concentration, and the Converse Problem". Trans. N.S. Inst. Sci., vol. 10, pp. 67-78, 1898-9. Also, Ueber die Bestimmung der Dissociation von Zusammengesetzten Losungen von gegebener Concentration und uber das umgekehrte Problem. Zeitschrift fur physikalische Chemie, Bd. 33, ss. 529-540, 1900.

(See also Papers mentioned above on Properties of Solutions.)

Educational Pamphlets

"The Conditions of Scientific Progress",-an Address. 1880. Halifax, N.S.

"A Short Statement of the Advantages of University Consolidation". 1881. Halifax, N.S.

"Technical Education Abroad and At Home". 1882. Halifax, N.S.

"Address on the Work of a Scientific Society". 1888. Halifax, N.S.

"Address on the Utility of Museums". 1890. Halifax, N.S.

"On Calculus Dodging and other Educational Sins". 1890. St. John, N.B.

"The Utility of Knowledge-Making as a Means of Liberal Training". 1899. Halifax, N.S.

Scientific Papers

By Physical Laboratory Students of

Dalhousie University

1893-1900

"On the Measurement of the Resistance of Electrolytes"-by F. J. A. McKittrick. Trans. N.S. Inst. Sci., vol. 8, pp. 381-390, 1894.

"On the Calculation of the Conductivity of Mixtures of Electrolytes having a Common Ion"-by Douglas McIntosh. Trans. N.S. Inst. Sci., vol. 9, pp. 120-133, 1895-6; Phil. Mag., vol. 41, pp. 510-516, 1896; and Chemical News, London, vol. 74, pp. 35-36, 1896.

"On the Calculation of the Conductivity of Aqueous Solutions containing Potassium and Sodium Sulphates"-by E. H. Archibald. Trans. N.S. Inst. Sci., vol. 9, pp. 291-301, 1897-8.

"On the Calculation of the Conductivity of Aqueous Solutions containing the Chlorides of Sodium and Barium"-by T. C. McKay. Trans. N.S. Inst. Sci., vol. 9, pp. 321-334, 1897-8.

"On the Calculation of the Conductivity of Aqueous Solutions containing Sodium Chloride and Potassium Sulphate"-by E. H. Archibald. Trans. Roy. Soc. Can., ser. 2, vol. 3, sec. 3, pp. 69-77, 1897. (See also Phil. Mag., vol. 45, pp. 151-159, 1898.)

"On the Relation of the Surface Tension and Specific Gravity of certain Aqueous Solutions to their State of Ionization"-by E. H. Archibald. Trans. N.S. Inst. Sci., vol. 9, pp. 335-347, 1897-8.

"On the Calculation of the Conductivity of Aqueous Solutions containing the Double Sulphate of Copper and Potassium"-by E. H. Archibald. Trans. N.S. Inst. Sci., vol. 9, pp. 307-320, 1897-8. (See also Phil. Mag. vol. 46, pp. 509-519, 1898.)

"On the Calculation of the Conductivity of Aqueous Solutions of Potassium-Magnesium Sulphate"-by T. C. McKay. Trans. N.S. Inst. Sci., vol. 9, pp. 348-355, 1897-8.

"On a Test, by the Freezing-point Method. of Ionization Co-efficients, determined by the conductivity methods for solutions containing Potassium and Sodium Sulphates"-by E. H. Archibald. Trans. N.S. Inst. Sci., vol. 10, pp. 33-48, 1898-9, and Chemical News, London, Vol. 80, pp. 46-47, 57-59, 68-69, and 76-77, 1899.

"On the Conductivity, Specific Gravity and Surface Tension, of Aqueous Solutions containing Potassium Chloride and Sulphate"-by James Barnes. Trans. N.S. Inst. Sci., vol. 10, pp. 49-66, 1898-9.

"Note on the Variation with Tension of the Elastic Properties of Vulcanised India-rubber"-by W. A. MacDonald in conjunction with J. G. MacGregor. Proc. N.S. Inst. Sci., vol. 10, pp. 28-34, 1898-9.

"On the Relation of the Viscosity of Mixtures of Solutions of certain Salts to their State of Ionization"-by James Barnes. Trans. N.S. Inst. Sci., vol. 10, pp. 113-128, 1899-1900.

