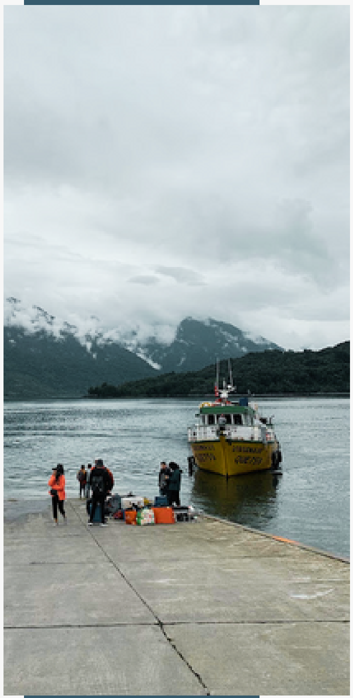
Studying Underwater Currents

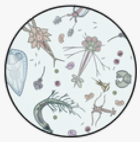


Learning Goals

1. Explain why it is important and challenging to measure ocean transport, and describe a method oceanographers use to collect these measurements.
2. Apply the basic principles of neutrally buoyant ocean floats such that they can predict the impact of volume and mass change on the buoyancy of these objects.
3. Identify sources of error, both in the laboratory and the ocean, and consider design choices to mitigate these uncertainties.

Oceanography

Three main disciplines that rely on eachother



Biological

Interaction of living organisms and their environment.
*Not the same as marine biology

Chemical

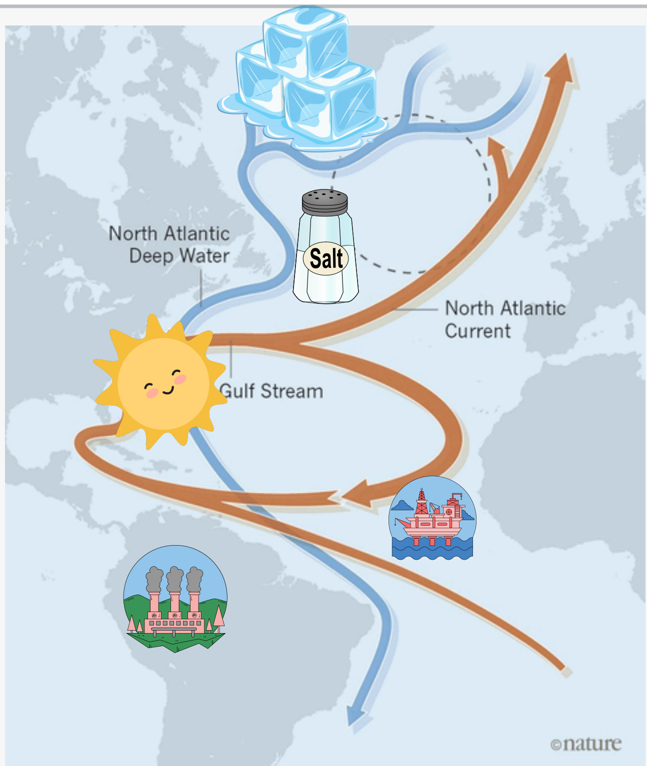
Processes that control the transport and cycling of chemicals and elements.

Physical

Dynamics that govern the movement and mixing of seawater and its properties.

