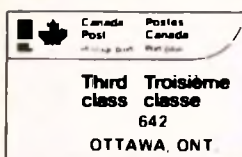


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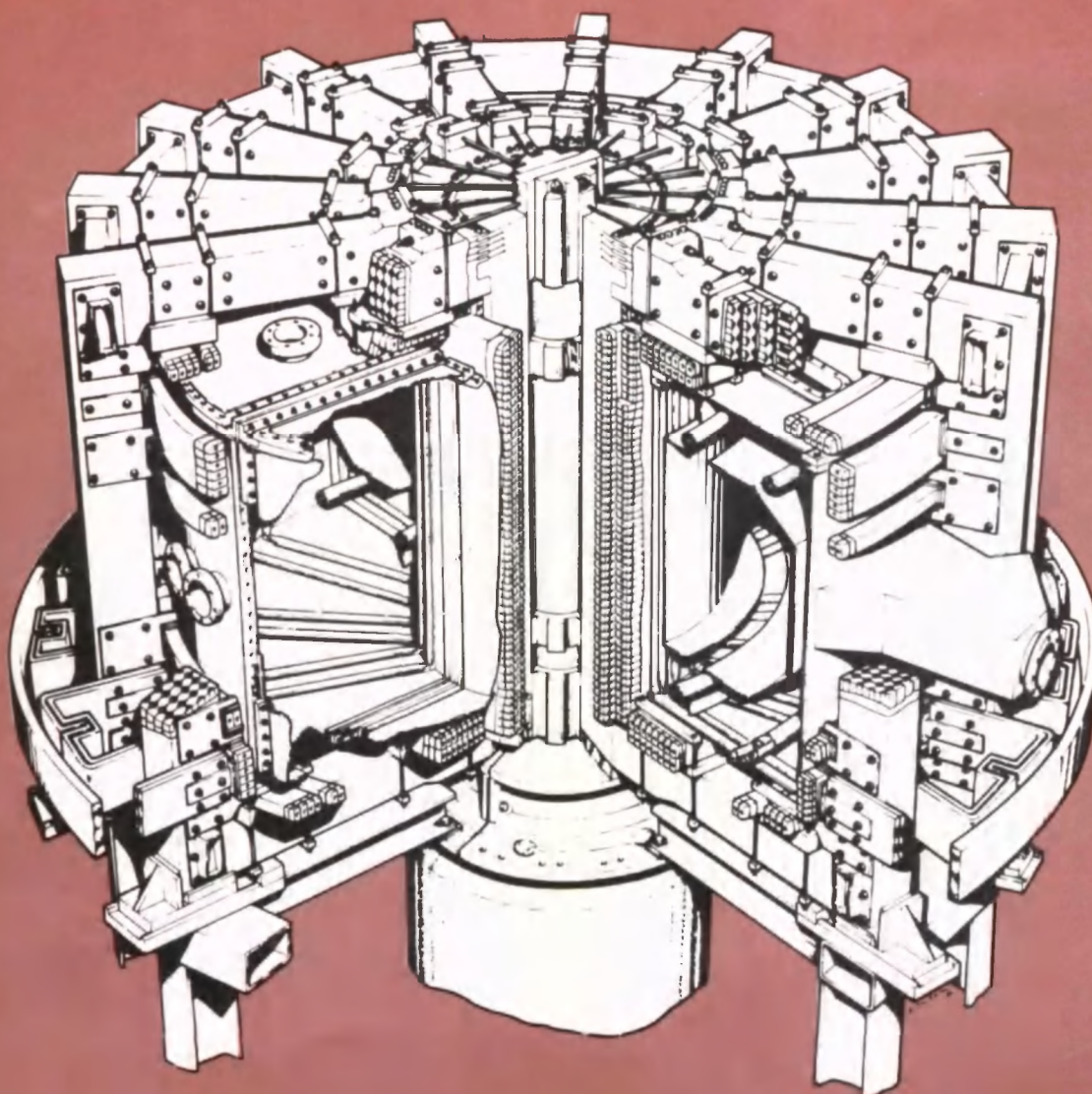


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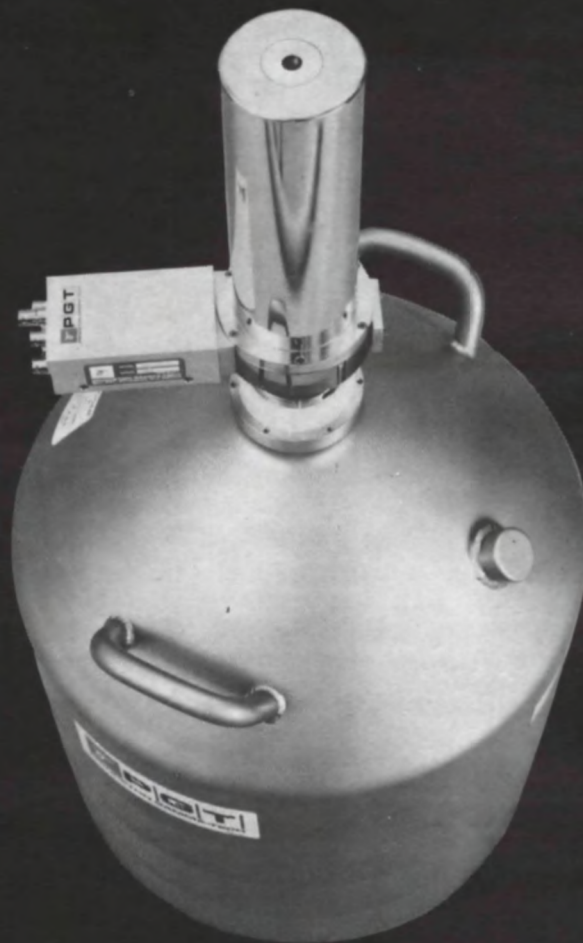
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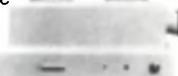
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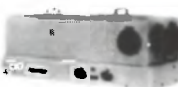
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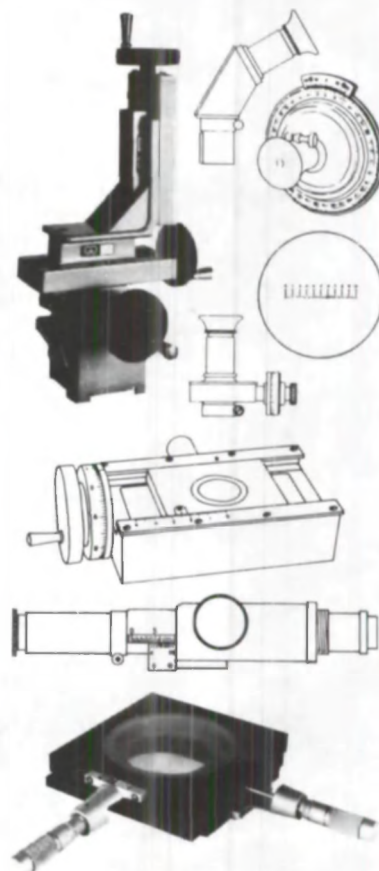


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EDITORIAL

SUMMARY REPORT OF THE SPECIAL COMMITTEE ON X

This was the title used by Warren Weaver in his proposal to simplify the job of government agencies who have to answer the question: should we undertake an intensified programme of activity "X"? He suggested that instead of appointing a committee of experts on subject "X", and have them write a report, with a Summary at the front and a long Technical Section at the back, that a Universal Summary Report be drafted, and the Special Committee be eliminated. Here is his proposed draft:

1. This is a scientific field of critical importance, with obvious and widely ramified interconnection with national defense and with the health of our national economy. The intellectual and esthetic importance of deepening our knowledge in this area cannot be overemphasized.
2. This field has been meagerly supported in the past, and there is every reason to expect that modest but suitable financial support (say, roughly 20 times the present level) could lead promptly to results of the highest significance.
3. There is ample evidence that recent scientific leads and exciting new experimental techniques are now available which combine to make the present moment a particularly fortunate and promising one for undertaking an energetic attack.
4. The long and careful study which your committee has carried out has resulted in assigning a very high priority to X. A substantial development must proceed without delay if we are to capitalize on the enthusiasm of the experts who are devoted to this field and who have developed a momentum which is a great present asset, but which might decay rapidly if encouragement is not promptly supplied.
5. Your Committee deeply deplores--indeed condemns--international rivalries in science. But we nevertheless feel compelled to point out that the Russians appear to be, in this field X, well ahead of us.
6. Your Committee thus recommends the immediate creation of a National Institute on X (the forms will provide space here for other terminology, but it is expected that the phrase given will serve in most instances), together with a broad program of research grants, fellowships, travel grants, and so on (here again, there may be exceptional instances which will require minor changes in wording), to be carried out... (the form will offer an assortment of phrases here, from which the users may choose; for example, "in all suitable institutions," "throughout the waters of the oceans of this planet," "within the deep core of the earth," "in the arctic and antarctic areas," "throughout the troposphere," "in space," etc.). Your Committee estimates that roughly one hundred million dollars will

be needed for initial capital facilities, including \$850,000 for architects' fees, plus annual operating sums of ten to thirty million dollars (these estimates are necessarily preliminary--that is, too small).

I was reminded of this article, written more than 20 years ago, by reading three of the reports on Future Research Opportunities in Physics, commissioned last year by the Natural Sciences and Engineering Research Council.

Letters/Lettres

La prise de position du président de l'ACP, Monsieur Marmet, sur "les actions politiques et l'ACP" (La Physique au Canada, 37, 99, 1981), m'a tout simplement sidéré. Je ne m'attarderai pas à la thèse, fort douteuse, selon laquelle une association ne peut modifier ses objectifs sans trahir la liberté de ses membres, même si cette modification est souhaitée et votée par la majorité. Car il ne s'agit pas de cela. Monsieur Marmet reconnaît lui-même qu'un des buts de l'ACP est de "promouvoir pour le plus grand bien de l'humanité l'application des découvertes faites dans le domaine de la physique". Comment peut-il conclure, en deux lignes et sans justification, "qu'entreprendre des actions politiques liées au désarmement (...), n'a rien à voir avec cela"? Il est clair que la conception d'armes de destruction massive, ainsi que de plusieurs types d'armes conventionnelles, repose en grande partie sur des découvertes de la physique. Si la production de telles armes, à un rythme effréné, ne contribue pas au plus grand bien de l'humanité (ce qui me paraît tout à fait évident), l'ACP doit, selon sa constitution, promouvoir le désarmement. Or, comment cette promotion sera-t-elle efficace si elle n'est pas menée là où les décisions sont prises, c'est-à-dire dans l'arène politique? L'ACP n'a donc pas le choix. Pour véritablement remplir ses objectifs, tels que présentement définis, elle doit se prononcer résolument en faveur du désarmement, et utiliser toute son influence pour orienter à cet effet les politiques nationales.

Il est clair que la promotion du désarmement va se heurter à de puissants intérêts, en particulier dans l'industrie militaire qui emploie de nombreux physiciens. Je suis toutefois persuadé qu'avec leur sagesse et leur rejet des solutions rapides, pour reprendre les termes de Monsieur Marmet, les physiciens pourront contribuer de manière originale à la réorientation de l'industrie militaire vers une production plus conforme aux buts de leur association.

Louis Marchildon
Attaché de recherche CRSNG
Département de physique
Université du Québec à Trois-Rivières

Developments In Fusion Energy In Canada

by *M.P. Bachynski,*
MPB Technologies Inc.

1. Introduction

Controlled fusion (the fusing of the isotopes of hydrogen so as to convert mass into energy) has in recent years become the most vigorously pursued new energy concept.

