Introduction to Fluid Mechanics

School of Electronic, Electrical, and Mechanical engineering
Faculty of Engineering

Who am I? – educational journey

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Undergraduate: Mathematics – University of Cambridge

Jobs: Research intern at DAMPT, Cambridge

PhD: Scholarship by University of Bristol

Engineering Courses at UoB

- Aerospace Engineering – understanding aeromechanics and how to build systems for controlling flight; from planes to space shuttles
- Civil Engineering – improving the built environment we live in; from buildings to transport networks and even our water supply
- Engineering Design – learning how to solve problems creatively and lead complex engineering projects
- Engineering Mathematics – using mathematical and data modelling to solve real-world problems in areas like social media or climate change
- Mechanical Engineering – how materials behave and what we can use them for; from making better batteries to building robots
- Electrical and Electronic Engineering – gaining skills to work in industries such as consumer electronics, alternative energy and transport
- Computer Science – using algorithms and programming, seeing how humans and computers interact; from networks to cybersecurity

Mechanical Engineering at UoB

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Mechanical Engineering at UoB

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Year 1 - First-year students studying Aerospace Engineering, Civil Engineering, Mechanical Engineering, Mechanical and Electrical Engineering, and Engineering Design all start their degree with a broad knowledge of the fundamentals and a command of the skills that underpin modern engineering.

Year 2 - Second year students continue to cover the fundamental principles of mechanical engineering. Teaching is delivered via lectures, seminars, laboratories, design classes and short projects in modelling and manufacturing.

Year 3 - In your third year you will apply the principles you have learnt to real, complex engineering applications. A major element is the open-ended individual research project, which requires independent and creative thinking.

A- level standard offer - A*AA including A*A (in any order) in Mathematics and any one of Physics, Chemistry, Further Mathematics, Computer Science, or Electronics

Here’s what we’ll talk about today

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- Understand what fluid mechanics is
- Look at some applications of fluid mechanics
- To understand that there are different types of flows
- Understand why fluid mechanics is important

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- Transitional flow: type of flow that is a mixture of laminar and turbulent flow

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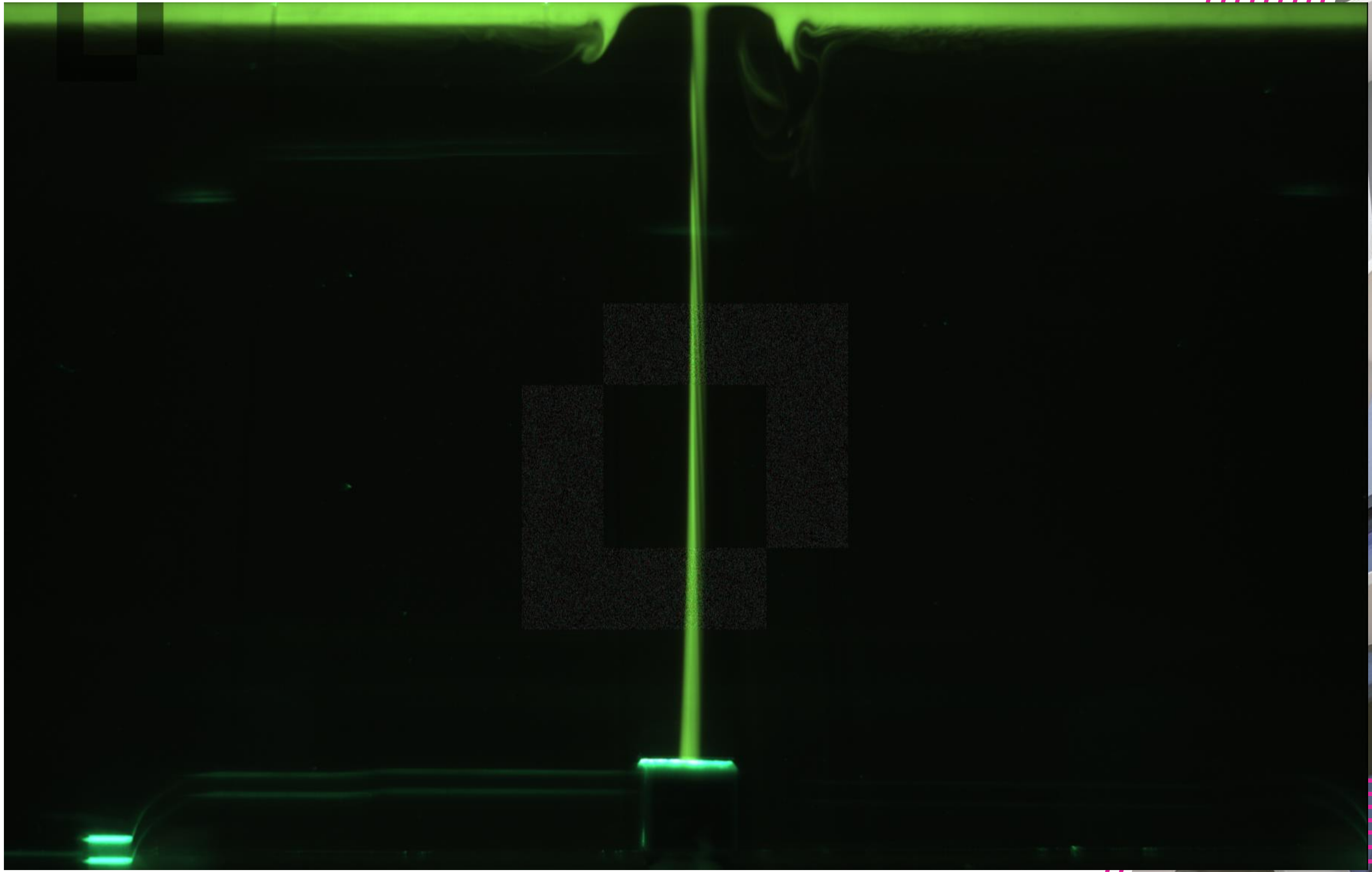
The Reynolds number is a dimensionless quantity which can be calculated using the formula below

$$Re = \frac{\rho v l}{\mu} = \frac{v l}{\nu}$$

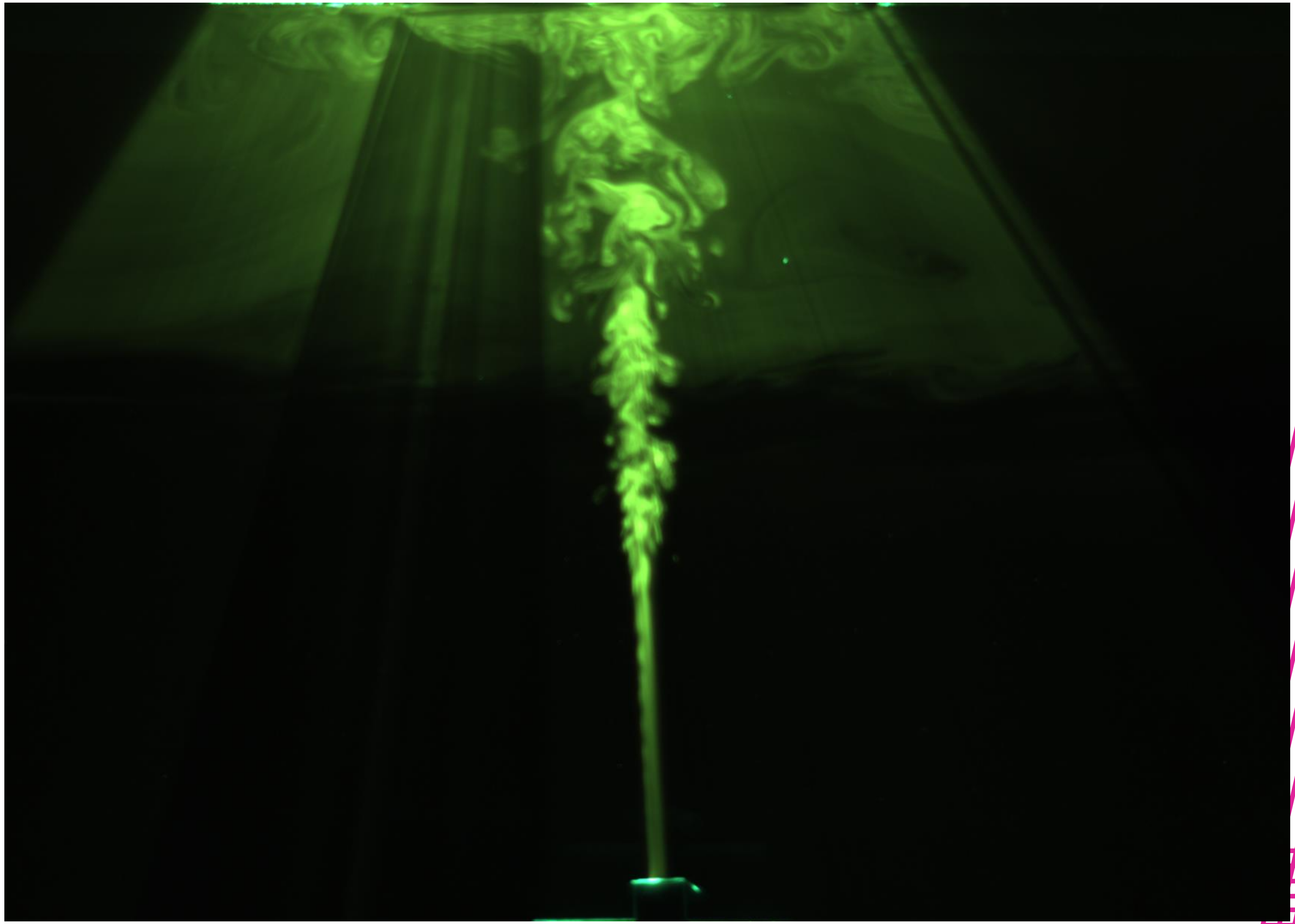
Where:

v = Velocity of the fluid
l = The characteritics length, the chord width of an airfoil
ρ = The density of the fluid
μ = The dynamic viscosity of the fluid
ν = The kinematic viscosity of the fluid