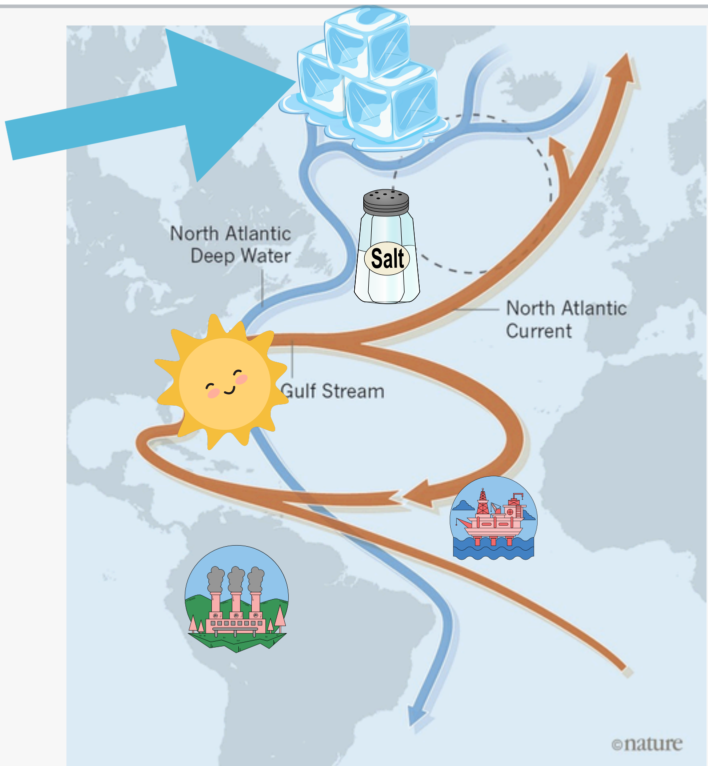
Oceanographers are scientists that study all things ocean related, from mapping the seafloor to assessing the biodiversity of plankton. There are three main disciplines (biological, chemical, and physical), but all three topics are closely related so oceanographers need to have a keen understanding of biology, chemistry, and physics to uncover the mysteries of the ocean.

Skills testing question: Are marine biologists and biological oceanographers the same thing?.. No - While they're closely related, marine biologists typically focus on a particular species (ex. a whale) and oceanographers tend to focus on ocean processes (ex. the processes governing the availability of whale food).



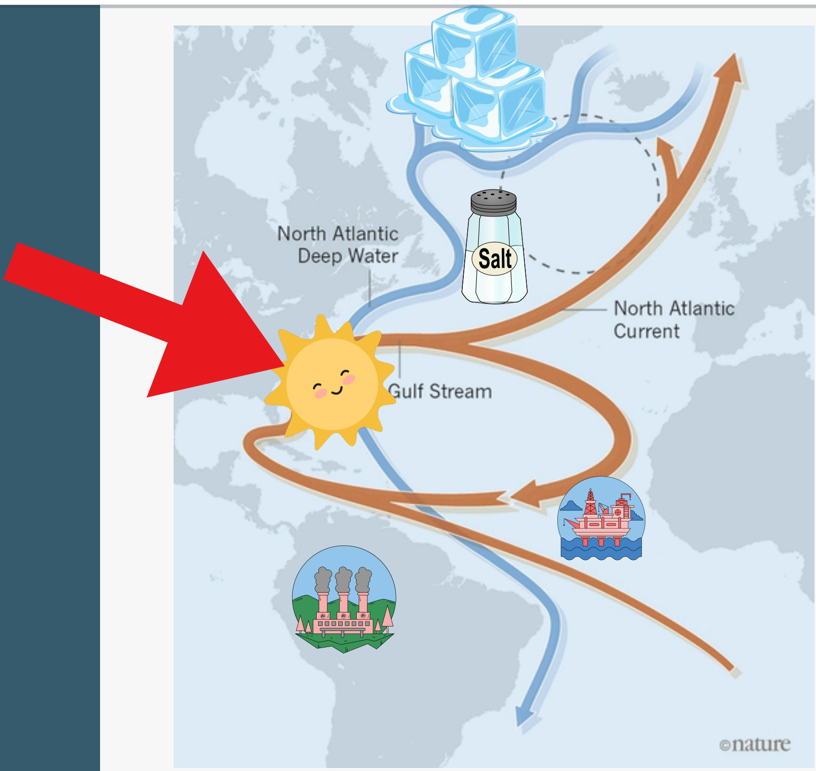
Care about the motion of the ocean (and how its changing)

In this activity we are focusing on the discipline of physical oceanography. Physical oceanographers study the motion of the ocean. The red and blue arrow in this figure show the Atlantic Meridional Over Turning Circulation (a.k.a. the Atlantic portion of the ocean conveyor belt). The temperature of water and how much salt is in it impacts the density of water. Warmer water (in red) flows above cold water (in blue) because warm water is lighter, its this density difference and earth's rotation that drives this large scale circulation.



