THE MYSTERY OF RISING BALLOONS

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Why do balloons rise in air? How high can they go? When do they drift to the ground? How do we test these possibilities?

For many of us, the sight of a balloon bobbing in the air can evoke many memories. Like that of watching the ceremonial release of a bunch of gaily coloured balloons at a function. Or of one of our balloons flying out of reach when the string accidentally slipped out of our grasp — a sight that may have driven many of us, as children, to tears. I remember racing after such balloons, hoping that they would eventually land on the ground. But those rascals always escaped me!

Have you ever wondered why balloons rise in air? A textbook will tell you that an object surrounded by air rises upwards when the weight of air displaced by it is equal to the lifting force (buoyancy) acting on it. But what does this cryptic-seeming explanation mean? Under conditions of normal temperature and atmospheric pressure, one cubic meter of air weighs 1250 grams. Therefore, an object with a volume of one cubic metre will float in air if its weight is 1250 grams, fall to the ground if its weight exceeds 1250 grams, and rise upwards if its weight is less than 1250 grams. In other words, any object whose weight is less than the weight of the same volume of air will rise upwards. The gas balloons that we see in celebrations are usually filled with helium gas — the second lightest gas. This means that the combined weight of the balloon, the gas within it, and the string attached to it is still less than the weight of air displaced by the inflated balloon. This is why gas-filled balloons rise in air.

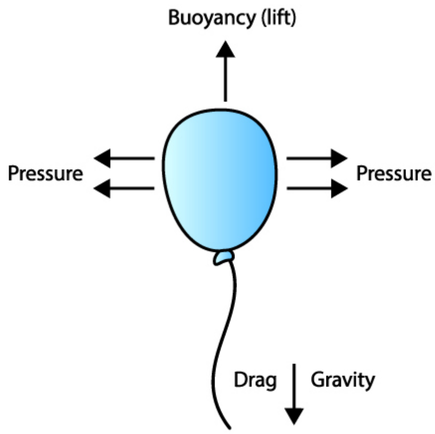

Fig. 1. A helium balloon rises to height where the buoyant force pulling it upwards will equal the gravity pulling it downwards. As it moves higher, the air pressure outside it decreases. When it falls lower than the air pressure inside, the gas within the balloon expands. License: CC0.

Box 1. The game of bobbing balloons:

Releasing the second balloon in my room reminded me of a game I had read about somewhere. Two or three balloons filled with gas are released in a room. The balloons immediately nest at the ceiling of the room. When they are sprayed with a few drops of water from a syringe, the balloons start descending. They rest on the floor till the water drops dry off before they begin to ascend towards the ceiling again. Depending on when and how much water they are sprayed with, they can change course — flying upwards or floating in the middle like Trishanku personified. Having thought of this, I spent the next few minutes playing this game with the balloon in my room. I had such fun that I paid no heed to the question that provoked this experiment. But you may have guessed that the weight of the balloon remains more than the weight of the air displaced by the balloon as long as the water droplets stay on the balloon. If the water evaporates or the droplets roll off its surface, the weight of the balloon goes back to what it was before, and the balloon rises towards the ceiling once again.

How high would a rising balloon go? It will continue to rise as long as the weight of the air displaced by the balloon is greater than the weight of the inflated balloon. As it moves higher, the density of air around it decreases. Thus, the weight of air displaced by the rising balloon also decreases. When the weight of this displaced air becomes equal to the weight of the helium in the balloon, the balloon will stop rising (~ 32 km above the Earth's surface). At this point, the buoyant force pulling the balloon upwards will equal the gravity pulling it downwards (see **Fig. 1**).

What will happen to the balloon once it reaches this height? One possibility is that the gas in the balloon will slowly leak out. This could happen if the mouth of the balloon is not tied tightly enough or tiny holes appear in its thin stretched rubber when it is inflated. This will reduce the speed with which it ascends in air. When the balloon reaches the height at which its weight equals the buoyant force acting on it, it will stop and sway in the sky for a while before drifting down to the ground. To test this possibility, I used a 3-metre-long string to tie a tightly stretched balloon to the railing on the roof of my house. Eager to fly off, the released balloon went as high as it could, after which it stood tall and proud, swaying just a bit in the wind. The string by which it was attached to the railing was taut. I released another balloon in my room (see **Box 1**). Almost immediately, it hit the ceiling. I decided to leave both balloons like that for a day. By the next day, both had gone limp, and were lying on the floor. The gas had leaked out of them. This confirmed the first possibility.

Another possibility is that the balloon will burst somewhere up in the sky. Since atmospheric pressure decreases with increasing altitude, the higher the balloon goes, the greater the difference between the pressure inside and outside it. This difference in pressure will cause the gas inside the balloon to expand and the volume of the balloon to increase. This will eventually stretch the rubber of the balloon to a point where it bursts. The height at which a balloon reaches this point will depend on the altitude to which it rises (the higher the altitude, the lower the pressure, and the more likely the balloon is to burst) and the quality of rubber used to make it (the weaker the rubber, the sooner the balloon will burst). To test this possibility, I would have to release a balloon at a substantial height. I released one, with its string attached, at a height of 300 metres above sea level, where the atmospheric pressure is about 734 mmHg. The balloon flew upwards for a while, before the wind carried it away from me. I used a toy telescope to follow its movement. Till the time I could see it, it hadn't burst. Also, and this could just be my perception, it did not seem to rise beyond a certain height. If this was a height of about 50 metres, the balloon would have reached a total height of 350 metres above sea level, where it would experience an atmospheric pressure of 730 mmHg. (I have calculated the atmospheric pressure for these altitudes with the help of a calculator on this website: http://www.altitude.org. I don't know whether this calculation takes account of temperature, humidity, and the latitude-longitude of my location). At this point, it is likely that the pressure outside would be very different from the pressure within the balloon, but I haven't thought of a way to test whether the balloon will burst due to this difference. If you could offer any suggestions, it would help take this experiment forward.

Key takeaways

- A helium balloon rises in air because the combined weight of the rubber with which it is made, the gas filled into it, and the string attached to it is still less than the weight of air displaced by it.
- A balloon will continue to rise in air till the weight of air it displaces becomes equal to the weight of the balloon.
- As it rises upwards, the air pressure outside the balloon will decrease, becoming lower than the air pressure inside it. Whether the balloon drifts to the ground or bursts in the sky will depend on the altitude to which it rises, the quality of rubber, and how leak proof it is.

Notes:

1. This article was first published in response to a Sawaliram question in Sandarbh, Issue 88, pg 21-25. URL: https://www.eklavya.in/magazine-activity/sandarbh-magazines/250-sandarbh-from-issue-81-to-90/sandarbh-88/978-sawaliram-88.
2. Source of the image used in the background of the article title: Helium Balloons. Credits: stux, Pixabay. URL: https://pixabay.com/photos/balloon-helium-air-flying-bright-3360126/. License: CC0.

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