

## PHYSICS IN DAILY LIFE: FLYING (S)LOW

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When thinking about energy-efficient travel, why not use our imagination and try to construct a vehicle that has zero resistance? In fact, we do not have to invent it. It already exists. It's the airship, or zeppelin, named after its developer, the German count Graf Ferdinand von Zeppelin. It does not need high speeds to stay airborne, in contrast to a plane. Neither does it have the annoying rolling resistance of a car. So this looks like the ideal way of transport, viewed from a perspective of energy.

Or does it? All the above may be true if we just want the zeppelin to float at a fixed spot. But what happens to its efficiency once it starts moving?

We can easily make a back-of-an-envelope estimate. All we have to do is to work out the air resistance of the airship, keeping in mind that the resistance (in newtons) is equivalent to the energy use per unit distance (in joules per metre, or kJ/km if you wish). To keep it simple, let us compare the airship with a car. This is a fair comparison: in contrast to a plane at high altitude, a car moves through air at ambient pressure, just like a zeppelin. After all, zeppelins are bound to fly low, since Archimedes' law would not allow them much lift in thin air.

And if we consider speeds of 100 km/h at the very least (just think of a zeppelin in headwind!) the rolling resistance of the car can be ignored, since it makes only a minor contribution at such high speed.

So let us look at the air resistance, or drag. We may remember that it is given by  $F = C_D A (\frac{1}{2} \rho v^2)$ , where  $C_D$

is the drag coefficient,  $A$  the frontal surface area,  $\rho$  the air density and  $v$  the speed. For a fair comparison we should take the value of  $A$  per passenger in both cases. For a car, this is about  $0.5 \text{ m}^2$ . For a zeppelin we may take the dimensions of the Hindenburg, the airship that made history when it tried to land in New Jersey back in 1937. It had a diameter of 41 metres and carried about 100 passengers. This yields a frontal area of  $13 \text{ m}^2$  per passenger. Obviously, there is no way that this can compete with a car. Even if we take into account that the value of  $C_D$  for the cigar-shaped zeppelin may be lower than the value for a car by a factor of three (0.1 vs. 0.3, say), the airship loses by an order of magnitude.

We can check our estimate using the Hindenburg's technical data. It had a top speed of 135 km/h and its engines had a power  $P$  of 3560 kW in total. If we work it out, realizing that  $P = Fv$  we find that, indeed, a car beats the airship by a factor of 7 or 8.

If we remember that a full airplane is about half as fuel-efficient as a full car, we conclude that a plane is also superior to the zeppelin by a wide margin, even though its speed is much higher.

This may come as a surprise, but the reason is obvious. For one thing, the airship has this enormous volume, giving rise to large air resistance.

Secondly, the density of the air through which it moves is larger by a factor of 4 compared with the air at cruising altitude of a plane.

The conclusion is inevitable. There is no bright future for the airship, even if the price of energy goes soaring. Unless we *really* take our time and go slow. ■

