To experimentally demonstrate the law of dynamics.

Mariam Husain XI B

The Cathedral & John Connon School

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Introduction

COVID19 changed the landscape of the lives of all humanity, everywhere. I observed that coupled with loss of life and livelihoods, there was a loss of certainty. Perhaps our brains are programmed to feel satisfied only when questions are answered. Unanswered questions are pebbles in shoes, we like certainty. It was those years of lockdown and online school, that took me back to my early love of physics. It offered solace, constants with uniform rules. It didn't matter what colour, creed, or social standing a person had, if they wanted to measure time, they had to do the same set of things. It gave me a new way to experience my father's knowledge as we had long discussions and led me to conclude that physics lets us be truly equal. The unpredictable nature of human beings and the unforeseeable prognosis of microbiological assaults were less disturbing when I closed my eyes and visualised electrons orbiting atoms. The comfort of physics lay in the explanation that nothing was static anyway.

The laws of physics are established by generalizing experimental facts. They express the objective regularities existing in nature. The fundamental method of investigation in physics is the running of an experiment i.e., the observation of the phenomenon being studied in accurately controlled conditions.

This project deals with the experimental verification of laws of dynamics. Newton's laws can be easily found valid by experimentation. I use the elevator to find the weight changes due to acceleration and deceleration of the elevator. I then use the same data to compute the changes in acceleration by dividing the time the elevator takes to travel into small time segments. Armed with this data and the theory of kinematics, I then compute the velocity of the elevator in each of those time segments. Once, I have the velocity and acceleration for each time segment I then compute the distance traveled by the elevator. Once I have the height traveled by the elevator, I use it to compute how far a person can see from that elevation, given the curvature of the earth and compare it with a person standing at sea level.

It is my modest endeavour to show the beauty of physics, the interlinkage of various physical quantities and the relative ease with which one can understand the nature of our universe.

Law of Dynamics

The fundamental law of dynamics implies that body cannot change its velocity by itself without interaction with surrounding bodies. Every change in the magnitude or direction of a body's velocity is caused by the action of external bodies upon in. This action is characterized by forces. *The fundamental law of dynamics (Newton's second law of motion) expresses the relation between force and the change in velocity of interacting bodies.*

This is expressed as follows.

$$\mathbf{F} = m\mathbf{a}$$

Where F is the force (vector quantity), m is the mass of the body and a is the acceleration (vector quantity) experienced by the body.

Using the fundamental law of dynamics, we can determine the forces acting on a body, or the character of its motion if the forces are given. Thus, if the motion equation is given, we can determine the acceleration of the body. When we know the acceleration and the mass of the body, it is easy to find the acting force.

The following rules should be observed in setting up the motion equation. First, all forces acting on the body (including the reactions) should be found. Second the resultant of these forces should be determined and finally based on the fundamental law of dynamics we equate the resultant force with the product of the mass by the acceleration. The motion equation obtained in this way is then solved to find the unknown quantities.

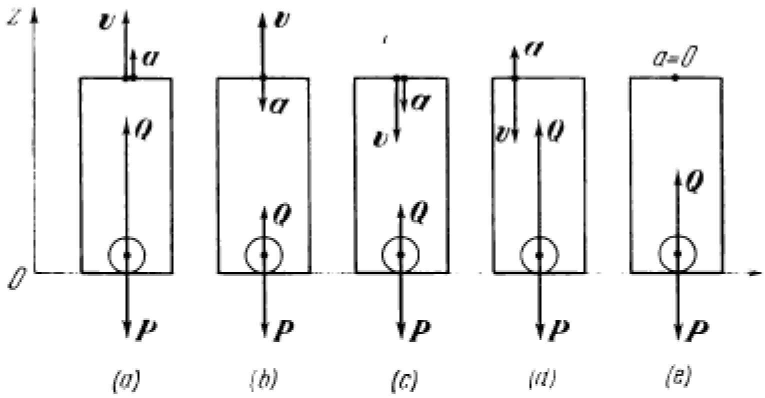
To understand this better let us look at what happens to the forces acting on a body which is moving in an elevator. There are five possibilities/cases as the elevator moves

a) vertically upward with acceleration (start of an elevator's journey upwards)
b) vertically upward with deceleration (end of an elevator's journey upwards)
c) vertically downward with acceleration (start of an elevator's journey downwards)
d) vertically downward with deceleration (end of an elevator's journey downwards)
e) with uniform velocity (segment of an elevator's journey when it is moving with uniform velocity)

