The physics of complex systems: from traffic jams to nanoscale transport phenomena

by Christophe Rossel
EPS TIG Chair – DOI: 10.1051/epn/2024205

Understanding transport phenomena is essential in various fields of physics and engineering including thermodynamics, fluid dynamics, material science, optics, *etc.* By studying how quantities such as mass, charge, energy, momentum or angular momentum are transported in various systems, scientists can develop mathematical models to predict, simulate and control specific processes. Particularly interesting is the concept of conduction that refers to the transfer of energy through the movement of particles in a medium or in vacuum. Three different types of classical behaviour, depending on the type of energy being transferred are heat or thermal conduction, electrical conduction and acoustic conduction. The Boltzmann transport theory and statistical physics allow us to develop microscopic models for macroscopic quantities such as mobility, diffusion coefficient, and conductivity in materials. Of course, today the field of transport is much more complex if one considers quantum mechanics with the quantisation of physical properties, relativity and space-time concept, quantum entanglement, uncertainty principle and wave-particle duality that apply in quantum chemistry, quantum field theory, quantum technology, and quantum information science.

In this EPN issue large scale transportation such as the movement of humans, goods, vehicles on land as well as motion of particles at the nanometric scale are presented.

In *Traffic flow from a physics perspective,* A. Schadschneider describes collective phenomena in nonequilibrium systems such as traffic jams and pedestrian dynamics. It is a very interesting topic because most likely we all experience nerve-breaking long lanes on the road and the stress in crowd streams.

In his contribution, *A physicist's approach to public transportation networks*, Y. Holovatch shows how statistical analysis and data processing work when dealing with a complex system of many interacting agents "non-physical" in nature.

V. Rodriguez-Franco *et al.* bring us to the molecular level by describing the *Controlled transport by molecular machines: exploring biological motors and their physics.* Biological machines are fascinating objects that play a crucial role in a variety of cellular processes. It is exciting to read how it is possible to manipulate and monitor the motion of molecular motors that are a paradigm for mass, energy, and information transport processes in the cell.

Certainly, most of us have performed once in our studies a Browian motion experiment. In *Zooming in on Brownian motion with optical trapping microscopy*, M. G. Raizen and colleagues explain how ultra-precise measurements of Brownian motion in various fluids can be done and how picosecond pulsed lasers can be used to measure the effects of flow compressibility on Brownian particles.

With N*on-equilibrium orbital angular momentum for orbitronics*, D. Go *et al.* brings us to the manipulation of magnetisation by electrical current in spintronics and the description of devices such as the spintronic memory based on the giant and tunneling magnetoresistance effects in heterostructures. Spintronics research has focused primarily on the spin degree of freedom, but the authors show that in non-equilibrium the orbital angular momentum of electrons can play an important role, leading to a new interdisciplinary field of research called "orbitronics".

I wish you an interesting reading experience. ■