Section 2 - Science Content

Drag & Equilibrium

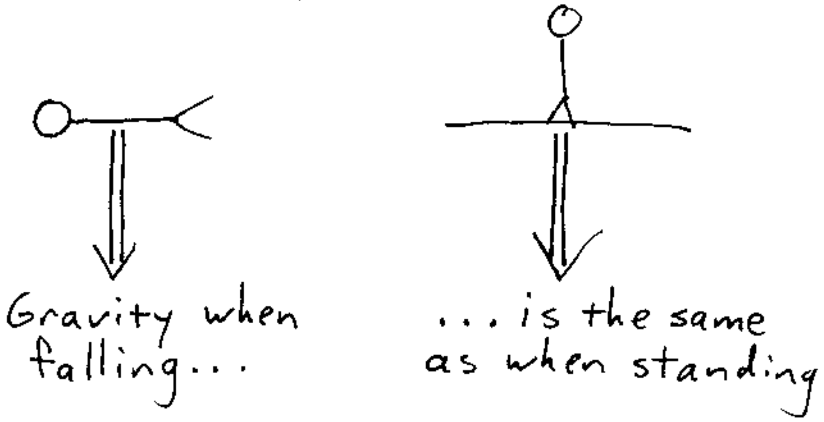
Why does your parachute fall at a steady speed but a bowling ball does not?

When an object such as a parachute is falling through the air, there are only two forces acting on it — gravity and air resistance (or *drag*). To understand what happens as the object falls, you have to think about how both of these forces act *together* and *at the same time*.

Gravity is a force that the Earth exerts on the object. Gravity is turned on all the time, even when the object is not falling, it always pulls toward the Earth, and it is always the same size.

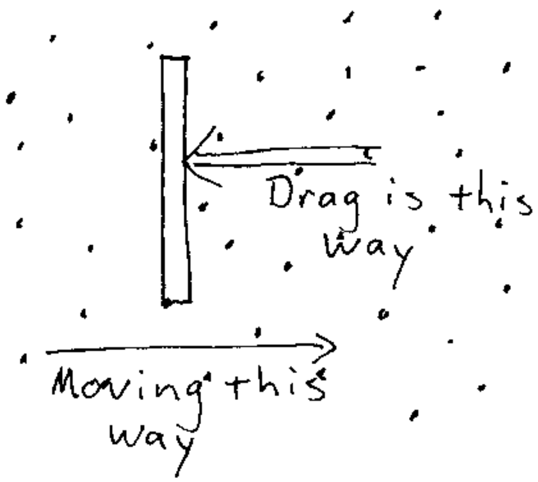
Science Rules of Thumb for Gravity:

- Gravity pulls objects toward the Earth.
- The force of gravity is bigger if the object has more mass.
- But for the same object, the force of gravity doesn't change.



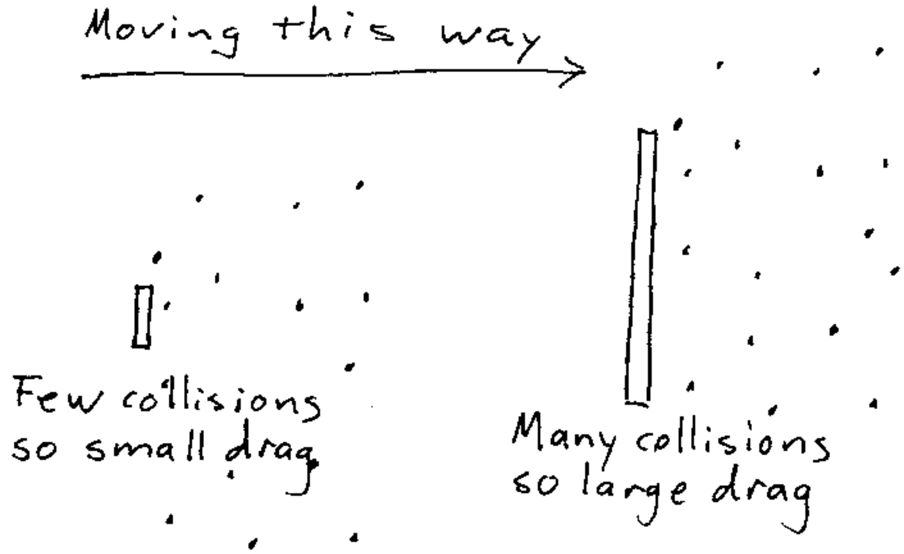
Drag is a little more complicated. Drag is only turned on when an object is moving through a gas (like air) or a fluid (like water). When the object is not moving, there is no drag. Drag happens because a moving object collides with air molecules. You might think that wouldn't produce a big force, and you would be right. But there are a *lot* of air molecules so all those little forces add up. Each of them pushes the object backwards, so drag always pushes opposite to the motion.