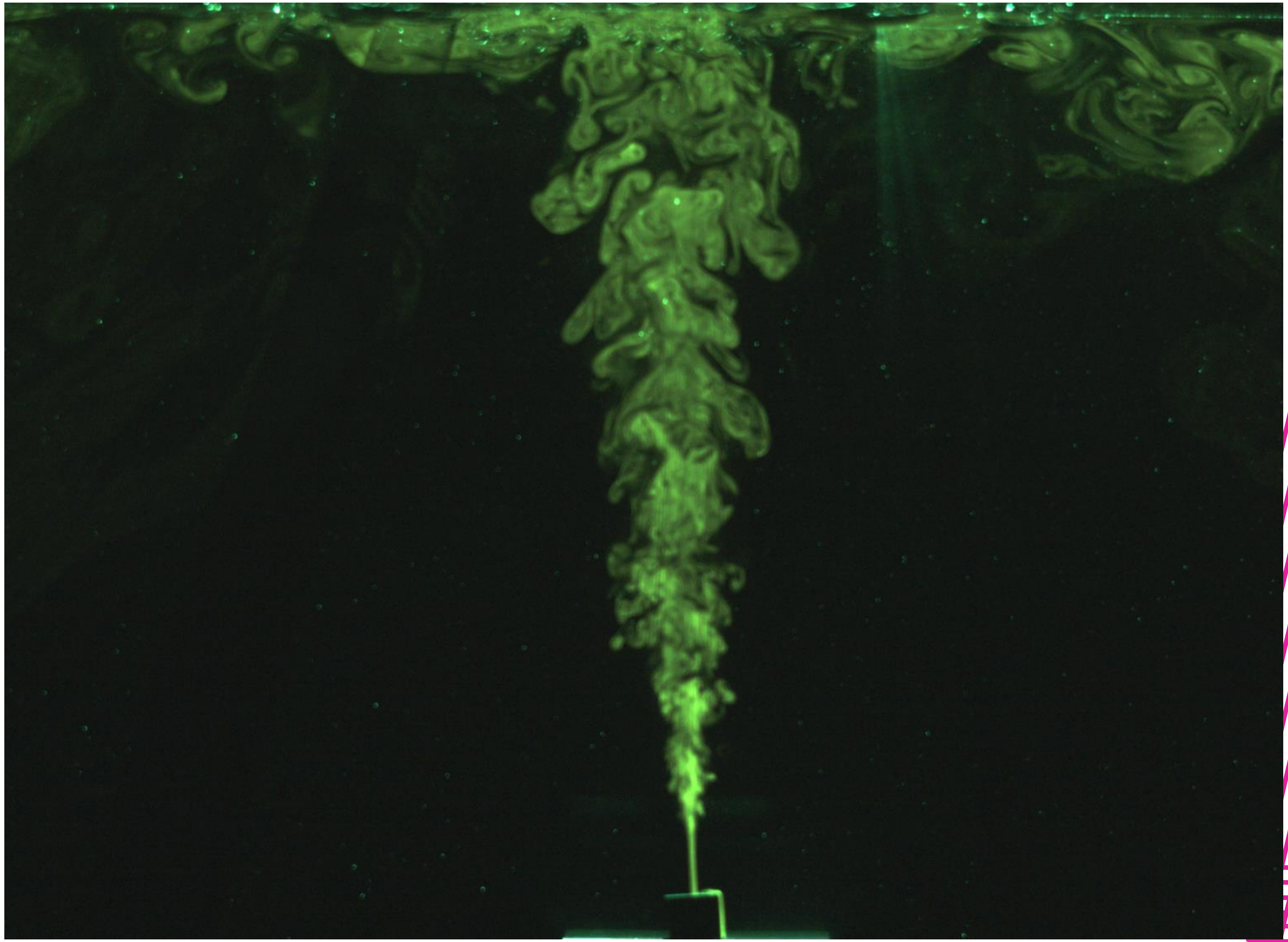
Laminar flow (Re lower than 2100)



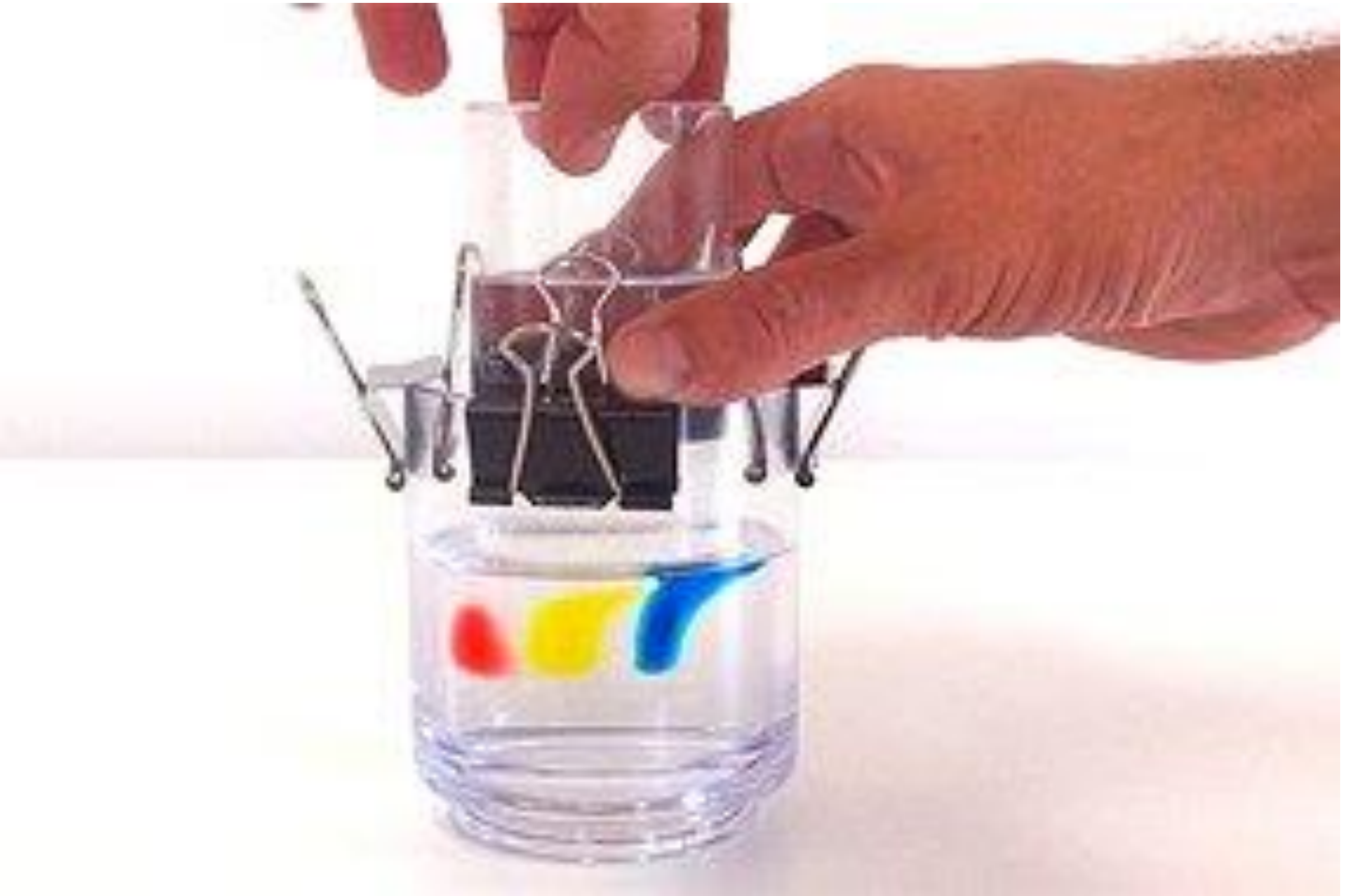
Transitional flow (Re between 2100 and 4000)



Turbulent flow (Re greater than 4000)



Laminar flow experiment



https://youtu.be/UpJ-kGII074?feature=shared

Laminar flow experiment

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- This experiment works because of laminar flow!

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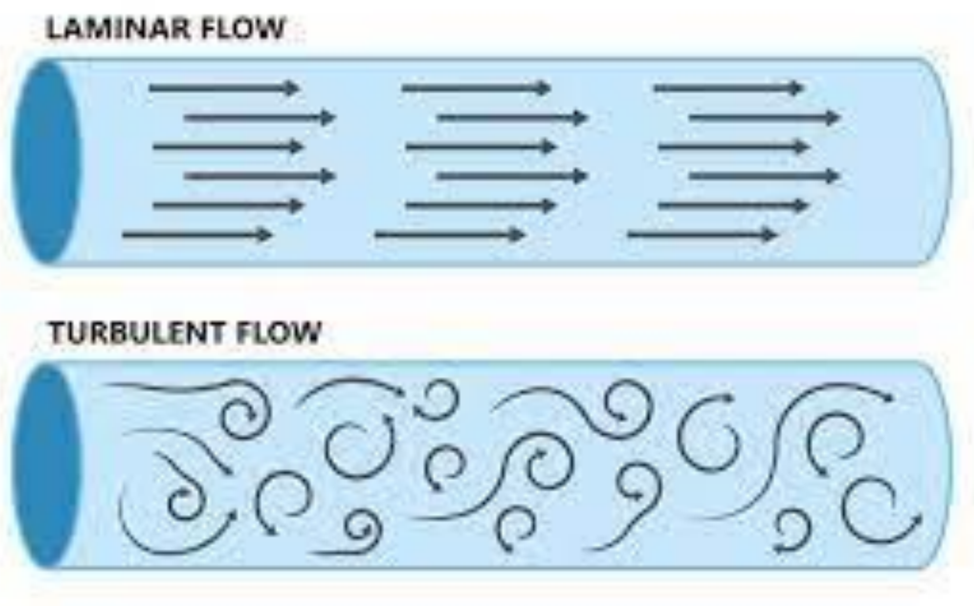
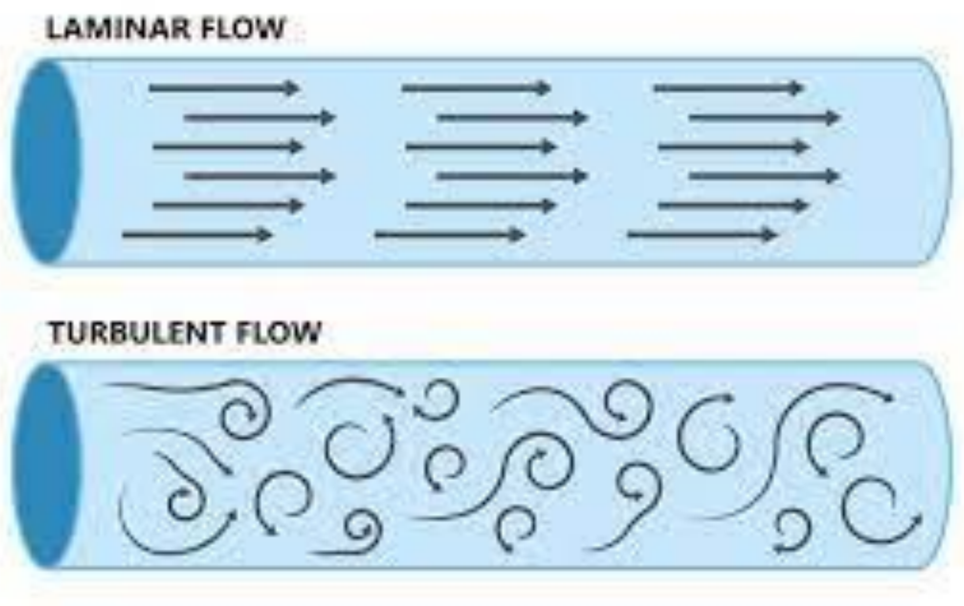
- This is an example of a low Reynolds number laminar flow, which means there are many parallel layers of the liquid.



