

A few facts about kites and flight

What is a kite?

“A kite is a heavier-than-air, tethered aircraft kept aloft close to a perpetual stall by the wind.”

A kite has three essential characteristics:

- A structure designed to produce lift from the wind,
- A flying line (tether) that keeps the kite from flying away,
- A bridle that aligns the face of the kite to the proper angle in the wind for lift. In some cases, the flying line attaches directly to the kite's face or keel and governs its angle of attack.

Drachen Foundation

“A kite uses the power of the wind to keep it up. The wind goes against the pull of the string and supports the kite in the air. An ordinary flat or bowed kite flies by directing the breeze downward so the kite is pushed upward. The kite's tail helps to stabilize it and keep it flying smoothly.”

Boeing – wonder of flight

Think of the kite sail as being like a boat sail. The wind pushes on the kite and wants to push it along like the sailing boat. But the kiteflier is holding on to the kite line tethering it down. Because the kite is tilted up (by the angle of the bridle and the weight of the tail) the air is deflected downwards and the kite is pushed upwards.

What lifts a kite?

All heavier-than-air objects must overcome gravity to fly. To stay aloft a kite must be supported by uplifting forces. Most kites make use of an airfoil, a shape or surface that deflects airflow to produce different air pressures. The shape of a kite causes air to flow faster over the top surface when the kite is angled into the wind. The basic principle of kite flying has to do with a difference in air pressure: when air moves quickly over a surface, its pressure decreases; when air moves slowly, its pressure increases.

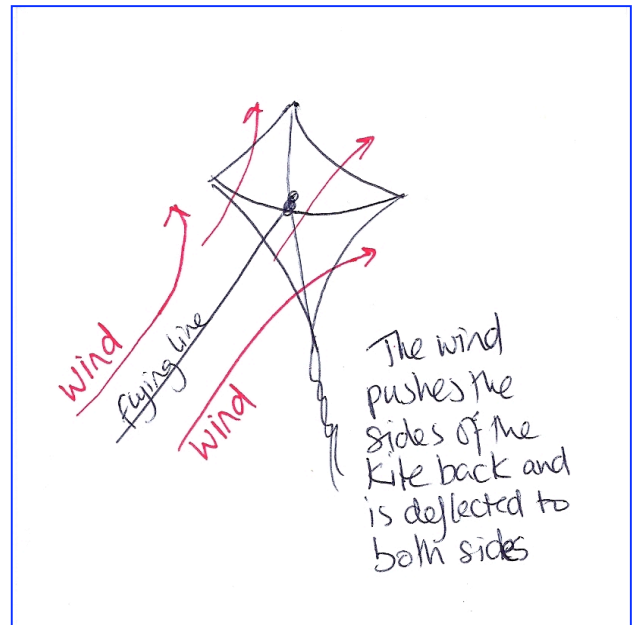
What are the Forces at play?

Thrust and *lift* are the forces that enable a kite to defy gravity. Thrust is created by wind; the velocity of the wind affects how well a kite flies. Lift is produced when bridle and line hold a kite at an angle into the wind. The correct angle causes air to move more slowly across the face of the kite to push upward. At the same time air moves across the back of the kite more quickly to reduce pressure and create additional lift. *Drag* and *gravity* pull downward on a kite. Drag is determined by the weight of the kite, its design and the flying angle set by line and bridle. A kite must have more lift than drag to fly. However, some drag is necessary to give a kite stability.

Smithsonian Institute - About Kites Exhibit Panels - Colorful Tales

Why do kites fly? What happens to the wind when it hits the kite?

Wind moving across the sail of a kite has to go somewhere. Because your kite is attached to a line, the point of attachment is being pulled down towards you and everything else is being pushed up and away from you by the wind. The kite is flexible so it bends with the wind and allows some air to slip by at its edges. The wind is deflected equally to both sides of the kite and because of the angle of attack and the fact that the lower section of the kite is heavier than the upper part, more wind is diverted downwards.



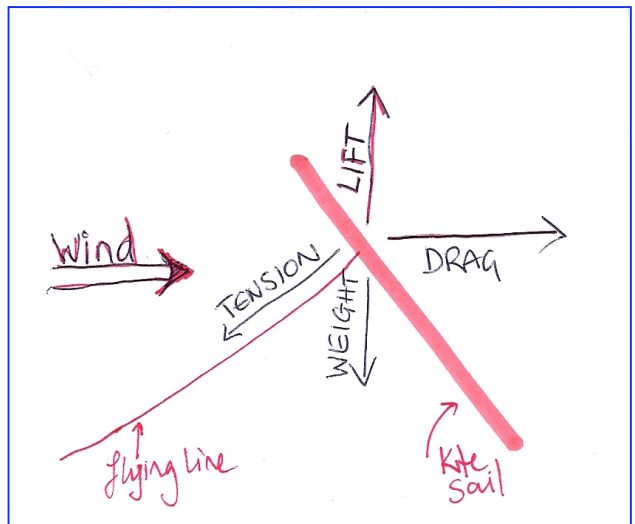
What forces are operating?