The reasons for the high degree of activity in fusion as an energy source can be summarized as:

- the process is more environmentally acceptable
- It is inherently safe (no possibilities of "melt down", no runaway reactions, no weapon grade material in the fuel)
- the fuel is universally abundant (deuterium from sea water, tritium bred from lithium)
- possible future advanced fuel cycles where the energy is totally in the form of charged particles would have no associated radioactivity and the possibility of direct energy conversion at efficiencies up to 90%.

Above all, fusion offers the possibility of a major solution to electrical energy generation (as compared to a peripheral or special situation solution offered by many other energy technologies).

The current international budget devoted to fusion is of the order of \$2 billion annually. Major successes have been achieved by these international programs; demonstration of energy break-even is expected in 1982/83 in facilities currently being completed; various engineering demonstration power plants are being planned for around 1990; commercial reactors are expected early in the next century. It is anticipated that the annual budget for fusion will increase to at least of the order of \$4 billion (constant 1980 dollars) by the year 2000.

2. Towards a National Fusion Program in Canada

Discussions of a fusion program in Canada have extended for at least the last decade. A major study project for a Canadian programme on controlled thermonuclear fusion (Project Fusion Canada) was completed in November, 1974. The study recommended that Canada initiate a co-ordinated r&d program in the field of controlled fusion with the immediate goal of the program to be the development of a "scientific know-how, engineering and technological awareness capability".

The federal government was slow to react to the Project FC study. About the only direct tangible result from the study was the appointment of the National Research Council of Canada as the lead federal agency responsible for fusion r&d. One of the first steps taken by NRC was

the formation in mid-1977 of an Advisory Committee on Fusion Related Research to advise NRC on matters relating to the planning, context and implementation of a proposed Canadian program of r&d related to nuclear fusion.

In July 1978, NRC announced the establishment of a National Fusion Program with a modest initial budget. The objective of the national program was to establish and maintain in Canada the necessary expertise as a foundation from which the capability of providing fusion reactors can be developed, if and when engineering and economic feasibility has been demonstrated. The roles of the various sectors of the scientific community were identified. The universities were to train manpower, perform the more basic, relevant r&d and collaborate with facilities within and outside Canada. The Federal government was to provide overall management and funding responsibility and to arrange for the establishment and operation of national facilities. The Provincial governments were to collaborate with the National Fusion Program and coordinate provincial interests in fusion. Industry was to build up Canadian industrial capability for eventual implementation (i.e. preparedness) through r&d, design, construction and operation of fusion related equipment and facilities in keeping with the federal contracting out policy.

Although well intended, NRC could not have foreseen the length of time the budget for the National Fusion Program would remain "modest". Due to a series of delays resulting from changes of government and sheer inaction at the federal level the National Fusion Budget remained for the next three years at an annual level of the order of \$ 0.26 million. The best that could be accomplished was the support of several studies and the temporary posting of a couple of engineers at foreign fusion laboratories. Meanwhile fusion related activities in Canada limped along in a variety of diverse directions, with no facilities of significance and with the ranks continuing to be depleted by the loss of key personnel to the expanding U.S. program. The only positive encouragement during this period was provided by the Natural Science and Engineering Research Council who through their strategic grants competition kept the various university fusion related activities alive by awards of grants totaling of the order of \$750,000 annually.

This period has been one of immense frustration to the Canadian fusion community in general and to the members of the NRC Advisory Committee in particular. The Advisory Committee, made up of senior representatives from the various fusion

related activities in government, universities and industry, decided as a final concerted effort to make direct representation to the Federal ministry responsible for fusion r&d. The result was a brief submitted in March, 1980 directly to the Minister of State for Science and Technology. In the brief the Committee stressed that Canada is the only important industrialized nation which does not have a serious fusion program. With the rapid advances being made in the world towards the goal of fusion energy it is important that Canada develop a technological base from which well informed decisions regarding the role of fusion for Canadian needs can be made. Furthermore, it is essential that Canadian industry be put in a position to supply at least some of this country's requirement for fusion hardware in the future and if possible to compete for the supply of some specialized sub-systems and auxiliary equipment on a world wide basis. This is a long term process which cannot be completed overnight. Although immediate opportunities for international collaboration exist today, once energy "breakeven" has been demonstrated (1983), a nation which does not have a credible fusion program will likely be excluded.

The immediate goal for Canada must be to establish a national program of technological and scientific capability and industrial preparedness which would permit Canada to gain access to and be in a position to use the vastly increasing international pool of knowledge and technology on fusion energy.

Achievement of the above goal will require: the federal government to take the lead in funding and initiating the program, a coordinated effort by federal and provincial governments, the utilities and Canadian

industry, concentration on a few selected areas in order to achieve and maintain international credibility by contributing to the world pool of knowledge, intensive international collaboration and a strategy to ensure adequate and properly trained manpower.

Recommendations for a minimal National Fusion Program for Canada to achieve the above goals included:

1. Development of a National Capability consisting of concentrated centres in
 - a) inertial confinement - a national laser fusion facility with emphasis on CO₂ lasers established around the NRC laser capability,
 - b) magnetic confinement - a Tokamak technology fusion facility at IREQ (Hydro-Quebec), Varennes, operated as a national facility, and
 - c) selected technologies - specialization in one or two selected engineering technologies associated with fusion power systems.
2. Implementation of an intensive program of international collaboration through:
 - planned seconding of scientific and engineering staff to major international projects
 - formal bilateral agreement between major Canadian centres and foreign centres
 - expression of interest and plan for involvement in the next major international or U.S. fusion facility.
3. A minimal budget as shown in Table 1.

TABLE 1 - RECOMMENDED MINIMAL BUDGET FOR CANADIAN NATIONAL FUSION PROGRAM

(All units in 1979 millions of Canadian Dollars)

FISCAL YEAR	79/80	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88
. Federal Funds for National Fusion Program	0.3	3.0	6.0	9.0	12.0	15.0	12.0	12.0	12.0
. NRC In-house Laser Fusion Group	0.9	1.2	1.5	2.0	2.0	2.0	2.0	2.0	2.0
. Total Federal Funds	1.2	4.2	7.5	11.0	14.0	17.0	14.0	14.0	14.0
. Other Sources of Funds for National Fusion Program*	0.7	1.8	6.5	12.0	14.0	8.0	3.0	3.0	3.0
. TOTALS	1.9	6.0	14.0	23.0	28.0	25.0	17.0	17.0	17.0

*Includes: Provincial Government/Utilities/Foreign, etc.

3. The Varennes Tokamak National Facility

One of the studies supported under the meagre funds of the Canadian National fusion budget was the conceptual design of a quasi-steady state Tokamak. The interest in a high duty cycle system stems from the fact that Tokamak reactors will require operations at long pulse durations. The consequence of long pulsed operation gives rise to various thermal and stress effects, impurity build-up and material problems to be found only in eventual reactors. Thus, a facility to investigate these technology oriented problems can both make an important contribution to world wide fusion technology and develop the expertise essential for the design of possible Canadian sub-systems. A conceptual design for such a unique facility was completed in the early autumn of 1980.

The first real breakthrough in a National Fusion Program for Canada came on January 16, 1981 when the Minister for Science and Technology, John Roberts, announced the federal government's participation in the construction of a controlled thermonuclear fusion facility in Varennes, Quebec. The federal financial contribution to the Tokamak project is expected to be \$18.7 million over five years. The cost will be shared equally by the National Research Council of Canada and Hydro-Quebec. Under the direction of Hydro-Quebec, the Institute de recherche d'Hydro-Quebec (IREQ), two local universities (INRS - Energie and the University of Montreal) and two high technology companies (MPB Technologies Inc. and Canatom Inc.) constitute a consortium to be responsible for the implementation of the project.

The technological program planned for the Varennes Tokamak national facility includes:

- the investigation of fast plasma current reversal
- the control of impurities using magnetic field divertors
- the control of the plasma under high duty factor conditions
- the investigation of hot liners, thermal effects and wall materials
- the study of electro-technical problems
 - components and magnets under high duty factor operations
- the direct operation of the system from the electrical grid, and
- the development of advanced diagnostics instrumentation, particularly far infra-red laser techniques and laser fluorescence techniques.

A conceptual sketch of the machine is shown on the cover. The machine parameters are:

- MAJOR RADIUS 0.83 m
- MINOR RADIUS 0.25 m
- TOROIDAL FIELD 1.5 T
- PLASMA CURRENT 280 kA
- PULSE LENGTH, TOROIDAL FIELD ≤ 30 s
- PULSE LENGTH, OHMIC HEATING ~ 100 ms
- PULSE TRAIN LENGTH ≤ 30 s
- TIME BETWEEN PULSES 5 min.

The plasma parameters expected to be achieved are:

- ELECTRON DENSITY (Ave.) $1-5 \times 10^{19} \text{ m}^{-3}$
- ELECTRON TEMPERATURE 450 eV
- ION TEMPERATURE (Max.) 500 eV
- ENERGY CONFINEMENT TIME > 5 ms

The facilities of the Varennes Tokamak will be available to scientists and engineers from across Canada for advanced research and technology development.

The Varennes Tokamak is at present the only Canadian international-scale experimental project in fusion research. It is expected to give Canada both access to the results of international research - the cost of which is beyond this country's means, and to train a group of experts specialized in magnetic fusion. The latter could lead to a new Canadian industry in thermonuclear components and sub-systems.

4. Other Activities

A second study, performed under contract to NRC, evaluated concepts for a Fusion Engineering and Materials Development Program for Canada. Analysis of a number of options led to the identification of "fusion fuels", in particular tritium technology as the main element of the recommended programs. Four inter-related areas, - fusion fuel systems, materials development, equipment development and safety and environment with tritium as the common theme were suggested to make up the programme. Fusion fuels systems includes fuel purification, fuel production and isotope separation; materials development includes research related to the interaction of hydrogen isotopes with materials, such as hydrogen related metallurgy, ceramics and organics, and irradiation effects; equipment development includes instrumentation, hydrogen compatible components, testing and certification, and remote maintenance and handling, and safety and environment to encompass monitoring, safety systems, and biology and health physics.

The choice of tritium was based on a number of considerations including the current Canadian expertise in Canada (principally at Ontario Hydro and AECL) developed in conjunction with fission reactors, the international need for tritium in the period 1985-2000 for experimental fusion reactors, the availability of tritium from the Ontario CANDU power plants and the current difficulties in obtaining and transporting tritium which is classified by many nations as a strategic material.

The goal of the proposed program is to establish r&d activities leading to an industrial base which would enable Canada to supply tritium related sub-systems for international prototype and future fusion power reactors to be built in the next two decades.

Both the government of Ontario and a number of Ontario institutions have expressed a strong interest in the fusion fuels programme.

A detailed plan for the third component in the development of a national capability, namely inertial confinement, has not as yet been prepared. NRC is currently reviewing the scientific goals for the Inertial Confinement component of the National Fusion Program, as the first step towards proceeding with the Inertial Confinement Feasibility Study.

Meanwhile laser and laser-plasma related experiments and development are continuing in the laboratories of the National Research Council, at a number of universities (principally, B.C., Alberta, McMaster, INRS-Energie and Laval) and in a number of Canadian industrial firms who are successfully competing in international markets with their lasers and associated products.

On the international scene, Canada is a participant in the International Energy Agency (IEA) Agreement on the TEXTOR project - a Tokamak designed for wall interaction and other technologies studies nearing completion at

Jülich, Germany. Canada has two engineers currently assigned to this project. Canada also recently signed an IEA implementing agreement for a programme of research and development on radiation damage in fusion materials. Discussions on potential co-operative arrangements with the U.S. programme have taken place and are expected to resume once the reorganization by the new U.S. Administration is complete.