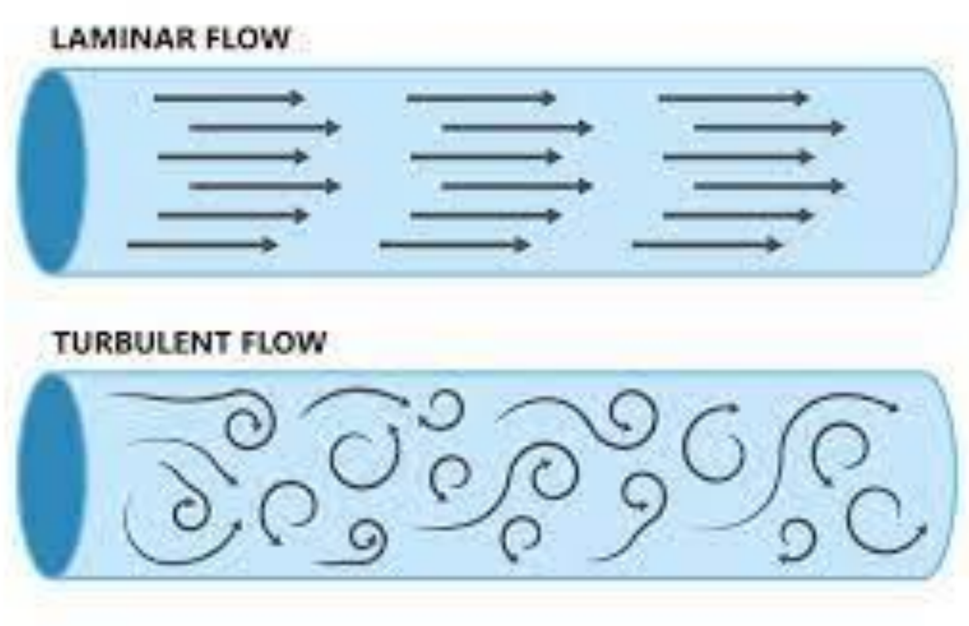
Laminar flow experiment

- This experiment works because of laminar flow!
- This is an example of a low Reynolds number laminar flow, which means there are many parallel layers of the liquid.
- As the smaller cup is rotated, the dyes remain within their original layers.



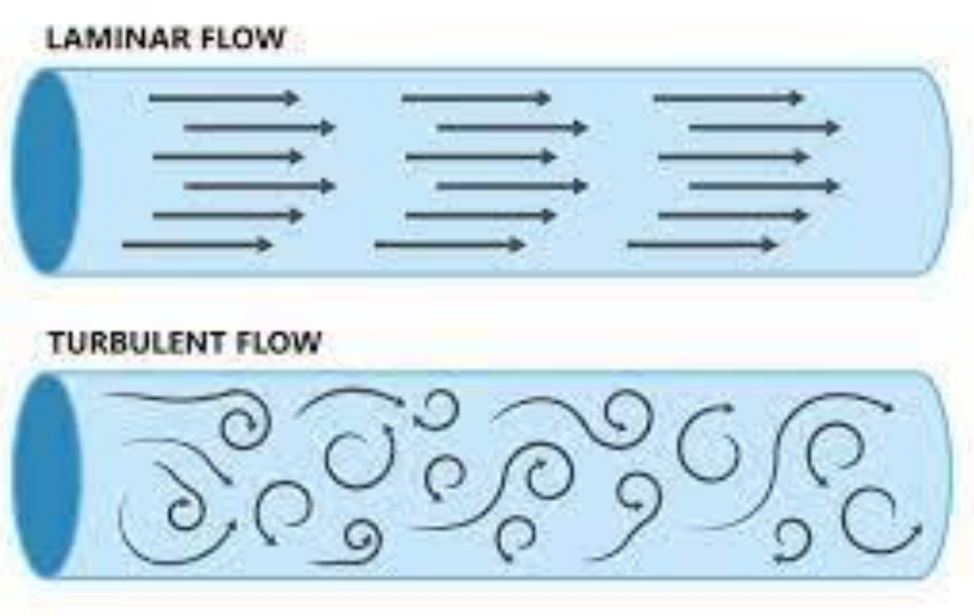
Laminar flow experiment

- This experiment works because of laminar flow!
- This is an example of a low Reynolds number laminar flow, which means there are many parallel layers of the liquid.
- As the smaller cup is rotated, the dyes remain within their original layers.
- As the crank is turned backward, the process is inverted.



Laminar flow experiment

- This experiment works because of laminar flow!
- This is an example of a low Reynolds number laminar flow, which means there are many parallel layers of the liquid.
- As the smaller cup is rotated, the dyes remain within their original layers.
- As the crank is turned backward, the process is inverted.
- Since there is no turbulence in this laminar flow, the process can be inverted almost perfectly!

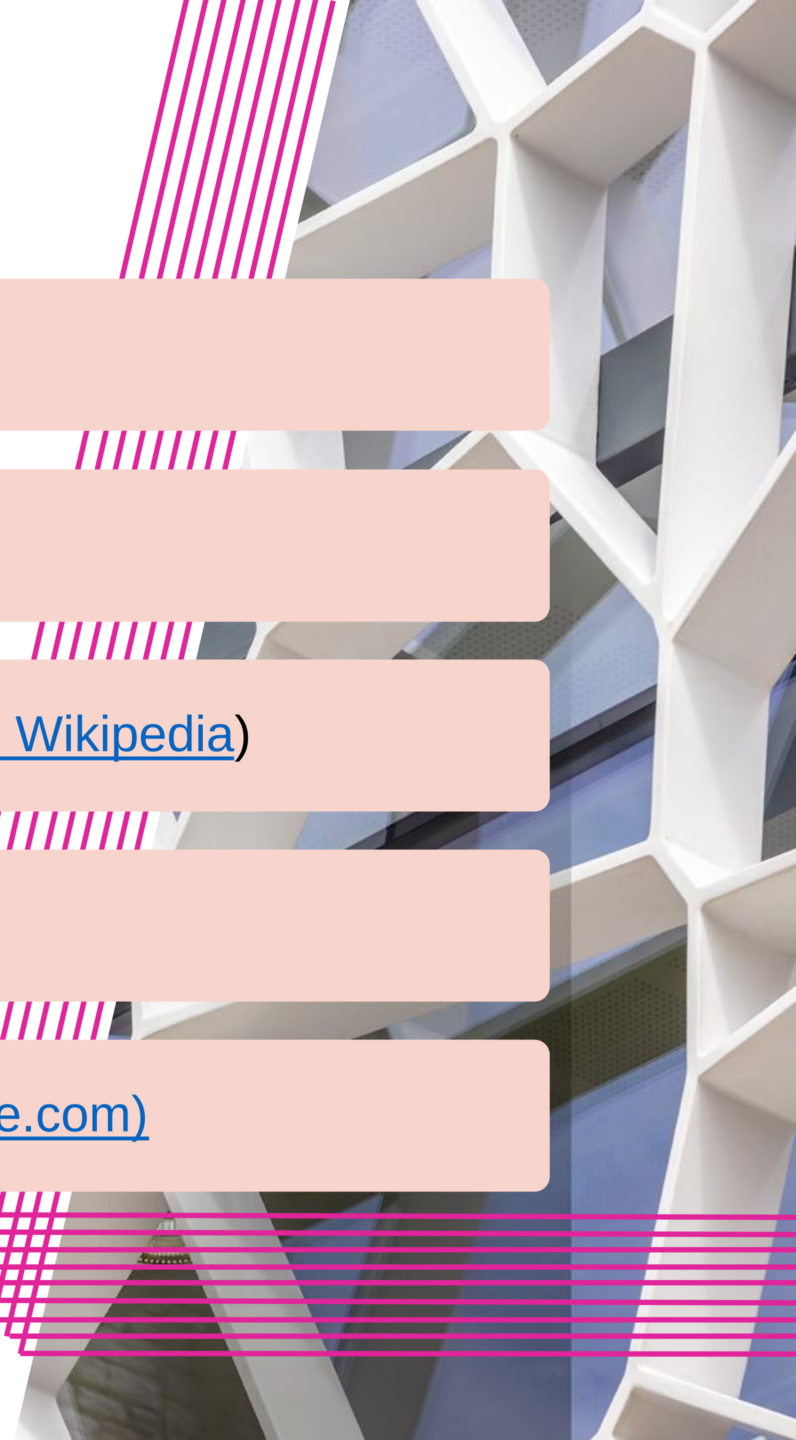


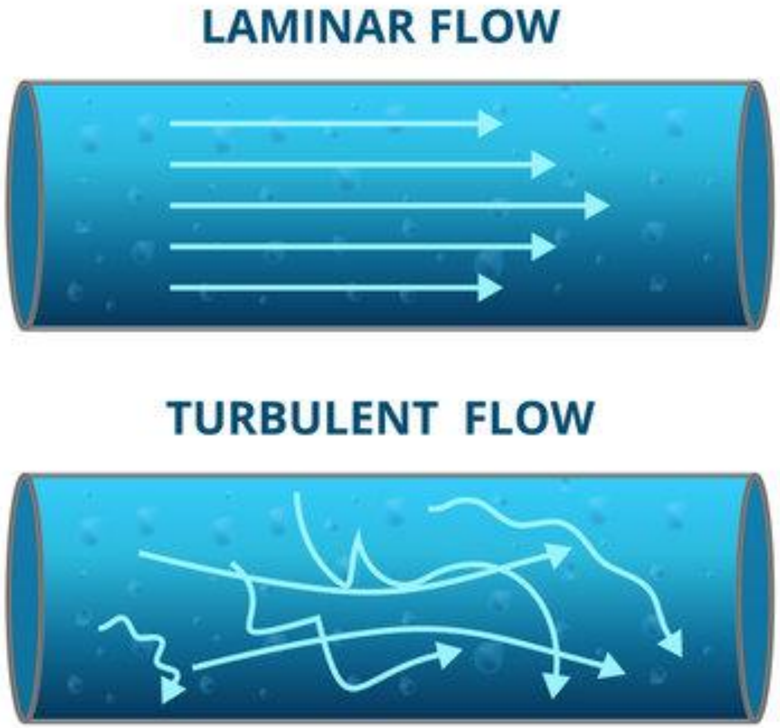
Can anyone think of any examples of fluid mechanics in action?

