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COMPUTER SIMULATION OF KINETIC PROPERTIES OF PLASMAS

Progress Report

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DISCLAIMER

ABSTRACT

The research is directed toward the development and testing of new numerical methods for particle and hybrid simulation of plasmas, and their application to physical problems of current significance to Magnetic Fusion Energy. During the present period, research on the project has been concerned with the following specific problems:

A. Computer simulations of drift and dissipative trapped-electron instabilities in tokamaks, including radial dependence and shear stabilization.

B. Long-time-scale algorithms for numerical solutions of the drift-kinetic equation.

C. Computer simulation of field-reversed ion ring stability.

D. Nonlinear, single-mode saturation of the bump-on-tail instability.

RESEARCH ACCOMPLISHED SINCE LAST RENEWAL

A. Computer simulations of drift and dissipative trapped-electron instabilities in tokamaks, including radial dependence and shear stabilization.

(a) The study of the curvature and gradient drift resonance instability has been completed. This research was presented in the paper "Curvature drift resonance effects on trapped-electron modes" by T. L. Crystal and J. Denavit, Sherwood meeting, Pocono Manor, 1979. This paper is in final stages of preparation for submition to The Physics of Fluids. Numerical methods used in this study are the subject of a separate paper "Computer simulation of trapped-electron modes in tokamaks" by T. L. Crystal and J. Denavit, submitted to the Journal of Computational Physics.

(b) Computer simulations of the radial dependence and shear stabilization of drift waves are currently being done in cooperation with Oak Ridge National Laboratory. Preliminary results on these simulations were presented in the paper "TEDI - a numerical simulation of the time evolution of drift waves" by C. O. Beasley, W. I. van Rij and J. Denavit, Sherwood meeting, Pocono Manor, 1979.

(c) Computer studies of the radial dependence of trapped-electron modes are presently under development. These modes require consideration of both energy and pitch angle of the particles, and poloidal mode coupling must be included in the computations. This results in greater complexity and computer requirements than in the case of drift waves. This research is also done in cooperation with the Kinetic Theory Group at ORNL and the principal investigator (J. Denavit) will spend two weeks at Oak Ridge during the summer to facilitate this cooperation.

B. The development of long-time-scale algorithms for numerical solutions of the drift-kinetic equation have been continued and recent results using time filtering of high-frequency oscillations are presented in the paper "On numerical solutions of the Vlasov equation with filtering in time" by T. L. Crystal, J. Denavit and C. E. Rathmann, submitted to Comments on Plasma Physics and Controlled Fusion.

C. Computer studies of field-reversed ion ring stability have been continued in cooperation with Cornell University. The basic method and verification studies of the RINGHYBRID code are presented in the paper "A linearized 3-D hybrid code for stability studies of field-reversed ion rings" by A. Friedman, R. N. Sudan and J. Denavit, submitted for publication in the Journal of Computational Physics. Studies of plasma confinement in axially symmetric ion rings have been presented in the paper "Numerical simulation of plasma confinement and heating by field-reversed ion rings" by A. Mankofsky, R. N. Sudan and J. Denavit, Sherwood meeting, Pocono Manor, 1979.

D. The single-mode saturation of the bump-on-tail instability has been studied using two different particle simulation methods (a) a short-time-scale method with $\Delta t = 0.2\omega_p^{-1}$ and (b) a long-time-scale method developed earlier in the program allowing time steps $\Delta t \gg \omega_p^{-1}$. These methods are in close agreement with each other and the computations carried out thus far confirm the O'Neil saturation theory, rather than the Simon-Rosenbluth theory.

PERSONNEL

During the present period (1 February 1979 to 30 September 1979) research on the project is carried out by the following personnel:

1. Principal Investigator:

   Professor J. Denavit, 20% of time from 1 February 1979 to 15 June 1979

   Full time from 16 June 1979 to 22 July 1979

2. Research Associates:

   Thomas L. Crystal, full time from 1 April 1979 to 31 May 1979

   Carl E. Rathmann, full time from 25 June 1979 to 17 August 1979

LIST OF PUBLICATIONS

1) Publications submitted or in preparation during the past year

Title	Authors	Journal/Status	Percent DOE Support (under present contract
"On Long-Time-Scale Solutions of Plasma Kinetic Equations"	T. L. Crystal J. Denavit C. E. Rathmann	Comments on Plasma Physics and Controlled Fusion	70%
"Computer Simulation of Trapped-Electron Modes in Tokamaks"	T. L. Crystal J. Denavit	Submitted to Journal of Computational Physics	100%
"A Linearized Hybrid Code for Stability Studies of Field-Reversed Ion Rings"	A. Friedman R. N. Sudan J. Denavit	Submitted to Journal of Computational Physics	20%
"Curvature and Gradient Drift Effects on Trapped-Electron Modes"	T. L. Crystal J. Denavit	To be submitted to The Physics of Fluids	100%

2) Publications submitted during previous years

"Spectral Formulation of the Dissipative Trapped-Electron Instability"	J. Denavit C. E. Rathmann	Published in The Physics of Fluids 21, 1533 (1978)	100%
"Long-Time-Scale Simulations of Resonant Particle Effects in Langmuir and Whistler Waves"	C. E. Rathmann J. Vomvoridis and J. Denavit	Published in Journal of Computational Physics, 26, 408 (1978)	50%
"Numerical Study of Two-Dimensional Generation and Collapse of Langmuir Solitons"	N. R. Pereira R. N. Sudan and J. Denavit	Published in The Physics of Fluids 20, 936 (1977)	33%
"Numerical Simulation of One-Dimensional Langmuir Solitons"	N. R. Pereira R. N. Sudan and J. Denavit	Published in The Physics of Fluids 20, 271 (1977)	33%

"Collisional Effects on Electron Heating Due to Parametric Instability"	J. Denavit	Published in The Physics of Fluids 19, 972 (1976)	33%
"Numerical Simulation Methods for Collisional and Turbulent Heating in Plasmas"	C. E. Rathmann	Ph.D. Dissertation Northwestern Univ. (August 1975)	50%
"A Long-Time-Step Particle-Pushing Algorithm"	C. E. Rathmann and J. Denavit	Proc. 7th Conf. Num. Sim. of Plasmas (Courant Inst. June 1975)	50%
"Whistler Sideband Instability"	J. Denavit and R. N. Sudan	Published in The Physics of Fluids 18, 575 (1975)	25%
"Effect of Phase-Correlated Electrons on Whistler Wave-packet Propagation"	J. Denavit and R. N. Sudan	Published in The Physics of Fluids 18, 1533 (1975)	25%
"Simulation of Collisional Effects in Plasmas"	C. E. Rathmann and J. Denavit	Published in Journal of Computational Physics 18, 165 (1975)	50%
"Two-Dimensional Stability of Langmuir Solitons"	J. Denavit, N. R. Pereira and R. N. Sudan	Published in Physical Review Letters 33, 1435 (1975)	33%
"Theory of Triggered VLF Emissions from the Magnetosphere"	R. N. Sudan and J. Denavit	Published in Physics Today, Vol. 12, Dec. 1973	25%
"Discrete Particle Effects in Whistler Simulation"	J. Denavit	Published in Journal of Computational Physics 15, 449 (1974)	50%