Care about the motion of the ocean (and how its changing)

When ice melts in the arctic does this increase or decrease the density of water around it?
(answer= decrease because fresh water has no salt in it, making it lighter)



Care about the motion of the ocean (and how its changing)

What about when water is evaporated at the equator? (answer= increase because evaporation removes water only, so the salt concentration of the water increases).

Physical oceanographers care about these currents because they transport properties that marine cretures rely on (like nutrients and oxygen) around the ocean, and regulate heat across the globe. Knowing how currents like these move is also important for tracking the movement of pollution; we can respond to environmental emergencies like oil spills more effectively if we have a good idea of where the oil is going to go.

How we get answers

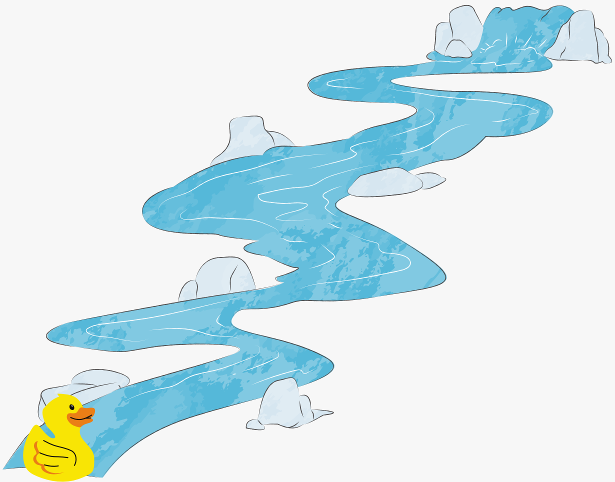
Lagrangian Tracking

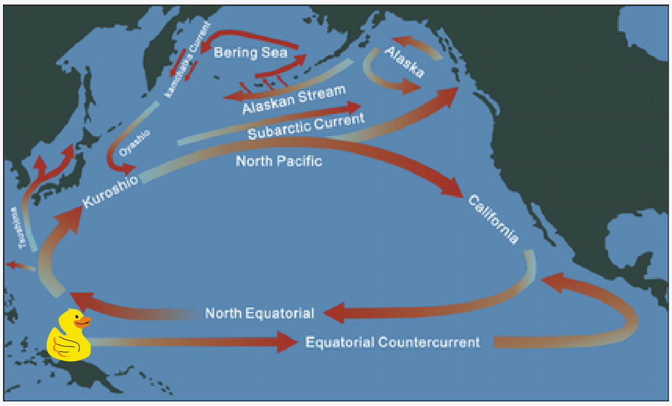
So, we know that understanding the paths and speed of currents is important, and that if the density of water changes so do those paths and speeds. But how do oceanographers study where and how currents moves?

One common way is Lagrangian tracking - the tracking of free-floating objects to see the complex paths they follow. For example, lets say you were at a river and wanted to see which way the water flowed. If you dropped a rubber duck at the top of the river what would happen? It would flow downstream! Pretty obvious right?

How we get answers

Lagrangian Tracking





But you can do the same thing in the ocean. The journey that our rubber duck takes tells us a lot about the currents its interacting with. We can think of currents like many intertwined rivers in the ocean... just there aren't clear boundaries between rivers.. and they move..

Look at the map on the right - by following the arrows where do you think our duck would end up? Alaska? The Bering Sea? Japan? Back down to California? It's hard to say for sure based on the map alone! This is where Lagrangian tracking comes in.

