INTRODUCTION
Observing Waves at the Shore

This is a course on the kinematics and dynamics of **Waves in the Ocean**. Before we start the lecture, let's get in the right frame of mind and watch the delightful show of waves coming onto the beach.

You can see the **waves arriving at the shore**. Depending on the roughness of the sea, they may be rolling over and breaking, or just undulating. They are always **coming towards the beach**, but they never get any closer. Except for tidal waves of or tsunamis, waves do not actually invade the land.

Have you ever thought about that?

How is that possible? What is it that is actually coming towards the beach? ***What is a wave?***

It is not water… well there is water coming towards the shore, but somehow it is not going to cover you up. You can sit on the beach and sunbathe and apart from tides or tsunamis you've got nothing to worry about. However, there is definitely something **coming towards you** that has a **lot of energy** associated with it.

So, what kind of movement are you are looking at? If you look far out to sea, it is just sort of undulating, but as it gets closer, it seems to get bigger, and then it gets so big that it cannot support itself, and then it tumbles and falls over.

Why does that happen? What circumstances cause the wave to break? What kind of movement is there underneath the wave?

It is obvious that there is a **vertical oscillation** with water going up and down. Is that all there is? Or is there also a back and forth horizontal motion associated with the wave?

Why do waves always come straight to the beach? Why don't they go across the beach or away from the beach?

⇨ In this course, we will need a **mathematical formalism** to describe the ocean waves. Can we write down **an equation** on the blackboard that gives us a perfect description of what happens on and under a wave, so that we can understand or conceptualize the kinematics and dynamics of the waves and infer something about the circulation?

Forcing

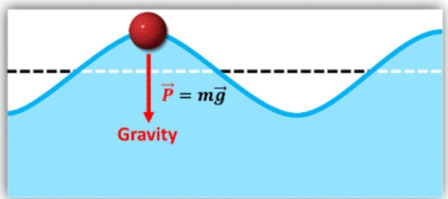
⇨ On a rough day, the waves on the shore can be really big because something has happened far out to sea that has set in motion a series of events that will gradually reach the beach a few days later. The wind transfers energy to the surface of the water and generates wind waves (swell). The larger the pressure system, the stronger the wind. And the stronger the wind, the bigger the waves will be. Large weather systems out at sea can trigger ideal surfing conditions or quite dangerous sea states for swimming at the shore.

Restoring force

⇨ ***What makes a surface wave oscillate up and down?***

A wave oscillates because it has a kind of home position, and if you move it away from this **equilibrium position**, it will be attracted back to it. And if you move it away in the other direction, it will still be attracted back to its equilibrium position, creating an oscillation (just like a mass-spring system).

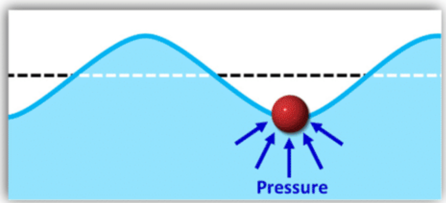
So, we need some kind of **force** to bring it back to its equilibrium position. What is this **restoring force in the case of ocean surface waves**?



- The force that brings lifted water down to its equilibrium position is the **gravity force**. Water has gone up and then it falls back down.

- *What about a wave that has gone down?* It gets pushed back up to its equilibrium position. This is not due to gravity. What is pushing the water parcel back up?

↳ It is **buoyancy**, and the physical force involved in buoyancy is the difference between gravity and **pressure**.



⇨ **Pressure** pushes an object up when it is submerged in water. In fact, pressure pushes it in **all directions**: up, down, and sideways too. If the force pushing the object to the right is the opposite of the force pushing it to the left, the object will not move sideways. But because the pressure increases with depth, the pressure below (pushing it up) is greater than the pressure above (pushing it down), so the net pressure force is upwards.

↳ This is the same for a parcel of fluid. It occupies a certain amount of space, and the net force pushing it upwards is equal to the weight of the water being displaced. This is Archimedes' principle.

⇨ The restoring force is gravity and we call these waves **gravity waves**.

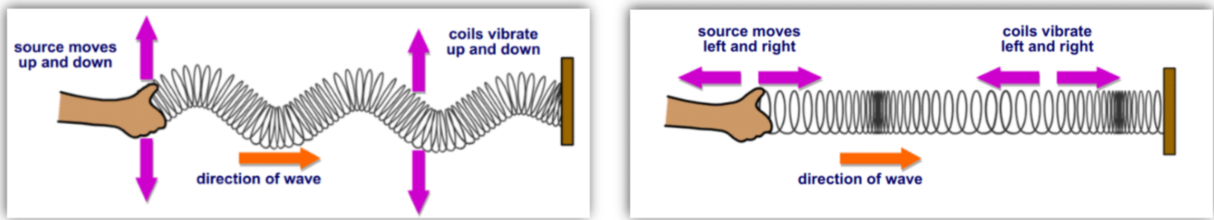
⇨ Later in the course, we will discuss other quantities that define an equilibrium state, such that any deviation from this "comfort zone" can give rise to a restoring force and create an oscillation around the equilibrium state. For example, we will consider the conservation of the **vorticity** involved in the propagation of **Rossby waves** (see **#WAVE3.4**).

⇨ Waves are triggered by a **restoring force** and we have **different types of waves**:

• There are waves for which the restoring force is perpendicular to the direction of propagation. This is the case with light, radio, or electromagnetic waves in general. Electric or magnetic forces create an oscillation that is perpendicular to the direction of propagation.

↳ These waves are called **transverse waves**.

• There are also **longitudinal waves**. These are waves for which the restoring force is in the same direction as the propagation. Sound waves are a classic example. Sound produces compression and decompression in the same direction as its propagation.



A Slinky can be used to model both transverse (left) and longitudinal (right) waves

What about the ocean surface waves, are they transverse or longitudinal waves?
(see **#WAVE2.1b**)

Videos of the lectures

⇨ Videos of the lectures are available on **Nick Hall's YouTube channel** at *https://www.youtube.com/watch?v=Kfau5lriojo&list=PLDrzzwhdpdSAt9-pBgN7mux5g3qCM3gzA*.

↳ If you enjoy the course, don't forget to **like and subscribe to the YouTube channel**.

COURSE OUTLINE

This class consists of **five chapters**.

1) We will start with the **general properties of waves** (see **#WAVES1**). We will talk about their amplitude, their period, their speed. We will define 7 properties that can describe a wave.

2) In the second chapter, we will focus on surface gravity waves. We will discuss the properties of **deep and shallow water waves** (see **#WAVES2**).

3) We will then consider the propagation of **waves in geophysical fluids** (where the rotation of the planet becomes important). How the earth's rotation affects the waves (see **#WAVES3**).

4) In Chapter 4, we will go back to smaller scales and study waves that propagate below the surface. **Internal waves** (see **#WAVES4**) are waves that exist within the body of the fluid (not just at the surface).

5) The last lecture is a bit more descriptive. We will have a look at **tides** (see **#WAVES5**). These are gravitational waves caused by the gravitational pull of the sun and moon on the earth's oceans.

Here is a list of **recommended books** if you want to learn more about wave propagation. The course is inspired by these books:

Books:
Waves, tides and shallow water processes, *Open University*
Waves in the Ocean and Atmosphere, *Pedlosky*
Vibrations and waves in physics, *Main*
Introduction to GFD, *Cushman-Roisin*
Atmospheric and Oceanic Fluid Dynamics, *Vallis*