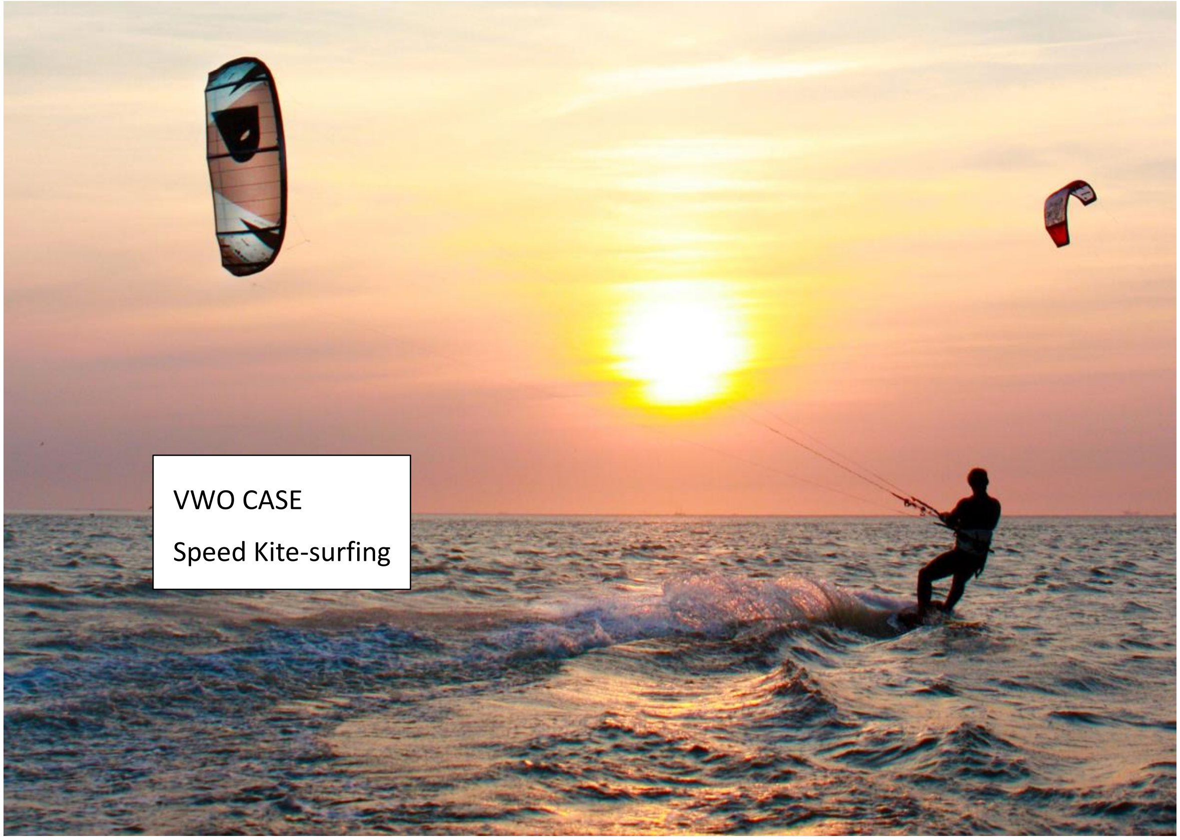

VWO CASE
Speed Kite-surfing

Wind energy is taking a more prominent role in our daily lives. Because harvesting this energy is a lot better for the environment than constantly burning oil, more wind turbines can be seen in our landscape.

Wind turbines are not the only way to convert wind power into energy. The Delft University of Technology is for instance investigating how to use kites to generate energy from the wind. Also scientists are looking into how kites can pull ships across sea.

This speed kitesurfing project shows you in a spectacular way how much energy is actually contained in wind. After all, if you can race over the water at 100 km/h using only a kite and the wind, why would you still want to use a motor?

In this case you will not only learn to kite-surf using math, but we will also help you try to break all the kitesurfing speed records! So perhaps you will have found a way to break the world-speed-record or just another great idea to harvest the wind…

1. Introduction

In 1972 Tim Colman was the first wind powered speed-record holder on water with a speed of 49 km/hour. Since then there has always been a battle between sailors and wind-surfers to be the fastest on water. Especially the sailors would start multi-million euro projects to try to prove that they were still the fastest on water. But in 2008 is was the French wind-surfer Antoine Albeau who holds the record at an astonishing 91 km/h!

