Turbulence yields secrets to 73-year-old experiment

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A simple but groundbreaking experiment performed more than 70 years ago finally has been explained by scientists at the University of Illinois at Urbana-Champaign. The solution sheds new light on fluid turbulence -- the last major unsolved problem in classical physics.

"Turbulence is the jittery, swirling behavior of a gas or liquid when flowing next to a wall or around an obstacle," said Gustavo Gioia, a professor of theoretical and applied mechanics at Illinois. "Although most of the flows that surround us in everyday life are turbulent flows over rough walls, these flows have remained one of the least understood phenomena of classical physics."

In 1933, Johann Nikuradse carefully measured the friction a fluid experiences as it is forced through a pipe at varying speeds. Nikuradse found that the friction gets smaller as the speed gets larger, but then surprisingly increases at high speeds before attaining a constant value. This mysterious behavior, which must be taken into account by engineers in applications ranging from airplanes to oil pipelines, has now been explained.

In a paper to appear in the Feb. 3 issue of the journal *Physical Review Letters*, Gioia and graduate student Pinaki Chakraborty show how this behavior arises from fundamental properties of the way in which energy is distributed among the swirling eddies that populate a turbulent flow.

"As a result of our theoretical explanation, engineers can now calculate the friction force found along rough walls, rather than rely upon a chart or table based on the Nikuradse data," Chakraborty said.

In related work, to appear in the same issue of Physical Review Letters, Illinois physics professor Nigel Goldenfeld shows how the behavior implies that the turbulent state is not random, but contains subtle statistical correlations that are similar to those known to exist at phase transitions, such as the onset of magnetism in crystals.

"These findings suggest a new tack for theorists trying to understand turbulence," Goldenfeld said. "The roughness of the pipe walls is important and affects the flow in ways previously overlooked."

The researchers hope that as a result of these discoveries, the approaches that solved the problem of phase transitions will now find a new application in providing a fundamental understanding of turbulence.

Source: University of Illinois at Urbana-Champaign