Drag & Equilibrium (cont.)



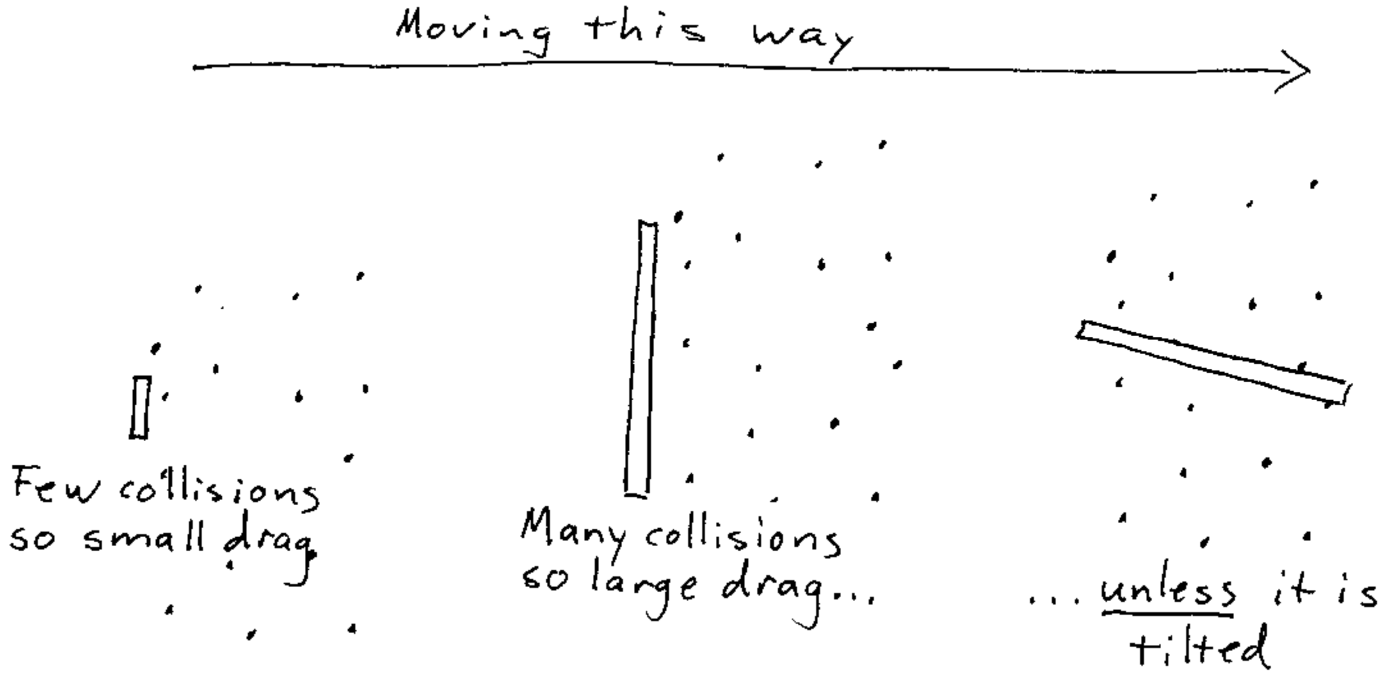
Drag depends on a lot of variables, but there are two that are important for parachutes. One of them is speed. The faster the object moves, the more air molecules it will hit in the same time, and it will hit each of them harder. This means that the drag will get bigger.

The other important variable is area — how much of the surface of the object is colliding with the air? A big object can hit more air molecules than a small one, so the drag will be bigger.



But if you tilt the big object, then you can make the drag smaller!

Drag & Equilibrium (cont.)

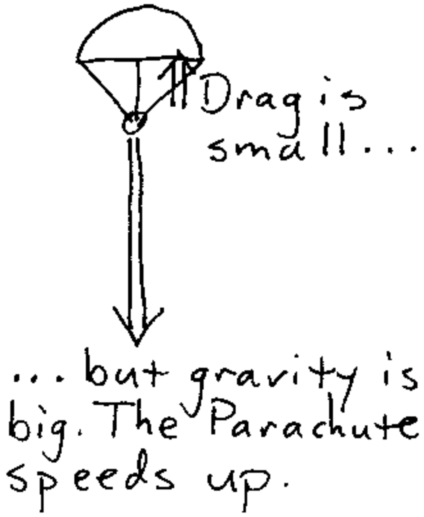


Science Rules of Thumb for Drag:

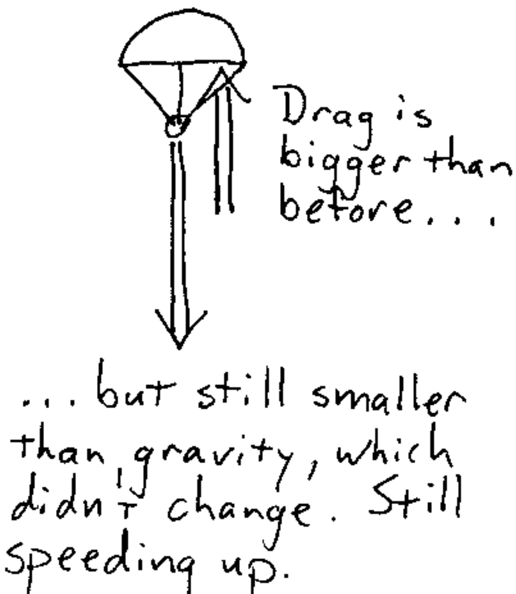
Going faster makes drag bigger.
Increasing area makes drag bigger.
Tilting makes drag smaller.
Always pushes opposite to the motion.

Parachutes: Two Forces at the Same Time

When a parachute first starts to fall, it is not moving very fast. This means that drag is very small. Gravity and drag are in a tug of war. The parachute is being pulled downward by gravity harder than it is being pushed upward by drag. This makes it fall faster and faster.

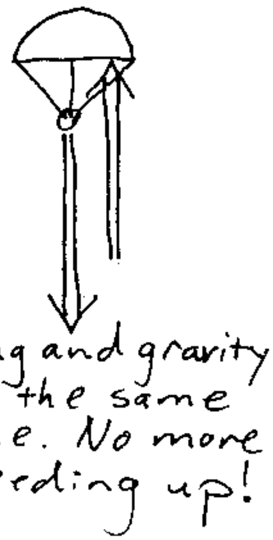


As the parachute speeds up, the rules of thumb tell us that gravity stays the same size but drag gets bigger. Drag is working against gravity, partly balancing it. The parachute still speed up but not as quickly. This is like adding people to the losing side in a tug of war. They might still lose, but not as badly.



Parachutes: Two Forces at the Same Time (cont.)

The parachute keeps speeding up until, at some point, drag is exactly the same size as gravity. The parachute is being pulled down just as hard as it is being pushed up. Gravity and drag exactly balance — this is called *equilibrium*.



Since drag is trying to slow it down just as hard as gravity is trying to speed it up, the parachute can't speed up any more. It falls at a steady speed from then on. This is like adding just enough people to the losing side in a tug of war so that the two sides are exactly balanced, and neither one can win.

Extra Mile

1. Next time you are riding in the car, try holding your hand out the window. Can you feel how the drag changes as the car changes speed? Try holding your hand at different angles. How does the drag change?

2. Once, I was watching a James Bond movie. Someone fell out of an airplane without a parachute, and James Bond put on a parachute (but he didn't open it yet) and jumped out too. The person without the parachute was laying flat while falling, but James Bond pointed his head toward the ground as he fell.

Parachutes: Two Forces at the Same Time (cont.)

I'm sure you've seen movies like this. Eventually, James Bond caught up, grabbed the falling person, and opened his parachute, saving the day!

Why did pointing his head at the ground make a difference? If he was lying flat, could he still have caught up?

3. Everybody knows that swishing your hand around in water creates a lot more drag than swishing it around in the air (but if you don't, try it and see). Why? What is different about the water? See if you can find something that falls through water (or even better through oil) at a steady speed, just as your parachute falls through the air.

Parachutes in Real Life: Different Designs Meet Different Challenges

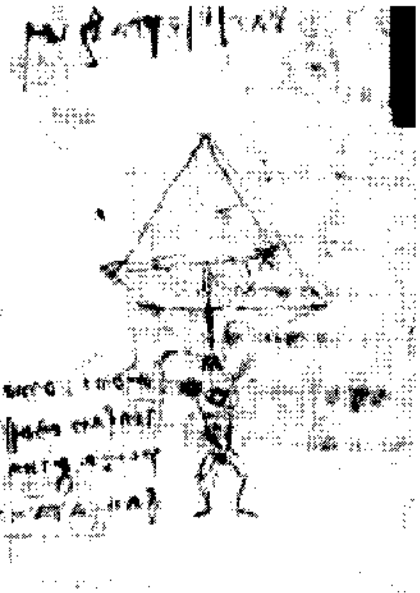
Parachute Science

Parachutes are designed to slow things down. Usually, we think of parachutes being used to slow down a skydiver falling from an airplane. But parachutes have many other uses as well.

