LEBANESE UNIVERSITY
Faculty of Sciences II

SCIENTIFIC REPORT

Optics/Thermo Lab P3303

Experiment 2 A: KINETIC THEORY OF GASES

By

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I- Abstract

This experiment covers the Kinetic Theory of Gases and the distribution of particles(balls)

into a closd environment(compartments). The balls are subjected to vibrations to mimic the movement of particles and their distribution and then count the amount of balls inside each particle of the recording chamber. The properties of a perfect gas must be deduced from this experiment as well as the effect of gravity on the distribution of the balls.

Key words: *gaussian*, *histogram*,*standard deviation*, *mean*, *gas*

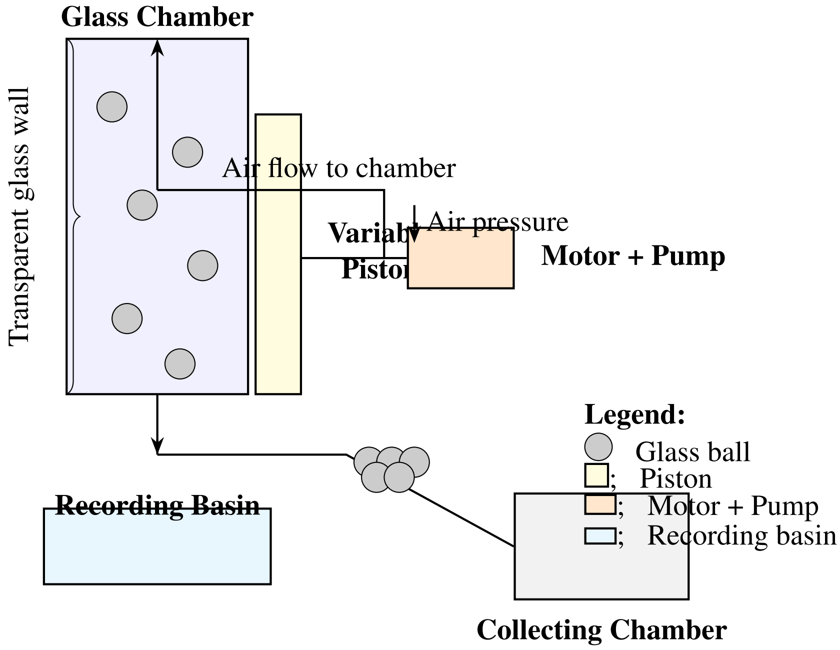


Diagram I: Basic Experimental Set up

Photo I: Equipment used in the experiment[3]

II- Introduction

The **Kinetic Theory of Gases** states that molecules inside solids, liquids, and gases inside are in constant movement depending on the temperature of it. To elaborate, initially at $0\ K$, the atoms are fixed. As the temperature T increases, atoms will start to vibrate until they reach $T = 10\ K$ where **collisions** between them start to occur. The experiment performed in the Thermodynamics Lab is a demonstration of the Kinetic Theory of Gases by subjecting molecules to a gravitational force at *different* temperatures in order to study the properties of a **Perfect** gas.Also, the effect of gravity on the balls will studied. [1]

Refer to **Diagram 1** for a simple diagram of the experiment.

III- Procedure

The steps of the experiments are:

1. Start by placing balls inside the basin.
2. Position the piston to $30mm$.
3. Connect the variable resistance to the circuit.
4. Let the apparatus run for a specified amount of time.
5. After unplugging the circuit, count the number of balls in each compartment of the recording chamber as accurately as possible.
6. Repeat the experiment many times.

Note that the experiment should run for t= 1 min; 2 min; 3 min. After counting every ball in each compartment at different times, the results found are in the following tables:

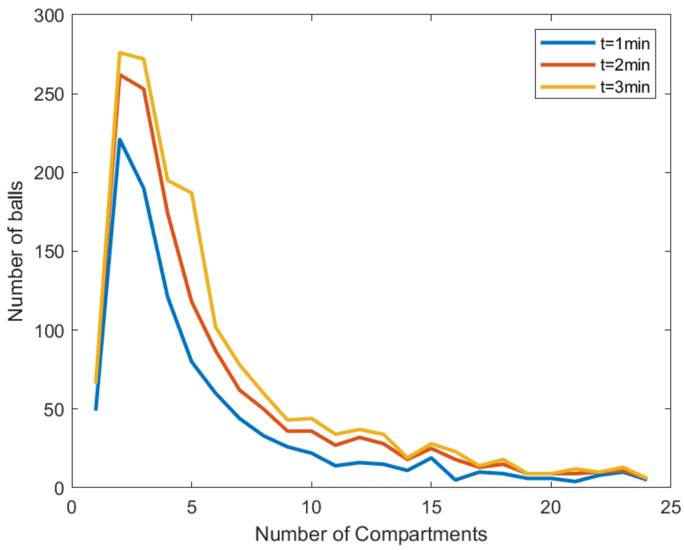
Compartment	1	2	3	4	5	6	7	8	9	10	11	12
$t = 1$ **min**	49	221	190	121	80	60	44	33	26	22	14	16
$t = 2$ **min**	66	262	253	174	118	87	62	50	36	36	27	32
$t = 3$ **min**	66	276	272	195	187	102	78	60	43	44	34	37

Table I: Number of balls in compartments 1–12 at different times.