"On the Calculation of the Conductivity of Aqueous Solutions containing Hydorchloric and Sulphuric Acids"-by James Barnes. Trans. N.S. Inst. Sci., vol. 10, pp. 129-138, 1899-1900.

"On the Depression of the Freezing-point by Mixtures of Electrolytes"-by James Barnes. Trans. N.S. Inst. Sci., vol. 10, pp. 139-161, 1899-1900.

"On the Relative Bulk of Weak Aqueous Solutions of certain Sulphates and their Constituent Water"-by C. M. Pasea. Trans. Roy. Soc. Can., ser. 2, vol. 6, sec. 3, pp. 27-36, 1900.

"On the Variation of the Rigidity of Vulcanised India-rubber, with Tension"-by T. C. Hebb. Trans. N.S. Inst. Sci., vol. 10, pp. 273-286, 1899-1900.

"On the Depression of the Freezing-point in Solutions containing Hydrochloric and Sulphuric Acids"-by James Barnes. Trans. Roy. Soc. Can., ser. 2, vol. 6, sec. 3, pp. 37-54, 1900.

PAPERS PUBLISHED BY AUTHUR STANLEY MACKENZIE

"On the attractions of crystalline and isotropic masses at small distances". Phys. Rec. 2:321-343, 1895. (His Ph.D. Thesis, Johns Hopkins University.)

"The laws of gravitation; memoirs by Newton, Bouguer and Cavendish". N.Y., American Book Co. (c1900) 160 p.

Northway, M.I. & Mackenzie, A.S. "On the period of a rod vibrating in a liquid". Phys. Rev. 13: 145-164, 1901.

"The question of the divisibility of the atom". Franklin Institute. Journal. 153:451-468, 1902.

"An instrument for drawing sine curves". Phys. Rev. 15: 366-367, 1902.

"On some equations pertaining to the propagation of heat in an infinite medium". Amer. Phil. Soc. Proc. 41:181-199, 1902.

"The deflexion of x-rays from radium and polonium". Phil. Mag. Ser. 6, 10:538-548, 1905.

"Recent physical development". Convocation Address, Fall Convocation, September 1905.

"Secondary radiation from a plate exposed to rays from radium". Phil. Mag. Ser.6, 14:176-187, 1907.

Creighton, H.J.M. & Mackenzie, A.S. "Influence of radium on the decomposition of hydriodic acid". Amer, Chem. J. 39:474-493, 1908.

"Greetings from Canada". Society for the Promotion of Engineering Education. Proc. 25:20-25, 1917.

"The war and science". Royal Soc. of Canada. Trans. Ser.3, 12:1-6, 1918.

"Problems in medical education". Congress on Medical Education, Licensure, Public Health and Hospitals, Chicago, February 15-18, 1926. Proceedings.

"Dalhousie University, Halifax, N.S.". Royal Architectural Institute of Canada. Journal. January-February, 1926.

"Munroe Day - March 9th, 1928". Dalhousie Univ., Bull., #2, July 1928.

PAPERS PUBLISHED BY DR. H. L. BRONSON

"Clark and Weston Standard Cells". H.L. Bronson and A.K. Shaw. The Electrician, Feb. 10, 1911.

"The Distribution of the Active Deposit of Radium in an Electric Field". H.L. Bronson and E.M. Wellisch. Phil. Mag. 23, 714-729, 1912.

"Electrical Resistance and Temperature Coefficient of Ice", by J.H.L. Johnstone, N.S.I.S. XIII, 126-144, 1912.

"A Physical Measurement of X-Rays". N.S.I.S. XIV, 17-29, 1915.

"On the Initial Charged Condition of the Active Deposit of Radium, Thorium and Actinium", by C.H. Henderson with H.L. Bronson, Royal Soc. of Canada X, Sect. III, 151-167, 1916.

"Some Notes on the Halifax Explosion". R.S.C., XII, Sect. VII, 31-35, 1918.

"The Ratio of the Electric Units of Charge". George C. Laurence, N.S.I.S. XVI, 183-187, 1926.

"On the Specific Heat of Tungsten, Molyhdenum and Copper". H. L. Bronson, H.M. Chisholm and S.M. Dockerty. C.J.R. 8, 282-303, 1933.

"On the Specific Heat of Copper from -78° to $0^{\circ}C$". S.M. Dockerty. C.J.R. 9, 84-93, 1933.