Given the body in the elevator is stationary with respect to the lift, it moves with the same acceleration as the lift with respect to the earth. We know from Newton's third law that the floor of the lift exerts the same force on the body that it exerts on the floor, but these are in opposite direction. Hence, the body is subject to two forces – the force of gravity **P** and the reaction force **Q** of the floor.

Let us select a coordinate system, with the z-axis vertically upward. Then the reaction is a positive vector, and the gravity force is negative. The sign of the acceleration vector depends upon the character of the motion.

Below is an illustration of the above five possibilities with the respective forces shown along with the acceleration vector (**a**) and the velocity vector (**v**).



In all cases the sum of resultant forces should be equal to the product of mass of the body and acceleration it experiences.

$$\mathbf{P} + \mathbf{Q} = m\mathbf{a}$$

<u>Case a</u>: The elevator moving upwards with acceleration.

$$\mathbf{P} + \mathbf{Q} = m\mathbf{a}$$

In scalar form the signs of vectors need to be accounted for

$$-P + Q = ma$$

$$-mg + Q = ma$$

Where g is the acceleration due to gravity on earth.

$$Q = mg + ma = m(g + a)$$

The body therefore feels heavier when an elevator starts to move up from a stationary state.

<u>Case b</u>: The elevator moving upwards with deceleration.

$$\mathbf{P} + \mathbf{Q} = m\mathbf{a}$$

In scalar form the signs of vectors need to be accounted for

$$-P + Q = -ma$$

$$-mg + Q = -ma$$

Where g is the acceleration due to gravity on earth.

$$Q = mg - ma = m(g - a)$$

The body therefore feels lighter when an elevator starts to slowdown while moving vertically upwards.

<u>Case c</u>: The elevator moving downwards with acceleration.

$$\mathbf{P} + \mathbf{Q} = m\mathbf{a}$$

In scalar form the signs of vectors need to be accounted for

$$-P + Q = -ma$$

$$-mg + Q = -ma$$

Where g is the acceleration due to gravity on earth.

$$Q = mg - ma = m(g - a)$$

The body therefore feels lighter when an elevator starts moving downward with acceleration

Case d: The elevator moving downwards with deceleration.

$$\mathbf{P} + \mathbf{Q} = m\mathbf{a}$$

In scalar form the signs of vectors need to be accounted for

$$-P + Q = ma$$

$$-mg + Q = ma$$

Where g is the acceleration due to gravity on earth.

$$Q = mg + ma = m(g + a)$$

The body therefore feels heavier when an elevator starts to decelerate while moving vertically downward.

Case e: The elevator moves at uniform velocity.

$$\mathbf{P} + \mathbf{Q} = m\mathbf{a}$$

In scalar form the signs of vectors need to be accounted for

$$-P + Q = 0$$

Uniform velocity would mean acceleration is zero.

$$-mg + Q = 0$$

Where g is the acceleration due to gravity on earth.

$$Q = mg$$

The body therefore feels neither heavier nor lighter but just as it would have felt had it been stationary on the surface of the earth.

If the lift moves with acceleration with respect to the earth the force which a body exerts, its weight, is not equal to the force of gravity. If the acceleration of the lift is directed opposite to the acceleration of gravity, the force exerted on the support is greater than the force of gravity. When the direction of acceleration of the lift coincides with that of the acceleration of gravity, the force exerted on the support is less than the force of gravity. For the special case when a = g it follows from the equation that