Compartment	13	14	15	16	17	18	19	20	21	22	23	24
$t = 1$ **min**	15	11	19	5	10	9	6	6	4	8	10	5
$t = 2$ **min**	28	18	25	18	13	15	9	9	9	10	11	6
$t = 3$ **min**	34	19	28	23	14	18	9	9	12	10	13	6

Table II: Number of balls in compartments 13–24 at different times.

Now refer to plot the graph of the number of compartments as a function of t=1 min and 2 min and 3 min(**Graph I**.



Graph I: Basic plot of the number of compartments as a function of the number of balls

IV- Results and Analysis

Now for the analysis of **Graph I**, **Table I** and **Table II**. **Graph I** is a very basic plot that seems to look like *bell curve* or in other words, the famous ***Gaussian Curve*** but it is not smooth. To further perfect **Graph I**, it is possible to draw 3 different *bar graphs* along with the ***Gaussian fitting*** curve using software like OriginPro 8.5 (or MATLAB). In **Graphs III, IV and V**, in order to draw the curve the fitted curve, we need to use this equation and iterate(or just use a *built-in* function):

$$y = A \exp\left(- \frac{(x-\mu)^2}{2\,\sigma^2} \right) \tag{1}$$

Where A is the amplitude, μ and σ are the mean and standard deviation for a **table of frequency**(APPENDIX). In **Graph II**, the variation of number of balls as a function of number of compartments was fitted and bar graphs were plotted to see the behavior of the gaussian-like curve. In order for a more accurate study, one can also transform the bar graph into a histogram. **VERY IMPORTANT** to visually represent the upcoming statistical measurements on a histogram because the measurements of means and standard deviations are that of the balls and not the compartments.(Hence why the upcoming graphs don t have compartments on any axis).

From **Graphs III, IV and V**, you can see **histograms** of the frequency of number of balls in intervals of 25 balls along with its appropriate **gaussian fitting** and that the results **SKEWED** to the *right*. Skewness, by definition, is how asymmetrically the data is distributed around its mean. This is an asymmetric skewness as shown by the gaussian curve which also skewed to the right indicating that the data is **NOT** a perfect gaussian bell curve. In this case, we speak of probabilities instead of the specific place where a ball might land where we integrate under the curve and the area is the probability of presence. Note that the $-\sigma$ part was neglected because it is meaningless in our case as we cannot have negative amount of balls in a compartment.[2]

