Lab 1 – Balloon Lab

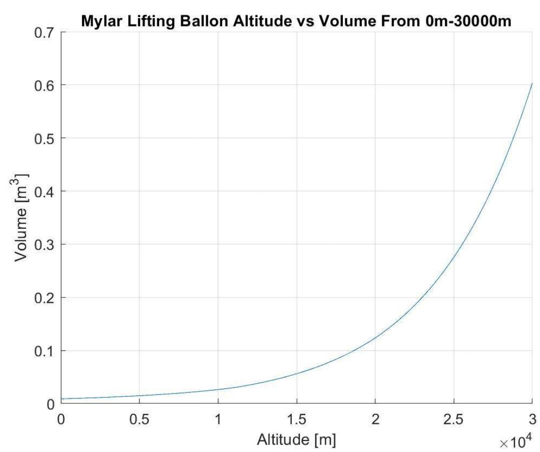
Haley Hastedt, Gwyneth Lowry, Jared Steffen, Grayson Gallawa,
Andrew Biedron, and Isabella Davila
University of Colorado Boulder

I. Introduction

For this lab, we completed our analysis of experiment 1 by using the provided videos and experimental data to plug values into our derived equation for neutral buoyancy. For experiment 2, we took data from an in-class hot air balloon demonstration to use in our neutral buoyancy equation.

To simplify our calculations, we assumed that air behaves as an ideal gas under the conditions we are concerned with. With regards to the helium balloon, we assumed that its shell is infinitely stretchable and the mass remains constant. We also assumed that there are no stress or strain forces acting on the shell of the balloon. With regards to the hot air balloon, we were able to assume that the volume is fixed and the temperature that the hot air balloon fails at is 522 K. We also assumed that there was no pressure difference between the room and the inside of the hot air balloon. None of the assumptions are too crazy, so the assumptions are believed to be valid.

II. Experiment 1 Analysis



a. Calculated buoyant force

$M_{He}g = \rho_{air}\nu_{disp}g - m_{payload}g - m_{balloon}$ $\leftarrow Neutral\ buoyancy$

$M_{He} = 0.00129\ kg$ $\leftarrow Force\ balance$ $M_{He} = 0.001651$ kg $\leftarrow Ideal\ gas\ law$

$F_B = 0.116715\ N$ $\leftarrow Experimental\ (measured)$ $F_B = 0.116715\ N$ $\leftarrow Calculated$

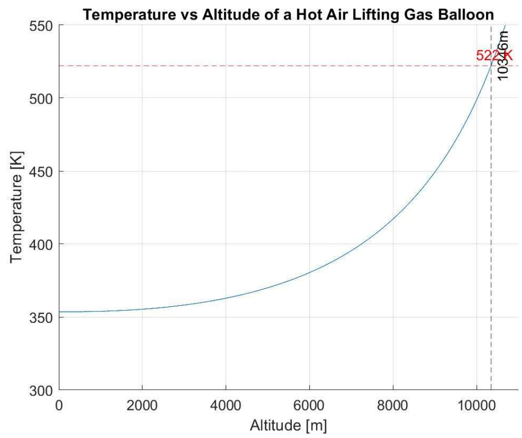
The differences in the measured and calculated neutral buoyancy force are negligible. They have a difference of 0.006 N. Some potential causes of this difference could be rounding error and random error such as human error when collecting data.

When heating the lifting gas balloon the temperature, pressure, and volume are all changing. As the temperature and pressure decrease with altitude, the volume of the balloon increases. This is due to pressure and temperature being directly proportional in the ideal gas law. On the other hand, volume is inversely proportional to both pressure and temperature. This trend can be described as exponential, and is visually represented in the graph above. The largest change that could be made in order to make this model more accurate would be to assume the mylar balloon can only stretch to a certain volume and wouldn't continue the exponential trend we see above.

The thermodynamic process of heat transfer is at play while heating the lifting gas. The thermodynamic process that occurs as the balloon is heated up is as the lifting gas is heated, it gains more energy and the temperature and pressure increase. In order to account for this, the volume of the balloon also gets bigger, which decreases the density of the lifting gas and system. This increase in volume and decrease in density is what allows the balloon to gain buoyancy.

In order to get better results, instead of using the data that was provided to us, we could have performed the experiment ourselves to ensure that our data was recorded accurately and precisely. This would minimize the error, allowing us to improve our experiment.

III. Experiment 2 Analysis



The graph above represents an exponential mathematical trend, the temperature slowly rises at first, but as altitude gets higher, the temperature quickly increases. A force balance between the buoyancy of the balloon and the gravitational force of the balloon, air, and payload was used to determine the temperatures as altitude increases. The values obtained do make sense, as we would expect the balloon temperature to slowly rise at first, and then drastically increase towards the end when the balloon gets harder to maintain neutral buoyancy. It was also assumed that the balloon had a fixed volume throughout the process and that the weather was not extreme when the balloon was taking off. One way to improve this model w
ould be to include a changing mass as the fuel is being used up and to assume the volume can change slightly.

