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Computer Program (P1-GAS) Calculates P-0 and P-1 Transfer Matrices for Neutron Moderation in Monatomic Gas

The problem:

To generate multigroup thermal neutron scattering cross sections for use in the latest neutron transport theory programs, it is necessary to have the group-to-group elastic transfer kernels. Below 1 eV experimental crystalline transfer kernels may be used; and at about 1 eV it is necessary to analytically generate the elastic transfer kernels. The problem to be solved here is the generation of the P-0 and P-1 transfer matrices for neutron moderation in a monatomic gas.

The solution:

The equations programmed in the P1-GAS Fortran IV Program are essentially those derived by Clendenin and others. These equations for the elastic scattering kernels are based on the following conditions: (1) there is isotropic scattering in the center-of-mass coordinate system; (2) the scattering cross section is constant, i.e., independent of the velocities; and (3) the target nuclear velocities satisfy a Maxwellian distribution. The monatomic gas model has the advantage that the differential cross section (matrix elements) may be expressed analytically.

How it's done:

To calculate the elastic scattering transfer matrices for a neutron in a solid moderator, one of three models may be used, depending on the energy of the neutron and the temperature of the moderator. When the neutron energy is greater than a few eV, the scattering process depends only weakly on the fact that the target nuclei are bound in the lattice and the fact that the target nuclei have thermal motion. Thus, the moderator nuclei may be treated as free and stationary. In this model the neutron energy cannot increase as a result of a collision. For lower neutron energies, which shall be referred to as the thermal range, "upscatter" can occur due to the thermal motion of the moderator nuclei. For neutron energies less than about 1 eV, the interaction of the neutron range, i.e., for energies above about 1 eV, the gas model described here is applicable. In the gas model, no account is taken of the fact that the scattering nuclei are bound in ordered fashion in the lattice; however, the thermal motion of the target nuclei is taken into account.

When neutrons are moderating in a monatomic gas such as helium, the results of P1-GAS are directly applicable. In this case the thermodynamic temperature of the gas characterizes the Maxwellian distribution. However, for a molecular gas such as hydrogen, the results in general do not apply since the internal degrees of freedom (vibrations and rotations) are not treated in the gas model.

Quantities are printed out in the program that provide a check of the calculation, to see whether or not specific conditions are satisfied by the transfer matrices.

Notes:

1. This program is written in Fortran IV and MAP for the IBM 7090/7094 computer.
2. One of the input quantities to the P1-GAS program is the temperature of the gas. Lamb first showed (for the resonance absorption of neutrons) that a Maxwellian distribution may be used for the nuclear velocities in a Debye solid. Nelkin and Parks showed this also true for slow neutron scattering. However, the Maxwellian distribution is not

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characterized by the thermodynamic temperature T of the moderator, but an effective temperature T^1 directly. Actually, there are a number of ways of obtaining T^1. Additional information is contained in the following references:

(a) Clendenin, W. W., *Journal Nuclear Energy,* Part A. *13*, 25 (1960)

(b) Lamb, W. E. *Physical Review, 55,* 190 (1939)

(c) Nelkin, M. S. and Parks, D. El, *Physical Review,* 119, 1060 (1960).

(d) Johnston, A. S., Westinghouse Astronuclear Laboratory, (WANL)-TME1640, July 1967.

3. Inquiries concerning this program may be made to:

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No patent action is contemplated by AEC or NASA.

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