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ACOUSTIC SCATTERING AND PROPAGATION

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Final Report

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1. Introduction

My co-workers and I have worked on a variety of problems during the last two and one-half years, i.e., from Sept. 1, 1985 to March 31, 1988. This work has led to new results which are presented in a number of manuscripts. Some of the results are described in Section 2, and the status of the various publications is described in Section 3.

2. Main Results

A. Previously, Dr. J.G. Watson and Prof. Keller wrote two papers on rough surface scattering: "Reflection, Scattering and Absorption of Acoustic Waves by Rough Surfaces," *J. Acoust. Soc. Am.* **74**, 1887-1894, 1983; "Rough Surface Scattering via the Smoothing Method," *J. Acoust. Soc. Am.* **75**, 1705-1708, 1984. In the first of these we used the Born approximation to obtain in a unified way the first and second moments of the acoustic fields scattered by four kinds of slightly rough surfaces. We also showed how to modify or renormalize the results to eliminate divergences which occur at grazing incidence. Then we showed how these results were related to those obtained by Twersky's self-consistent method. In the second paper we solved the same problems by the smoothing method and showed that the results were exactly the renormalized ones we obtained before. Thus we related the Born expansion, the renormalized Born expansion, Twersky's method and the smoothing method.

In the last few years we have extended this work to scattering from rough interfaces for which Twersky's method has not been developed. The results are similar to our previous ones but more complicated. We have completed the work, and have nearly completed a manuscript on it.

B. During the last two years Prof. Keller and his former student Dr. William Boyse have been working on the propagation of short waves in random media. In his thesis Dr. Boyse had completed various aspects of this work by using the regular perturbation method. Since then, we have been extending that work by utilizing the methods of Khashminski, and of Kohler and Papanicolau in a manner similar to that of White and his co-workers. Various results have been obtained, but the work is not yet complete.

C. Profs. Keller and Weinstein have determined the pass and stop bands, and the dispersion equation, for waves in a plane-stratified medium. The essential new feature is that the variations in the medium are assumed to be large.

D. Profs. Keller and Bai have calculated the dispersion equation for sound waves in a medium containing rigid spheres arranged in a simple cubic lattice. The wavelength is assumed to be large compared to the radius of a sphere. The spheres are allowed to touch one another. The first few pass bands and stop bands are found.

E. Profs. Keller and Ahluwalia have analyzed scattering of sound by slender bodies. The wavelength is assumed to be long compared to the radius of a cross-section of the body, but either long or short compared to its length.

F. Prof. Keller and his student Dan Givoli have developed a method for reducing wave propagation problems in infinite domains to problems in finite domains without spurious reflection from the artificial boundary. It has been combined with the finite element method and works much better than other schemes proposed previously.

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3 Publications

A. Prof. Joseph B. Keller and co-authors

1. "Review of Stochastic Wave Propagation" by K. Sobczyk", *SIAM Review* **28** 593-594 1986.
2. "Scattering by a slender body", (with D.S. Ahluwalia) *JASA* **80** 1782-1792 1986.
3. "Finite elastic deformation governed by linear equations", *J. Appl. Mech.* **53** 819-820 1986.
4. "Pouring Flows", (with J.M. Vanden-Broeck) *Phys. Fluids* **29** 3958-3961 1986.
5. "Finite amplitude vortices in curved channel flow", (with W.H. Finlay and J.H. Ferziger), Proc. of the 25th AIAA Aerospace Science Meeting, Reno, Jan. 1987.
6. "Free surface flow due to a sink", (with J.M. Vanden-Broeck) *J. Fluid Mech.* **175** 109-117 1987.
7. "Weir Flows", (with J.M. Vanden-Broeck) *J. Fluid Mech.* **176** 283-293 1987.
8. "Acoustoelasticity", *Dynamical problems in continuum physics*, eds. J.L. Bona, C. Dafermos, J.L. Ericksen and D. Kinderlehrer, Springer-Verlag, New York, 1987, pp. 193-203.
9. "Impact with an impulsive frictional moment", *ASME J. Appl. Mech.* **54** 239-240 1987.
10. "Effective conductivities of reciprocal media", *Random Media*, ed. G. Papanicolaou, Springer-Verlag, New York, 1987, pp. 183-188.
11. "Addendum: Asymptotic theory of nonlinear wave propagation", (with S. Kogelman), *SIAM J. Appl. Math.* **47** 454 1987.
12. "Caustics of nonlinear waves" (with J. K. Hunter), *Wave Motion* **9** 429-443 1987.
13. "Asymptotic behavior of stability regions for Hill's equation", (with Michael Weinstein), *SIAM J. Appl. Math.* **47** 941-958 1987.