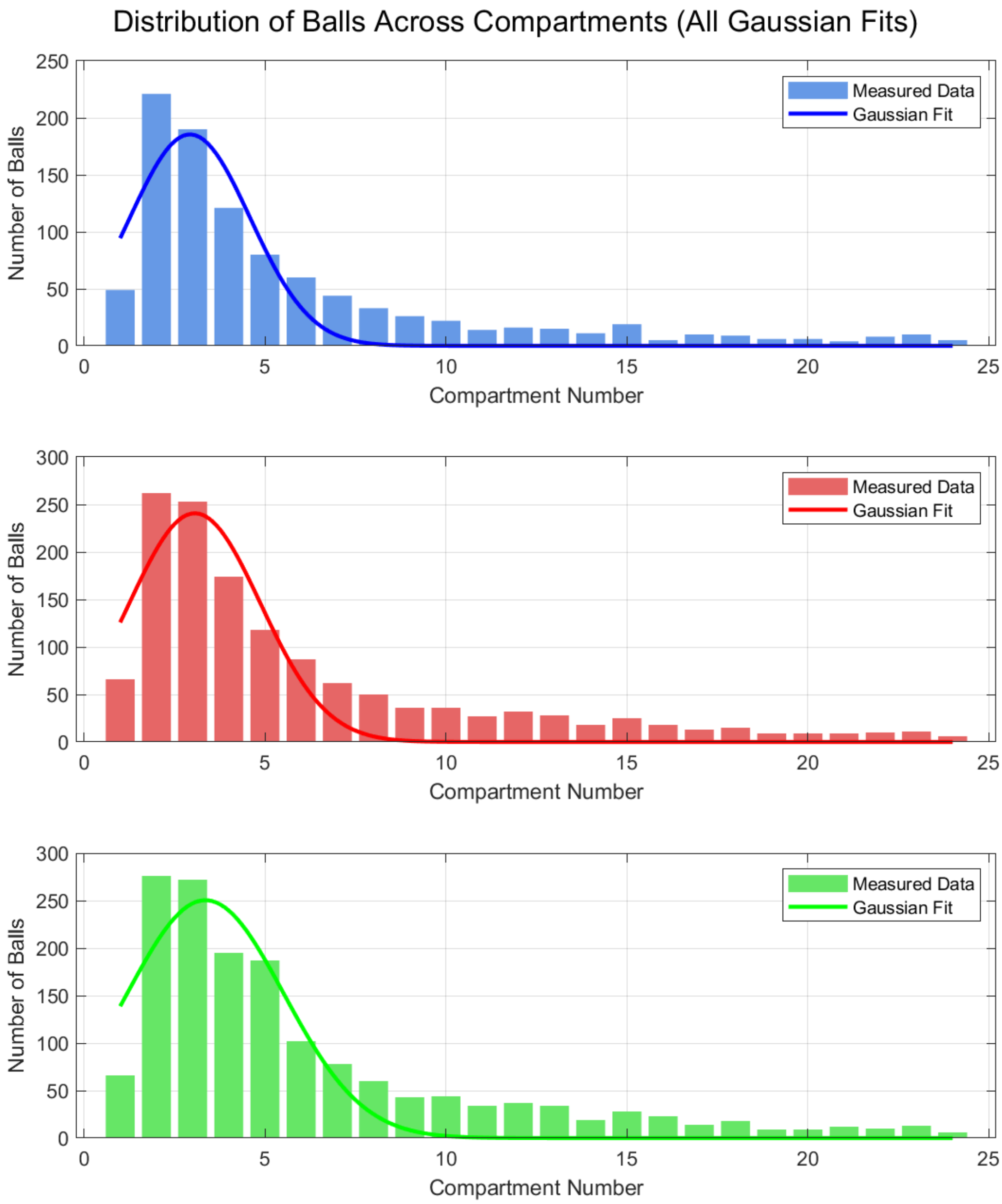
Now, in order for the study to be complete, there must be an interpretation of the errors:

1. **Random Errors**: Random errors include the balls falling out of the compartments of the recording chamber because of the gaps on the top of the compartment. To fix this type of error, one must be extra careful when holding the recording chamber of the experiment and not letting them fall while counting. In addition, another source of random errors is the collision of balls with the walls of the apparatus and a lot of balls are going to fall out of it.

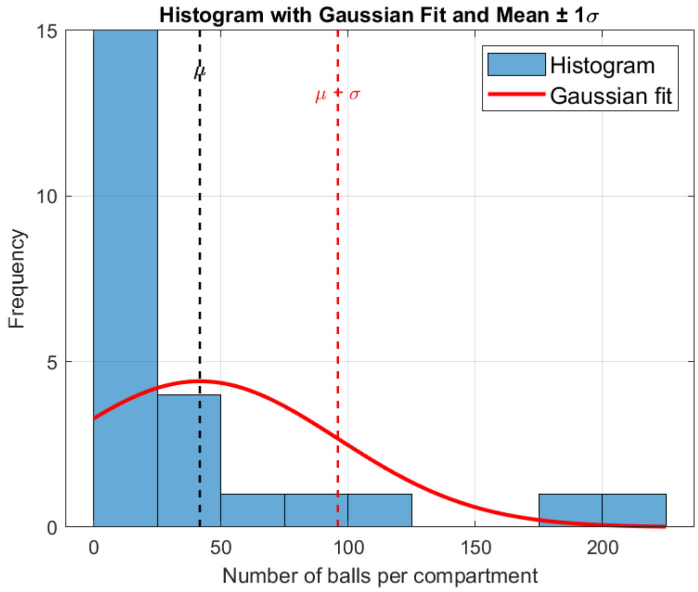
2. **Reading/Human Errors and Blunders**: The most obvious error in this experiment because no technology is used to count 1000+ balls. A human will most probably not be able count that much balls accurately especially when the human eye can fail them or when the balls are overlapping. To fix this error, one must get good sleep and eat properly to be attentive and count properly. Another blunder is letting the balls while not being careful while taking the recording chamber out of the apparatus. To solve this issue, always remove the chamber slowly and carefully.

3. **Instrumental Errors**: No device was used to take measurements in this part of the experiment but it is always appropriate to make sure the apparatus used is in good condition(other than measurement taking instruments in this case).