"The Heat Capacities of Ag, Ni, Zu, Cu and Pb from -80° to $120^{\circ}C$". H.L. Bronson and A.J.C. Wilson. C.J.R. 181-193, 1936.

"The Heat Capacity of Cu". H.L. Bronson, E.W. Hewson and A.J.C. Wilson. C.J.R., 194-199, 1936.

"The Heat Capacity of Bismuth from -80° to $120^{\circ}C$". H.L. Bronson and L.E. MacHattie. C.J.R., 177-182, 1938.

PAPERS PUBLISHED BY DR. J. H. L. JOHNSTONE

"The Electrical Resistance of Ice".
Trans. N.S. Inst. of Science, 1912.

"On the Electrical Resistance of Acetic Acid in the Solid and Liquid Phases". Trans. N.S. Inst. of Science, Vol. XVII, 222, 1914.

"The Relative Activity of Radium and Uranium with which it is in Equilibrium". J.H.L. Johnstone and B.B. Boltwood. American Journal of Science, Vol. L, 1-19, 1920.

"On the Variation of the 'Emanating Power' of Certain Uranium Minerals with Temperature and a New Secondary Radium Emanation Standard". Trans. Roy. Soc. of Can. Sect. III, 101-109, 1921.

"The Variation of Dielectric Constant with Frequency".
J.H.L. Johnstone and J.W. Williams.
Phys. Rev. Vol 34, 1483-1490, 1929.

"The Acadian Newfoundland Earthquake".
Trans. N.S. Inst. of Science, Vo. XVII, 223-237, 1926-1930.

"Research in the Physical Sciences in the Universities of the Maritime Provinces". (Symposium. Opening of Maritime Regional Laboratory, Halifax, June 16, 1952, and published by the National Research Council).

Numerous "Classified" Papers on Magnetism and Acoustics written during the 1939-45 World War.

PAPERS PUBLISHED BY DR. G. H. HENDERSON

"The Distribution of the Active Deposit of Thorium in an Electric Field". Trans. N.S. Inst. Sci. 14, 1, 1914.

"The Distribution of the Active Deposit of Radium in an Electric Field". Trans. N.S. Inst. Sci. 14, 123, 1916.

"On the Initial Charged Condition of the Active Deposits of Radium, Thorium and Actinium". Trans. Roy. Soc. Canada, 10, Sect. 3, 1951, 1916.

"A New Method of Determining the Temperature Variation of the Thermal Conductivity of Gases". Phys. Rev. 15, 46, 1920.

"Radiation Error in Measurement of Gas Temperatures". Phys. Rev. 15, 58, 1920.

"The Range and Ionization of the α - Particles from RaC and ThC". Phil. Mag. 42, 538, 1921.

"An Attempt to Influence the Random Direction of α - Particle Emission". Proc. Camb. Phil. Soc. 21, 56, 1922.

"Alpha-particles as Detonators". Nature 109, 749, 1922.

"The Straggling of α - particles by Matter". Phil. Mag. 44, 42, 1922.

"The Decrease of Energy of α-particles on Passing Through Matter". Phil. Mag. 44, 680, 1922.

"Changes in the Charge of an α-particle Passing Through Matter". Proc. Roy. Soc. A, 102, 496, 1923.

"The Capture and Loss of Electrons by α-particles". Proc. Roy. Soc. A, 109, 157, 1925.

"An Installation for the Preparation of Radium Emanation for Therapeutic Use". Trans. N.S. Inst. Sci. 17, 14, 1926.

"An Attempt to Demonstrate the Existence of the Short Range α-particles from Radium". G. H. Henderson and J. L. Nickerson. Trans. N.S. Inst. Sci. 17, 256, 1929-1930.

"The Range of the α -particles from Thorium". G. H. Henderson and J. L. Nickerson. Phys. Rev. 36, 1344, 1930.

"Simple Apparatus for Purifying Radon".
Amer. F. Roentgenol. 26, 630, 1931.

"With the Cambridge Eclipse Expedition".
Dalhousie Rev. 12, 297, 1932.

"A May-fly from the Halifax Region".
Proc. N.S. Inst. Sci. 19, 154, 1934.

"A Quantitative Study of Pleochroic Haloes, I". G. H. Henderson and S. Bateson. Proc. Roy. Soc. A, 145, 563, 1934.