World Speed Sailing Records for 500 Meters

Year	Sailor and Nationality	Watercraft	Location	Speed (Kts)
1972	Tim Colman GBR	Crossbow	Portland, UK	26.3
1973	Tim Colman GBR	Crossbow	Portland, UK	29.3
1975	Tim Colman GBR	Crossbow	Portland, UK	31.1
1975	Tim Colman GBR	Crossbow II	Portland, UK	31.8
1977	Tim Colman GBR	Crossbow II	Portland, UK	33.8
1977	Tim Colman GBR	Crossbow II	Portland, UK	34.4
1980	Tim Colman GBR	Crossbow II	Portland, UK	36
1986	Pascal Maka FRA	Windsurfer	Sotavento, ESP	38.86
1988	Erik Beale GBR	Windsurfer	Stes.Maries, FRA	40.48
1990	Pascal Maka FRA	Windsurfer	Stes.Maries, FRA	42.91
1991	Thierry Bielak FRA	Windsurfer	Stes Maries, FRA	43.06
1991	Thierry Bielak FRA	Windsurfer	Stes.Maries, FRA	44.66
1993	Thierry Bielak FRA	Windsurfer	Stes Maries, FRA	45.34
1993	Simon McKeon AUS	Yellow Pages	Sandy Point, AUS	46.52
2004	Finian Maynard BVI	Windsurfer	Stes.Maries, FRA	46.82
2005	Finian Maynard BVI	Windsurfer	Stes.Maries, FRA	48.7
2008	Antoine Albeau FRA	Windsurfer	Stes.Maries, FRA	49.09

What the sailing and wind-surfing community did not count on was that a new sport would emerge, Kitesurfing! Just by using a kite and a small board, these kitesurfers were reaching incredible speeds and they are increasing each year and by 2007 the French kitesurfer had already reached 89 km/h.

In Delft there is one aerospace technology student who is convinced that kitesurfing will eventually be the fastest of all water sports, his name is Rolf van der Vlugt. He expects that soon speeds of more than 100 km/h will be reached because of three major advantages:

1. The kite of a kitesurfer is always higher in the sky than a wind-surfing sail or the sail on a sailing boat. The higher, the more wind.
2. A kitesurfer has more control over his kite than sailors or wind-surfers have over their sails. All the forces that are exerted by the wind are transferred through the waist of the kitesurfer. This makes the ride much calmer than when the sail is attached to the board.
3. The fins on a kite-surf board are very small which means they can get very close to the shore line. When there is an offshore wind, the water is very smooth just next to the shore which makes it ideal to reach high speeds.

The best way to prove that kitesurfers can reach 100 km/h is of course to show it, so Rolf has started his Master Thesis on speed kitesurfing at the TU Delft. He needs your help to create ideas to reach 100 km/h, in this case we need a clever design to be the fastest!.

The rules

The WSSRC (World Sailing Speed Record Council) keeps track of the person who currently holds the speed-record. Every new attempts has to be recorded using an official video timing system. The speeds should be measured over a course of 500 metre. The rules are simple:

- Only wind power is allowed as propulsion
- The attempt must be held on water, so not on ice or land!

2. Kitesurfing

In this case you will design a kite-surf board and kite which will be used to break the speed-record. Where to start? First we have to analyse the kite and board system and know what it looks like. Then, when we know the workings of the system we will brainstorm on possible improvements.

We can see from photographs that we are dealing with a person on a board being dragged along by the kite. So the entire system consists of:

1. The Kite
2. The kitesurfer
3. The Board

For each of these parts we will see how they work by doing some assignments.

3. Assignments

The kite

The kite supplies the dragging force to pull the surfers through the water, but how does this actually work?

By sitting at your desk, it can be hard to imagine how objects can be lifted through the air. When you are riding your bike into the wind you may start to understand it better. With full force you are pedalling but still you cannot go very fast. The air is applying a force on your body.

What you are actually feeling is a higher air pressure on the front of your body and a lower air pressure on your back. This means that the force you feel is a difference in air pressure, high pressure on your front, low pressure on your back. There is also friction when cycling, but we will not consider that for now.

So now when you know that the force applies by the air is caused by a difference in air pressure, it is easier to understand how an object like a kite or an aeroplane can fly.

Kites and aeroplane wings have specially curved surfaces to guide the air around them. These surfaces create low pressure on top of the surface and high pressure on the bottom. This force is always generated perpendicular to the flow of air. The force is called lift force, which is the force responsible for dragging the surfer. The faster the wind blows and the bigger the kite, the greater the force becomes.

There is also a second force caused by the wind, the drag force. This force works in the same direction as the flow of air.

