The neutrons released in a nuclear reactor can be used for many scientific and technical investigations. Beams of neutron that originate in a reactor vessel are mainly used in scattering experiment to find answers to fundamental questions about the structure and composition of materials used in medicine, mining, transportation, building, engineering, food processing and scientific research.

Neutrons have zero electrical charge and penetrate materials more effectively than X-rays. Neutrons penetrate most materials to depths of several centimetres. In comparison, X-rays and electrons probe only near the surface. The deBroglie wavelength of thermal neutrons is comparable to X-rays and the spacing of atoms in the atomic lattices of solids. These properties make neutrons an especially useful tool in industrial materials analysis.

X-rays and electrons are scattered by atomic electrons whereas neutrons are scattered by atomic nuclei. This results in a number of differences, perhaps the most important being in the scattering from light elements. Whereas one electron on a hydrogen atom can be hard to find by X-ray or electron diffraction, the hydrogen nucleus scatters neutrons strongly and is easily found in a neutron diffraction experiment. Hence, neutron beams are useful in determining the structure of solids containing hydrogen bonds found in organic molecules.

Neutrons, though electrically neutral, act as small magnets, and are uniquely powerful in the atomic scale study of magnetism.

Neutrons are also uniquely suited to the study of the dynamic processes (e.g. thermal vibrations) in solids.

Neutron scattering is used in many different scientific fields. Neutrons can be used to study the dynamics of chemical reactions at interfaces for chemical and biochemical engineering, in food science, drug synthesis and healthcare. Neutrons can probe deep into solid objects such as turbine blades, gas pipelines and welds to give microscopic insight into the strains and stresses that affect the operational lifetimes of crucial engineering components. Neutron studies of nanoparticles and magnetism are used for the development of next-generation computer and IT technology, data storage, sensors and superconducting materials.

Neutron scattering is a delicate and non-destructive measurement technique, making it ideal for use in heritage science.
Understanding magnetism
The neutron is capable of seeing both the nuclei of atoms and at the same time the magnetic interactions of their electrons. Neutron scattering has made seminal contributions to our understanding of magnetism – from the early demonstration of anti-ferromagnetism in simple systems through to the complex magnetic structures found in hard magnets or the synthetic multilayer structures used for data-storage applications.

Investigating polymers
Neutrons have been used to investigate polymers since the early 1970s. Originally, neutron research unveiled the structure and formation of polymers to understand how they assembled and bonded. Now neutron science is studying the dynamics of thin polymer films, further increasing their range of applications into areas such as anti-reflective coatings and time-release medications. The significant difference in the neutron scattering cross-section between hydrogen and deuterium allows selective “labelling” of chemically specific parts of complex molecular systems, giving a unique insight; this powerful technique is used for almost all soft-matter studies.

Revealing invisible worlds
Neutron diffraction has been used to reveal the molecular structure of both crystalline and disordered materials since the early days of the discipline. Powerful computational modelling applied to neutron data allows accurate structures of pharmaceutical compounds to be derived, material structures in fuel-cell and battery electrodes to be optimised, and the orientation and packing of molecules in liquids and glasses to be understood. When materials bend, break or disintegrate it is their atomic structure that changes. Neutrons are used in a wide range of engineering applications to test the strength and suitability of materials under certain conditions, from studying the performance under strain of materials in aeroplane wings or train wheels to safely extending the operating life of nuclear power stations.

Biophysics: neutrons and the body
A real understanding of the essential processes of life requires knowledge of how proteins and other macromolecules perform their roles. This is giving new insight into the way drugs and medicines move through the body and how they can be controlled and delivered to the specific area of concern. Neutron science continues to break new ground in investigating how drug-delivering polymers can move through membranes, how antibodies are structured and how active parts of medicines interact with lipids and proteins.

Unlocking the potential of hydrogen
Hydrogen has the largest scattering interaction with neutrons of all the elements in the periodic table. Early experiments showing how hydrogen diffuses in simple metals have been built on to provide data supporting the development of materials for fuel cells and hydrogen storage. Hydrogen has been identified as a fuel with great potential for providing clean energy for transport, but its use is constrained by our inability to store it in a dense enough form suitable for vehicles. Neutron studies, currently being undertaken, will facilitate the understanding and development of materials that can store hydrogen safely and efficiently.
Unveiling our heritage

The delicate, sensitive and deeply penetrating nature of neutron beams enables heritage scientists to determine unique information from historic objects, museum artefacts or geological fossils with no risk to their value or integrity. Adapting techniques from crystallography and engineering, analysis of crystal structures in ceramic or pottery fragments can determine the period and region of manufacture and reveal ancient trade routes, while texture analysis of metal objects can identify manufacturing techniques and forgeries.