Calculated temperature for neutral buoyancy: 110.12 ºC

Observed temperature for neutral buoyancy: 145.95 ºC

One possible reason for this difference is error in the collection of experimental data. When doing the experiment, the balloon achieved neutral buoyancy before we expected it to, so the data we collected that was supposed to represent the moment neutral buoyancy was achieved likely represents the balloon conditions slightly after neutral buoyancy is achieved. In addition, when finding the internal temperature of the hot air balloon, we averaged the temperature readings from the four internal thermocouples. This could be slightly off from the true average internal temperature of the balloon. Also, we observed internal pressure to increase slightly during the experiment, but this increase is negligible thus we can assume the pressure remains constant. One step we could take to improve our results would be to be more accurate when determining the moment neutral buoyancy is achieved. We could also use more internal thermocouples to get the average internal temperature.

IV. Conclusion

For the mylar balloon, the helium was assumed to be an ideal gas, and for the hot air balloon, the air was assumed to be an ideal gas. As seen on Figure 3 in the Appendix, the hot air balloon goes up and the temperature increases up until the balloon fails at 522K. As the mylar balloon goes up, the temperature will decrease because the temperature inside the balloon will be very close to the temperature outside the balloon, which decreases as altitude increases. Also seen on Figure 3, the hot air balloon has a constant volume of 0.1314 m^3 as it ascends, but the volume of the mylar balloon does increase as it ascends. The hot air balloon has a fixed volume since it cannot expand past a certain point, which means that the structure will fail at a certain point. However, the mylar balloon is stretchable to a degree. A force balance equation between the buoyancy of the balloon and the weight of the balloons/payloads was used to determine the buoyant forces and temperatures required for neutral buoyancy for the balloons. This mathematical trend would be exponential, as the temperature slowly rises at lower altitudes, then quickly spikes at higher altitudes. These results show that both balloon types are viable for different types of uses. Longer duration balloon flights would use a helium balloon due to the fact that hot air balloons would need to carry their fuel on board, which would make it heavier than needed. Helium balloons would also be more beneficial for high altitude flights as the hot air balloon structures would fail past a certain point. For sight-seeing tours, hot air balloons would be the most feasible since they are going to take place at low altitude and only for a few hours at max. These results do reflect on real-life missions regarding helium and hot air balloons.

III. Appendix

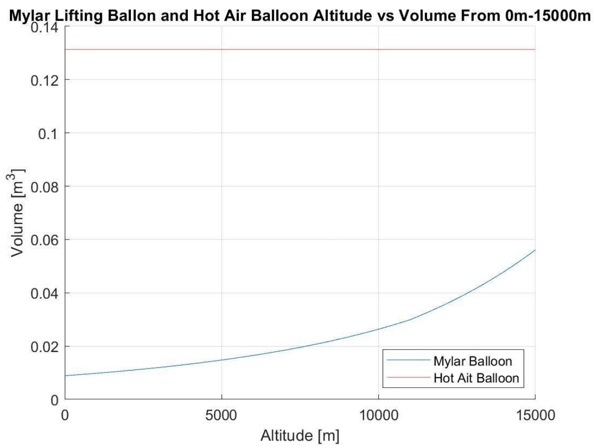


Figure 3

Code

```
clc
close all

% Experiment 1

% Altitude
alt = 0:30000; %[m]

% Atmoscoesa Function Call
[T,a,P,rho] = atmoscoesa(alt);

% Mass of Balloon + Helium
m = 0.00129 + 0.009569; %[kg]

% Gas Constant
R = 287.5; %[J/kg*K]

% Calculated Volume
V = (m .* T * R)./P; %[m^3]

% 30000 Plot
figure (1);
hold on
grid on
ylabel('Volume [m^3]')
xlabel('Altitude [m]')
title(['Mylar Lifting Ballon Altitude vs Volume ' ...
    'From 0m-30000m'])
plot(alt,V)
hold off
```

```
% Experiment 2

% Altitude
alt2 = 0:17500; %[m]

% Atmocoesa Function Call
[T2,a2,P2,rho2] = atmoscoesa(alt2);

% Constants
m_balloon = 0.03; %[kg]
V_given = 0.1314; %[m^3]

% Calculations
T_calc = (P2 * V_given)./(R * ((rho2 .* V_given) - m_balloon)); %[K]

% Max Temperature Plot
figure (2);
hold on
grid on
ylabel('Temperature [K]')
xlabel('Altitude [m]')
title('Temperature vs Altitude of a Hot Air Lifting Gas Balloon')
plot(alt2,T_calc)
xlim([0 11000])
ylim([300 522])

% Find Where Structure Fails
```

```
max_alt = find(T_calc>522);
max_alt_ans = max_alt(1,1);

% Finish Plot
xline(max_alt_ans,'k--',{'10346m'})
hold off
```