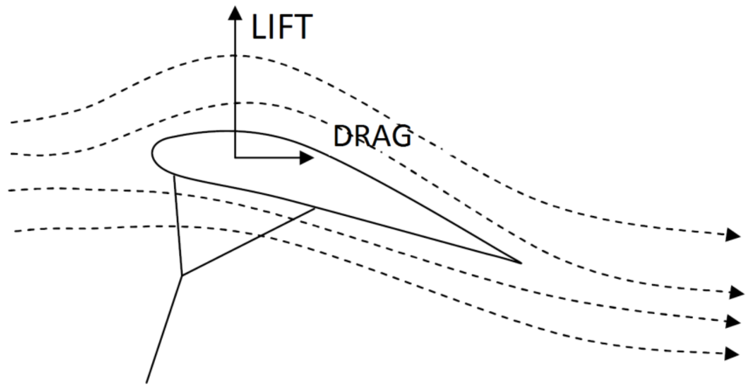
To calculate both of these forces, we use the lift and drag formulas.

Formula for lift force:

$$L = 0.5\rho v^2 C_L A$$

Formula for drag force:

$$W = 0.5\rho v^2 C_D A$$



The symbols in these equations can be explained as:

L = Lift force [N]

W = Drag force [N]

P = Air density [kg/m^3] = 1,29 kg/m^3

V = Wind speed [m/s]

C_L = Lift coefficient [ ] = 0,8

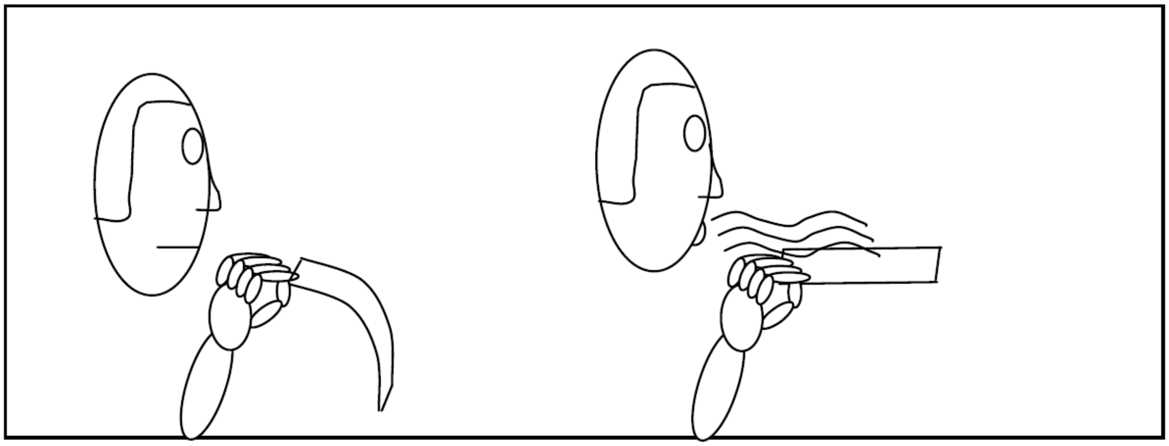
C_W = Drag coefficient [ ] = 0,1

A = Area of the kite [m^2] = for example 7m^2

The lift coefficient and the drag coefficient are dependent of the shape of the kite. A well designed shape has a high value for C_L but a low value for C_W. This means Rolf wants to design a kite with high lift but low drag coefficients.

Experiment

You will get a strip of paper. Hold the strip at the end with your thumb and index finger, the piece of paper will just hang down. Now blow lengthwise over the top of the strip of paper. Can you explain what is happening?



Brainstorm and discussion

What should a good kite look like? What size should it have?

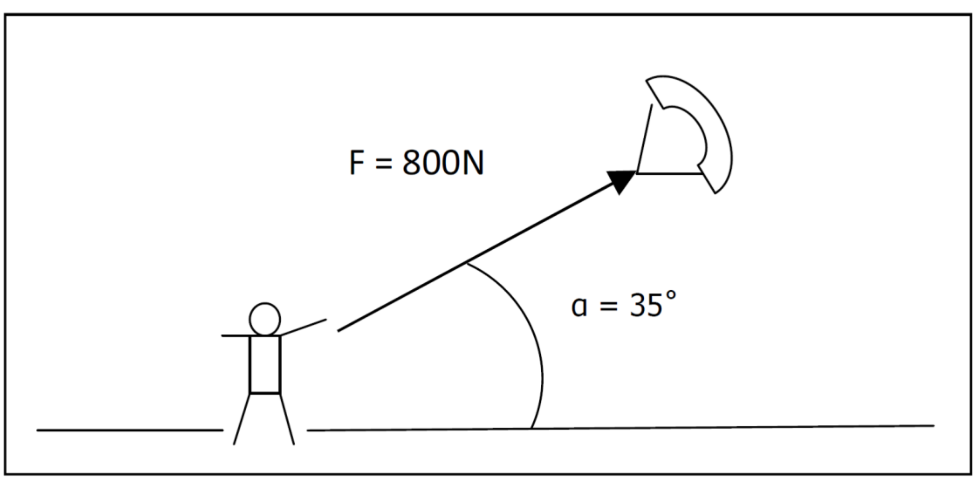
Discuss whether a larger kite is always better and why. What could go wrong?