Here are a few examples:

Here are a few examples:

- Water coming out of a tap
- Cars moving through traffic
- Pattern formation in boiling liquids (Rayleigh–Bénard convection - Wikipedia)
- The motion of people in crowds
- Somerset Starling Murmurations | Bristol Nature Channel (youtube.com)





Now let’s classify these flows into laminar, turbulent or transitional

What is shown in this image?

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Where does Fluid mechanics come into nuclear energy generation?

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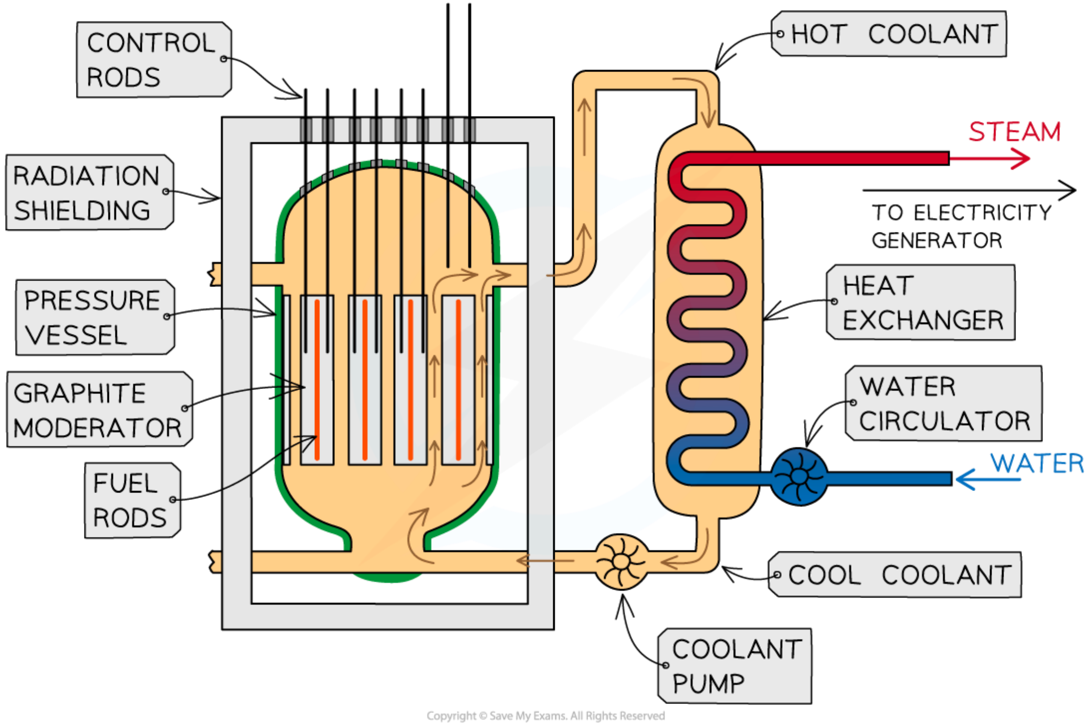

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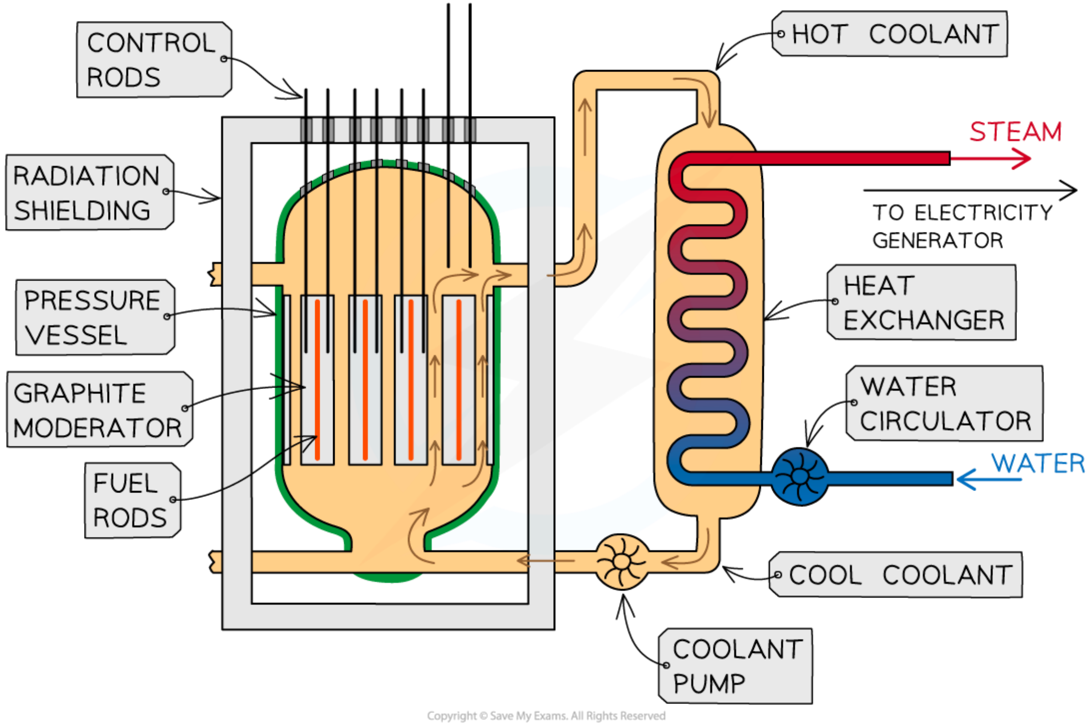

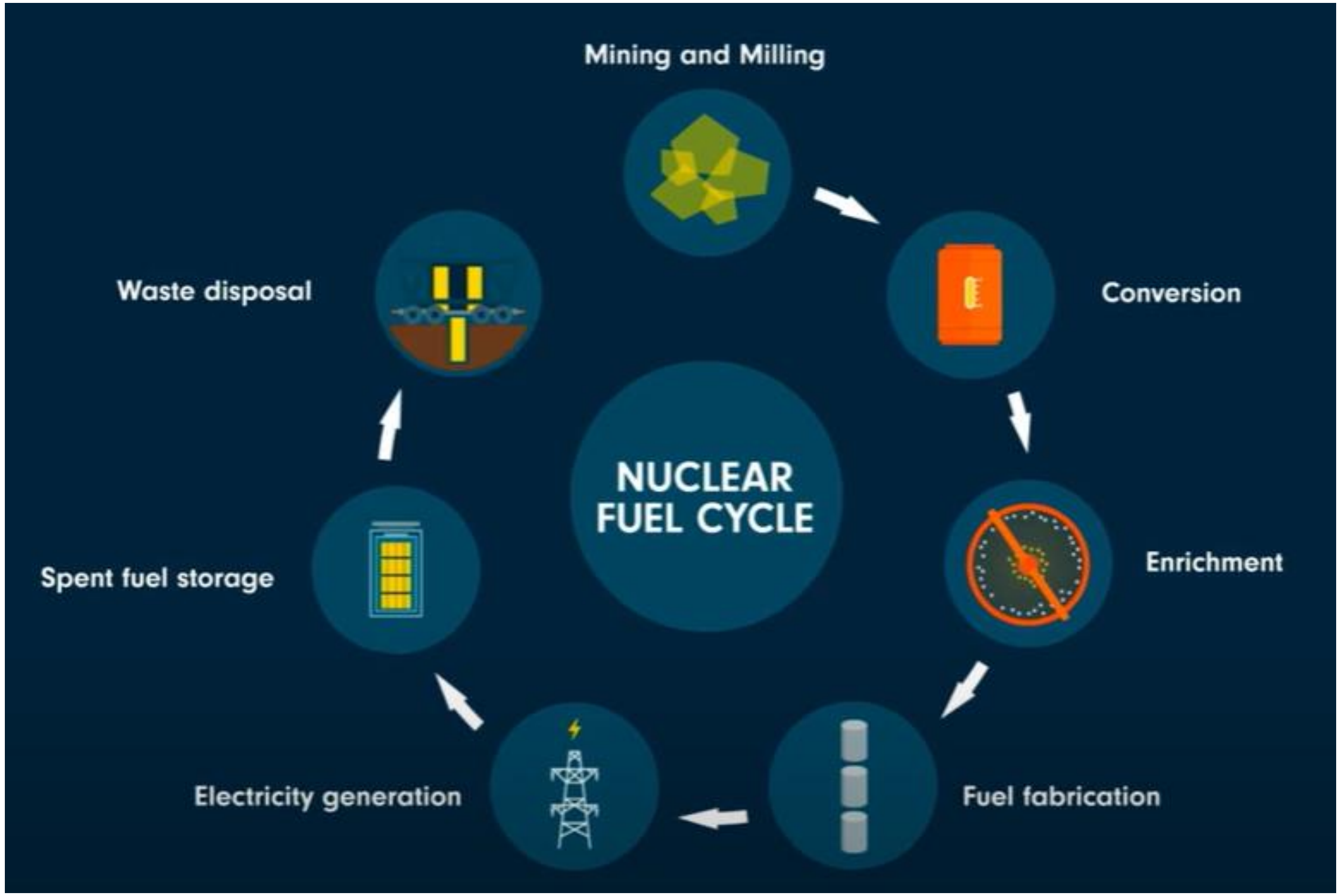

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Nuclear Waste Is Piling Up. Here's How to Fix the Problem

OCTOBER 18, 2023 | 5 MIN READ

Nuclear Waste Is Piling Up. Here's How to Fix the Problem

My research

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My research

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- The problem is nuclear waste produces hydrogen gas.
- This poses a safety risk as hydrogen can be explosive.
- This hydrogen gas flows out of the waste packages.
- My research looks at how this hydrogen collects and how we can reduce the explosion risk.