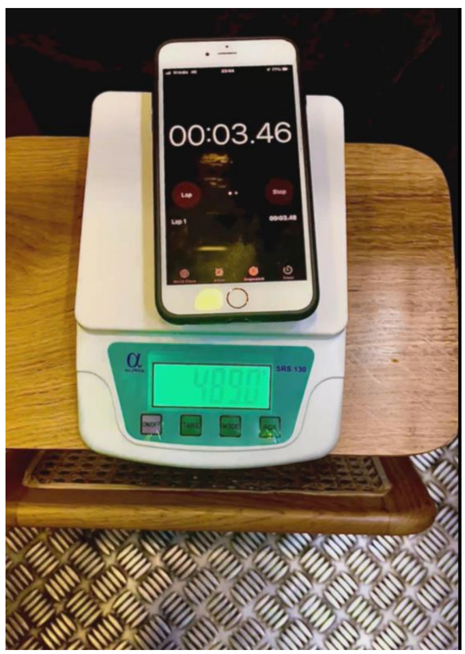
Q = 0, i.e., the body exerts no force on the support or in other words it becomes weightless. This is the case with astronauts in space, who are constantly in a 'state of free fall' and hence they feel weightless. Only in case when the elevator moves at uniform velocity with respect to earth is the force exerted on the support equal to the gravity force (case e).

Experiment for observing the fundamental law of dynamics in an elevator.

Experiment setup

1. Location: My residential building which has 22 floors.
2. Electronic weighing scale accurate to 0.1 gram.
3. Stopwatch on a phone accurate to 0.01 seconds.
4. A small table
5. Phone video recorder

I mounted the electronic weighing scale on a table in the elevator. On the electronic weighing scale, I placed a weight and an iPhone which had a running stopwatch on display. I then recorded the change in readings of both the weighing scale and the stopwatch as the elevator climbed up the 22 floors and climbed down the 22 floors. Here is the image of the setup.



Once the videos were recorded, I played them using Windows Media Player. In order to be able to read changes in the weight I slowed down the speed of the video to 0.125x the original. I then played the video and recorded the time when the weight changed along with the new weight reading.

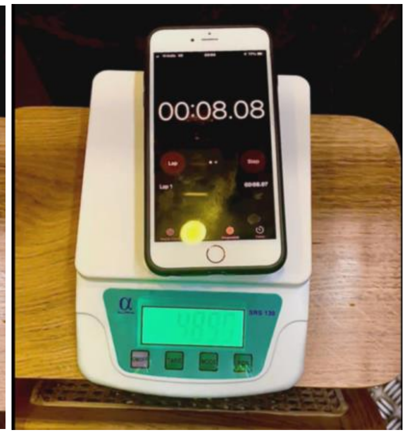
Experimental readings

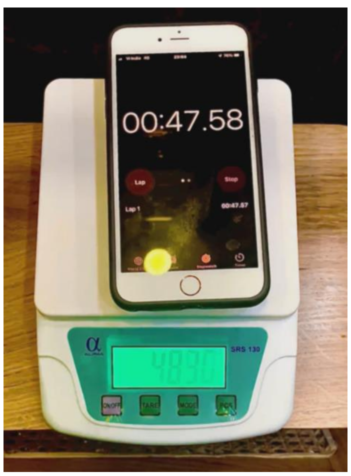
Case 1: Elevator going up

1. The weight on the electronic balance when the lift is stationary was 489 gm.
2. At about 00:05:25 (5.25 seconds), the weight starts increasing.
3. At about 00:06:38, the weight reaches the maximum of 540 gm.

