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ILLINOIS STYLE: New UI research looks into classic unsolved problem

By GREG KLINE
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CHAMPAIGN, Ill. -- Put a cutting board in the bottom of your kitchen sink and turn on the faucet.

You should see a thin film of water in the rough circle that makes up the middle, a band of roiling, albeit miniature, rapids after that and finally a stretch where the puddle you've made flattens and flows with more or less even regularity.

You're seeing a liquid flow in its transition to turbulence, often referred to as the last major unsolved problem in classical physics.

Gustavo Gioia started thinking about turbulence because of the meanders on rivers like the Sangamon -- rather than his kitchen sink -- and meeting colleagues who also liked to speculate about what makes flowing liquids turbulent.

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Now, Gioia, University of Illinois Professor Nigel Goldenfeld and graduate student Pinaki Chakraborty have taken a step toward a solution for fluid turbulence.

Goldenfeld, a physics professor, emphasized that their findings don't solve turbulence, one of the few physics questions for which a bounty has been placed on the answer.

But the UI research might help explain some of the fundamentals behind the jittery, swirling behavior of liquids and gases when they flow, which plays a role in everything from what makes it rain to how rivers run and how fish swim in them.

"I do think that what we've done is the first new step in this direction for a long time," Goldenfeld said.

While most of the flows around us in everyday life are turbulent flows over rough walls and obstacles, they have remained one of the least understood phenomena of physics, said Gioia, a theoretical and applied mechanics professor.

And yet, they have to be accounted for in a variety of practical situations.

Build an oil pipeline, for instance, and you have to factor in the friction the flow will experience to know how big a pipe you need to move it.

Likewise with air flowing around an airplane wing, where a design that decreases friction even a little could be worth billions in saved fuel costs, Goldenfeld said.

Johann Nikuradse, a German engineer, fashioned one of the best tools scientists and engineers have for understanding turbulence in experiments in the 1930s. He carefully measured the friction a fluid experiences as it is forced through a pipe at varying speeds, resulting in tables that can be used to figure out friction's impact in a particular project.

Nikuradse also found that friction decreases as speed increases but then, surprisingly, increases at even higher speeds before attaining a constant value.

But being able to account for that phenomenon using experimental data, which also has to be generated for new materials as they come along, isn't the same as understanding why it occurs, allowing it to be calculated, or modeled, mathematically.

That's where the work by Gioia and Chakraborty, a graduate student in theoretical and applied mechanics, comes in.

Over time, they came up with a theory that the phenomenon Nikuradse observed arises from the way energy is distributed in the eddies populating a turbulent flow.

Married to work done previously by other researchers and applied in calculations, their theory yielded results that mirrored, and even improved upon in some ways, the results yielded by the tables.

"We were surprised," Gioia said. "It was unbelievable."

Chakraborty said engineers should now be able to calculate friction's impact, rather than relying on tables based on the Nikuradse data.

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