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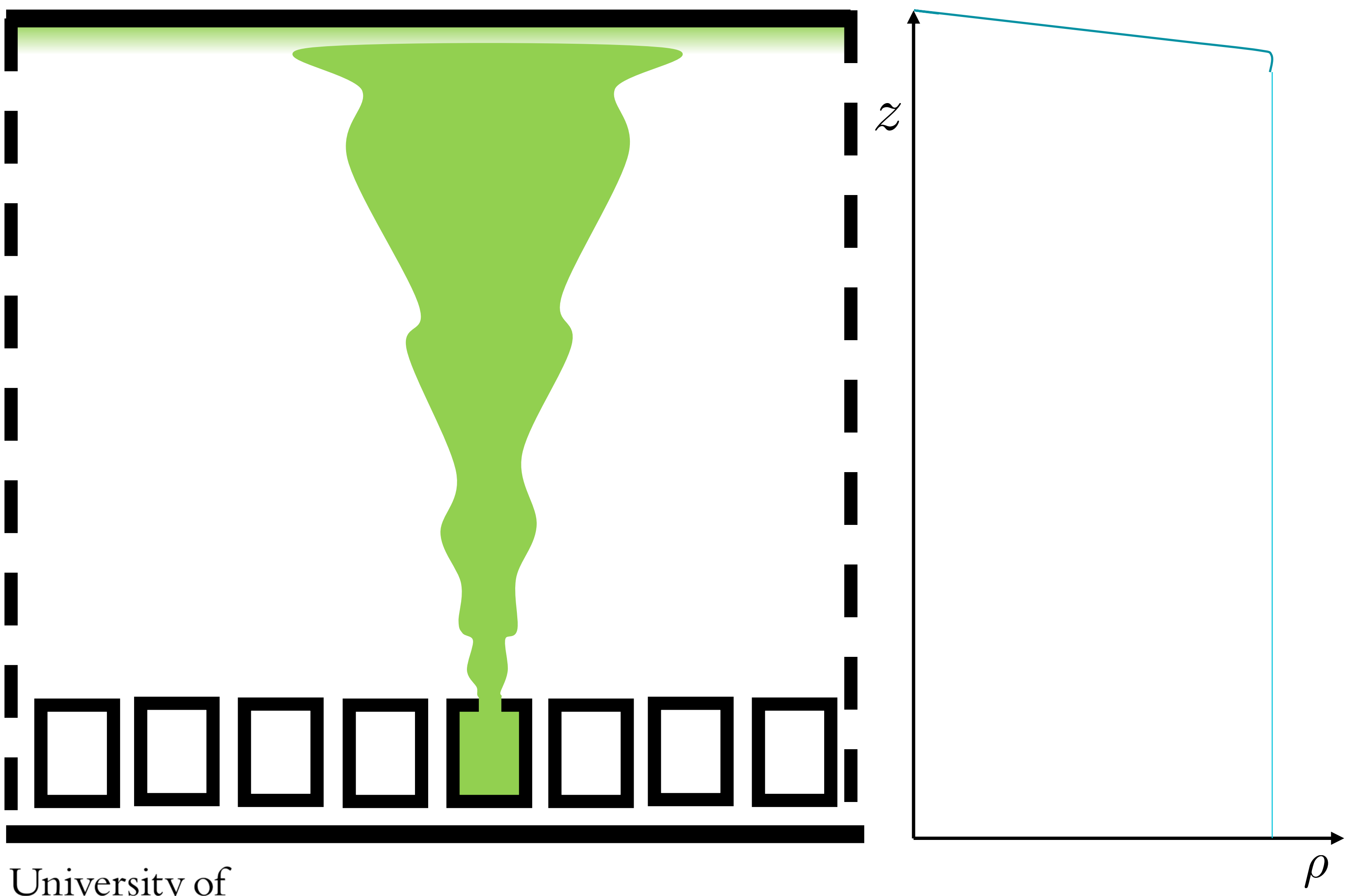

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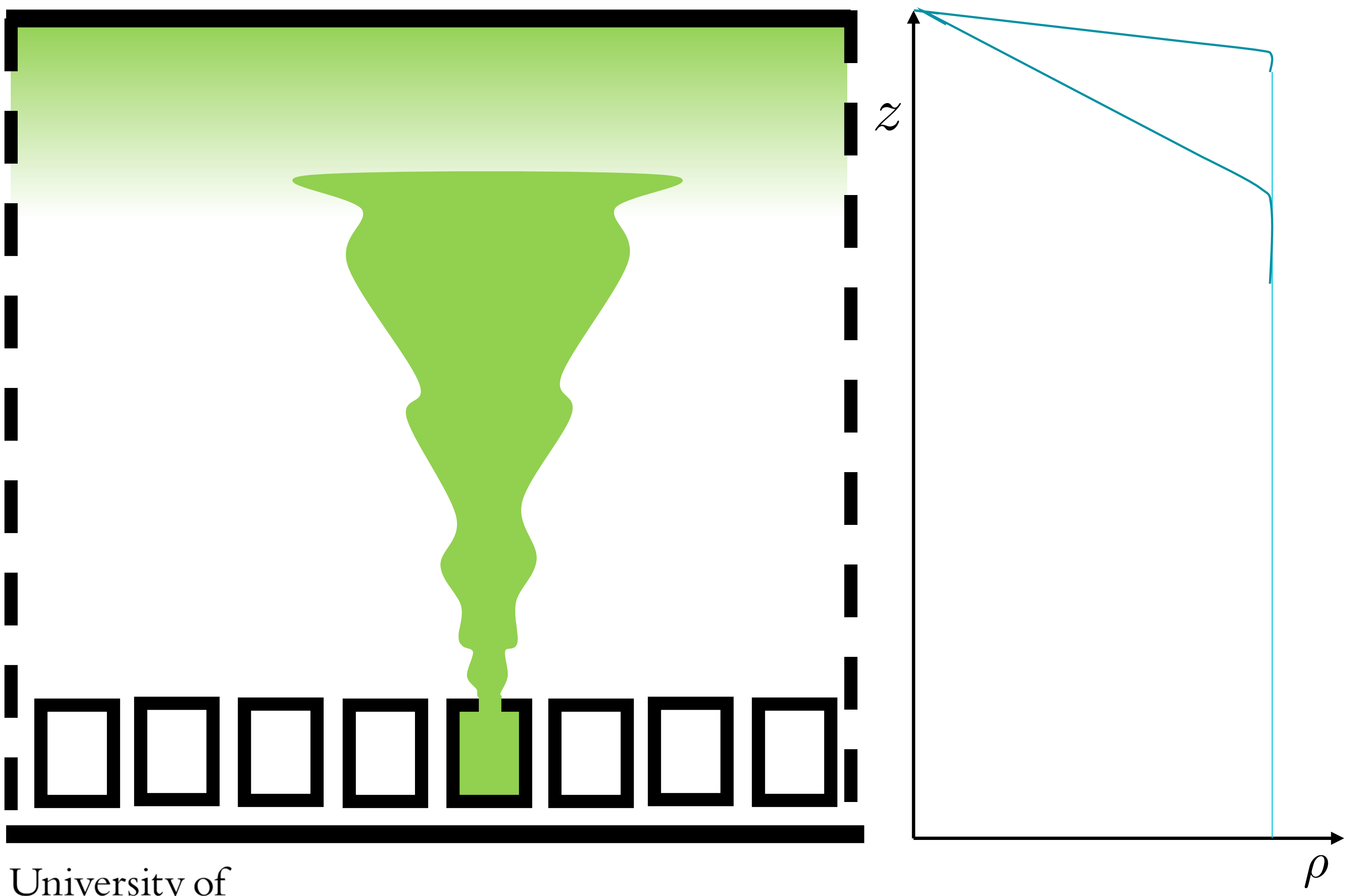

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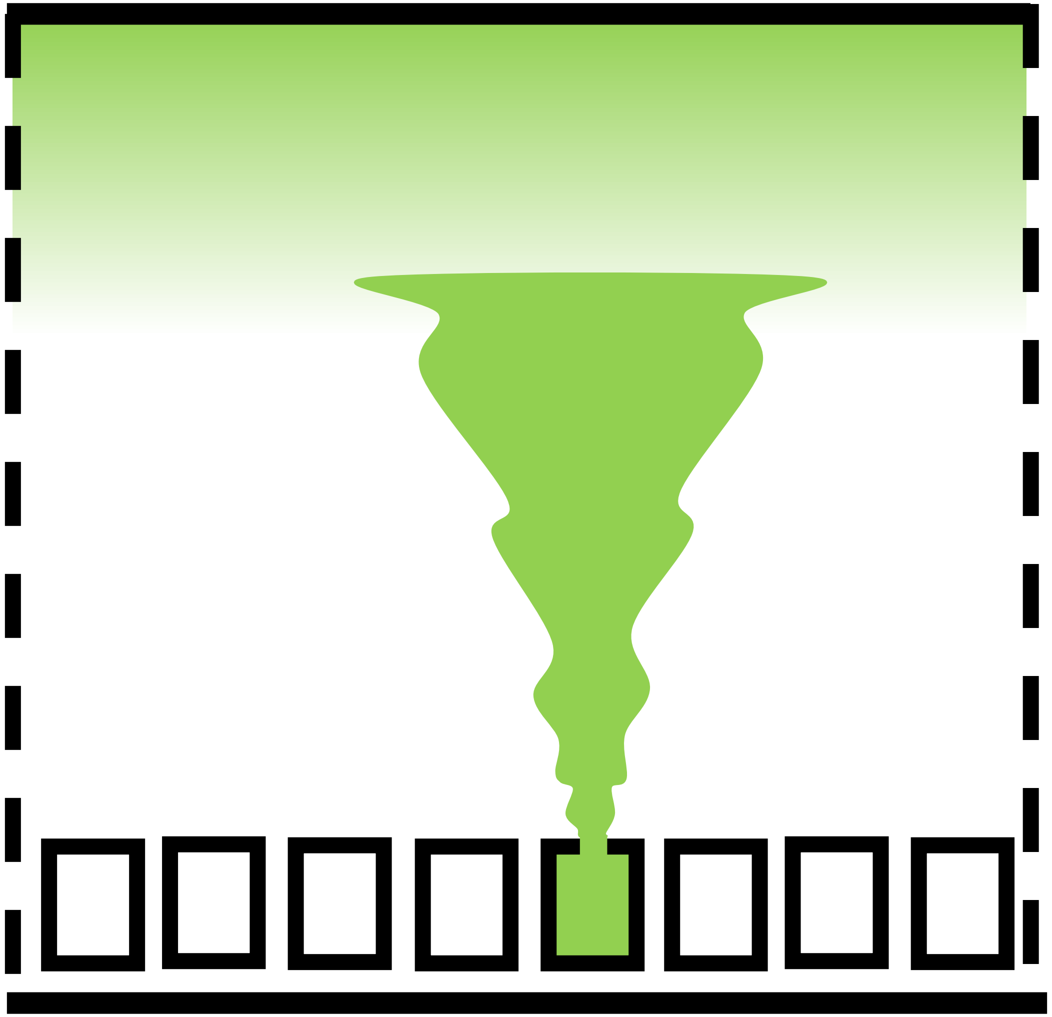