Early Designs: Low drops, rigid structures

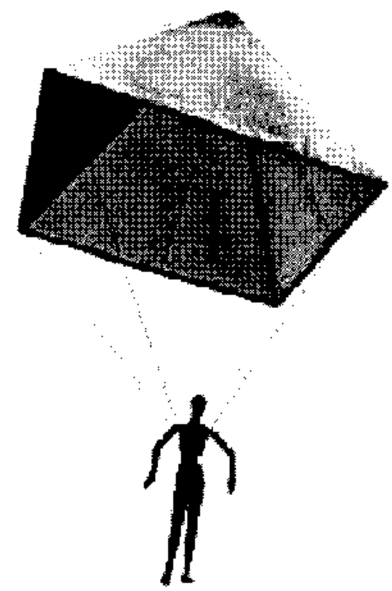
The earliest parachutes weren't used for anything very high off the ground. In China, in the 12th century, an umbrella-like parachute was used for circus stunts. Some medieval thinkers also designed, and even tested, escape parachutes. In the late 1400's, the artist and inventor Leonardo daVinci thought of a parachute that could be used to leap from a tower, perhaps to escape a fire. daVinci's parachute sketches were pyramid-shaped (picture 1).

Leonet, the Leonardo da Vinci museum



Leonardo's sketch

Leonet, the Leonardo da Vinci museum



Adrian Nicholas' model

There's no evidence that daVinci actually tried his idea out, but 500 years later, on July 2nd, 2000, a faithful copy was made and successfully tested by a British adventurer named Adrian Nicholas and a team from Oxford university that included experts on da Vinci, a motor engineer, and computer scientists who conducted computer simulations of the project. The parachute is about 90 kg. (about 200 lbs), or 40 times heavier than a modern parachute. It is 24 ft. square (about the size of a large beach umbrella) and made out of wooden poles, four triangular pieces of canvas that form a pyramid, and ropes that suspend the jumper. DaVinci didn't design a way to make the parachute collapsible; rather than have the whole thing land on his head, Mr. Nicholas cut daVinci's parachute loose at 2000 feet and released a modern-day parachute to carry him to the ground.

Parachutes in Real Life: Different Designs Meet Different Challenges

Parachute Science (cont.)

Medieval-era parachutes had many different shapes, but they were almost always rigid structures. One kind had a square of cloth attached to a wooden frame. DaVinci's parachute was pyramid-shaped. Another common type was an umbrella-shaped parachute that was reinforced by a central stem.

Jumping from balloons

For a few centuries, parachutes were mainly used by performers who jumped off of towers or platforms – not a real long distance. But in the 18th century, when hot-air balloons were developed, people wanted to be able to jump from higher distances, and new shapes were needed for that. Also, people became quite interested in using parachutes as escape devices. The first emergency landing from a hot-air balloon was in 1808. After that, many people became interested in designing more effective parachutes – ones that might fall slower, that might be easier to use, that might fall more gently. The first change made was to the parachute's shape. In the early 1800's, a fellow named Sir George Cayley designed a parachute shaped like an upside-down cone, and that shape soon became the standard. It fell more slowly than did the other shapes and was a bit easier to carry around.

Controlling oscillation

The cone worked well, except that it tended to oscillate, or ride like a choppy wave. It was improved by a French astronomer named Lelandes, who theorized that the motion occurred because air was trapped under the surface and spilled out, first under one side and then the other. He designed a parachute with a hole at the top, using the same cone shape, and still rigid, that allowed air to escape upward at a constant rate (rather than out the sides).

Designing better parachute release methods

The next improvement in parachute design came in 1804 in France, when a parachute designer named Bourget realized that the parachute didn't need to be held open by a structure; it could be collapsible, because air pressure would hold it open once the fall started. But it wasn't until 1908 that a parachutist could pull a ripcord to open a packaged parachute; before this, the parachute was either thrown into the air behind the person or fastened beneath the note-air balloon (or later, plane) body. Attaching the parachute to the body of the vehicle was called automatic release. (Would we call that "automatic" nowadays? Why not?)

How airplanes advanced parachute technology

The invention of the airplane, and World War I, were both important in sparking parachute development. Throughout most of WW I, parachutes were of the automatic type described earlier. It took many years before the "free" parachute, attached only to the parachutist, was safe enough to be standard.

In the 1920s, seat-type escape parachutes were designed to help plane crews escape damaged planes. At the same time, a triangular parachute canopy was developed and became the standard canopy shape for that time. Other aspects of parachute design -- making it easy to wear, making it easy to release -- were developed around this time too.