"A Quantitative Study of Pleochroic Haloes, II", G. H. Henderson and L. G. Turnbull, Proc. Roy. Soc. A, 145, 582, 1934.

"A New Method of Determining the Age of Certain Minerals".
Proc. Roy. Soc. A, 145, 591, 1934.

"May-fly Fishing".
Dalhousie Rev. 15, 60, 1935.

"A Quantitative Study of Pleochroic Haloes, III, Thorium".
G. H. Henderson, C. M. Mushkat and D. P. Crawford.
Proc. Roy. Soc. A, 158, 199, 1937.

"Some New Types of Pleochroic Haloes".
Nature, 140, 191, 1937.

"Range of Thorium α-particles". G. H. Henderson and G. C. Laurence. Phys. Rev. 52, 46, 1937.

"A Quantitative Study of Pleochroic Haloes, IV, New Types of Haloes". G. H. Henderson and F. W. Sparks. Proc. Roy. Soc. A, 173, 238, 1939.

"A Quantitative Study of Pleochroic Haloes, V, the Genesis of Haloes". Proc. Roy. Soc. A, 173, 250, 1939.

"Graduate Schools for Canadian Universities".
Dalhousie Rev. 28, 1, 1948.

PAPERS PUBLISHED BY DR. W. J. ARCHIBALD

"The Process of Diffusion in a Centrifugal Field of Force". Part II. Phys. Rev. Vol. 54. 371-374, 1938.

"The Process of Diffusion in a Centrifugal Field of Force". Part I. Phys. Rev. Vol. 53. 746-759, 1938.

"The Complete Solution of the Differential Equation for the Confluent Hypergeometric Function", Phil. Mag. Vol. XXVI, 415-419, 1938.

"The Specific Heat of a Monatomic Liquid". Physical Review, Vol. 56, 926-932, 1939.

"The Integration of the Differential Equation of the Ultra-centrifuge". Annals of the New York Academy of Science. Vol. XLIII, Art. 5, 1942.

"An Approximate Solution of the Differential Equation of the Ultracentrifuge", Journal of Applied Physics, Vol. 18, No. 4, 362-367, 1947.

"A Demonstration of Some New Methods of Determining Molecular Weights from the Data of the Ultracentrifuge".

"Precision Determination of Nuclear Gyromagnetic Ratios". W.J. Archibald, E.W. Guptill and E.S. Warren. Can. Journal of Research A, Vol. 28, 359-366, 1950.

"The Spinning Nucleus in a Magnetic Field: A Source of Classroom Problems". American Journal of Physics, Vol. 20, No. 6, 368-373, 1952.

"Field Equations From Particle Equations". Canadian Journal of Physics, Vol. 33, 565-572, 1955.

PAPERS PUBLISHED BY DR. A. D. MacDONALD

"High Frequency Gas Discharge Breakdown in Helium". A.D. MacDonald and S.C. Brown. Phys. Rev. 75, 411, 1949.

"Microwave Gas Discharge Breakdown in Helium". A.D. MacDonald and S.C. Brown. Phys. Rev. 75, 1324, 1949.

"High Frequency Gas Discharge Breakdown in Hydrogen". A.D. MacDonald and S.C. Brown, Phys. Rev. 76, 1634, 1949.

"Limits for the Diffusion Theory of High Frequency Gas Discharge Breakdown". S.C. Brown and A.D. MacDonald. Phys. Rev. 76, 1629, 1949.

"Properties of the Confluent Hypergeometric Function". Jour. of Math. and Phys. 28, 183, 1949.

"Theory of Speech Masking by Reverberation". R.H. Bolt and A.D. MacDonald. Jour. of the Acoustical Society of America 21, 577, 1949.

"Electron Diffusion in a Spherical Cavity". A.D. MacDonald and S.C. Brown. Can. Journ. of Physics 28, 168, 1950.

"Tables of the Function $e^{-\alpha z} M(\alpha; \beta; z)$."
Can. Jour. of Physics 28, 175, 1950.

"High Frequency Gas Discharge Breakdown in Neon". A.D. MacDonald and D.D. Betts. Can. Jour. of Physics 30, 565, 1952.

"High Frequency Breakdown in Neon". Phys. Rev. 88, 420, 1952.