How we get answers

Lagrangian Tracking

Curt Ebbesmeyer with the four types of toys that fell overboard

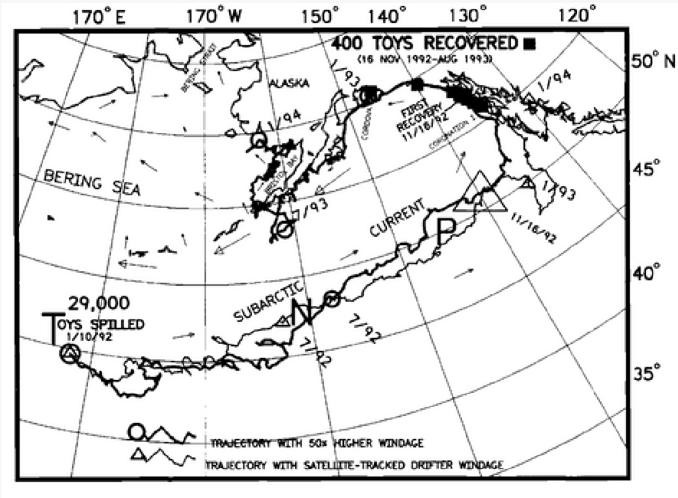
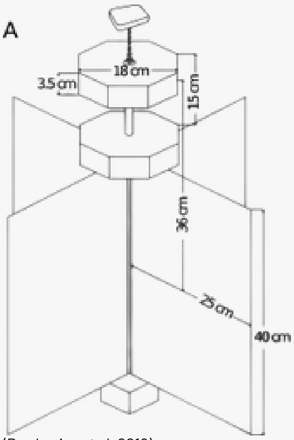


Fig. 2. Site where 29,000 children's bathtub toy animals washed overboard on January 10, 1990

(Ebbesmeyer & Ingraham, 1994)

This type of Lagrangian tracking with bath toys isn't just a fun example, it actually happened! In 1990, 29,000 floating bath toys were spilled into the North Pacific. The paths they took gave us new insight into the Subarctic Current.

Surface Drifter



(Pawlowicz et al. 2019)

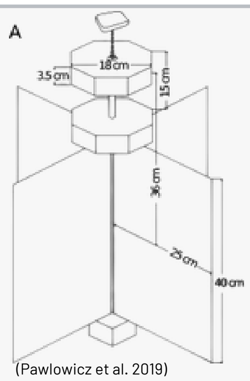
Sub-surface float

We can do better than bath toys though, oceanographers now build simple robots to track the specific currents they're hoping to learn more about.

In the left is an example of a drifter built to track surface currents. Its built to have as much surface area bellow the surface and as little above the surface as possible, so that it moves according to surface currents, not according to wind. The GPS at the top needs to be above the water to transmit a signal.

On the right is a sub-surface float designed to track underwater currents. Its carefully ballasted to sink to a specific depth. At the end of its measurement period the weight at the bottom is dropped and the float pops back up to the surface where it begins to transmit a GPS signal so oceanographers can know where the subsurface current took it!