5. Conclusion

A major commitment has been made by the Federal Government and Hydro-Quebec for the construction of a magnetic fusion national facility at Varennes, Quebec based on a quasi-continuous operating Tokamak. A decision at the national level has yet to be taken on other projects being advocated as essential components of a national fusion programme - namely fusion fuels technology and inertial confinement. As well, a meaningful programme of international co-operation is yet to be implemented. Meanwhile, fusion research and development remains high on the list of the priorities of the National Research Council of Canada and decisions on those other areas can be expected in due course.

Elegy For An Electronic Suicide

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Artist: Max Stiebel

When I came to the Foster Radiation Laboratory at McGill in 1952, kicksorters with multiple channels were far beyond our means. Yes, we called them kicksorters; nowadays they are solemnly called multichannel pulse analyzers. They sort out the electrical impulses ("kicks") from nuclear radiation detectors according to size. A 10-channel kicksorter would sort all the pulses from 0 to 1 volt and record them in channel 1; those from 1 to 2 volts would go into channel 2, and so on.

The resulting 10-point pulse spectrum would be pretty crude. For modern high-resolution nuclear detectors, we now use kicksorters with thousands of channels, based on the latest solid-state electronics. Such a highly detailed pulse spectrum gives accurate information about the energies and intensities of nuclear radiations. In the old days, though, the detectors themselves were crude, and we were lucky to have kicksorters of even a few channels.

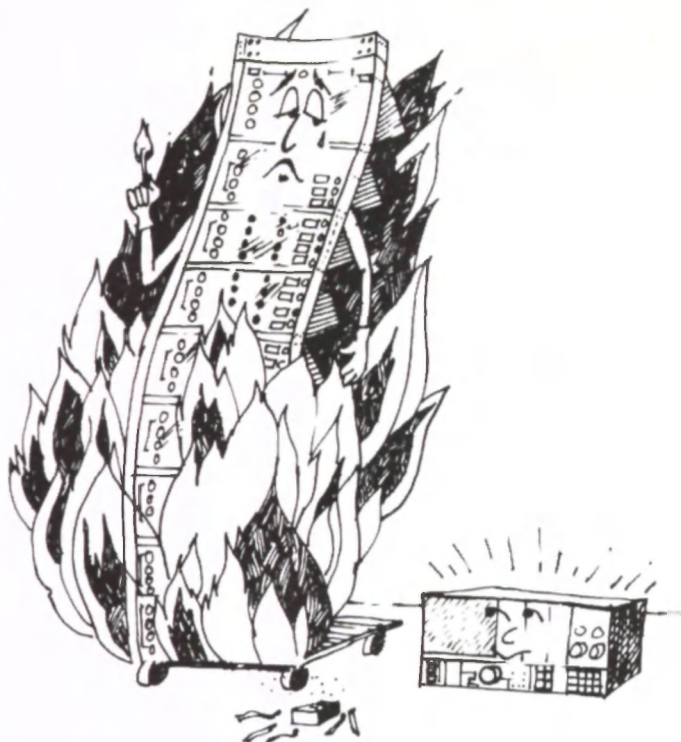
In 1952, even those few kicksorters that did have multiple channels were found, not in impecunious university laboratories, but in well-supported government institutions. The Chalk River Laboratories for example, had developed a 30-channel model that occupied 5 tall relay racks (those metal frames on which the currently chic "high-tech" decorators would

have us mount our stereo components). It was impossibly expensive and bulky for our lab. It also contained no means for observing the pulse spectrum while it was being measured, or for automatically recording the result. We just had to do better.

By 1954 we had developed and built our own 28-channel instrument on a single 6-foot relay rack. It contained 28 identical circuits of 7 tubes each, one for each channel. Provision was made for putting the accumulating spectrum "live" on an oscilloscope screen (probably the first analyzer to do so), and for recording the final spectrum on a paper chart. The device was self-contained and could be wheeled on its casters to any place in the lab. It cost perhaps \$1,500 in out-of-pocket expenses.

This was all very satisfactory, and we had no idea then that tragedy lay in the distant future.

Our 28-channel kicksorter saw intensive service over the next few years. By 1956 it had provided the data for a major survey of certain kinds of nuclear reactions caused by bombarding targets with high-speed particles from the cyclotron. In the late 50s it was recording results on the time needed by excited nuclei to emit their radiations, and on the processes that occur in samples of ordinary matter



bombarded with particles of anti-matter (positive electrons, in this case). It gave the data for many other scientific papers and theses, but it was never the subject of a proper publication itself; like many faithful servants, it was always taken for granted and seldom praised.

While all this was going on, of course, new developments were taking place in the design of kicksorters. A physicist in England had already proposed a more accurate way of sorting out pulses. After a slow start, transistors were replacing tubes and shrinking the size of equipment. New memory techniques were making it easy to store the data for large numbers of channels. Finally around 1960, a fully-developed transistorized kicksorter of 256 channels came on the market in the United States. We had to have it.

Somehow we got the money (I recall it as \$17 thousand, a huge sum), and the order was placed. The delivery of the unit was a moment

of high excitement. We could not believe how small it was; 256 channels, and it occupied only about a third of a relay rack! We mounted it and tried it out; it was marvellous. At the turn of a switch, we could record 1 spectrum of 256 channels, or 2 of 128 channels, or 4 of 64 channels.

We wheeled it in beside the old 28-channel machine, still plugged in and working on a 24-hour run. The new instrument was slick, painted and chromed, professionally labelled, and fully enclosed. The old servant was unpainted, with unmatched knobs, paper labels, ragged wiring, and an indecently exposed rear. Nobody even gave it a glance.

The next morning when I arrived at work, the shop foreman met me. He said he wanted to show me something; it was the 28-channel kicksorter. Early that morning it had caught fire near the bottom of its rack and had been completely consumed. Not so much as a shred of wire insulation or a resistor or a condenser-casing had escaped. This complete destruction was assured by the vertical arrangement of the 28 units, which gave the fire an excellent draft. Strangely, almost weirdly (and very luckily), nothing else was harmed. The glamorous new instrument standing alongside was not even scorched; neither was the ceiling above. The old 28-channel analyzer was loyal to the end.

We were still euphoric in the lab, and did not spend time grieving over the remains. Only a little later did I begin to feel qualms. In retrospect it seems such a clear case of suicide born of quiet jealousy and despair that I reproach myself for being callous. When I think about it now, I realize that I do not possess a single photograph or circuit diagram or detailed description of this instrument, which made a substantial contribution to my scientific life and to that of several others. We were all scientific ingrates, and bad historians to boot.

Well, old faithful kicksorter, this is my small attempt to make amends. I hope that in that great lab in the sky, you are still putting out your simple but neat spectra; I want you to know you were appreciated. Perhaps you'd like to hear that the 256-channel unit has been superseded too, and that nobody is sentimental about it. Thanks for everything.

Is Quantum Gravity Renormalizable?

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A. Introduction

1.1 Overview

During the past decade a great deal of time and effort have gone into solving one of nature's truly perplexing riddles: how to quantize Einstein's gravitational field in a logical and mathematically rigorous manner. It now seems fairly certain that this Gordian knot of modern physics will have to be solved somehow - either separately or in conjunction with the strong, electromagnetic and weak interactions - before a realistic unified theory of all fundamental forces can be constructed.

The purpose of this paper is to familiarize the reader with the principal problems encountered in the quantization of the gravitational field and to discuss some recent approaches dealing with the renormalizability of quantum gravity. The phrase "quantum gravity" is a short form for "quantum theory of gravity", "quantization of Einstein's theory of general relativity", or for "quantization of the gravitational field".

In sections B, C I shall describe the basic properties of the gravitational field and the various reasons for attempting quantization. In the subsequent section, I shall summarize the major steps needed to calculate, in the context of covariant quantization, a typical one-loop Feynman graph. While pure quantum gravity turns out to be finite, the interaction of gravity with other fields is unrenormalizable even at the one-loop level.

Higher-order loops pose formidable technical problems, even in pure gravity. In section E I shall describe two calculation techniques designed to reduce the computational difficulties: one is the axial gauge technique, the other an extended version of the background field method. The question of renormalizability is continued in section F, where I comment briefly on the encouraging results achieved in the framework of extended supergravity.

1.2 Historical Remarks

For centuries man has endeavoured to unravel the mysteries of the gravitational force and to comprehend the intimate connection that seems to exist between gravity and those other two equally puzzling concepts, Space and Time. In fact, scientists have been divided since ancient times into two broad categories: the "absolutists" who believed that space-time was in some sense absolute, and the "relativists" who thought of time and space merely as relative entities. We thus find Plato and Newton among the "absolutists", while Aristotle, Mach and Einstein belong to the "relativists". Even today the controversy

surrounding the existence of absolute space versus relative space (space-time) is not entirely closed.

The first mathematical theory of gravitation was proposed by Newton in 1687 in his famous *Principia* and stood unchallenged until superseded in 1916 by a radical new theory, Einstein's general relativity. Although the gravitational force is by far the oldest and weakest of the fundamental forces, it also turns out to be the most difficult one to handle mathematically. Yet, like the other well known forces of nature, gravity possesses its own typical units of length, time and mass. The latter can be constructed, in turn, from the three fundamental constants c (speed of light), h (Planck's constant) and G (Newton's constant), all of which are essential in the formulation of a relativistic quantum theory of the gravitational field. We have¹⁾:

$$L = (\hbar G/c^3)^{1/2} \approx 1.616 \times 10^{-33} \text{ cm},$$

$$T = (\hbar G/c^5)^{1/2} \approx 5.39 \times 10^{-44} \text{ sec.},$$

and

$$M = (\hbar c/G)^{1/2} \approx 2.177 \times 10^{-5} \text{ gm},$$

corresponding to an energy $E = (\hbar c^5/G)^{1/2} \approx 10^{19}$ GeV. The claim is that quantum fluctuations of space-time become violent at Planck lengths of the order of 10^{-33} cm.

B. Properties of the gravitational field

1. Properties

The gravitational force may be interpreted in two distinct ways. From a geometric standpoint, it may be viewed as a warping of the space-time continuum, while from a particle physicist's point of view, gravity is mediated by the exchange of an elementary particle g , called the graviton. Quantum gravity is essentially a particle physicist's approach to the quantization of the gravitational field, modelled, for example, after the successful theory of quantum electrodynamics (Table 1).

It is postulated that the particle of the gravitational radiation is the massless spin 2^+ graviton which, till now, has eluded experimental detection. The gravitational field is represented by the dynamical variable $g_{\mu\nu}$, a symmetric tensor of rank 2, so that Einstein's gravitational field equations in the presence of matter read

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -8\pi G T_{\mu\nu}(\text{matter}), \quad (1)$$

Table 1 Comparison between Quantum Electrodynamics and Gravitation in the Language of Particle Physics

	QED	GRAVITATION
Strength	10^{-2}	10^{-39}
Range	∞	∞
Particle exchanged	photon γ	graviton g
Mass	0	0
Spin/Parity	1^-	2^+

Feynman graph



where $R_{\mu\nu}$ denotes the Ricci tensor, $R = g^{\mu\nu}R_{\mu\nu}$ is the curvature scalar, $T_{\mu\nu}(\text{matter})$ is an arbitrary distribution of energy and momentum and G is the Newtonian constant. Due to the nonlinearity of (1), the gravitational force is self-interacting. Quantum gravity also possesses what is generally called a local non-Abelian gauge symmetry, which may be attributed to the fact that Einstein's relativity is covariant under general coordinate transformations

$$x_\mu \rightarrow x'_\mu = x_\mu + \xi_\mu(x), \quad \xi_\mu(x) \text{ arbitrary.} \quad (2)$$

This property is known as gravitational gauge invariance and leads, as we shall see, to certain mathematical difficulties.

2. Quantization Schemes

Attempts at quantizing Einstein's theory of general relativity go back several years during which time many ingenious ideas have been advanced to solve this challenging problem. One of the more successful quantization schemes is the technique of covariant quantization, originally proposed by Feynman²⁾ in 1963, which has since been employed with considerable success.