"The Acoustical Field Near a Circular Transducer". E.W. Guptill and A.D. MacDonald. Can. J. Phys. 30, 119, 1952.

"The Velocity of Sound in Glycerol". F.A.A. Fergusson, E.W. Guptill and A.D. MacDonald, J.A.S.A. 26, 67, 1954.

"The Effect of Mean Free Path Variation on Breakdown". I.A. MacLennan and A.D. MacDonald. Phys. Rev. 98, 55, 1955 (A).

"High Frequency Ionization Coefficient in Neon-Argon Mixtures". A.D. MacDonald and J.H. Mathews. Phys. Rev. 98, 1070, 1955.

"High Frequency Breakdown in Argon". A.D. MacDonald and J.H. Matthews. Can. J. Phys. 34, 395, 1956.

PAPERS PUBLISHED BY DR. E. W. GUPTILL

"Measurement of Nuclear Gyromatic Ratios".
E. W. Guptill, W. J. Archibald and E. S. Warren.
Can. Journal of Physics 28, 359, 1950.

"The Sound Field of a Piston Source".
Can. Journal of Physics 31, 393, 1953.

"The Acoustical Field Near a Circular Transducer".
E. W. Guptill and A. D. MacDonald.
Can. Journal of Physics 30, 119, 1952.

"An Exact Solution of Acoustical Field Near a Circular Transducer". Journal of the Acoustical Society of America 24, 784, 1952.

"The Velocity of Sound in Glycerol".
Fergusson, E. W. Guptill and A. D. MacDonald.
Journal of the Acoustical Soc. of America 26, 67, 1954.

"The Velocity and Attenuation of Sound in Solid Argon".
E. W. Guptill, C. K. Hoyt and D. K. Robinson.
Can. Journal of Physics 33, 397, 1955.

"The Velocity of Sound in a 2.7% He^3-He^4 Mixture".
C. C. Lim, A. C. Hollis Hallett, and E. W. Guptill.
Can. Journal of Physics 35, 1343, 1957.

PAPERS PUBLISHED BY DR. A. T. STEWART

"The Angular Correlation of Photons from Positron Annihilation in Light Metals". Physical Review 98, No. 2, 486-491, 1955.

"The Scattering of Slow Neutrons by Ortho- and Para-Hydrogen". A.T. Stewart and G.L. Squires. Physical Review 90, 1125, 1953.

"Conversion of Ortho- to ParaHydrogen in the Liquid Phase". G.L. Squires and A.T. Stewart. J. Chem. Phys. 22, 754, 1954.

"Analysis of Ortho- and Para-Hydrogen Mixtures by the Thermal Conductivity Method". A.T. Stewart and G.L. Squires. J. Sci. Inst. 32, 26, 1955.

"The Scattering of Slow Neutrons by Ortho-Para-Hydrogen". G.L. Squires and A.T. Stewart. Proc. Roy, Soc. A, 230, 19, 1955.

"Three-Quantum Annihilation of Positrons in Solids". R. L. Graham and A.T. Stewart, Can. J. Phys. 32, 678, 1954.

"Angular Correlation of Photons from Positron Annihilation in Light Metals". R.E. Green and A.T. Stewart, Phys. Rev. 98, 486, 1955.

"Angular Correlation of Photons from Positron Annihilation in Solids". A.T. Stewart. Phys. Rev. 99, 594, 1955.

"Scattering of Slow Neutrons by Photons in an Aluminum Single Crystal". B.N. Brockhouse, and A.T. Stewart. Phys. Rev. 100, 756, 1955.

"Momentum Distribution of Metallic Electrons by Positron Annihilation". A.T. Stewart, Can. J. Phys. 35, 168, 1957.

"Normal Modes of Aluminum by Neutron Spectroscopy". B.N. Brockhouse and A.T. Stewart. Rev. Mod. Phys. (Jan) 1958.

"Vibration Spectra of Vanadium and a Nln-Co alloy by Neutron Spectroscopy". A.T. Stewart and B.N. Brockhouse, Rev. Mod. Phys. (Jan) 1958.

PAPERS PUBLISHED BY DR. C. K. HOYT

"The Velocity and Attenuation of Sound in Solid Argon".
E.W. Guptill, C.K. Hoyt, and D.K. Robinson.
Can. Journal of Physics 33, 397, 1955.