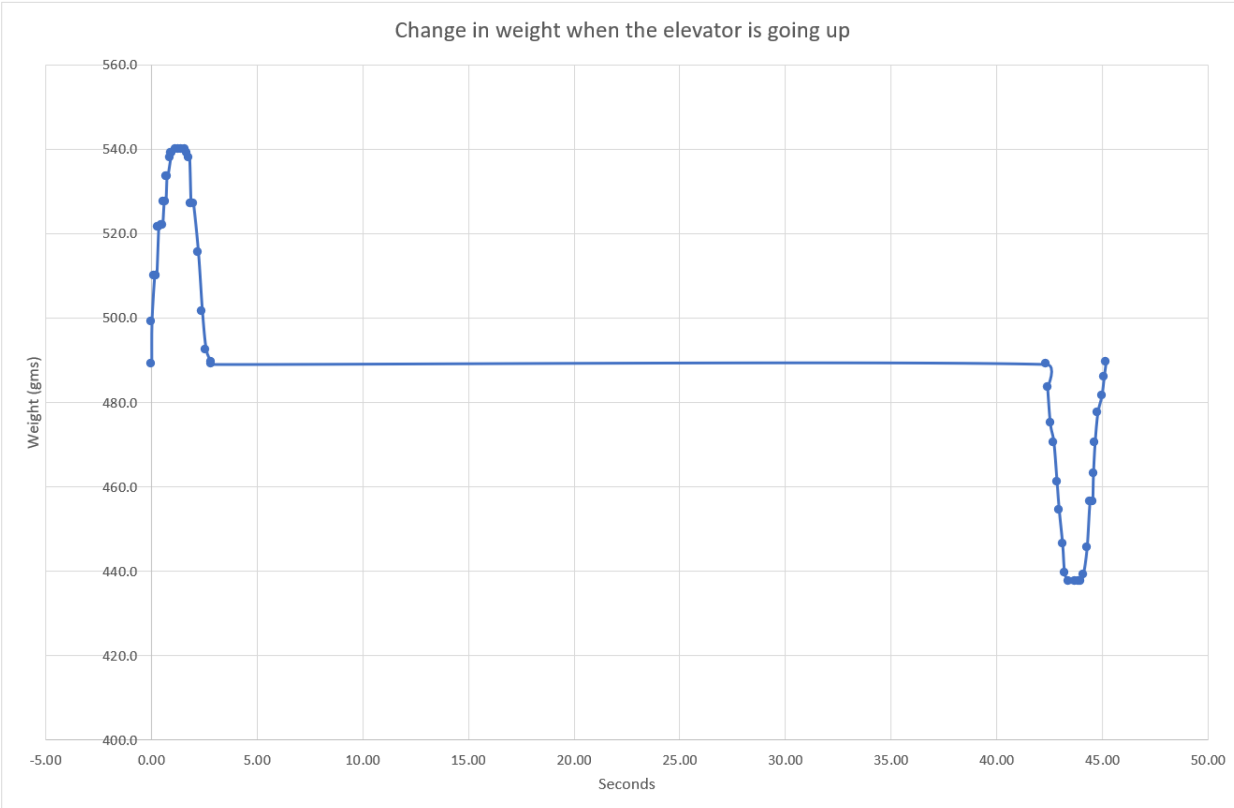
4. At about 00:08:08, the weight comes back to 489 gm and remains there till 00:47:58
5. At about 00:48:66, the weight hits the minimum of 437.5.
6. At about 00:50:42, the weight stabilizes at 489.5 gm.

Some images of the important inflexion points.





Below is the graph of all readings where the time lapsed in seconds are shown on x-axis and the weight readings are shown on the y-axis.

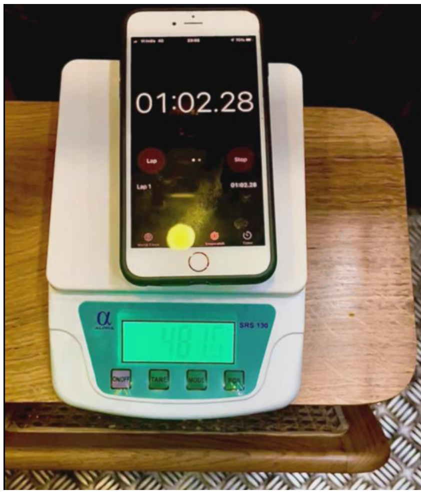


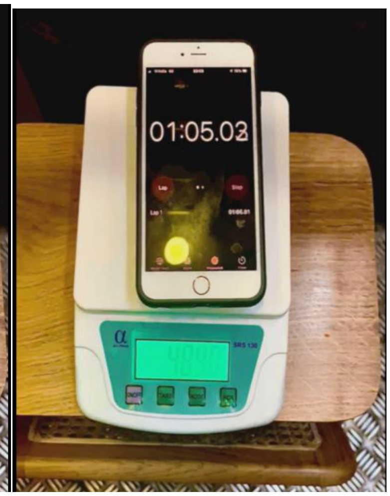
As can be seen by the graph above the initial period of the graph shows rise in weight as expected in case a, followed by no change in weight as expected by case e and finally it shows a drop in weight as expected by case b.