Roughly speaking, the technique of covariant quantization is based on the idea of keeping intact the tensor character of the field $g_{\mu\nu}$. The procedure then ensures Lorentz - invariant manipulations, but necessitates, in turn, the elimination of all unphysical particles of spin 0 and 1 from the final physical states. A discussion on other quantization schemes, such as canonical quantization, twistors and source theory, can be found in the excellent review articles by Isham³⁾.

C. Why quantize gravity?

As indicated earlier, the quantization of the gravitational field is plagued not only by physical and mathematical problems, but by

conceptual difficulties as well. Yet, despite these rather severe obstacles, most researchers in the field believe that there exist enough convincing reasons to continue the search for a quantized theory of gravitation - one that is free from ambiguities and internally consistent. Let us discuss some of the prominent reasons³⁻⁴⁾.

- (1) Since the strong, electromagnetic and weak interactions have already been quantized, scientists would be remiss, indeed, to leave gravity unquantized. Besides, some version of quantized gravity will surely be necessary in order to achieve unification of nature's fundamental forces.
- (2) Einstein's field equations in the presence of quantized matter (represented by $T_{\mu\nu}$) read

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu} R = -8\pi G T_{\mu\nu}(\text{matter}) \quad (3)$$

To establish "true" equality on both sides of this equation, it is almost mandatory to quantize the left hand side of (3) as well. The critical question, is "how"?

- (3) It is known that classical general relativity contains awkward space-time singularities and it is hoped that quantum gravitational effects will aid in suppressing the appearance of these potentially dangerous singularities. Scientists are also exploiting quantum gravitational effects to gain an understanding of such diverse problems as the homogeneity and isotropy of our universe, the 3°K background radiation and the apparent baryon asymmetry in nature³⁾.
- (4) Another reason for quantizing gravity is the purely intellectual challenge of trying to combine general relativity and quantum mechanics into a single theory.

D. Calculation of a Typical Feynman Graph

1. Basic steps

In this section I shall summarize the principal steps in the computation of a typical Feynman graph, emphasizing certain technical aspects symptomatic of a non-Abelian gauge theory. The gravitational field is described by the Einstein-Hilbert Lagrangian density

$$L = 2\kappa^{-2} \sqrt{-g} g^{\mu\nu} R_{\mu\nu}, \quad (4)$$

where $g_{\mu\nu}$ is the covariant metric tensor, $g \equiv \det g_{\mu\nu}$, $R_{\mu\nu}$ is the Ricci tensor given by

$$R_{\mu\nu} = \Gamma_{\mu\rho,\nu}^{\rho} - \Gamma_{\mu\nu,\rho}^{\rho} + \Gamma_{\mu\nu}^{\sigma} \Gamma_{\sigma\rho}^{\rho} - \Gamma_{\mu\nu}^{\rho} \Gamma_{\rho\sigma}^{\sigma} - \Gamma_{\mu\nu,\rho}^{\rho}, \quad (5a)$$

$$\Gamma_{\alpha\beta}^{\gamma} = \left(\frac{1}{2}\right) g^{\gamma\sigma} (g_{\alpha\sigma,\beta} + g_{\beta\sigma,\alpha} - g_{\alpha\beta,\sigma}), g_{\alpha\sigma,\beta} \equiv \partial g_{\alpha\sigma} / \partial x^{\beta} \quad (5b)$$

and

$$\kappa^2 = 32\pi G \approx 4 \times 10^{-44} (m_e)^{-2} \approx 4 \times 10^{-38} (\text{GeV})^{-2}$$

is the gravitational constant in natural units $\hbar = c = 1$. G denotes the Newtonian constant and m_e the mass of the electron, so that $\kappa^{-1} \approx 0.5 \times 10^{19} \text{ GeV}$ is seen to possess the dimension of a mass. The computation of a typical Feynman graph (cf. Fig. 1) involves the following steps⁵.

- (i) Expansion of L in terms of the physical graviton field $\phi_{\mu\nu}$ with $\kappa\phi_{\mu\nu} = g_{\mu\nu} - \eta_{\mu\nu}$ ($\eta_{\mu\nu} = (1, -1, -1, -1)$ being the Minkowski flat space metric):

$$L = \sum_{j=2}^{\infty} \kappa^{j-2} L(j) = L(2) + \kappa L(3) + \kappa^2 L(4) + \dots,$$

where the "free part" $L(2)$ yields the propagator and $L(3)$ describes the gravitational interaction to first order in κ .

- (ii) Inclusion in L of a gauge-breaking term, such as

$$L_{GB} = -(\alpha\kappa^2)^{-1} (\partial_{\mu} \sqrt{-g} g^{\mu\nu})^2, \quad (6)$$

to ensure that the propagators are unique, α being the gauge parameter. (Recall that quantum gravity possesses a local non-Abelian gauge symmetry!)

- (iii) Inclusion of fictitious particles, also known as Feynman-DeWitt-Faddeev-Popov ghosts, whose purpose is to restore both the unitarity of the scattering matrix S and the transversality of the scattering amplitudes.

- (iv) Application of steps (ii), (iii) to construct the appropriate generating functional Z from which the desired Green's functions and vertices may

then be derived. For quantum gravity, Z reads

$$Z[j_{\mu\nu}] = \int d[\bar{g}^{\mu\nu}] \Delta[\bar{g}^{\mu\nu}] \exp\{i \int d^4x [L + \kappa^{-1} \bar{g}^{\mu\nu} j_{\mu\nu} - (\alpha\kappa^2)^{-1} (\partial_{\mu} \bar{g}^{\mu\nu})^2]\}, \quad (7)$$

where L is given by (4), $j_{\mu\nu}$ is an external source function and $\bar{g}^{\mu\nu} = \sqrt{-g} g^{\mu\nu}$. The factor $\Delta[\bar{g}^{\mu\nu}]$ leads to the fictitious particles mentioned in (iii) which are needed to cancel the longitudinal polarizations arising from closed loops.

- (v) Regularization of the divergent Feynman integrals by means of some gauge-invariant prescription such as dimensional regularizations⁶⁻⁷.



Fig. 1 The Massless Graviton Loop

2. The self-energy of the graviton

Computation of the graviton self-energy, Fig. 1, leads to a pole term in the connected Green's function which may be removed by constructing the counter Lagrangian^{1,6}

$$\Delta L = \frac{\text{const} \sqrt{-g}}{(n-4)} (aR^2 + bR_{\mu\nu} R^{\mu\nu}) \quad (8)$$

where n is the dimensionality of space-time and a, b are constants. Since ΔL is not of the same functional form as the Einstein-Hilbert Lagrangian L in (4), it would appear at first sight that the graviton self-energy is unrenormalizable. Fortunately ΔL can be absorbed by rescaling the field variable $g_{\mu\nu}$,

$$g_{\mu\nu} \rightarrow g_{\mu\nu} + (n-4)^{-1} (\alpha R_{\mu\nu} + \beta g_{\mu\nu} R) \quad (9)$$

α, β being unobservable coefficients, so that the graviton self-energy loop turns out to be finite.

3. Coupling pure gravity to other fields

If the gravitational field is coupled to other fields, the situation becomes unpleasant even at the one-loop level, as demonstrated by the following two examples.

- (a) Gravity-scalar field coupling Suppose we allow the gravitational field to interact with a massless Klein-Gordon scalar field ϕ . Then the divergent terms behave like R^2 again, leading to the counter Lagrangian

$$\Delta L = \frac{\sqrt{-g}}{n-4} \frac{203}{80} R^2 \quad (10)$$

Since the original Lagrangian goes like R , this counter Lagrangian cannot be absorbed into the original Lagrangian. Consequently the gravity-scalar field interaction is unrenormalizable already at the one-loop level.

- (b) Gravity - Maxwell field coupling A similar result emerges if we consider the interaction between pure gravity and the Maxwell field, the counter Lagrangian being of the form⁸

$$\Delta L \sim \frac{\sqrt{-g}}{n-4} \frac{137}{60} R_{\mu\nu} R^{\mu\nu}. \quad (11)$$

By comparison, the original Lagrangian,

$$L_{G+Maxwell} = \sqrt{-g} \left(-R - \frac{1}{4} g_{\mu\alpha} g_{\nu\beta} F^{\mu\nu} F^{\alpha\beta} \right), \quad (12)$$

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu,$$

is linear in the curvature scalar R , so that this interaction is also unrenormalizable.

In summary, pure gravity turns out to be one-loop finite, but gravity in interaction with other fields is unrenormalizable even at the one-loop level.

E. What about higher-order loops?

Since pure gravity was shown to be one-loop finite, it seems reasonable to inquire whether the contributions from two-loop and three-loop diagrams can also be made finite. The answer to this question, at least on theoretical grounds, seems to be "no", a rather discouraging result.

But before we relegate gravity permanently to the class of non-renormalizable theories, it might be prudent to await the outcome of further practical computations. Since no one has, as yet, calculated the two-loop diagram (it contains over one million terms!) there is still hope for a consistent treatment of the virulent ultraviolet infinities. Fortunately, the computation of this diagram is now under serious consideration, its chances of success being enhanced by the availability of algebraic computer programs such as Veltman's Schoonschip, and by the development of sophisticated techniques which reduce the horrendous amount of algebra. I shall describe two such techniques, the background field method and the axial gauge technique.

1. Background field method^{1,6,9}

Suppose we have a field theory whose Lagrangian density L depends on the field A . The basic idea is to separate A into two components, $A = A^{cl} + \phi$, where A^{cl} is the classical field and ϕ the new quantum field, and then to insist that A^{cl} obey the classical equations of motion. The next step is to select a gauge which preserves the gauge invariance of A^{cl} , but breaks the gauge invariance of the quantum field ϕ .

The technical advantage of the background field approach is obvious: it reduces the number of Feynman diagrams and with it, the overall amount of algebra. The background field method is particularly powerful in the context of non-Abelian gauge theories and may be applied both at the one-loop and two-loop level.

2. Axial gauge method

This prescription also reduces the number of Feynman diagrams that need evaluating at a certain order of perturbation theory. Although the axial gauge has been applied extensively in calculations involving the Yang-Mills Lagrangian, it is a relative newcomer in quantum gravity. Here the axial gauge is characterized by the condition $n_\mu \phi_{,\mu\nu} = 0$, $n^2 \neq 0$, where n_μ is an arbitrary but constant four-vector, and $\phi_{\mu\nu}$ is the physical graviton field. The principal advantage of the axial gauge stems from the fact that there are no contributions to the amplitude from fictitious particles: the axial gauge is ghost-free.

Despite its apparent advantages, the axial gauge can lead, if not used judiciously, to ambiguous or even incorrect results. The reason is that the corresponding Feynman integrals are more difficult to evaluate: they contain unphysical singularities, related to the noncovariant vector n_μ , which must be circumvented by means of a suitable principle value prescription.

The axial gauge has recently been employed by Capper and the author¹⁰ to evaluate with the aid of the computer program Schoonschip, the self-energy of the graviton in the one-loop approximation. It was found that the self-energy is both non-transverse and non-covariant, even though the Ward identities are satisfied. The calculation also demonstrated that the principal value prescription is sufficiently powerful to cope even with the more potent singularities in the propagators and, secondly, that the axial gauge and its various generalizations constitute a perfectly self-consistent gauge.

Comparison of the axial gauge technique with the background field method suggests, nevertheless, that for a two-loop calculation in quantum gravity it might be easier to work with the background field method rather than with the axial gauge.

Preservation of explicit gauge invariance at the classical level is one of the chief advantages of the background field approach.