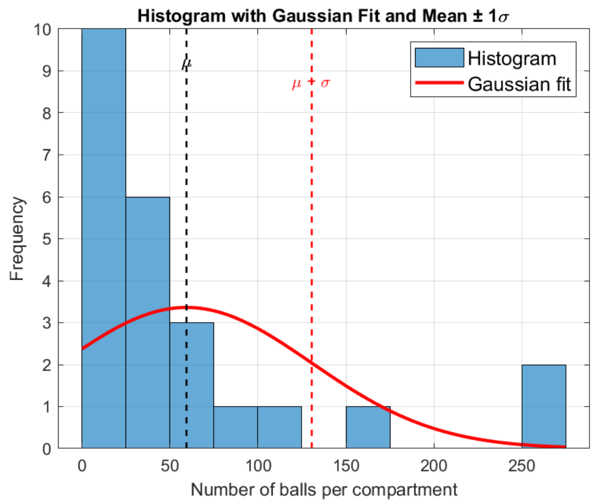
Some **additional** solutions to *eliminate* as much errors as possible include increasing the number of balls and repeating the experiments more times. Most of the errors were related to counting and the data because the experiment was performed only at 3 time intervals. Some of the notable statistical values and errors are:



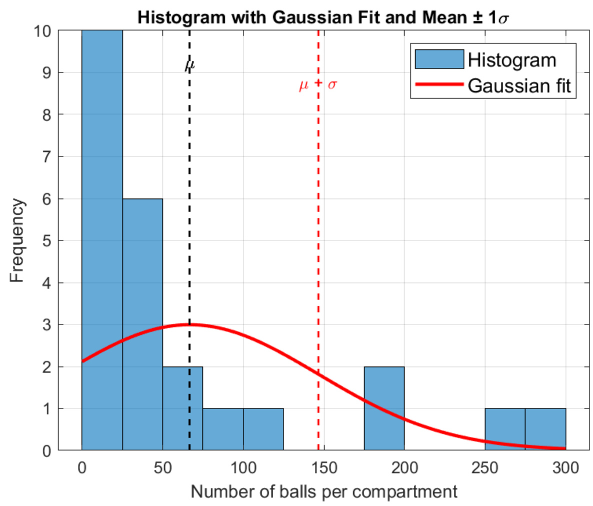
Graph II: Smooth Gaussian curve and Bar graph



Graph III: Histogram and Gaussian Fitting Curve at t=1min



Graph IV: Histogram and Gaussian Fitting Curve at t=2min



Graph V: Histogram and Gaussian Fitting Curve at t=3min

Table III: Statistical Uncertainties and Values

Time (min)	**Mean** $\pm u$ **(balls)**	**Standard Deviation** σ **(balls)**	**Mean Uncertainty** $u = \frac{\sigma}{\sqrt{N}}$
1	41.67 ± 11.09	54.33	11.09
2	59.38 ± 14.53	71.19	14.53
3	66.67 ± 16.31	79.93	16.31

V- Conclusion

Now for the most important part of the report: Was the goal of the experiment achieved? From all the **Gaussian** fitted curves and the bars, it was mentioned that the number of balls in the recording chamber was highest around the beginning. As one moves from one compartment to another, the amount of balls gradually decreased. This is one of the properties of a **Perfect** gas which mentions that the particles(balls) move(Maxwell-Boltzmann velocity distribution) and are distributed randomly along the gaussian which is skewed to the left which further verifies the property. Furthermore, gravity plays a role in distributing the balls so that they are **NOT** distributed in one specific compartment or location. Another noticeable detail is how poorly the gaussian curve is fitted along the bars of the histogram/bar graph. This is bound to happen because of how much balls one must count without the help of a machine or a program. This is why in **Table III** as well as the histograms, values like the mean of the distribution of **BALLS** was computed as well as how deviated the data was from the mean, also known as the *standard deviation* which is large and that is why the bell curve is **platykurtic**(its not a perfect gaussian distribution).[2]

VI- Appendix

$$\sigma = \frac{1}{N}\sum_{i=1}^{k} n_i(c_i - \mu)^2 \tag{2}$$

$$\mu = \frac{1}{N}\sum_{i=1}^{k} n_i c_i \tag{3}$$

$$A = \frac{1}{\sqrt{2\pi\sigma}} \tag{4}$$

N is the total frequency, $c_i = \frac{C_{i+}+C_{i-}}{2}$ is the midpoint of each bin(class) of the histogram, n_i is the frequency and k is the number of bins/classes.

(5)

VII- References

[1] N. Abboud, 'Chapter 2: Heat Conduction, Intro' Lecture, P3313: Heat Transfer, Lebanese University Faculty of Sciences II, Oct. 1, 2025

[2] K. Bitar, 'Chapter 2: Univariate Statistical Analysis' Lectures, S1101: Statistics, Lebanese University Faculty of Sciences II, Oct-Nov, 2023

[3] https://www.phywe.com/experiments-sets/university-experiments/maxwellian-velocity-distribution$_{1}0674_{1}1605/$