Assignment 1: How does the kite work?

a. Enter the formula for the lift in your calculator. Enter the wind speed (v) on the x-axis and the lift force (L) on the y-axis. Describe the graph you see.
b. Consider an 80 kg surfer on the beach with the kite straight above his head. Physics tells us that the force acting on my body is $F = m * g = 80\ kg * 9{,}81\ m/s^2 \approx 800\ N$. Find the air speed needed to lift the surfer off the beach on your calculator. Next use the BINAS to convert that to wind force (or use the wind force table on page 12).

How does the kite pull you forward?

We have just calculated how a kite can pull so much that you are lifted off the ground. However we do not want to fly into the air, but we want to go forward so we need to steer the kite. In the following image we can see where we want the kite.



c. Assume we steer the kite to a = 35° angle between the pulling direction of the kite and the horizon. The kite still has a pulling force of 800 Newton. How much is the force in horizontal direction?

The force you have just calculated is the force that will pull us along the water.

The Kitesurfer

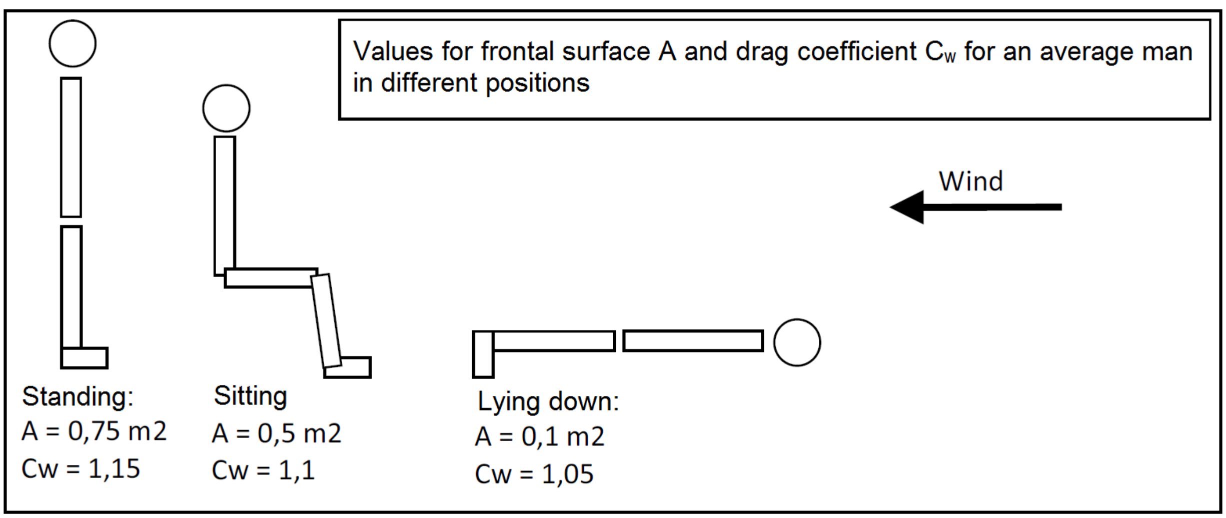
A kitesurfer controls both the kite and the board so everything is about balance. Just like a cyclist or a skier, their bodies are moved through the air which creates drag. If you want to break a speed-record you want to make this drag as small as possible.

To do this you could for instance make yourself small like a cyclist who is bent over his bike. Also by wearing an aerodynamic suit like an ice skater you can reduce the drag on your body.

Brainstorm and discussion

How could you reduce drag? Can a surfer best lie down, sit or stand? What else can you do to the suit to reduce drag? How could this look for the surfer?

Assignment 2: The Kitesurfer



We know that for instance cyclists, skiers and speed skaters make themselves as small as possible to reach higher speeds. We will now find the difference between standing and lying down.

We know the formula for the drag force from assignment 1:

$$W = 0.5\rho v^2 C_D A$$

Use the following values to answer the questions below:

P = Air density [kg/m^3] = 1,29 kg/m^3

V = Wind speed [m/s] = 20 m/s

a. What is the force on the body of the standing man?
b. What is the force on the body on the man lying down?
c. How can the kitesurfer reduce the drag even further? What value in the drag formula will be smaller when your solution is applied?
d. In the picture below you still see the surfer standing up. Give some reasons why this could be.