In recent years, designers who have been developing parachutes for combat situations have tried two kinds of designs. Some models can be steered by the parachutist for pinpoint landings. Some are designed to open at low altitudes so that they aren't easily spotted and so that the parachutist is in the air for the least possible amount of time.

Parachutes for different loads

Parachutes aren't only used to drop people to the ground. They are also used to drop cargo to the ground—sometimes, tons of material might be released from a cargo plane to be safely dropped to the ground. Cargo parachutes must manage heavy loads, and the parachute must be opened remotely or automatically. Dealing with heavy cargo means that the overall size of the parachute canopy must be greater (parachutes of about 24-28 ft. diameter are used for humans). But as the size increases, releasing and controlling a parachute gets more difficult. Nowadays, heavy cargo is usually dropped with a package of parachutes, arranged so that the weight is evenly distributed among them and so that they don't interfere with each other as they deploy.

Pioneer Aerospace Corporation

Dropping Heavy Equipment

Parachutes that don't drop down

Parachutes are also used for braking. In drag racing, cars reach speeds of over 300 miles an hour in a few seconds. Standard brakes don't work for slowing down safely from these speeds. Instead, parachutes are deployed out the back of the vehicle. The air they catch provides drag on the car. Parachutes are also used to help high-speed planes recover from spins and stalls when they can't be controlled by the pilot. Just as with drag racers, they provide a stable dragging force that allows the plane to slow down and stabilize its direction.

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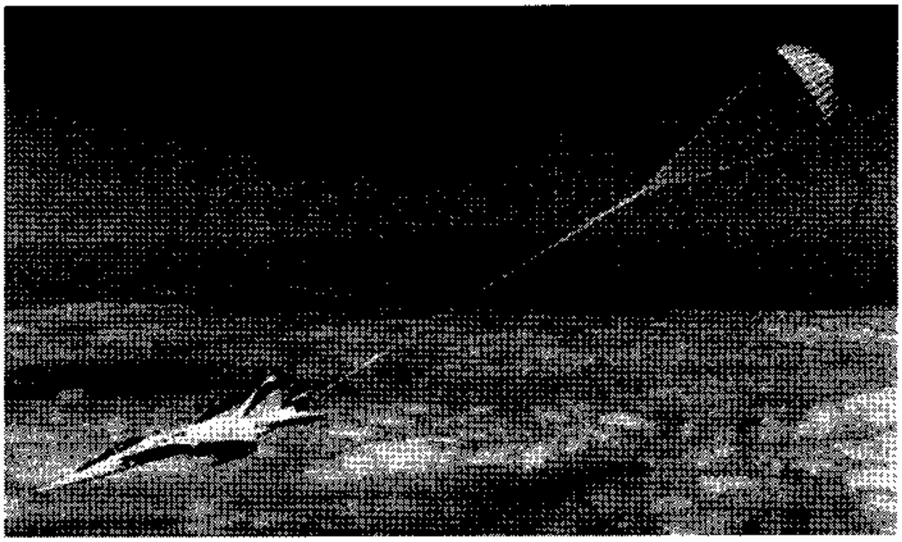
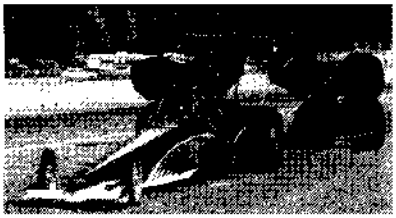


Braking an Airplane

Northern Thunder Drag Racing



Braking a Racer

Parachutes in Space

Since its start, the space program has used parachutes to help space capsules return to earth. Similar parachutes are used to land vehicles on Mars. Because the atmosphere is thinner than that of Earth, the speed of entry is different. Space capsules entering earth's atmosphere come in at about 300 miles per hour, but vehicles entering Mars' atmosphere need to come in at about 900 miles per hour (so they won't skip off the thinner atmosphere upon entry). This changes the height at which the parachute must be deployed. Also, because the temperature and atmospheric conditions are different on Mars than on Earth, different materials are used for parachutes used on the different planets.

A new twist on this idea is on the drawing board at NASA right now, as designers are developing an escape pod for the space station crew. The X-38 prototype lifeboat looks like a small space shuttle, but instead of gliding under its own power to earth, it will use a parachute delivery system. The technology that is being used is not brand new—NASA researchers are taking parachutes that already exist for other uses and applying them to the X-38. Using designs that are already in production allows NASA to make a cheaper design, have parts that can be replaced more easily, and also to take advantage of products that are already successful.

www.space.com/missionlaunches/launches/x38_parafoil_000414

X-36 Prototype Lifeboat