14. "Stability of periodic plane waves," (with P.K. Newton) *SIAM J. Appl. Math.* **47** 959-964 1987.
15. "Sound waves in a medium containing rigid spheres," (with Dov Bai) *JASA* **82** 1436-1441 1987.
16. "Effective conductivity of periodic composites composed of two very unequal conductors," *J. Math. Phys.* **28** 2516-2520 1987.
17. "Lower bounds on permeability" (with Jacob Rubinstein) *Phys. Fluids* **30** 2919-2921 1987.
18. "Ropes in Equilibrium", (with J. Maddocks), *SIAM J. Appl. Math.* **47** 1185-1200 1987.
19. "Misuse of game theory," *J. Chronic Diseases*, **40** 1147-1148 1987.
20. "Stability of plane wave solutions of nonlinear systems" (with P.K. Newton), *Wave Motion*, in press. (proofs 12/10/87).
21. "Fair Dice," *American Math. Monthly*, in press (June 1988).
22. "Precipitation Pattern Formation," (with M. Falkowitz), *J. Chem. Phys.*, **88** 416-421 1988.
23. "Resonantly interacting water waves," *J. Fluid Mech.*, in press. (accepted 11/2/87).
24. "Nonlinear hyperbolic waves," (with J. K. Hunter), *Proc. Royal Society*, in press. (submitted 12/10/87).
25. "Fast reaction, slow diffusion and curve shortening" (with J. Rubinstein and P. Sternberg), *SIAM J. Appl. Math.*, in press (12/87).
26. "Finite amplitude vortices in curved channel flow," (with W.H. Finlay and J.H. Ferziger), *J. Fluid Mech.* (accepted 11/87; to be shortened).
27. "Newton's Second Law", *Am. J. Phys.*, **55** 1145-1146 1987.
28. "Approximations for errors-in-variables regression," submitted 8/20/86, resubmitted 4/87, 11/17/87.
29. "Spilling" in *Science, Food and Drink* ed. Kuerti, submitted 6/5/87.

B. Other authors

Walter Craig

1. "Nonstrictly hyperbolic nonlinear systems," *Math. Annalen*, **277**, pp. 213-232 (1987).
2. "On water waves as Hamiltonian system," submitted to *Physica D*, May 1987.
3. "Symmetry of solitary waves," (with Sternberg, P.), in press, *Commun. P.D.E.*
4. "Dispersive equations," (with Goodman, J.), preprint.
5. "The Floquet exponent for Jacobi fields," submitted to *Inventiones Math*, Sept. 1987.
6. "A dynamical property of Einstein manifolds," in preparation.

Jacob Rubinstein

1. J. Rubinstein and S. Torquato, "Diffusion-controlled reactions: mathematical formulation, variational principles, and rigorous bounds," preprint.
2. J. Rubinstein and S. Torquato, "Flow in random porous media: variational principles and rigorous bounds on the permeability", (in press).

Peter Sternberg

Craig, W. and Sternberg, P.: "Symmetry of Solitary Waves," Communications in P.D.E.'s, (in press).

Kohn, R.V. and Sternberg, P.: "Local Minimizers and Singular Perturbations," submitted to Proceedings of the Royal Society of Edinburgh.

Owen, N. and Sternberg, P.: "Nonconvex Variational Problems with Anisotropic Perturbations," submitted to Annal. de L'Inst. H. Poincare Anal. Nonlin.

Sternberg, P.: "The Effect of a Singular Perturbation on Nonconvex Variational Problems," Archives for Rational Mechanics and Analysis, (in press).