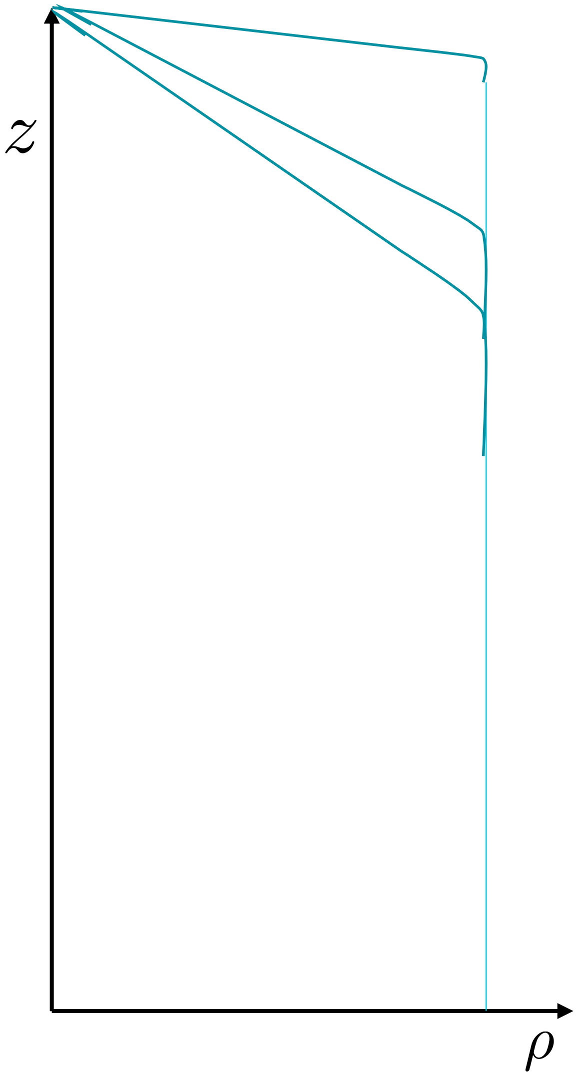
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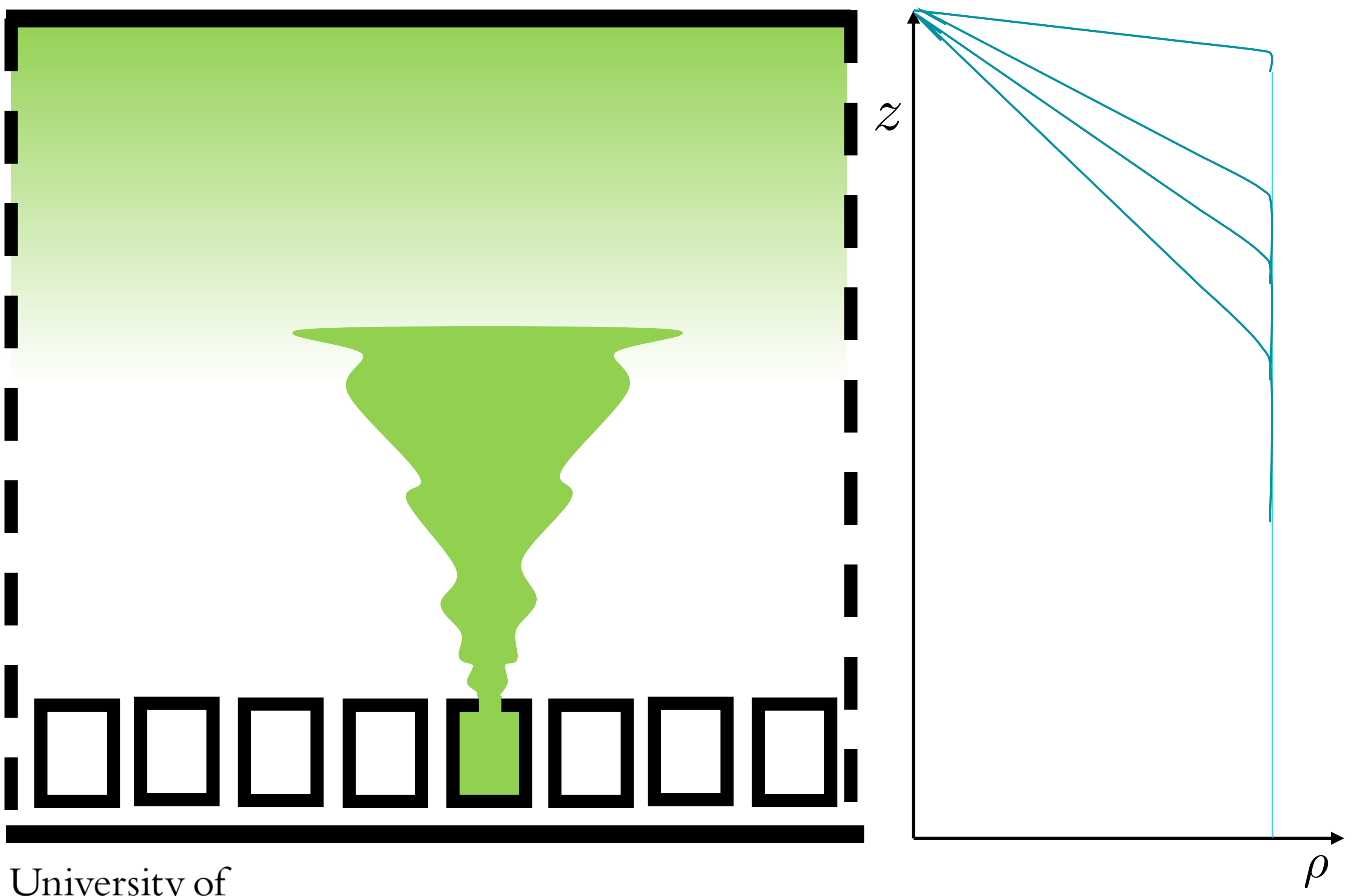

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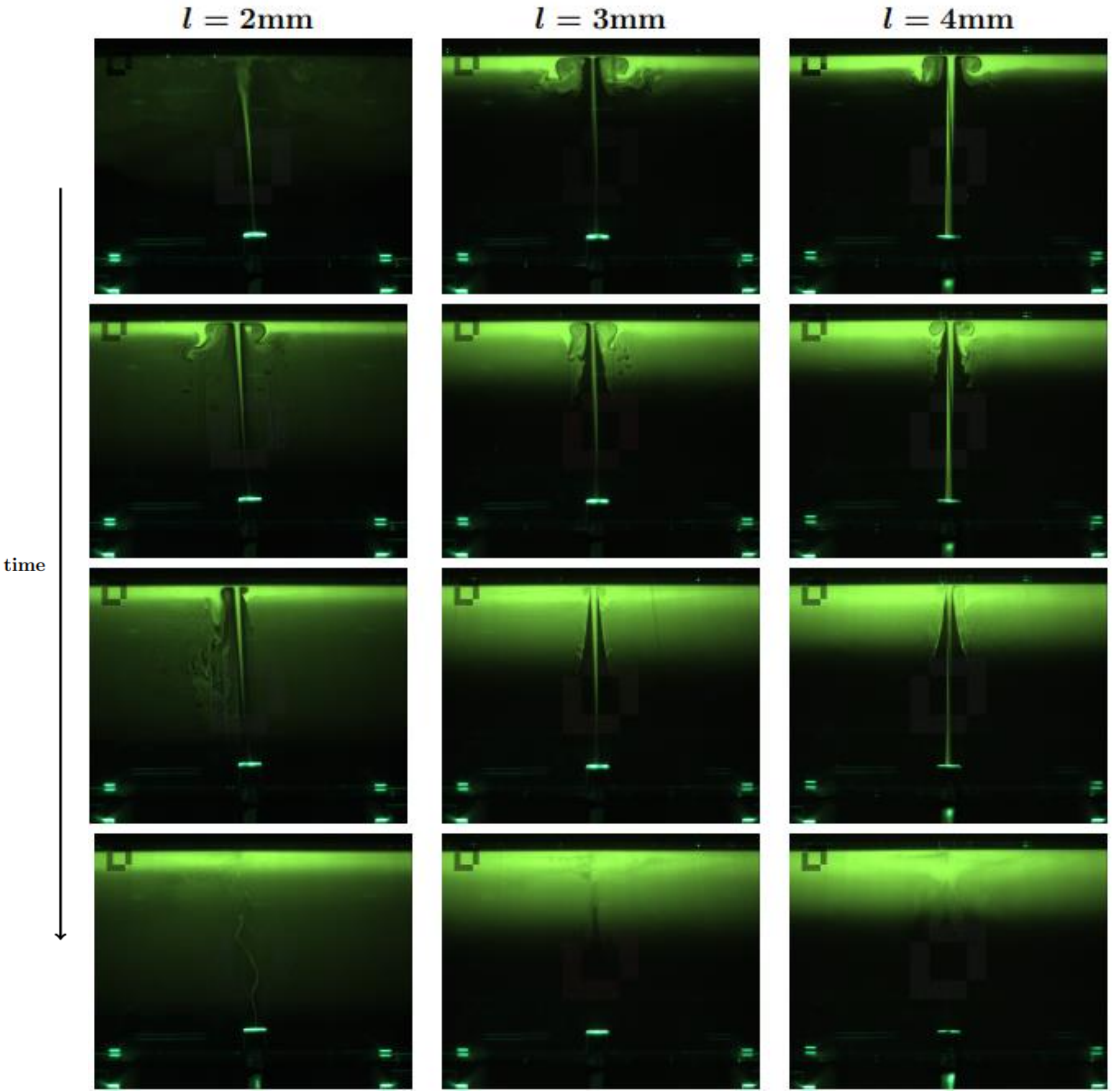

Research Support Office

Modeling hydrogen accumulation

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The Navier-stokes equation can help describe the motion of Fluids so can be used to create some models

$$\rho\left(\frac{\partial\vec{u}}{\partial t}+(\vec{u}\cdot\nabla)\vec{u}\right)= -\nabla p+\mu\nabla^2\vec{u}\cdot$$

Modeling hydrogen accumulation

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$$\rho\left(\frac{\partial\vec{u}}{\partial t}+(\vec{u}\cdot\nabla)\vec{u}\right)= -\nabla p+\mu\nabla^2\vec{u}.$$

This equation however has not been solved in three dimensions!