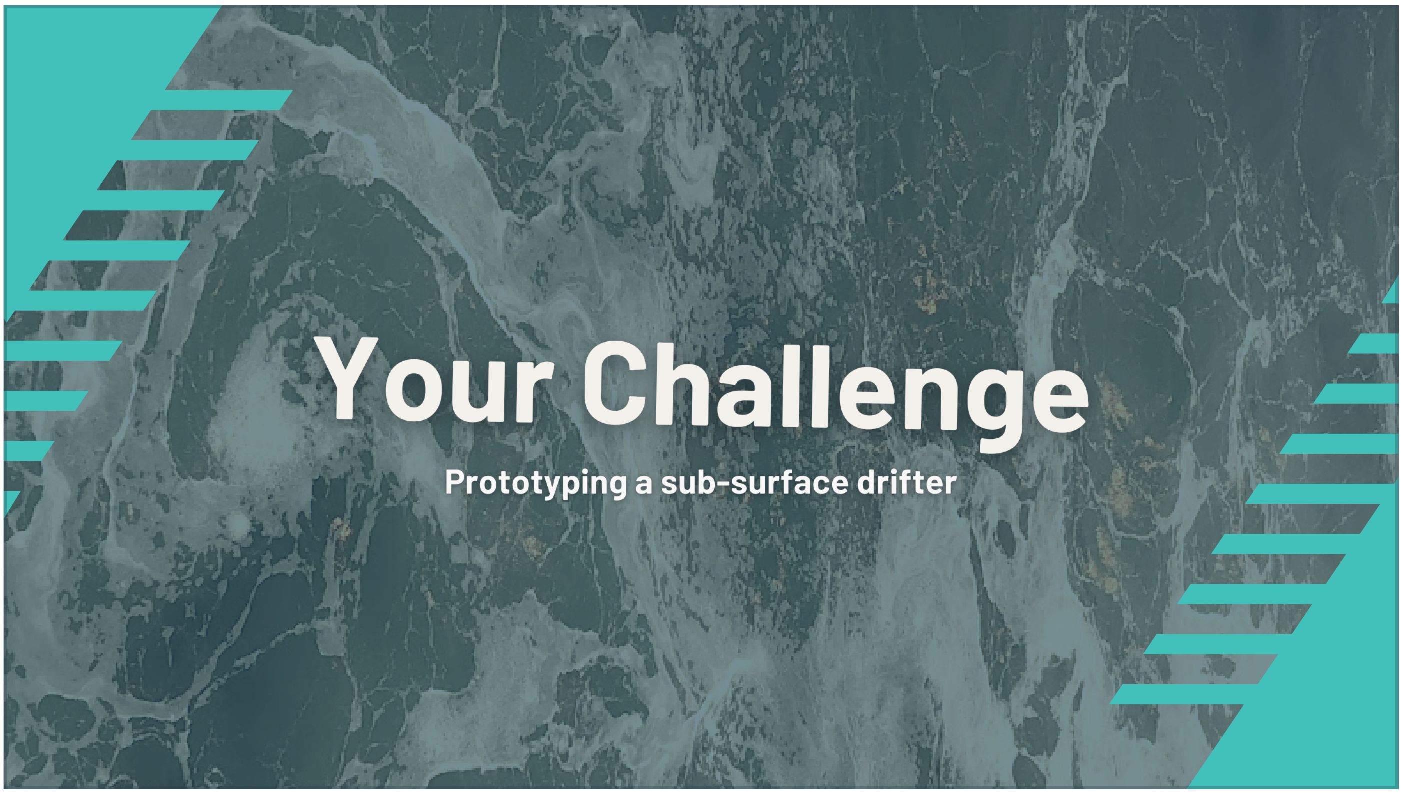
What sort of considerations do you think an oceanographer needs to think about while designing a surface or subsurface float?



(Pawlowicz et al. 2019)

Considerations when Making Lagrangian Measurements

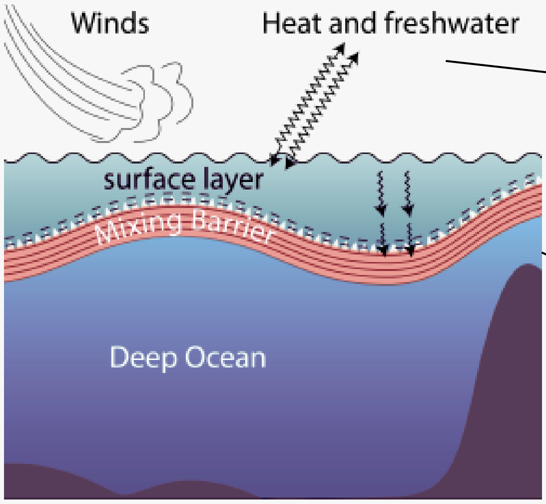
- What depth are you measuring at? How can you get/keep your drifter at this depth?
- What factors may affect the movement of your drifter? Are these all things you want to measure? If no, how do you minimise measuring these?
- How is the location and time recorded?
- Do you need to collect your drifter after its "done" following a track?
- What's your budget?