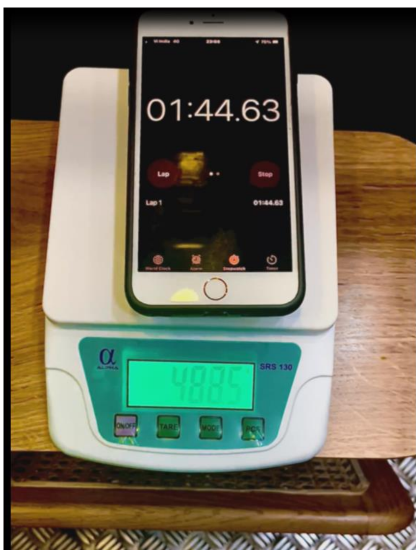
Case 2: Elevator going down

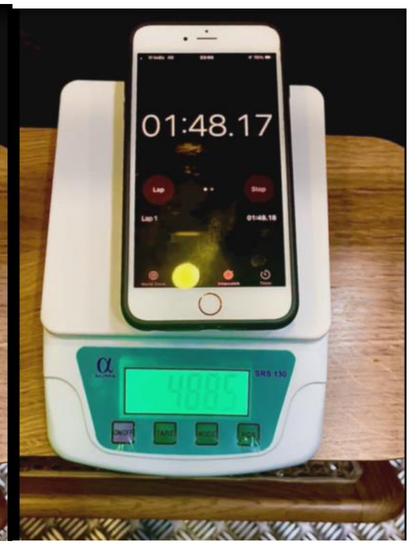
1. The weight on the electronic balance when the lift is stationary was 489 gm.
2. At about 01:02:28, the weight starts decreasing.
3. At about 01:03:41, the weight reaches the minimum of 438.5 gm.
4. At about 01:05:02, the weight comes back to 489 gm and remains there till 01:44:63
5. At about 01:45:93, the weight hits the maximum of 537.5 gm.
6. At about 01:48:17, the weight stabilizes at 489 gm.

Some images of the important inflexion points.

