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Ballistic motion of a Brownian particle

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This work contains plenty of intriguing physics. Related ballistic-to-diffusive behavior can be found in the transport of electrons in conductors, phonons in solids, and photons in opaque media. But perhaps even more prominent in physics today is the nature of an intervening subdiffusive plateau that develops for disordered liquids, colloids, bubbles, grains, and so forth that are on the verge of jamming.

For the Raizen–Li case of a single harmonically bound Brownian particle, it is possible to construct a mechanical analogue. A single centimeter-scale sphere driven stochastically in a horizontal plane by a turbulent but sub-levitating upward flow of air obeys not just equipartition and the Maxwell–Boltzmann speed distribution, but also the Langevin equation with colored noise satisfying the fluctuation–dissipation relation.[2] Therefore, the system has truly thermal behavior, but with a huge effective temperature, and the essence of Einstein's challenge is seen with the naked eye.

References

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2. R. P. Ojha et al., *Nature* **427**, 521 (2004); see also the videos accompanying the online version at http://www.nature.com/nature/journal/v427/n6974/full/nature02294.html.

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■ **Raizen and Li reply:** We are aware of the excellent work by Jixiang Zhu and coauthors, which we referenced in a recent review article.[1] Zhu and his team used dynamical light scattering to measure the mean square displacement $\langle \Delta r^2(t) \rangle$ of concentrated particles at short time scales and from it determined the velocity autocorrelation function. A more recent experiment with optical tweezers reported a similar result.[2] Neither of those prior experiments could resolve the instantaneous velocity of a Brownian particle, the topic of the 1907 paper by Albert Einstein. We stand by our assertion that the experiments reported in the Quick Study are the first such measurements.

The other work mentioned by Douglas Durian (his reference 2) examined the mechanical motion of a Ping-Pong ball in turbulent airflow. The researchers observed that the ball behaved like a Brownian particle and is a beautiful simulation with a macroscopic system. The effective temperature is on the order 10^{17} K, so that clearly is not the case discussed by Einstein, in which the Brownian motion is directly caused by the thermal fluctuations of molecules at the actual temperature of the system.

References

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Historical note on fiber bundles

C. N. Yang, in his clear review of Maxwell's equations and gauge theory (PHYSICS TODAY, November 2014, page 45), reports that his colleague mathematician James Simons exclaimed, "[Paul] Dirac had discovered trivial and nontrivial bundles before mathematicians." Remarkably, however, in 1931, the same year that Dirac discovered his monopole, Heinz Hopf discovered its fiber-bundle equivalent, now known as the Hopf fibration of the 3-sphere.[1]

Although Eli Lubkin pointed out the bundle structure of the Dirac monopole[2] in 1963 and Tai Tsun Wu and Yang provided a widely read description,[3] Andrzej Trautman apparently first noted its identification with the Hopf fibration[4] in 1977. Trautman's 1967 lectures at King's College London introduced some physicists to the mathematical equivalence of gauge theories and fiber-bundle theory, but not until 1970 were those lectures published.[5] Yang notes that the equivalence came as a shock to both physicists and mathematicians in the 1970s.

References

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Correction

February 2015, page 8—The headline for the second letter should read, "Discovering the ozone hole." ■