Your Challenge
Prototyping a sub-surface drifter

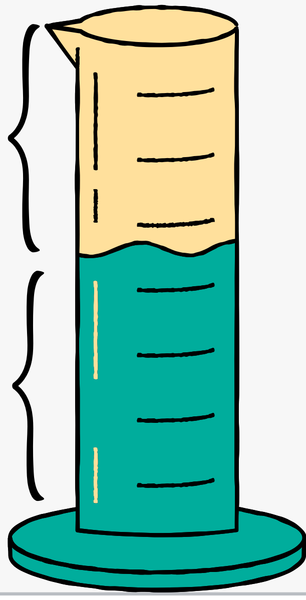
Overview

Ocean Layers

****Stratification** = the separation of ocean into vertical layers based on their density.
(warm/fresh water sits on top of cold/salty water)



Jean-Baptiste Sallée, 2021



The ocean is typically made up of a lighter, wind mixed, surface layer, atop a many layers of stratified water. When making a sub-surface float, you need to know the density of the ocean layer you're trying to get your float to sink to.

In our prototyping test we are approximating the ocean as two layers, the surface mixed layer is represented with oil and the deep ocean is represented by water. We're trying to design floats that target the pycnocline (ie. a layer of rapidly changing density), in our cade the interface between water and oil.

Overview

Depth targeting

Neutral buoyancy - to target a depth the drifter must have a weight equal to the weight of the fluids its displacing

$$F_{gravity} = F_{buoyancy}$$

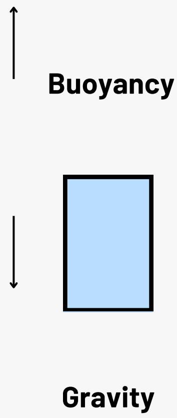
$$m_{drifter} g = V_o \rho_o g + V_w \rho_w g$$

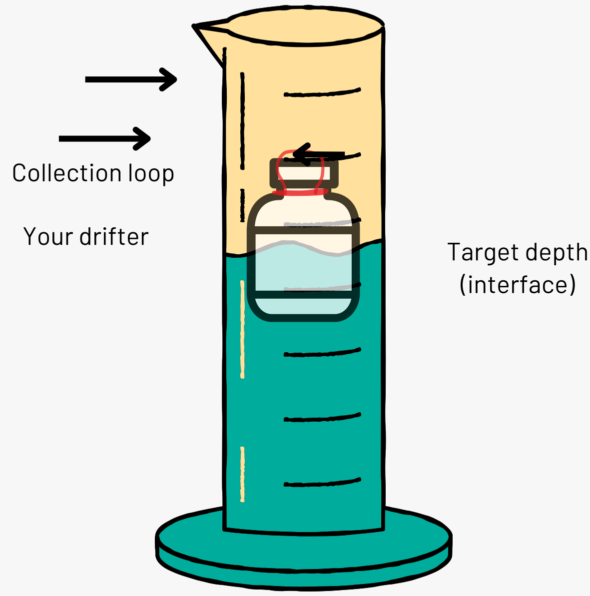
mass

gravity

volume

density

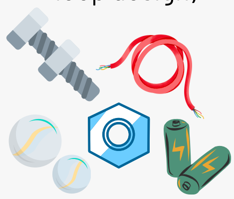




Materials

Laptop or calculator- to calculate volumes and densities

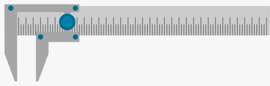
Bits and bobs (for drifter weight and collection loop design)



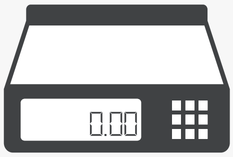
Thermometer

Drifter casing (nalgene sample bottle)

Calipers



Scale



Materials

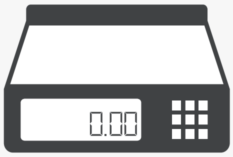
Research budget! - these items have costs (marked on materials table) make your design as low cost as you can

Laptop or calculator - to calculate volumes and densities

Bits and bobs (for drifter weight and collection loop design)

Thermometer

Scale



Drifter casing (nalgene sample bottle)