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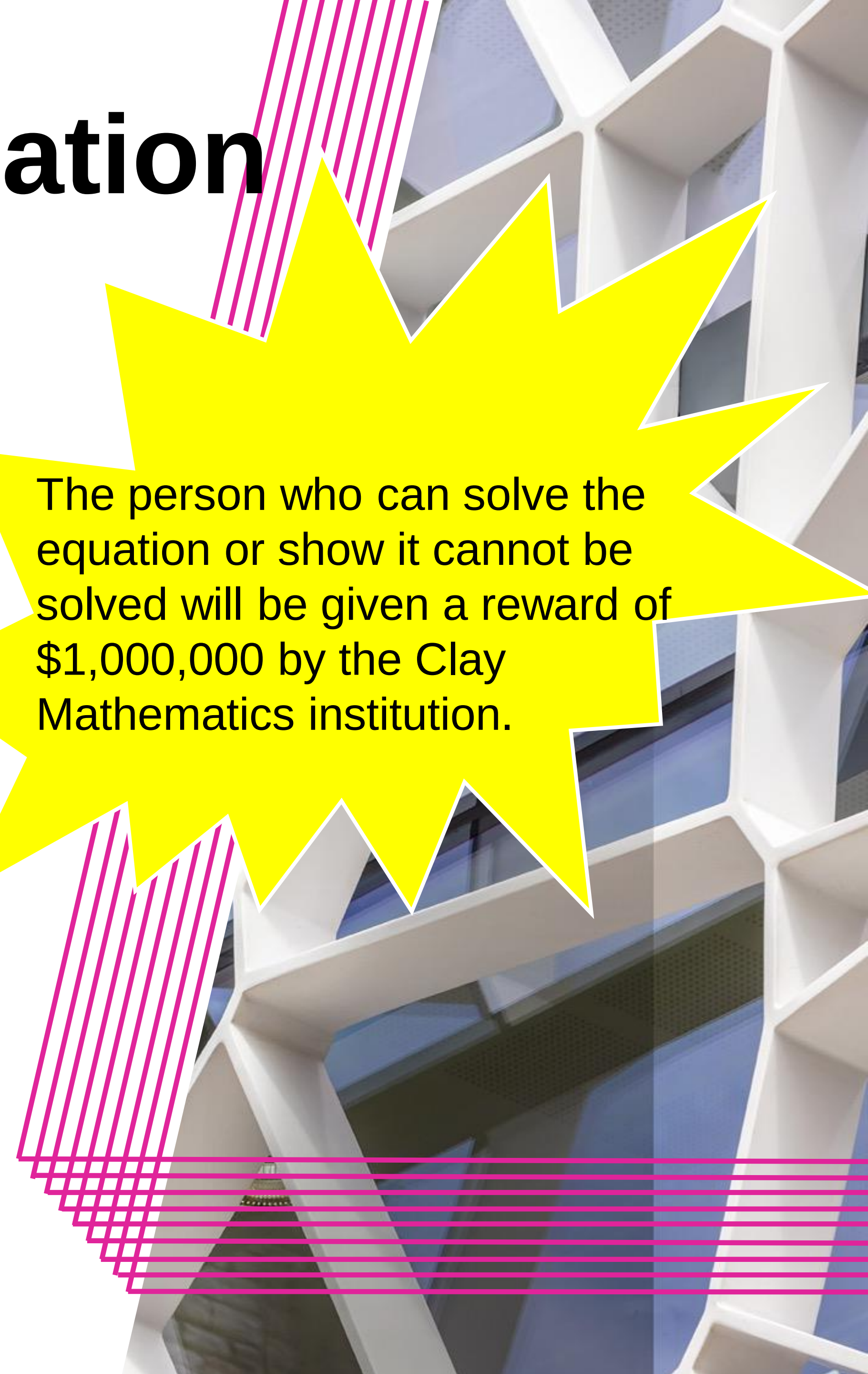

The person who can solve the equation or show it cannot be solved will be given a reward of $1,000,000 by the Clay Mathematics institution.

Why is the Reynold’s number useful?

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The Navier-stokes equation can be non-dimensionalised to get

$$Re\left(St\frac{\partial \mathbf{u}^*}{\partial t^*} + \mathbf{u}^* \cdot \nabla^* \mathbf{u}^*\right) = -\nabla^* p^* + \mu \nabla^{*2} \mathbf{u}^*$$

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where

$$\begin{aligned} \text{Reynolds number } Re &= \rho U L/\mu, \\ \text{Strouhal number } Sr &= L/UT. \end{aligned}$$

What happens when the Reynolds number is small?

$$Re\left(St\frac{\partial \mathbf{u}^*}{\partial t^*} + \mathbf{u}^* \cdot \nabla^* \mathbf{u}^*\right) = -\nabla^* p^* + \mu \nabla^{*2} \mathbf{u}^*$$

What happens when the Reynolds number is small?

$$0 = -\nabla^* p^* + \mu \nabla^{*2} \mathbf{u}^*$$

What happens when the Reynolds number is large?

$$Re\left(St\frac{\partial \mathbf{u}^*}{\partial t^*} + \mathbf{u}^* \cdot \nabla^* \mathbf{u}^*\right) = -\nabla^* p^* + \mu \nabla^{*2} \mathbf{u}^*$$

Now we can solve these simpler equations to create some models!

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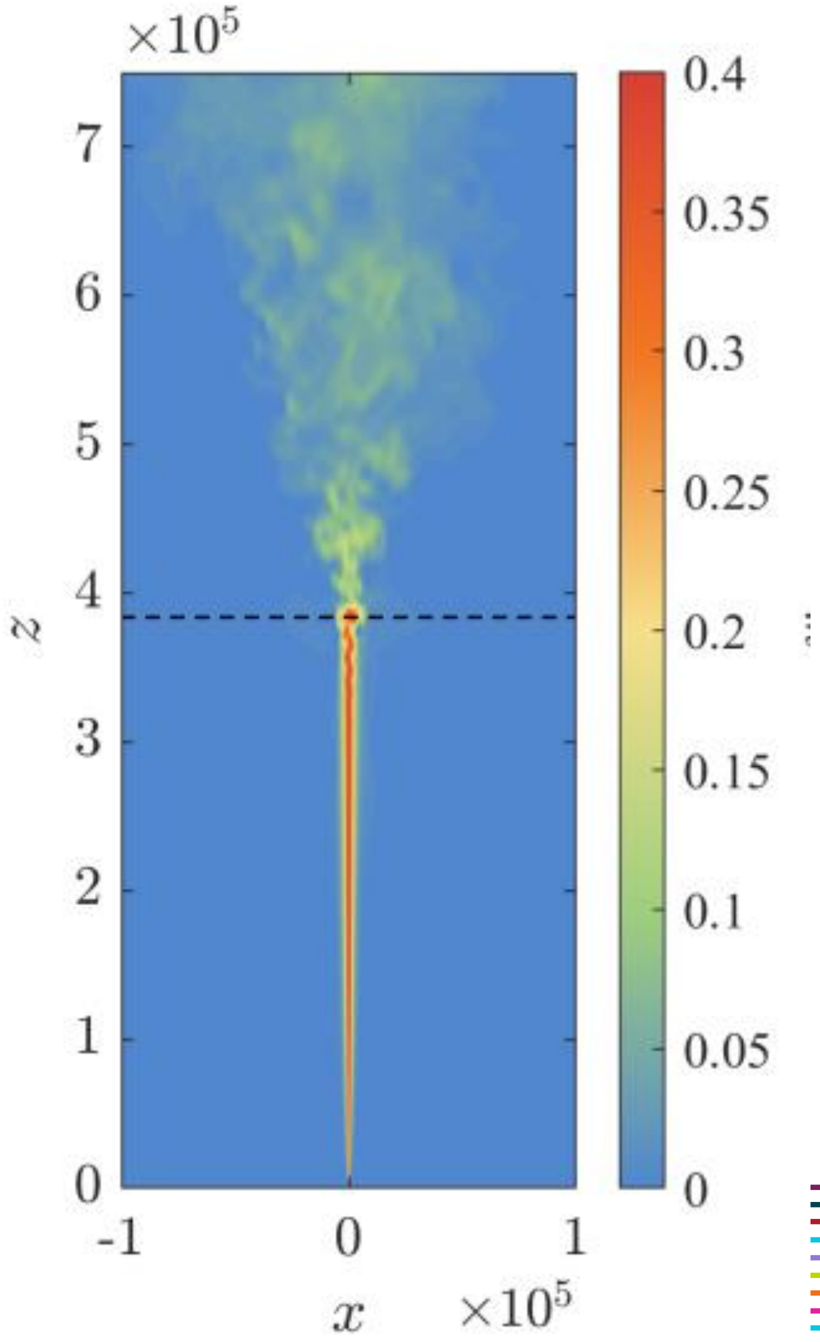
$$Re\left(St\frac{\partial \mathbf{u}^*}{\partial t^*} + \mathbf{u}^* \cdot \nabla^* \mathbf{u}^*\right) = 0$$

Now we can solve these simpler equations to create some models!

