INTRODUCTION TO THE NIST CENTER FOR NEUTRON RESEARCH (NCNR)

Modern technological society is dependent upon increasingly sophisticated use of materials, many of whose attributes are dictated by their sub-microscopic structural and dynamical properties. Our knowledge of these properties is provided by a wide range of scientific techniques of which the many types of scattering (for example, X-rays, light, electrons, neutrons) are arguably the most important. Of these probes, neutrons are perhaps least familiar, but they provide important advantages for many types of measurements.

Neutrons, as prepared for use at modern sources, are moving at speeds comparable to those of atoms moving at room temperature, thus providing the ability to probe dynamical behavior. At the same time, neutrons are well matched to measurements at length scales ranging from the distances between atoms to the size of biological or polymer macromolecules. Neutrons are sensitive to the magnetic properties of atoms and molecules, allowing study of the underlying magnetic properties of materials. They also scatter quite differently from normal hydrogen atoms than they do from heavy hydrogen (deuterium), allowing selective study of individual regions of molecular systems. Finally, neutrons interact only weakly with materials, providing the opportunity to study samples in different environments more easily (at high pressures, in shear, in reaction vessels, etc.), and making them a non-destructive probe. These favorable properties are offset by the relative weakness of the best neutron sources compared to X-ray or electron sources, and by the relatively large facilities required to produce neutrons. As a result, major neutron sources are operated as national user facilities to which researchers come from all over the United States (and abroad) to perform small scale science using the special measurement capabilities provided.

In addition to scattering measurements, neutrons can be used to probe the atomic composition of materials by means of capture and resultant radioactive decay. The characteristics of the decay act as “fingerprints” for particular atomic nuclei, allowing studies of environmental samples for pollutants (e.g., heavy metals), characterization of Standard Reference Materials, and many other essential measurements. While the scattering and capture users of neutrons are little concerned with understanding the inherent properties of the neutron, there are important areas in physics that can be explored by carefully measuring fundamental neutron behavior. Examples include the lifetime of the free neutron, an important quantity in the theory of astrophysics; the beta decay process of the neutron, the details of which are stringent tests of nuclear theory; and the effects of various external influences such as gravity or magnetic fields on neutrons.

The NCNR utilizes neutrons produced by the 20 MW NIST Research Reactor to provide facilities, including the nation’s only internationally competitive cold neutron facility, for all of the above types of measurements to a national user community. There are approximately 35 stations in the reactor and its associated beams that can provide neutrons for experiments. At the present time 26 of these are in active use, of which 6 provide high neutron flux positions in the reactor for irradiation, and 20 are beam facilities. A schematic layout of the beam facilities and brief descriptions of available instrumentation are given below. More complete descriptions can be found at http://www.ncnr.nist.gov/.

These facilities are operated both to serve NIST mission needs and as a national facility, with many different modes of access. Some instrumentation was built years ago, and is not suited to general user access; however, time is available for collaborative research. NIST has recently built new instrumentation, and reserves 33 % of available time for mission needs with the balance available to general users. In other cases, instrumentation was built and is operated by Participating Research Teams (PRT). PRT members have access to 75 % of available time, with the balance available to general users. In a special case, NIST and the National Science Foundation established the Center for High Resolution Neutron Scattering at the NCNR, with a 30 m Small Angle Scattering (SANS) instrument, a cold neutron triple axis spectrometer, and a perfect crystal SANS under construction. For these facilities, most time is available for general users. While most access is for research, whose results are freely available to the general public, proprietary research can be performed under full cost recovery. Each year, approximately 1600 researchers (persons who participated in experiments at the facility, but did not necessarily come here) from all areas of the country, from industry, academe, and government use the facility for measurements not otherwise possible. The research covers a broad spectrum of disciplines, including chemistry, physics, biology, materials science, and engineering.