Substituting $A = A^{cl} + \phi$ into the appropriate Lagrangian $L(A)$, we find that all terms linear in ϕ cancel, leaving just those proportional to ϕ^2 . Consequently the quantum field ϕ occurs only in closed loops, whereas the classical field appears necessarily in "tree-lines"¹¹. If the theory also contains fictitious particle fields, then these too occur in closed loops.

F. Supergravity

We have seen that the quantization of the gravitational field is plagued by several difficulties, both technical and conceptual in nature. Persistence of these problems has prompted physicists to search for alternate approaches to quantization. One of these is the theory of supergravity^{11,12} which has been developed during the past five years and has scored several remarkable successes.

The notion of supergravity is intimately connected with the concept of supersymmetry¹³, an internal symmetry like isotopic symmetry, that combines both bosons and fermions in one "super-theory". Theorists hope that a realistic supersymmetric theory will eventually unite all fundamental forces of nature and eliminate, at the same time, the ultraviolet infinities in quantum gravity. This supersymmetric theory or, more accurately, this local supersymmetric theory¹¹, is generally referred to as supergravity.

The "force" in supergravity is mediated by the exchange of the familiar spin -2 graviton and by a new fermion of spin 3/2, called the gravitino. Being fermions, these gravitinos must always appear in pairs. Roughly speaking we can think of supergravity as incorporating both general relativity and its quantum corrections. To be more specific, the theory makes new predictions for microscopic distances, while predicting the same results as general relativity over large distances.

The theory of supergravity, which in its simplest version contains only gravitons and gravitinos, has already branched out into several distinct companion theories. One of these, known as extended supergravity¹², may also contain particles of spin 1/2 and spin 1 that may be identified with electrons and photons. Such extended supergravity theories have been particularly successful: researchers were able to show, for example, that the infinities in these theories cancel both at the one-loop and two-loop level. This amazing result is due, no doubt, to the special symmetry of the theory and experts in the field are cautiously optimistic that this miraculous cancellation of the infinities will also persist in higher order.

Unfortunately, extended supergravity suffers from the same defect as its companion theories: it does not, as yet, constitute a physically realistic theory. For example, all of its particles possess zero mass and there is, furthermore, the worrisome presence of a cosmological constant. Only time will tell whether supergravity and its superman are on the right track.

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5. D.M. Capper, G. Leibbrandt and M. Ramon Medrano, Phys. Rev. D **8**, 4320 (1973).
6. G.'t Hooft and M. Veltman, Ann. Inst. Henri Poincaré, **XX**, 69 (1974). For a review on dimensional regularization and additional references, see ref. 7.
7. G. Leibbrandt, Rev. Mod. Phys. **47**, 849 (1975).
8. S. Deser and P. van Nieuwenhuizen, Phys. Rev. Lett. **32**, 245 (1974).
9. L.F. Abbott, Nucl. Phys. B **185**, 189 (1981).
10. D.M. Capper and G. Leibbrandt, Phys. Rev. D (to be published).
11. D.Z. Freedman, P. van Nieuwenhuizen and S. Ferrara, Phys. Rev. D **13**, 3214 (1976); S. Deser and B. Zumino, Phys. Lett. **62 B**, 335 (1976).
12. D.Z. Freedman and P. van Nieuwenhuizen, Scientific American, Vol. 238, February issue, pp. 126-143 (1978).
13. Y.A. Gol'fand and E.P. Likhtman, J.E.T.P. Lett. **13**, 323 (1971); J. Wess and B. Zumino, Nucl. Phys. B **70**, 39 (1974).

CAP AFFAIRS AFFAIRES DE L'ACP

DIVISION OF SURFACE SCIENCE

Plans for the coordinated meetings in 1982 are now finalized.

- A symposium titled Modern Aspects of Surface Science (organiser Dr. G. Scoles, Department of Chemistry, University of Waterloo) will be held at the 1982 CIC Annual Conference in Toronto (31 May - 2 June).
- The Eighth Canadian Seminar on Surfaces (organiser Dr. J.R. MacDonald, Department of Physics, University of Guelph) will be a 2½ day meeting at the University of Guelph (2-4 June).

Further general information from Dr. S. Ingre, Secretary-Treasurer Division of Surface Science, Bell-Northern Research, P.O. Box 3511, Station C, Ottawa, Ontario K1Y 4H7.

DIVISION EXECUTIVES

9. Division of Physics Education
J.R. Stevens, Chairman, University of Guelph
P.W. Whippley, Past-Chairman, U of Western Ont.
W. Brouwer, Vice-Chairman, Univ. of Alberta
D. Austin, Secretary-Treasurer, U of Alberta

NEWS/NOUVELLES

NSERC UNIVERSITY RESEARCH FELLOWSHIPS

The following list gives the names, affiliations, and fields of research of the Fellows in physics and related fields:

Chang, J.-S., McMaster, Engineering Physics
Daams, J.M., McMaster, Physics
Edwards, B.J., British Columbia, Theoretical Physics
Kunstatler, G., Toronto, High Energy Physics
Labrie, J.-P., Montréal, Physique nucléaire
Latta, B.M., Memorial, Physics
Liu, W.-K., Windsor & Waterloo, Molecular Physics
MacDonald, A.H., Dalhousie & Toronto, Physics
McCamis, R.H., Manitoba, Nuclear Physics
Ng, J.N.-H., B.C. & Alberta, Theoretical Physics
Page, J.H., Queen's, Physics
Roshko, R.M., Manitoba, Solid State Physics
Roy, R., Laval, Physique nucléaire
Rudaz, S., McGill & Toronto, Physics
Vandenberg, D.A., Victoria, Astronomy

UNDERGROUND LABORATORY FOR RESEARCH INTO NUCLEAR WASTE DISPOSAL

Atomic Energy of Canada Limited is planning to build a \$13.8 million underground research laboratory in hard rock near Lac du Bonnet, Manitoba. This laboratory is an important new part of the research program to assess the concept of safely and permanently disposing of nuclear fuel waste deep within hard rock formations.

Although other countries have underground research laboratories, this will be the first laboratory to be built below the water table, in an undisturbed granite formation. No nuclear wastes are to be used or disposed of in this laboratory. Instead, electric heaters will be emplaced in the rock to simulate the thermal effects of the waste in a disposal vault, and mildly radioactive tracers, similar to those used to find pipe leaks, will be used to follow water movement through the cracks.

The laboratory will consist of several small rooms, with shaft access, at a 300-500 metre depth. Exploratory drilling and other geophysical work is already underway, which will enable scientists to determine the optimum level for the laboratory, deep enough to be under the surface fractures caused by ancient geological processes, yet close enough to these cracks to study water movement through fracture networks in the rock.

By carefully analyzing the underground environment, scientists will be able to develop computer models that will predict how nuclear wastes would behave over thousands of years if made highly insoluble and buried deep in the rock of the Canadian Shield. This assessment is required before the disposal technology is implemented in Canada.

The Manitoba location was chosen for this phase of the research because it is located in a massive block of granite which is representative of the type of rock AECL has been studying in Ontario, and it is close to the Whiteshell Nuclear Research Establishment, which is coordinating Canada's research on nuclear fuel waste management.

AECL has leased the 975-acre site for 21 years from the Province of Manitoba. The lease contains a special clause forbidding the storage or disposal of nuclear waste at the site.

Atomic Energy of Canada Limited will pay the Rural Municipality of Lac du Bonnet a grant-in-lieu-of-taxes of over \$100,000 per year once the URL is operating. The laboratory is expected to provide some 50 jobs during construction and some 25 new jobs for its 15-year operating phase.

Meanwhile, the waste disposal research continues elsewhere. Rocks representative of the 1400 plutons (large mountains of crystalline rock underground) in the Ontario portion of the Canadian Shield continue to be studied, and work is continuing in the laboratories on processes for making nuclear fuel wastes highly insoluble prior to burial.

NSERC AWARDS FOR MAJOR RESEARCH EQUIPMENT

Some examples of major installation grants costing in excess of \$200,000 are given below. Most of the facilities purchased with these grants will be used not only by the grantee and his colleagues at the university, but also be researchers from neighboring universities and scientists from industrial and government organizations.

\$384,100 has been awarded to Dr. W.E. Jones of Dalhousie University, for the establishment of a high field nuclear magnetic resonance (NMR) regional centre.

An automated electron microprobe will be funded with a grant of \$422,000 to Dr. D. Francis of McGill University, mainly for research in the earth sciences.

A new mass spectrometer will be housed in the Chemistry Department of the University of Ottawa as a result of a \$540,000 grant to Dr. J.L. Holmes.

A \$400,000 grant has been awarded to Drs. A.K. Mackworth and R.J. Woodham of the Department of Computer Science, University of B.C., for an extension to their digital analysis system. The present facility is used by the Laboratory for Computational Vision (study of computational systems that interpret images).

CANADIAN PHYSICISTS PHYSICIENS CANADIENS

AT YORK UNIVERSITY.....Recent visitors include Professor Maurice Cohen, Department of Physical Chemistry, Hebrew University of Jerusalem, working with R.P. McEachran; Professor K.S. Jammu of Univ. of P.E.I. with A.I. Carswell; Dr. Jack Meek, presently at Geophysics Research Laboratory of the University of Tokyo, with G.G. Shepherd;; Professor Athar Naqvi of University of Riyadh, with W.W. Duley; Dr. John Humberston of University College London. A highlight of the recent International Conference on Positron Scattering and Annihilation in Gases was the award of an honorary D.Sc. to Sir Harrie Massey, FRS.

Recent arrivals include Dr. Rudy Wiens, for the SpaceLab/WAMDI project with G.G. Shepherd and W.A. Gault; Dr. Peter Jackson, formerly of the Universities of Toronto, Maryland and Waterloo, replacing Dr. C.R. Purton, Presently at Dominion Astrophysical Observatory, Penticton, B.C. and Dr. Philippe Baille, R.M.C. as adjunct member of CRESS. On sabbatical leave in 81/82 are Drs. Carswell and Stauffer.

AT THE UNIVERSITY OF WATERLOO.....Don Brodie has been appointed Director of the newly-formed Guelph-Waterloo Program for Graduate Work in Physics, (GWP)², a collaborative graduate and research program supervised by over 50 members of the Departments of Physics at the Universities of Guelph and Waterloo.

Kim Papp has been appointed Assistant Professor of Physics. Dr. Papp earned his Ph.D. degree at York University and completed a post-doctoral fellowship at the University of Chicago before coming to Waterloo. His field is theoretical astrophysics, particularly galactic dynamics and radiative transfer.

Wing-Ki Liu has joined the department as Research Assistant Professor of Physics, (NSERC Fellow). Dr. Liu obtained his Ph.D. degree at the University of Illinois and has previous experience at Oak Ridge National Laboratory, and California Institute of Technology as well as Waterloo. His research area is theoretical molecular physics, especially collision theory and transport and relaxation phenomena.

Jim Lepock has been promoted to Associate Professor of Physics, effective 1 July 1981.

A L'UNIVERSITE DE MONTREAL.....Dr. Bernard Maas, du Centre de Recherches Nucléaires, a, du 13 mai au 13 août 1981, étudié avec Dr. P. Taras "Les propriétés des niveaux de haut spin dans les réactions à ions lourds".

Dr. W. Stocker - Université de Munich, Dr. F. Tondeur - Université de Bruxelles, Dr. P. Quentin - Institut Lave-Langevin à Grenoble, Dr. M. Brack - Université de Regensburg, ont du 15 août au 15 septembre réalisé des "Calculs numériques des propriétés globales des noyaux" avec Dr. J.M. Pearson.

