**SOLITON**

A soliton is a solitary wave that behaves like a particle which satisfies the conditions of maintaining the normal shape even on moving at a constant speed and also on interaction with another soliton, it emerges from the collision being unchanged except possibly for a phase shift. In Mathematics and Physics, a soliton or solitary wave is a self-reinforcing wave packet that maintains its shape while it propagates at a constant velocity. Solitons are caused by the cancellation of non-linear and dispersive effects (property of certain systems where the speed of a wave depends on its frequency) in the medium. Solitons are the solutions of a widespread class of weakly nonlinear dispersive partial differential equations describing the physical systems. The phenomenon of soliton was first described in 1834 by John Scott Russell (1808-1882), who observed a solitary wave in the Union Canal in Scotland. He reproduced the phenomenon in a wave tank and named it the ‘Wave of Translation’.

A single consensus definition of a soliton is difficult to find out. Drazin and Johnson described three properties of solitons: 1)They are of permanent form, 2)They are localized within a region, 3)They can interact with other solitons and emerge to form the collision unchanged, except for a phase shift. More formal definitions exist but they require substantial mathematics. Moreover some scientists use the term ‘soliton’ for phenomena that do not have these three properties (for instance, the ‘light bullets’ of non-linear optics are often called solitons, despite losing the energy during interaction). Tsunamis behave like solitons with very large wavelength. There is no point trying to send a counter wave to neutralize one. Rogue waves are also to solitons. They could be 30 metres high and have a very steep slope.

Dispersion and non-linearity can interact to produce permanent and localized wave forms. Let us consider a pulse of light travelling in glass - this pulse can be thought of as consisting of light of several different frequencies. Since glass shows dispersion, these different frequencies travel at different speeds and the shape of the pulse therefore changes over time. However also the nonlinear Kerr effect occurs; the refractive index of a material at a given frequency depends on the amplitude of light. If the pulse has just the right shape, the Kerr effect exactly cancels the effect of dispersion and the pulse’s shape does not change over time, thus is a soliton.

Most exactly solvable models have soliton solutions, including the Korteweg-de Vries equation, the nonlinear Schrodinger equation, the coupled nonlinear Schrodinger equation and the sine-Gordon equation. The soliton solutions are typically obtained by means of the inverse scattering transformation and owe their stability to the integrability of the field equations. The mathematical theory of these equations is a broad and very active field of mathematical research. Some types of tidal bore, a wave phenomenon of a few rivers including the River Severn are ‘undular’ – a wavefront followed by a train of solitons. Other solitons occur as the undersea internal waves, initiated by seabed topography which propagate on the oceanic pycnocline.

‘Atmospheric solitons’ also exist such as the morning glory cloud of the Gulf of Carpenteria, where pressure solitons travelling in an inversion layer of temperature, produce vast linear roll clouds. The recent and not widely accepted soliton model in neuroscience proposes to explain the signal-conduction within neurons as pressure solitons. ‘Topological soliton’ also called a topological defect is any solution of a set of partial differential equations that is stable against decay to the ‘trivial solution’. The stability of soliton is due to topological constraints, rather than integrability of the field equations. The constraints arise almost always because the differential equations must obey a set of boundary conditions and the boundary has a non-trivial homotomy group, preserved by the differential equations. Thus the solutions of differential equation can be classified into homotopy classes. No continuous transformation maps a solution in one homotopy class to another. The solutions are truely distinct and maintain their integrity even in the face of extremely powerful forces. Examples of topological solitons include the screw dislocation in a crystalline lattice, the Dirac string and the magnetic monopole in electromagnetism, the Skyrmion and the Wess-Zumino-Witten model in Quantum field theory, the magnetic skyrmion in condensed matter physics, cosmic strings and domain walls in cosmology. An optical pulse whose parameters satisfy the condition N=1 is called the ‘fundamental soliton’. Pulses corresponding to other integer values of N are called higher-order solitons. The parameter N represents the order of the soliton.

*Applications of Soliton :*

1. In fibre optics - Much experimentations have been already done using solitons in fibre optics applications. Solitons in a fibre optic system are described by the Manakov equations. Solitons’ inherent stability make long distance transmission possible without the use of repeaters and could potentially double the capacity of transmission as well.
2. In biology – Solitons may occur in proteins and DNA. Solitons are related to the low-frequency collective motion in proteins and DNA. A recently developed model in neuroscience proposes that signals in the form of density waves, are conducted within neurons in the form of solitons. Solitons can be described as almost loseless energy-transfer in the biomolecular chains or lattices as wave-like propagations of coupled conformational and electronic disturbances.
3. In magnets – There also exist different types of solitons and other nonlinear waves. These magnetic solitons are an exact solution of classical nonlinear differential equations – magnetic equations (eg: the Landau-Lifshitz equation, Continuum Heisenberg model, Ishimori equation, nonlinear Schrodinger equation and others).
4. In nuclear physics – Atomic nuclei may exhibit solitonic behaviour. Here the whole nuclear wave function is predicted to exist as a soliton under certain conditions of temperature and energy. Such conditions are suggested to exist in the cores of some stars in which the nuclei would not react but pass through each other being unchanged, retaining their soliton waves through a collision between nuclei. The Skyrme Model is a model of nuclei in which each nucleus is considered to be a topologically stable soliton solution of a field theory with conserved baryon number.