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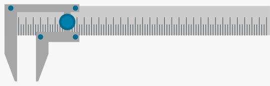

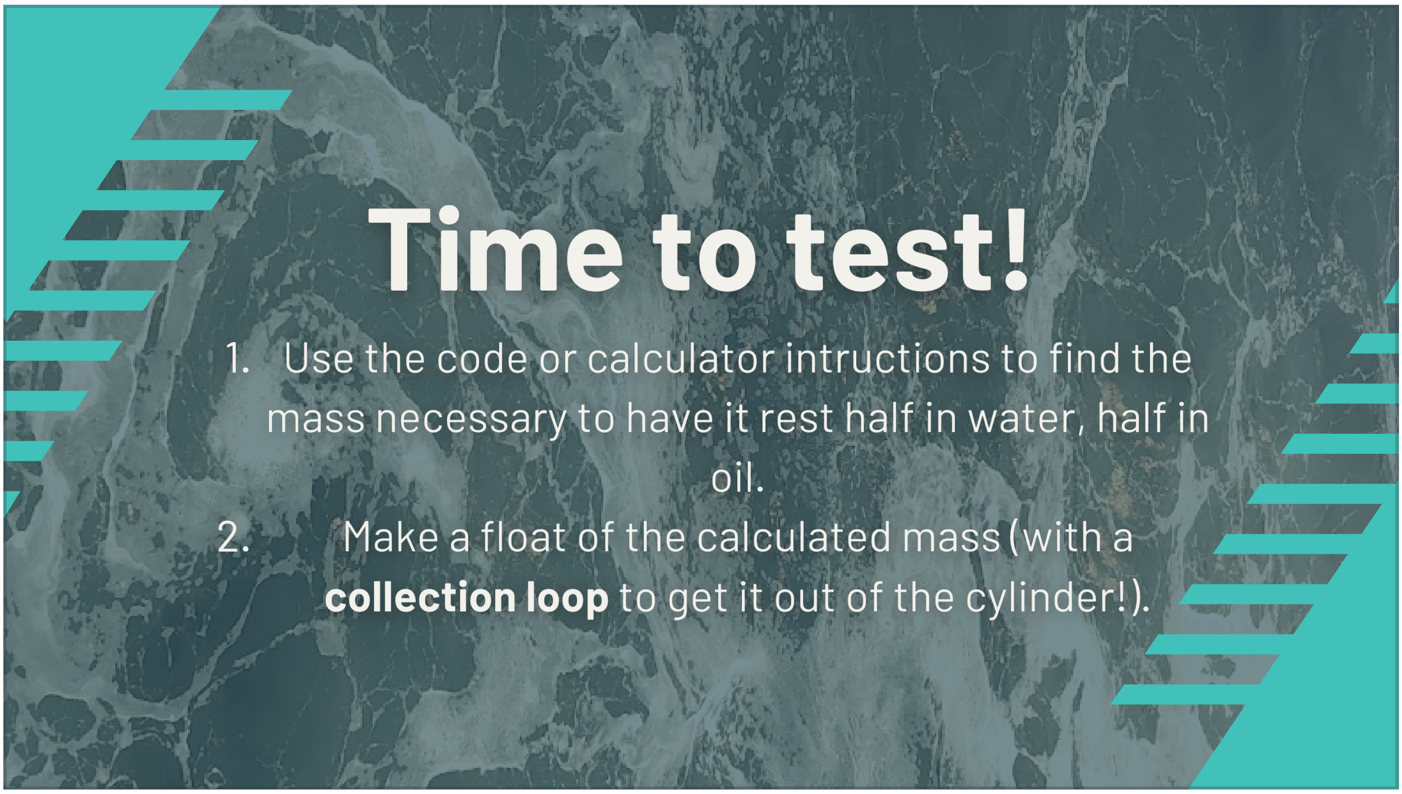
Time to test!
1. Use the code or calculator intructions to find the mass necessary to have it rest half in water, half in oil.
2. Make a float of the calculated mass (with a **collection loop** to get it out of the cylinder!).