Effective July 1, 1981 Dr. Sample will be leaving TRIUMF to take up new duties with the Research Secretariat of B.C. His address will be as follows:

Dr. J.T. Sample, Executive Director
Research Secretariat of B.C.
Ste. 301 - 7671 Alderbridge Way
Richmond, B.C.
V6X 1Z9

Books Received/Livres Reçus

The following books have recently been received for review. The books are listed according to the Physics and Astronomy Classification Scheme (PACS 1978). Conference proceedings are listed within their categories, but identified by the notation CONF following the publisher and date. Space may not permit reviews of all listed books to be published. Anyone wishing to write a review should request the book from the Book Review Editor, J. P. Svenne, Department of Physics, University of Manitoba, Winnipeg, Manitoba R3T 2N2.

00 General

Physics Reviews, Vol. 2. Soviet Scientific Reviews, Section A. I.M. Khalatnikov, ed. Harwood Academic Publishers, 1980; pp. x + 484. Price: U.S. \$108.00

A Perspective of Physics, Vol. 4, by Sir Harrie Massey. Gordon and Breach, 1980; pp. xxxiv + 349. Price: U.S. \$45.00

Stochastic Nonlinear Systems in Physics, Chemistry and Biology. Proceedings of the Workshop, Bielfeld, Germany, Oct. 1980. L. Arnold and R. Lefever, eds. Springer-Verlag, 1981, CONF; pp. viii + 237. Price: U.S. \$29.50

Nonlinear Finite Element Analysis in Structural Mechanics. Proceedings of the Europe - U.S. Workshop, Bochum, Germany, July, 1980. W. Wunderlich, E. Stein and K.-J. Bathe, eds. Springer-Verlag, 1981, CONF; pp. xiii + 777. Price: U.S. \$ 44.50

Physics in One Dimension. Proceedings of an International Conference, Fribourg, Switzerland, Aug. 1980. J. Bernasconi and T. Schneider. Springer-Verlag, 1981, CONF; pp. ix + 368. Price: U.S. \$34.00

Functional Analysis, by B. V. Limaye. John Wiley & Sons, 1981; pp. xii + 376. Price: U.S. \$17.95

Modern Physics for Applied Science, by B. C. Robertson. John Wiley & Sons, 1981; pp. 271. Price: U.S. \$21.95

Quantum Physics: A Functional Integral Point of View, by J. Glimm and A. Jaffe. Springer-Verlag, 1981; pp. xx + 417. Price: U.S. \$16.80 (paper)

Current Issues in Quantum Logic. Proceedings of a Workshop, Erice, Italy, Dec. 1979. E. G. Beltrametti and B. C. van Fraassen. Plenum Press, 1981, CONF; pp. ix + 492. Price: U.S. \$59.50

10 Elementary Particles and Fields

The New Aspects of Subnuclear Physics. Proceedings of the sixteenth International School of Subnuclear Physics; Erice, Italy, July-Aug., 1978. A. Zichichi, ed. Plenum Press, 1980, CONF; pp. viii + 805. Price: U.S. \$75.00

Particle Physics and Introduction to Field Theory, by T. D. Lee. Harwood Academic Publishers, 1981; pp. xvii + 865. Price: U.S. \$59.50 (cloth) \$19.50 (paper)

Techniques and Concepts of High-Energy Physics. Proceedings of a NATO Advanced Study Institute, St. Croix, Virgin Islands, July 1980. T. Ferbel, ed. Plenum Press, 1981, CONF; pp. xi + 541. Price: U.S. \$65.00

20 Nuclear Physics

The Many-Body Problem: Jastrow Correlations Versus Brueckner Theory. Proceedings of the Third Topical School, Granada, Spain, Sept. 1980. R. Guardiola and J. Ros, eds. Springer-Verlag, 1981, CONF; pp. v + 374. Price: U.S. \$23.00 (paper)

Radioactive Waste Management and Disposal. Proceedings of the First European Community Conference, Luxembourg, May 1980. R. Simon and S. Orlowski, eds. Harwood Academic Publishers, 1980, CONF; pp. xii + 693. Price: U.S. \$90.25

30 Atomic and Molecular Physics

A Course in Mathematical Physics, 3: Quantum Mechanics of Atoms and Molecules, by W. Thirring (tr. by E. M. Harrell). Springer-Verlag, 1981; pp. viii + 300. Price: U.S. \$28.00

40 Classical Areas of Phenomenology

Physics: Volume One, Mechanics, Waves and Thermodynamics, by D. E. Roller and R. Blum. Holden-Day, 1981; pp. xxiii + 818. Price: U.S. \$26.95

Lasers and Applications. Proceedings of the Sergio Porto Memorial Symposium, Rio de Janeiro, June-July, 1980. W. O. N. Guimaraes, C. T. Lin and A. Mooradian, eds. Springer-Verlag, 1981, CONF; pp. ix + 337. Price: U.S. \$34.00

Master Optical Techniques, by A. S. De Vany. John Wiley & Sons, 1981; pp. viii + 600. Price: U.S. \$55.00

The Photonic Field, by P. Moon and D. E. Spencer. M.I.T. Press, 1981; pp. x + 257. Price: \$32.50

50 Fluids, Plasmas and Electric Discharges

Seventh International Conference on Numerical Methods in Fluid Dynamics. Proceedings of the Conference at Stanford, Calif., June 1980. W. C. Reynolds and R. W. MacCormack, eds. Springer-Verlag, 1981, CONF; pp. viii + 485. Price: U.S. \$28.00 (paper)

60/70 Condensed Matter

Recent Developments in Condensed Matter Physics. Vol. 1: Invited Papers. Proceedings of the Condensed Matter Division of the European Physical Society Conference, Antwerpen, April 1980. J. T. Devreese, ed. Plenum Press, 1981, CONF; pp. xvii + 856. Price: U.S. \$85.00

Glassy Metals I. Ionic Structure, Electronic Transport and Crystallization. H. J. Güntherodt and H. Beck, eds. Springer-Verlag, 1981; pp. xiv + 267. Price: U.S. \$39.80

Nonequilibrium Superconductivity, Phonons, and Kapitza Boundaries. Proceedings of a NATO Advanced Study Institute, Acquafredda di Maratea, Italy, Aug. - Sept. 1980. K. E. Gray, ed. Plenum Press, 1981, CONF; pp. x + 699. Price: U.S. \$85.00

Mossbauer Spectroscopy II. The Exotic Side of the Method. U. Gonser, ed. Springer-Verlag, 1981; pp. xii + 196. Price: U.S. \$29.80

80 Cross Disciplinary Physics

Radiation Protection, Progress Report 1980, Commission of the European Communities, eds. Harwood Academic Publishers, 1981; pp. xxvi + 1342. Price: U.S. \$180.00

Picosecond Phenomena II. Proceedings of the Second International Conference, Cape Cod, U.S.A., June 1980. R. Hochstrasser, W. Kaiser and C. V. Shank, eds. Springer-Verlag, 1980, CONF; pp. xii + 382. Price: U.S. \$38.00

Oxides and Oxide Films, Vol. 6. A. K. Vijh, ed. Marcel Dekker, Inc., 1981; pp. xi + 345. Price: \$55.00

Very Large Scale Integration. D. F. Barbe, ed. Springer-Verlag, 1980; pp. xi + 279. Price: U.S. \$29.00

Thermodynamic Network Analysis of Biological Systems. 2nd Ed., by J. Schnakenberg. Springer-Verlag, 1981; pp. x + 149. Price: U.S. \$24.80 (paper)

Lasers in Photomedicine and Photobiology. Proceedings of the European Physical Society, Quantum Electronics Division Conference, Florence, Italy, Sept. 1979. R. Pratesi and C. A. Sacchi, eds. Springer-Verlag, 1980, CONF; pp. xiii + 235. Price: U.S. \$29.50

Physiological Optics, by Y. Le Grand and S. G. El Hage. Springer-Verlag, 1980; pp. xvii + 335. Price: U.S. \$ 46.00

Book Reviews

Critiques des Livres

PHYSICS PROBLEMS FOR PROGRAMMABLE CALCULATORS: MECHANICS AND ELECTROMAGNETISM, by J. Richard Christman. John Wiley & Sons, 1981; pp. xvi + 299. Price: U.S. \$7.95 (paper)

In these days of inflation, the reasonable price of this substantial and well produced book makes it an excellent choice for student use. The book is described as a supplement to the well-known Halliday-Resnick text and the author has tried to do three things. First to explain the structure and programming of some readily available programmable calculators. Second to demonstrate, by means of examples, typical numerical procedures, and third to show how real physical problems can be solved using calculators and numerical analysis.

The calculators envisaged are the TI A.O.S. and the H.P. reverse Polish machines together with unnamed and large devices which might well be PET's, Apples and TRS'80's. Simple descriptions of the machines are presented in appendices together with well-documented programmes in algebraic operating system (A.O.S.), reverse Polish, BASIC, FORTRAN and PASCAL. Whilst, of necessity, the treatment of high-level languages is relatively superficial, enough detail is given to enable any reasonably motivated student to make a start on actual programming and use. It is refreshing to notice that the author seems not to share the current craze for "structured programming". His PASCAL example is liberally sprinkled with GOTO's!

Numerical algorithms are presented in the body of the text along with examples from physics. Root-finding and plotting, curve fitting, numerical integration and linear simultaneous equations are the main mathematical systems to be discussed. The presentation is very clear; however, the almost complete failure of the author to discuss errors of computation and their estimation is a grave defect. This is particularly unfortunate since the techniques discussed, such as Simpson's rule, are well adapted to simple error estimation procedures.

Each of the chapters contains, in addition to numerical algorithms and programmes, worked physical examples and a large number of problems (with hints) for the student. Projectiles, central orbits and rotational dynamics are covered in the mechanics chapters. The field resulting from point charges, line charge distributions, potential, Kirchoff's laws and magneto-dynamic fields form the substance of the electromagnetic part.

There is a great deal of excellent material in this book which will be of considerable use to student and teacher alike. It can be thoroughly recommended.

A. D. Booth
Autonetics Research Associates,
Inc.
Sooke, B. C.

TOPICS IN APPLIED PHYSICS, VOL. 41: THE COMPUTER IN OPTICAL RESEARCH. B. R. Frieden, ed. Springer-Verlag, 1980; pp. xiii + 371. Price: U.S. \$58.00

This set of essays, by six expert authors, is a topical and exceptionally well written summary of what is available in this important field.

Unlike many compendia, this one is uniform in quality and the editor has been at pains to insure uniformity in quality and the editor has been at pains to insure uniformity of style and level.

The editor is evidently possessed of a sense of humour which unobtrusively adds pleasure to the reading. Samples of this are: "Computer terminal rooms are notoriously dull places, monopolized by the chatter of the high-speed printer and the visual blight of FORTRAN manuals.", from the Preface, and "This theorem applies so extensively that an aura has developed about it. 'To invoke' it (it is never merely 'applied') as in 'x must be normal because of the central limit theorem', is usually considered proof enough. Few have the temerity to question the statement, especially if it is said in an authoritative voice.", from a footnote to page 96.

There are six sections. The first, by Frieden, is a wide ranging introduction which covers not only lens design but also thin films, image analysis, computer simulation, holography, optical testing, medical and astronomical topics. The well chosen illustrations in this chapter whet the appetite for what follows.

The second chapter, by R. Barakat, discusses numerical methods in general but with particular emphasis on transform theory. Of particular note is the material on Filon's method for evaluation oscillating integrals and its recent extensions.

The editor returns in Chapter 3, on statistics. This is exceptionally well done and could well form an introduction to the subject in its own right. A technique for feature extraction which was unfamiliar to the reviewer is that of the F-test on Variance. The results of applying this test to a two dimensional set of observations with a 1/1 signal-noise ratio as illustrated in Figure 3.33, page 208, can only be described as staggering.

A. K. Rigler and R. J. Pegis discuss optimization methods in Chapter 4. The usual topics of steepest-descent, conjugate gradients and L. P. are all evaluated and the practical observations which are offered will be of value in fields quite far removed from Optics.

