https://doi.org/10.1038/s42254-026-00982-1

Physics students learn the ropes

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Could this be the world's only physics course with a swimming prerequisite?

Since 2024, students at Cornell University have had the opportunity to take Physics of Sailing, a course where about half the sessions happen on sailboats. On the lake, students conduct physics experiments based around their sailing activities – supplemented by lectures on topics like Newton's laws, oscillators and aerodynamics, along with types of tall ships and rules about right of way on the water. The course is run by Georg Hoffstaetter de Torquat, an accelerator physicist and keen sailor, who shared with *Nature Reviews Physics* how the course lets students experience physics problem solving in a new way.

How did you get started? Where did the idea for Physics of Sailing come from?

The course grew from two longstanding passions of mine: physics research and sailing. Like any physicist, I've always enjoyed asking why things behave the way they do. When I took my first sailing class on Lake Michigan as a physics graduate student, I found that the consequences of such questioning are felt particularly strongly on a sailboat. Breathless from being in the grip of wind and weather, I was, however, disappointed to learn sailing procedures, rules and sequences, but not the physics behind them. It was there, aboard a 40-foot sloop, that I dreamt of one day teaching a course on the physics of sailing. Thirty years later, I finally found the opportunity to develop this class at Cornell, where it was first offered in 2024.

Over three decades of teaching and research, the idea evolved beyond explaining why sailboats work. I wanted students to experience how physicists think: forming hypotheses, designing experiments, building mathematical models, understanding measurement uncertainties and communicating results through laboratory reports.

Were there any notable hurdles?

At Cornell, every new course must be approved by an educational policy committee. Because of the course's unconventional nature, I wasn't sure how it would be received. To my surprise, it was approved immediately, and I was encouraged to teach it the very next semester, before I had even finished developing all of the material.



The logistics were initially challenging. The course combines classroom instruction with weekly sailing sessions before fall break, followed by lectures, data analysis and report writing afterwards. Since most students have never sailed before, every boat carries an experienced sailor in addition to the students. Recruiting these sailors, renting boats, arranging insurance and coordinating schedules required substantial planning. Cornell's Merrill Family Sailing Center was instrumental in making it all possible.

What are the students like? What backgrounds do they have, and what are they looking for in the course?

The students come from remarkably diverse backgrounds. Only about 15% are physics majors, and some have not taken physics since high school. Most have never sailed before, although many already enjoy water sports through rowing, swimming or recreational boating.

Some enrol because they love physics. Others sign up simply because sailing sounds interesting and discover that physics becomes much more engaging when they can experience the concepts directly.

Some immediately grasp the mathematics, while others have exceptional physical intuition on the water. One pleasant surprise has been how naturally students with such different strengths learn from one another.

Have you received any notable or unexpected student feedback?

One of my favourite moments came after we had followed the America's Cup in class and discussed both boat performance and racing rules. At the end of the semester, the students gave me a large LEGO model of the winning New Zealand boat. [The America's Cup is probably the most famous sailing competition and the oldest continuous international sporting competition in general, won most recently in 2024 by the Royal New Zealand Yacht Squadron.] I quickly assembled it and then used it to quiz them on the different parts of the boat during the final exam.

Another memorable moment came when a captain of Cornell's varsity rowing team told me that the course had improved his understanding of rowing.

Several students have also told me that this was the first time they genuinely enjoyed physics because they could finally connect the equations to something tangible.

Tell us about a typical session on the water and a typical session indoors.

The classroom and the lake complement one another.

In class we develop the underlying physics: forces, torques, fluid dynamics, stability, waves, resonant oscillations and measurement techniques. Students then head onto the lake to test those ideas. They compare sail trims, measure boat speeds, investigate weather helm, explore how heel angle and weight distribution affect performance, and investigate the boat's stability against capsize. Before every experiment, they are asked to predict what will happen and then compare those predictions with reality.

The goal is that every sailing exercise becomes a physics experiment.

One challenge is that the lake is too cold in spring, so the course is offered in the fall. Since boats can only be rented before fall break, the

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practical work comes first, followed by deeper theoretical discussions and data analysis afterwards. In some cases, students perform experiments before they have formally encountered all of the underlying theory.

How does teaching around sailing rather than a traditional subject change how you teach?
Traditional physics courses are organized by disciplines: mechanics, electromagnetism, thermodynamics, fluid dynamics and so on.

Nature isn't.

This course is organized around a real physical system. Students don't ask, "Which chapter does this belong to?" They ask, "What physics do I need to understand what's happening?"

That reflects much more closely how physicists actually work. It also lets students see how ideas from many different areas of physics naturally interact while simultaneously practicing skills of a scientist, experimental design and execution, data analysis and scientific communication.

For me, this course is ultimately about teaching students to think like physicists. Sailing simply provides an extraordinarily rich laboratory where almost every observation leads naturally to a quantitative question. If students leave the course looking at the natural world with greater curiosity and greater confidence in their ability to understand it through physics, then I think we've succeeded. If they also discover a lifelong love of being on the water, that's an added bonus.

Has teaching the course changed how you think as a physicist?
Absolutely.

Watching students return to the harbour excited about real data that explain something they just experienced has reinforced for me how powerful learning becomes when the subject matter is immediately relevant.

It has also reminded me that physics education is about far more than mathematics. The equations remain essential, but students must also develop intuition: understanding which effects dominate a phenomenon, which can safely be neglected, and how to decide between competing explanations.

Finally, what's your favourite counter-intuitive fact about the physics of sailing?
One of my favourites comes from water waves. The dispersion relation of deep-water waves produces remarkably universal wake patterns. Ducks, kayaks, sailboats and even container ships all generate wakes with strikingly similar geometric features despite their enormous differences in size and speed.

I'm also still amazed that sailboats can travel upwind faster than the wind itself. Even though I know the physics and have experienced it myself it still feels almost magical.

Georg Hoffstaetter de Torquat was interviewed by Zoe Budrikis.

Published online: 22 September 2026

Competing interests
G.H.d.T. declares no competing interests.