So the wind causes **lift** (is this a push?)
The wind resistance of the sail (and the tail) causes **drag**.

The ratio of lift to drag will result in a kite which flies high or low – or maybe doesn't fly at all if there is too much drag and not enough lift.

The line experiences **tension** (is this a pull?) due to the fact that the wind is trying to move the kite which is attached to you (by the line you are holding).

There is also the **weight** of the kite itself which is being pulled vertically downwards by gravity.



In theory, if these 4 forces are in equilibrium, the kite will remain still. However in practice – there are some variables.

- Weight of the kite - this is fixed (unless something falls off the kite or a paper kite could absorb moisture).
- Lift - is dependent upon wind speed – this can vary.
- Drag is dependent on the size and shape of the kite and it's wind resistance –this is fixed.
- Tension - is dependent upon wind speed – this can vary.

Could length of the line affect the tension? Yes, the line itself has a weight and may be thin or thick causing more or less drag and altering the tension on the kite itself.

Other things that will affect the flight are:

The wind resistance of the kite sail – it may be wind proof fabric, it may have a very smooth surface or a rough one, it may be porous or have holes cut in it. This will affect how it receives and diverts the wind.

You could experiment with porosity and wind resistance making kites of the same size and shape but from various fabrics.

The tow point and angle of attack.

For simplicity the kite shown has only one bridle point, however, Some kites have a keel – just like some boats have. This helps to split the wind and direct it down each side of the kite allowing the kite to be pushed upwards.

The dihedral

Many kites are designed with a dihedral – an angle formed by the two wings of the kite

How does a kite fly?

There are two main principles involved in the aerodynamics of a kite:
The first is Newton's Third Law of Motion and the second is Bernoulli's Theorem.

Newton's Third Law states that for every action force, there exists a reaction force that is equal in magnitude but opposite in direction.

The kite is attached to the ground by the tension in the line and pulled downwards by the force of gravity. The kite is kept in the air by lift. To raise and lower the kite in the air we can use lift by increasing and reducing the tension in the string.

Bernoulli's Theorem explains why the kite has lift. The kite creates an obstacle to the normal airflow that causes the air to change direction and speed. If you hold the kite out flat to the wind like a wing, beneath the kite the wind is slowed down and therefore the pressure of the wind increases to compensate. Above the kite, the air is not slowed down and sometimes is sped up so that pressure either stays the same or decreases. The pressure difference between the kite's bottom and top surfaces causes the lift force.

Vocabulary for kites and flight

Balance, symmetry, asymmetry
stability
tension, lift, weight, drag
air lift
aerodynamic
heavier-than-air devices
action & reaction
wind resistance

OWN notes

Types of kite

Some kites are flat, others are bowed and others have pockets which the wind can blow into. A 'flat' kite held at the right angle into the face of the wind will allow the wind to be deflected equally to each side of the kite (outwards and downwards) pushing the kite upwards. This is why if you made a square kite you don't simply tie your line to the middle point to get it to fly.

Some kites do the opposite to the flat kite and collect the wind inside them – more like a bag of wind – again if the angle is right – the wind moves inwards and downwards pushing the kite upwards.

Generally kites come in the following categories

- Flat kites – mostly these need a tail for stability
- Bowed kites – usually start out flat and then are bent into a bowed shape by using a taut line which pulls two points together leaving the surface curved or bowed against the wind.
- Box kites or cellular kites are truly 3 dimensional with a rigid frame and one or more cells which the wind travels through.
- Delta kites are generally dart shaped and flexible often with a keel
- Parawings are the original soft kite made with no sticks but a series of bridles of different lengths to hold the kite sail in position
- Canopy kites – such as a sled kite may have longitudinal sticks but no horizontal bracing. They are flexible and fill with air rather than brushing it off the surface.
- Parafoil kites - Look like a flying duvet – a soft kite which fills with air into its pockets. Many interesting shapes can be created using patterns to make kites that look like animals, ...

“A single line kite flies because its centre of lift position (CL, where lift forces act) is above its centre of gravity (CG, where weight forces act). The pendulum effect that this creates causes such kites to point upwards, and upwards they will fly, until they get to a line angle at which wind generated lift exactly matches the kite's weight (when the kite is said to be at its apex)- disregarding dynamic effects of course.” Peter Lynn (engineer and kite designer)

Some web references for kites and flight

www.drachen.org/learn/kite-basics

www.grc.nasa.gov/WWW/K-12/airplane/kitefly.html

www.boeing.com/companyoffices/aboutus/wonder_of_flight/how_things.html

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www.aeronautics.nasa.gov/fap/all_about_flight.html

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www.my-best-kite.com/how-does-a-kite-fly.html

<http://gombergkites.com/nkm/why.html>