The Kite-Surf Board

The surfer is standing on a surf board to be able to stand up on the water. The board itself floats but it is not buoyant enough to float with the surfer on it. To stay on the water the board needs speed, the board moves along and presses down on each new bit of water. This creates a force that pushed the surfer out of the water. This means the board planes on the water.

To go as fast as possible, the water must be very smooth. Waves make the surfer bounce on the water which reduces speed. Strong winds are also important for speed. The problem is that strong winds create more winds. As a designer you try to come to a solution for this contradiction. What the sea surface looks like you can find in the table on page 12.

As a speed kitesurfer you want a board with the smallest amount of drag. The more drag there is, the less you can use the pulling force from the kite for speed. However, some drag is always needed to be able to steer the board. This means there is another contradiction for the designer.

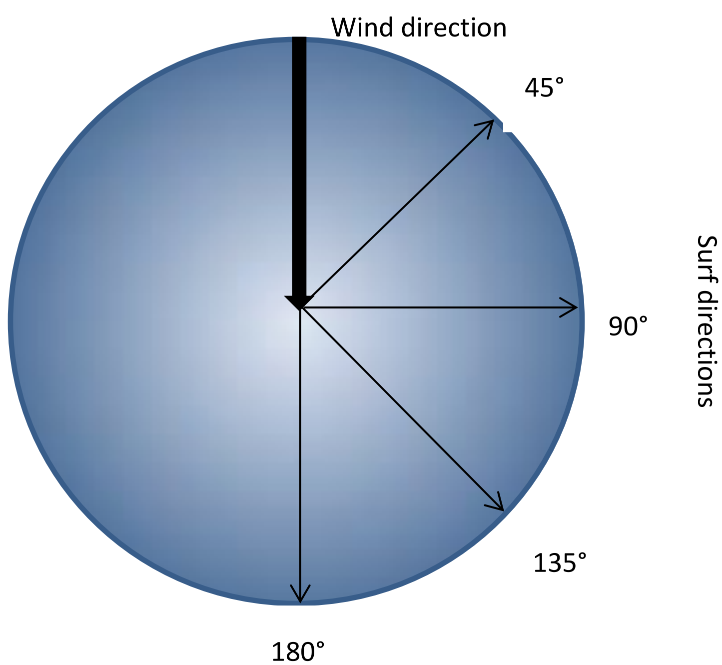
Something else that is very important is the surfing direction in relation to wind direction which we are going to take. Do we want to surf along with the wind, into the wind or somewhere in between? In this question we will focus on what direction is the fastest.

The kitesurfer does not only steer the kite but also the board.

Have a vote on what you think is the fastest direction.

What is the fastest direction to surf? 0° 45° 90° 135° or 180°?

Assignment 3: Surf direction



a. Just like a sailing boat, a kite surfer can sail into the wind, not straight into the wind direction but at an angle. This has got something to do with how a wing works, as described in assignment 1, explain how a kite can move into the wind.

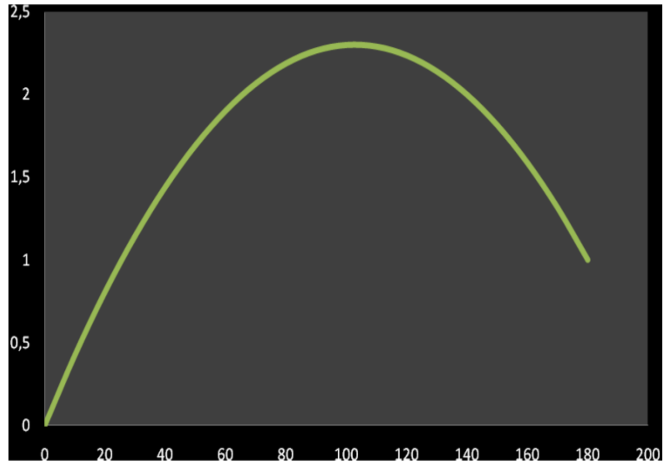
The following formula shows the sailing speed for each direction.

V_s = Sailing speed [m/s]

V_w = Wind speed [m/s]

A = Sailing direction [°]

$$\frac{V_s}{V_w} = \frac{-2{,}18}{10000}\alpha^2 + \frac{4{,}48}{100}\alpha$$



b. Is the following statement correct? The kitesurfer can sail quicker than the wind.
c. Calculate using the derivative of the formula what the quickest direction is and how fast the surfer will go.