ASEN 2002 Design Pre-Lab I

Mia Abouhamad, Abdulla Alameri, Daniel Barth, Zihao Ding, Chava Friedman, Eric Hunnel, Vinay Simlot, Ryan Smithers

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I. Free Body Diagram of Helium Balloon

Two forces were involved in determining whether the balloon floats: the force of gravity and the buoyancy force, shown on Figure 1. The buoyancy force based on the density of helium compared to air can balance, or even exceed the force due to gravity, forcing the balloon upwards.

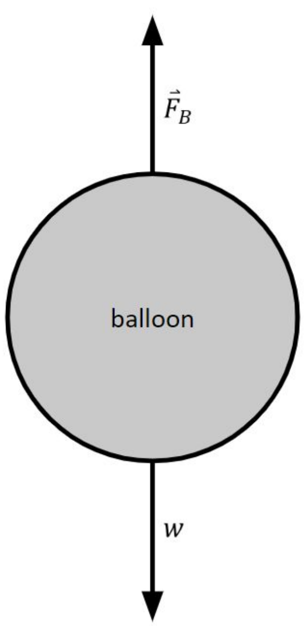

Figure 1 : Neutral Buoyancy

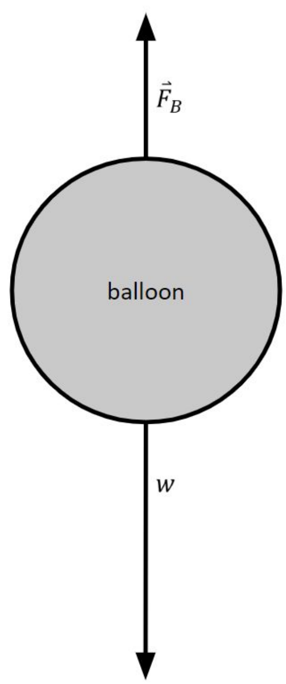

Figure 2 : Negative Buoyancy

The local temperature was 22 degrees Celsius, provided by the TAs, and the local pressure was $83.4 \pm 0.4\, kPa$ from the NCAR foothills laboratory.

II. Negative Buoyancy

When the balloon was placed in front of the heater, a heat transfer took place. The balloon had a lower temperature than the air on the other side of the mylar, so the helium in the balloon started heating up to try and be in thermal equilibrium with its surroundings. When this took place, the pressure of the balloon increased; in addition, the density of the helium decreased enough, and the "slightly-negative" balloon moved upwards. When the heat source was taken away, the balloon had to undergo another heat transfer to reach thermal equilibrium with the room-temperature air, so it lost thermal energy. The balloon's pressure and density also returned to its previous values before the thermal process was started.

III. Volume Measurement

Method 1, which involved estimating the volume of the balloon as a cylinder, resulted in a significantly larger measurement than in Method 2 in which the balloon's volume was estimated using the displaced volume of water. The approximation in Method 1 likely lead to a severe overestimate due to the balloon's curvature not being accounted for which is observed when the data provides an estimate that is over 300 in^3 larger than the estimate using Method 2.

The first method provided an estimate the contradicted the estimate found in the second method, the uncertainty bounds did not overlap for either measurement. Method 1 was also significantly less precise, which was to be expected due to the procedure of estimating the spherical object as a cylinder. Due to the discrepancy between the measurements being so great, it was decided that the measurement used in Method 2, which had significantly less uncertainty and a smaller overestimate (due to the volume of the hands pushing the balloon into the water), should be used in calculations modeling the balloon going forward.

Table 1: Comparing the volumes of the balloon calculated by different methods (all values m^3)

	Volume	Uncertainty
Method 1	0.0173	0.0007
Method 2	0.0121	0.0004

IV. Mass Budget

The mass of the helium was measured using two methods: the density of the helium gas multiplied by the volume, and the ideal gas law. The difference between both calculated values was about half a gram. This was due to the Helium density being calculated with an interpolated density at the pressure of 83.4 kPa. When the ideal gas law and the density based calculation were calculated using the pressure at sea level, the values were much closer. However, the ideal gas law still assumes that the Helium would behave as an ideal gas, which would not be true in practice.

For both calculations, the volume of the balloon was included in the calculations, so the mass calculated is slightly higher than the true value. Both estimations assume that the gas inside of the balloon is pure Helium.

Mass of Helium required to displace the air around the balloon was calculated using the density of Helium and the volume of the balloon.

Table 2: Comparing the mass of Helium by measured volume and the ideal gas law

	Mass (g)	Uncertainty (g)
Measured Volume	1.9431	0.0004
Ideal Gas Law	1.6338	0.0238
Mass Weighted Average	1.9430	0.0004

Table 3: Mass fractions of each portion

	Fractional Mass	Uncertainty
Balloon	0.0428	4.92E-04
Helium	0.1575	3.79E-04
Payload	0.0428	4.92E-04

V. Design Modifications

There are multiple possible methods for increasing the amount of payload possible to carry using the balloon. One possible method would be to have a method of heating up the gas inside the balloon during travel which would cause the helium in the balloon to expand and increase the buoyant force pushing upward on the balloon. Similarly, increasing the volume of the balloon with all other variables kept constant would increase the buoyant force as well based on the formula $F_B = \rho g V$.

Another approach to increasing the amount of payload possible to carry would be to decrease the total mass of the system not including the payload. For example, one could make the shell of the balloon thinner and decrease the force due to gravity pulling the balloon downward. It could also be possible to make the shell out of entirely different material that has a lower density and would therefore contribute less to the weight of the system.