The penultimate chapter, on Optical Astronomy, by L. Mertz starts with a discussion of Stonehenge as an archeological computer! Much of the discussion concerns the automation of data handling but there is a most perceptive account of the impact of speckle imaging on the design of future large optical telescopes.

The final chapter by W. J. Dallas, forms an in-depth study of computer-generated holograms. This subject is not well covered in available literature and the present account is a timely contribution.

It should be evident that the reviewer is enthusiastic about this book. It is a change to read a book which is well produced, well written and informative on subjects which are the cutting edge of modern computer technology.

A. D. Booth
Autonetics Research
Associates, Inc.
Sooke, B. C.

CRYSTALS: GROWTH, PROPERTIES, AND APPLICATIONS. VOL. 2. H. C. Freyhardt, ed. Springer-Verlag, 1980; pp. vi + 197. Price: U.S. \$48.40

This volume, the second in a series, includes four review articles. The first, by Kurt Nassau and Julia Nassau (U.S.A.) is entitled "The Growth of Synthetic and Imitation Gems". The first gem to be successfully duplicated was ruby, at the turn of the century by Verneuil, but since then diamonds, emeralds, sapphires, quartz and others have been made artificially. Production of some gem materials is measured in hundreds of tons a year. A series of crystals has been used in imitation of diamond, culminating with cubic zirconia. Methods of growth range from high pressure for diamond to gel precipitation for opal (which is not a single crystal). All are clearly described, although an aspiring amateur gem grower may be deterred by the cost. Readers familiar with Kurt Nassau's excellent book "Gems Made by Man" (Chilton 1980), which includes an exceptionally good set of colour photographs of gems, will find this article a valuable complement. The article concentrates on the technical aspects of gem production, while the book also describes the history of gems and gem production.

The second article is "The Growth of Large Crystals from the Vapor Phase", by Erick Schönherr (West Germany). The author uses the term "large" to indicate that the size of the crystal is limited only by the amount of source material; and restricts the discussion to materials which evaporate congruently. The final crystals may be as large as melt-grown crystals. After a concise description of evaporation, mass transfer and crystal growth, most of the article is devoted to the practicalities of growth. This section is well written and profusely illustrated, and is likely to be useful to experts as well as beginners. Tables listing crystals grown from vapour, with references, conclude the article.

The next article, by D. E. Ovsienko and G. A. Alfintsev (Ukrainian S.S.R.) is called "Crystal Growth from the Melt: Experimental Investigation of Kinetics and Morphology". The title is almost a misnomer since to many readers, the phrase "growth from the melt" is likely to evoke silicon, sodium chloride and other commercially important materials. The authors, on the other hand, deal with a group of organic materials such as salol and benzophenone, and metals such as bismuth and gallium, whose melting points are 25 - 271 °C. Once this is understood, the article seems useful. The authors are particularly concerned with the growth velocity and melting entropy of their materials. They present many examples not only on normal growth but also on the trapping of impurities and the formation of unstable growth shapes.

The final article is "Morphology and Physical Properties of Gamma Iron Oxide", by Allan H. Morrish (Canada). This material has the distinction of being the most widely used material for magnetic recording devices such as tapes while being unusually difficult to prepare in single crystal form. Single crystals have only been grown as epitaxial films, and these seem not to be the same as small particles. Nonetheless, what is known about the material is ably reviewed. This includes the crystal structure, conversions to and from other forms of iron oxide, and of course the magnetic properties.

The volume, which is well produced, should be useful for libraries and for individuals with an interest in any of the foregoing topics.

F. R. Lipsett
National Research Council
Ottawa

ELEMENTS OF SOLID STATE PHYSICS, by M. N. Rudden and J. Wilson. John Wiley and Sons, 1980; pp. xi + 186. Price: U.S. \$40.00

Il est indéniable que la révolution électronique ait eu une influence déterminante sur notre société moderne et sur la vie de tous les jours: les mots "état solide" font maintenant partie du langage courant. Cependant, bien peu en connaissent le sens exact; de fait, même pour les physiciens, l'expression est de facture relativement récente. En effet, la préhistoire de la physique du solide (et des semi-conducteurs en particulier) ne remonte qu'au début des années '20, alors que R. W. Pohl s'intéresse au comportement des électrons dans les cristaux. La révolution éclate en 1948 lorsqu'un petit dispositif au silicium, le transistor, est utilisé avec succès comme amplificateur. Cette révolution connaît son apogée avec la découverte du circuit intégré, le *très* illustre "chip".

Le présent ouvrage constitue une édition complètement remodelée et réaménagée de "A Simplified Approach to Solid State Physics" (Butterworth, 1971). Au contraire de plusieurs autres livres traitant du même sujet, celui-ci ne suppose aucune connaissance préalable des mécaniques quantique et statistique. De ce point de vue, il est donc auto-suffisant puisque tous les principes fondamentaux nécessaires à la compréhension sont illustrés et expliqués à l'aide de modèles simples.

Cette monographie se veut donc une introduction très élémentaire à la physique du solide. Cependant, le titre aurait tout aussi bien pu se lire "Introduction à la physique des semi-conducteurs". La gamme de sujets traités est en effet fort réduite et se borne à ceux dont la connaissance est essentielle à la compréhension des semi-conducteurs: introduction à la physique moderne, conduction et magnétisme (théories classiques), bandes d'énergie, conduction (théorie quantique), structure cristalline et, enfin, dispositifs semi-conducteurs, le point culminant du traité.

L'ouvrage est très court et d'une lecture aisée; en effet, les auteurs en ont réduit le contenu mathématique à sa plus simple expression, de sorte que le livre s'adresse à un public assez vaste, mais conviendrait parfaitement à une classe de grands commençants en sciences. En fait, dans un cours de physique proprement dit, il trouverait mieux sa place comme lecture d'appoint pour, par exemple, éclaircir un point demeuré obscur en classe. D'ailleurs la présentation en fait une référence attrayante, par ses nombreuses figures empreintes de netteté et de simplicité. Un certain nombre d'exemples et de problèmes constitue un complément indispensable au texte lui-même.

Ce petit volume semble donc être d'une lecture toute désignée pour quiconque possède quelques notions élémentaires de physique et s'intéresse de près (ou de moins près) à l'évolution de la technologie des dispositifs semi-conducteurs.

Laurent J. Lewis
Département de physique
Université McGill

INTRODUCTION TO THE MAGNETIC PROPERTIES OF SOLIDS, by A. S. Chakravarty. John Wiley and Sons, 1980; pp. xv + 696. Price: U.S. \$65.00

The field of magnetism in solids is so vast that it would take a stout heart to attempt to cover the whole territory in a book of merely seven hundred pages. Wisely, A. S. Chakravarty does not attempt to do this, despite the title of his book.

The first half of the book is mainly concerned with the paramagnetism of transition metal compounds, including a lengthy exposition of crystal field theory for the (3d)ⁿ complexes, a field in which the author has considerable expertise. This part of the book covers much of the same ground as J. S. Griffith's *The Theory of Transition Metal Ions*, from which several figures and tables have been reproduced.

Less satisfactory is the treatment in the second half of the book of ordered magnetic systems, mainly ferromagnets and simple antiferromagnets. There one finds standard descriptions of mean-field theory, itinerant ferromagnetism, spin-wave theory in the style of Holstein and Primakoff, and the once fashionable theories employing double-time temperature-dependent Green's functions. There is also a short chapter on spin glasses. However, one will look in vain for more than a brief mention of magnetic domains, neutron scattering, magnetic resonance and relaxation, magnetic anisotropy and magnetostriction, the formation of localized moments in alloys, and critical phenomena in magnetic systems. Furthermore, the rare earth metals and compounds are excluded from the entire book.

Thus, Chakravarty's book will be most useful to those who wish to acquire a detailed knowledge of the electronic states of transition metal ions in complexes of various symmetries.

David Goodings
McMaster University

ADVANCED CALCULUS AND ITS APPLICATIONS TO THE ENGINEERING AND PHYSICAL SCIENCES, by J. C. Amazigo and L. A. Rubinfeld. John Wiley and Sons, 1980; pp. viii + 407. Price: U.S. \$20.95

Since mathematics is usually viewed as a tool in the physical sciences, its principles only make sense when used to solve a problem. On the other hand, one is not likely fully to understand non-elementary physical theories without at least a basic knowledge of Advanced Calculus. These two arguments by themselves fully justify the need for an Advanced Calculus course in the curriculum of any science program.

This book does not deal with mathematical physics, but is rather oriented towards the applied sciences. Nevertheless, it is suitable for science undergraduates with a standard basis of elementary calculus; the following traditional topics are examined: functions of several variables, vectors and vector fields, differential calculus, extrema, integrals, calculus of variations, infinite series and partial differential equations.

Generally speaking, such material could be dealt with in two quite different ways: first, the "Descartes" way, which is a structured, rigorous and academic approach; second, the "American" way, which is more applications-inclined and where the rigor is somewhat sketchy. The authors chose the second way: they feel that too much rigor is not desirable, since too few students can really deal with it. However, the basic mathematical principles are presented in such a way that the reader sees their connection with reality; in their absence, you may well end up with technicians instead of scientists.

Apparently, the authors firmly believe in the virtue of examples, as these constitute a large part of the book. Examples motivate and generate theories and therefore improve intuition. Reversely, intuition is based on experience; note that experience is not always a pleasant one: one can learn a lot from a problem whose solution does not conform to his expectations; this is the price he has to pay for the success of his theory.

Technically, the book is not a masterpiece; the figures are not particularly appealing and the presentation, as a whole, is rather old-fashioned: the text is closely packed and certainly would benefit from a better "mise en page", with the use of colors and shades and even a larger format. However, the various topics examined are discussed in a logical easy-to-follow way; the notation is quite standard and the book includes a reference list of about 50 titles, in addition to the answers of all (answerable) problems.

En résumé, bearing in mind the relative aridity of the subject, the authors have done a good job. As mentioned earlier, the presentation is however not appealing; considering the audience to which the book is intended, this problem could be serious. As a whole, it is a good text, but it will probably not become a classic. To finish with optimism, a little word from the authors: "Many of the outstanding mathematicians have also been excellent physicists and engineers".

Laurent J. Lewis
Department of Physics
McGill University

MATHEMATICAL PROBLEMS IN THEORETICAL PHYSICS.

K. Osterwalder, ed. Springer-Verlag, 1980; pp. viii + 412. Price: U.S. \$27.70 (paper)

This collection is volume 116 in the "Lecture Notes in Physics" series and represents the papers presented at the conference held in Lausanne during August 1979.

An enumeration of the paper titles would be, by itself, over long. The general topics covered are: Schrödinger Operators, Statistical Mechanics, Quantum Field Theory, Gauge Theory, Dynamical Systems, Supersymmetry and C^* Algebras.

In most cases the main papers are preceded by a summary paper which discusses "recent" (in the 1979 sense) progress.

Many of the papers are so badly put together as to convey little information and some refer to other papers, presumably presented informally at the conference, which do not appear in the volume. (For example the intriguing "Why is there a solid state?" by C. Rodin p 163.)

There are some excellent presentations, for example those of J. H. Combes on recent developments in Quantum Scattering Theory, the review of the work of the Cambridge group on Gravitational Instantons by G. W. Gibbons and the paper on Constructive Field Theory by A. Jaffe.

The standard of reproduction is exceptionally poor. The publishers seem to have made no attempt to produce a reasonably homogeneous volume and the presentation range from illegible handwriting to fully justified text-editor output such as that contained in the excellent paper on Time dependent phenomena in Statistical Mechanics by O.E. Lanford.