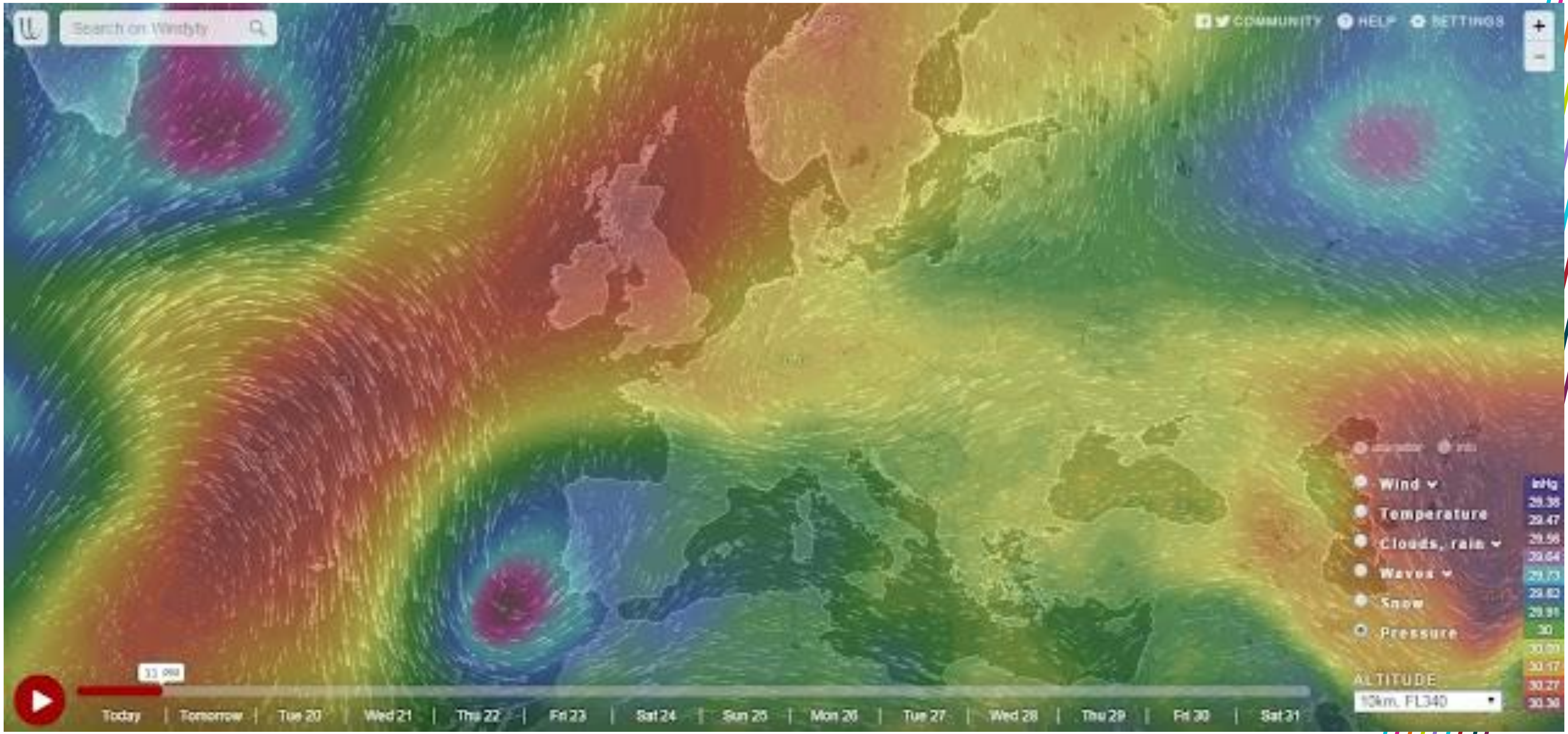
An example of a model



Which of these scenarios can the Navier stokes equation model?

Weather

Weather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SETTINGS
Wind
Temperature
Clouds, rain
Waves
Snow
Pressure
ALTITUDE
10km, FL340
inHg
Today
Tomorrow
Tue 20
Wed 21
Thu 22
Fri 23
Sat 24
Sun 25
Mon 26
Tue 27
Wed 28
Thu 29
Fri 30
Sat 31

The design of aircraft wings

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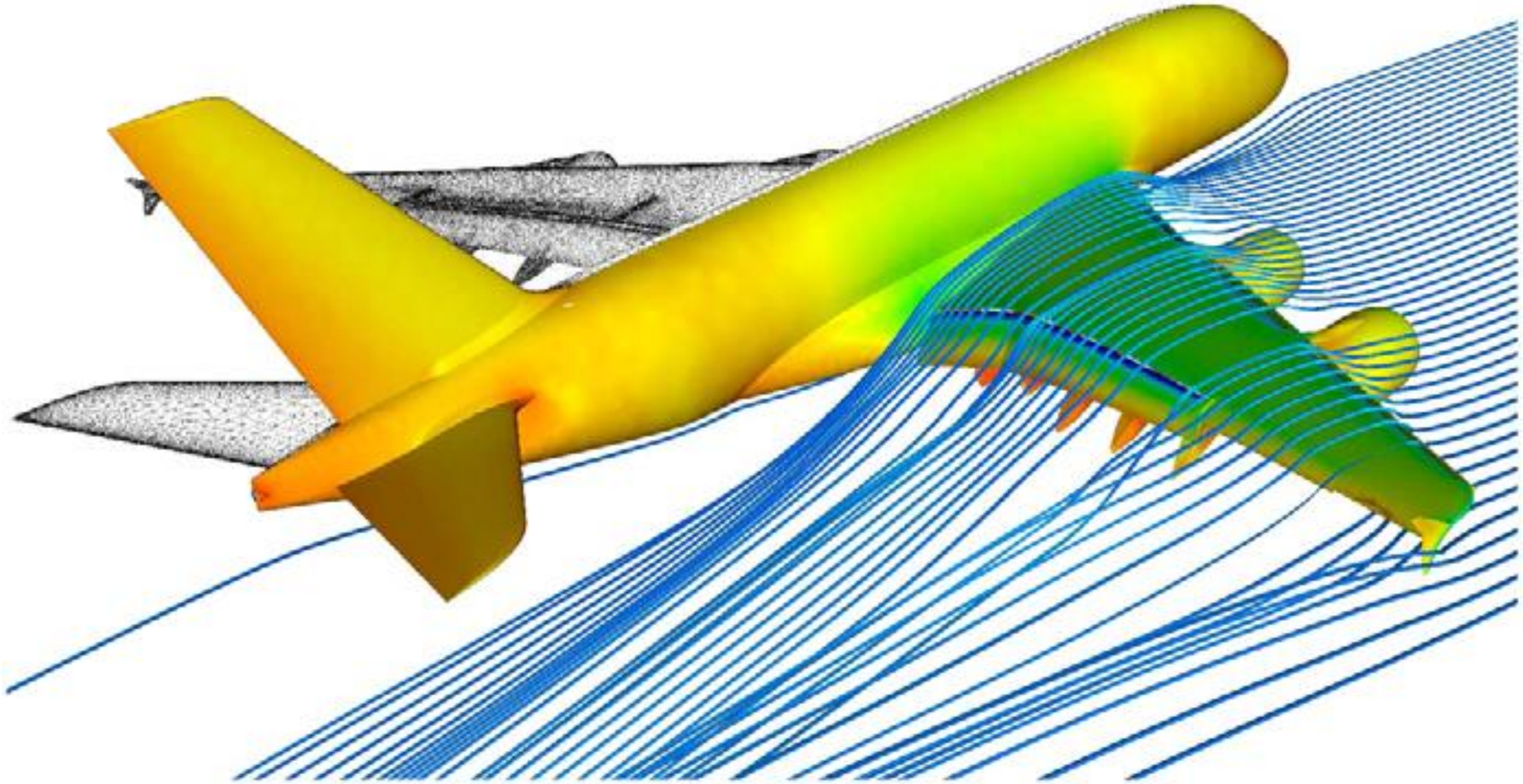


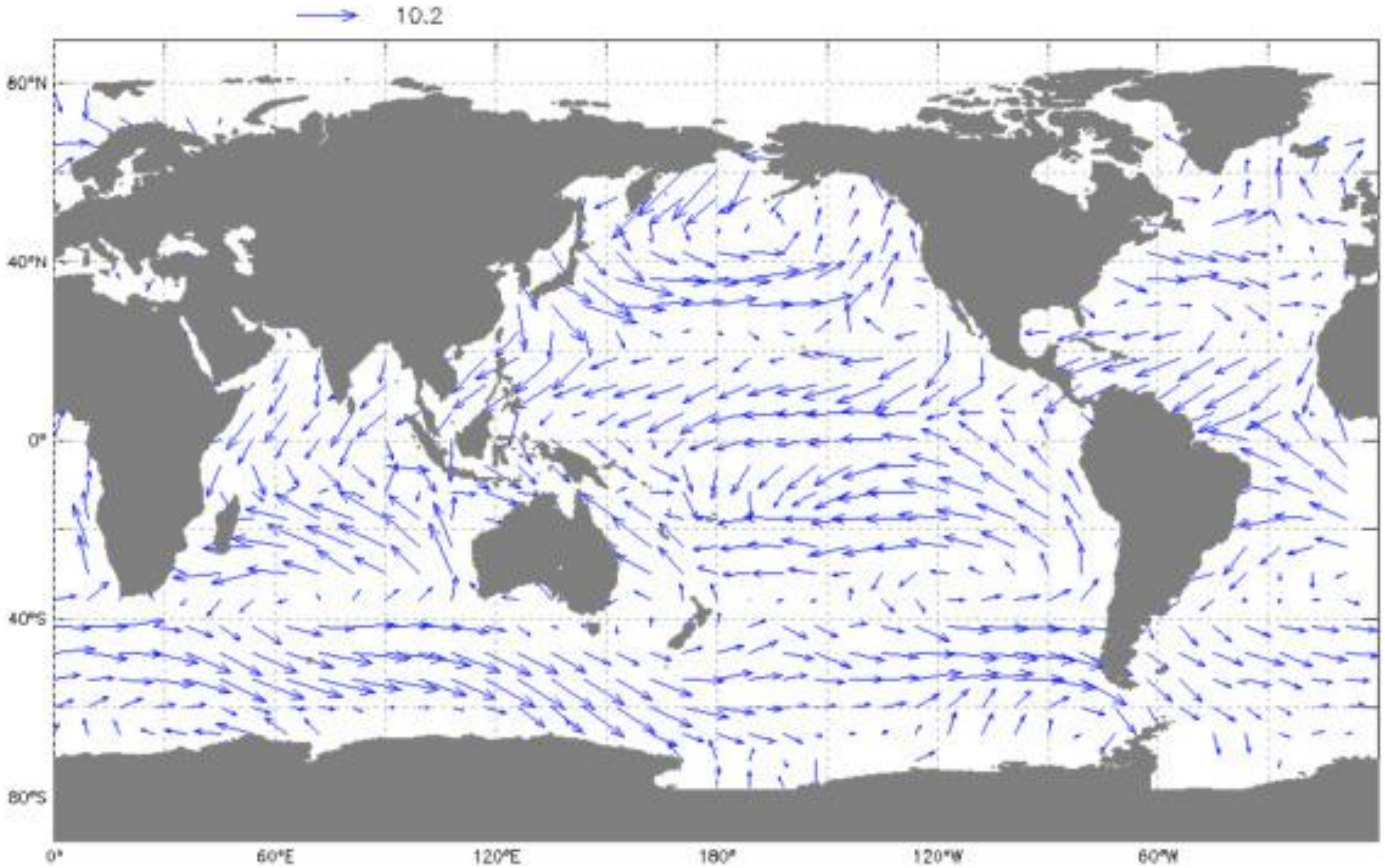
Motion of a single bacteria

Motion of a single bacteria

No- The Navier-Stokes equations cannot compensate for the physical model of the flow at very small scales

Ocean flow

Ocean flow



Between the North sea and Baltic sea

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No- the density of these two seas is different so the Navier-stokes equation cannot be used

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Any questions?

Thank you!

Please complete this evaluation form >>>

General UoB queries (including Engineering admissions info):

- choosebristol-ug@bristol.ac.uk

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