A summary opinion of this limp covered book would be that, for the average theoretical physicist it is too directed to a small "in Group" to be valuable whilst, for the specialist worker, most of the papers no longer represent the state of the art.

A. D. Booth

SOLITONS: An emerging subject.

SOLITONS. R. K. Bullough and P. J. Caudrey, eds. Springer-Verlag, 1980; pp. xviii + 389. Price: U.S. \$44.90 and
SOLITONS, by G. Eilenberger. Springer-Verlag, 1981; pp. viii + 192. Price: U.S. \$29.00

The first of two new books on this subject is:

SOLITONS, Eds. R. K. Bullough and P. J. Caudrey (Topics in current physics, Vol. 17).

This book is important for two reasons. First that the subject of solitons is attaining importance, not only in its native field of hydrodynamics but also for its potential applications in quantum mechanics. Second, and perhaps even more significant, is the fact that the interest in solitons has resulted in the development of new techniques for the analytic solution of partial differential equations.

The soliton, or form-invariant travelling wave packet, was first observed by John Scott Russel and reported to the British Association in 1834.

The fundamental partial differential equation was derived by Korteweg and de Vries and reported in 1895 but general solution methods had to await the work of such people as Kruskal in 1967 and by Zakharov, Wadati and Toda in the 1970's.

In this new book a systematic account of physics and techniques is presented in 12 chapters each written by acknowledged experts in the field.

First is a detailed account of the history of the solitons by the editors. This contains detailed references and is a most readable introduction to the subject. Soliton physics is next treated by Lamb and McLaughlin with special emphasis on plasma physics. Bullough and his colleagues follow with a study of the double Sine-Gordon equation and its application to spin waves in ^3H .

Chapters 4 to 6, by Toda, Hirota & Newell provide a mathematical discussion of general methods of solution and lead naturally to Zakharov's chapter which is both theoretical and concerned with practical non-linear optics.

The remaining chapters (8-12) contain a discussion of the inverse scattering method by M. Wadati, the inverse spectral transform by Calogero and Degasperis and more general discussions of quantum mechanical applications by Novikov, Faddeev & Luther.

Copious references accompany the individual chapters and additional material is provided as an appendix. This is a most authoritative reference text on a subject of increasing importance.

The second book:

SOLITONS, by G. Eilenberger (Solid-State Sciences, Vol. 19) is written at a slightly more elementary level and has the advantage of the homogeneity which comes from single authorship. It is suitable for the physicist, or student, who has no previous acquaintance with the subject but has an adequate background in partial differential equations and field theory.

The topics covered are similar to those of the previous book: Korteweg-de Vries, the inverse scattering transformation, the Sine-Gordon equation and the Toda lattice.

Emphasis is placed on the physics of the situations described and, although the treatment is rigorous and mathematical it is still readable.

Like the Bullough book, this too has a number of elegant computer plots of solitons and their interactions. These make the nature of the processes studied come to life. The only criticism of a really excellent presentation is that the author, although bent upon keeping physics and reality in the foreground, does not mention the work of Scott Russel. This is a minor point and does not really detract from a most useful text.

A. D. Booth

ELEMENTS OF SOLITON THEORY, by G. J. Lamb, Jr. J. Wiley & Sons Inc., 1980; pp. xii + 289. Price: U.S. \$29.95

Judging by the number of books and articles which have recently appeared, the occurrence, study and search for soliton solutions of non-linear equations, and their connection with the inverse scattering problem, is one of the major fields of interest in the analysis of contemporary experimental physics as well as a research matter in its own right for mathematical physicists.

The textbook (as claimed by its author) is an excellent introduction for the neophyte who wants to acquire a good working knowledge in the field. The mathematical aspects are reduced to standard differential and integral calculus and are sufficient to obtain explicit solutions to equations describing non-linear processes. The emphasis is on concepts and applications, which should appeal to a large audience working in different fields.

Divided in nine chapters, the book deals first with some background information, then with one-dimensional scattering theory, the inverse scattering in one-dimension, the (celebrated) Korteweg-deVries equation, evolution equations related to a two-component system, numerous applications (cubic Schroedinger, ion plasma waves, sine-Gordon, vortex filament, coherent optical pulse propagation, propagation in an amplifier, etc...), Backlund transformations and finally, perturbation theory.

The book is articulate and clear. A number of well chosen problems are scattered throughout the work which concludes with a comprehensive list of references (we can only regret that the more mathematically oriented classic "Inverse Problems in Quantum Scattering Theory" by Chadan and Sabatier (1977), was omitted from the references list).

In conclusion, this is a good introduction to the subject.

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Dr. H. Fearing
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Prof. E. H. Pinnington
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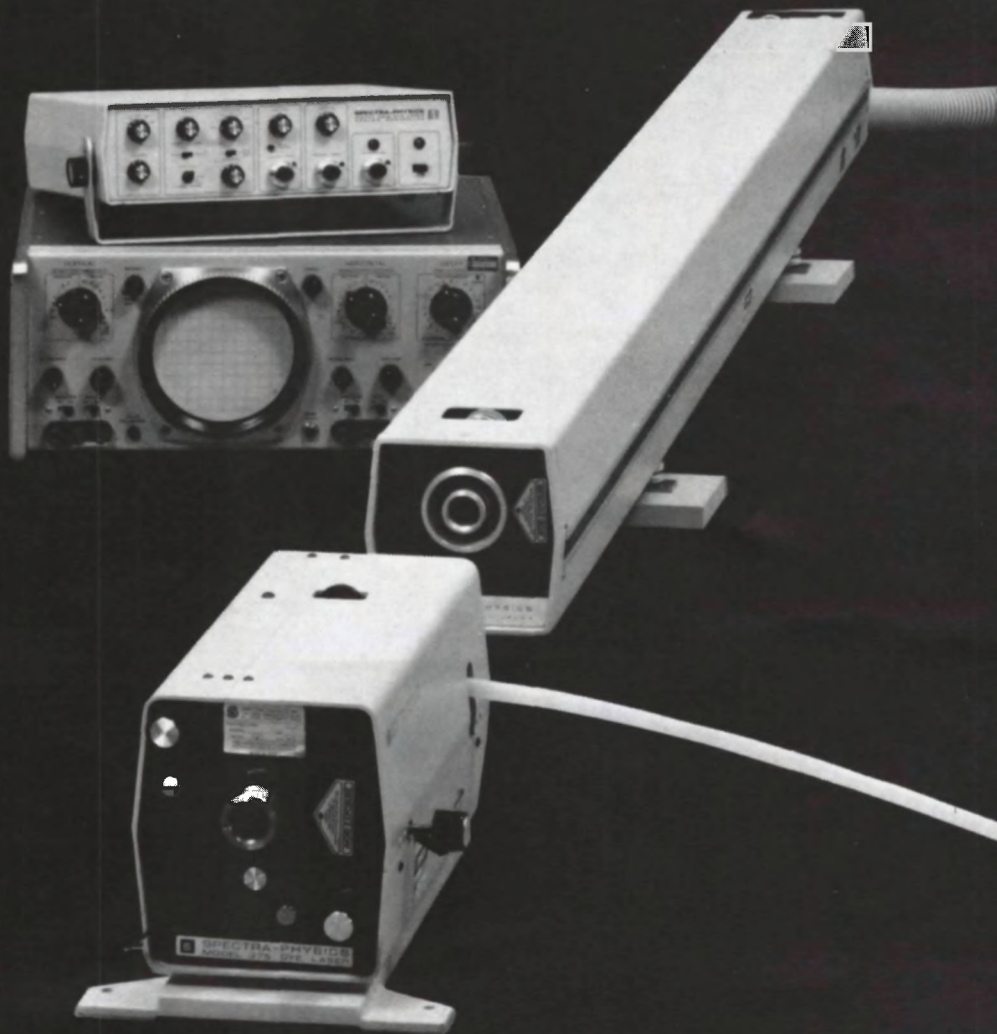
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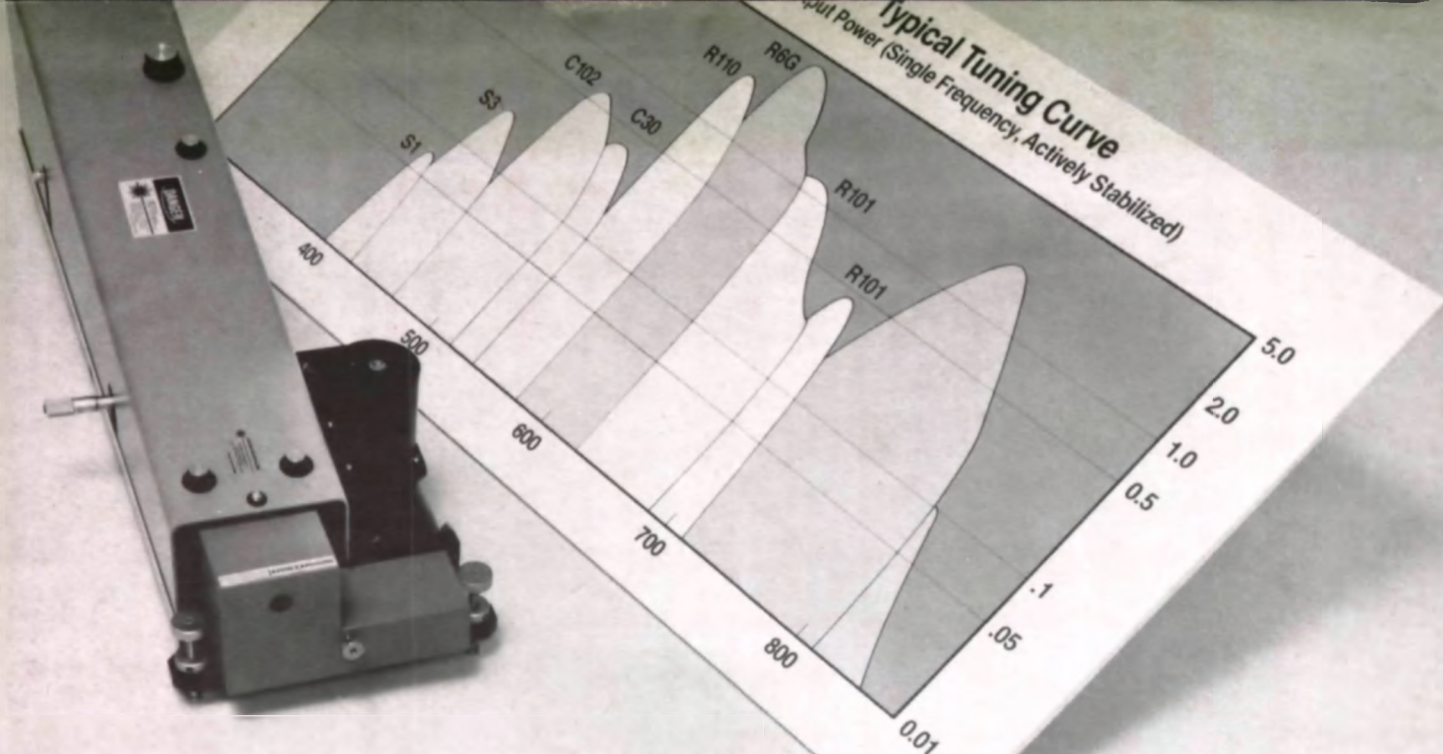
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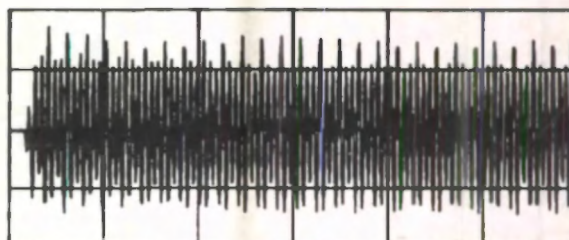
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