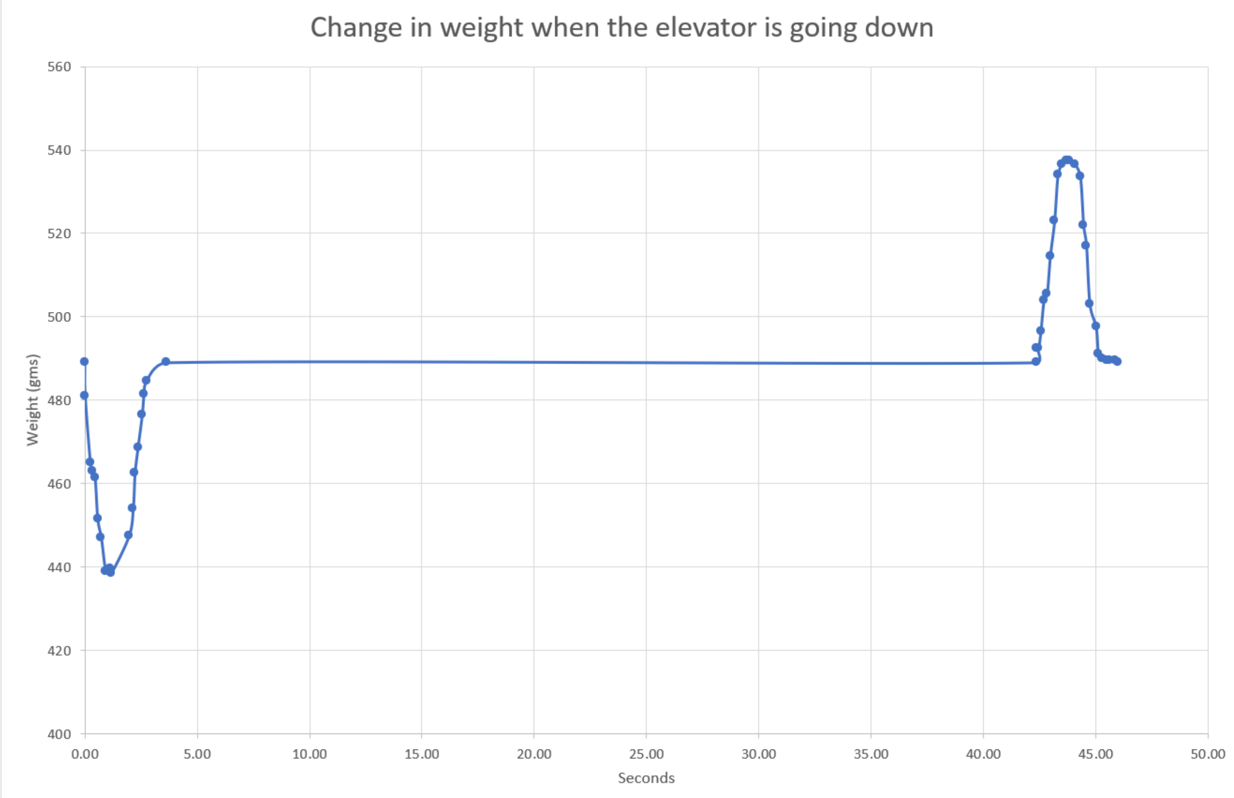








Below is the graph of all readings where the time lapsed in seconds are shown on x-axis and the weight readings are shown on the y-axis.



The above graph shows fall in weight initially as expected by case c, followed by no change in weight as expected by case e and finally it shows a rise in weight as expected by case d.

Summary observations

	Elevator going up	Elevator going down
Duration of the ride (seconds)	45.18	45.91
Base weight (gm)	489.0	489.0
Maximum weight (gm)	540.0	537.5
Minimum weight (gm)	437.5	438.5
Initial period of acceleration (seconds)	2.84	3.64
Period of zero acceleration (seconds)	39.50	38.73
Final period of deceleration (seconds)	2.84	3.54

The above graphs and table show the following

- The weight of the object changes during periods of acceleration and deceleration of the elevator as predicted by the law of dynamics.

- The weight remains constant during the period when the elevator experiences no acceleration or deceleration.

Within the error range of the instruments and software used, one can therefore conclude that the fundamental law of dynamics has been experimentally observed.

To determine the height of the building or the distance traversed by the elevator

We can use the weight readings obtained in the earlier experiment to determine the acceleration of the elevator/body. We know that in vector format

$$\mathbf{Q} = m\,(\mathbf{g}+\mathbf{a})$$

Let the weight be w gm when the object is stationary with respect to earth. Now in the elevator let the changed weight (during acceleration and deceleration) be x gm.

$$\mathbf{w} = m\mathbf{g} \text{ and } \mathbf{x} = m(\mathbf{g}+\mathbf{a})$$

$$\mathbf{x}/\mathbf{w} = (\mathbf{g}+\mathbf{a})/\mathbf{g} = 1 + \mathbf{a}/\mathbf{g}$$

$$\mathbf{a = g\ (x/w\text{-}1) = g((x\text{-}w)/w)}$$

The above equation shows that the acceleration (a) is proportional to change in weight. Suppose the body weighing 489 gms at rest, weighs 499gms in case a, then the acceleration **a** is (10 gms / 489 gms) times g. The extra weight corresponds to the extra acceleration on top of the acceleration due to gravity. Similarly, when weight drops, we can compute **a** but in that case it will be negative.

We therefore can compute **a** for all five cases in small increments as the data we have.

In case a and case d, acceleration will be positive while in cases b and c it will be negative. However, in case a, acceleration and velocity vectors are in same direction so they can be added. In case b, they need to be subtracted as final velocity will be zero. Similarly, we calculate the acceleration when the elevator is going down. Here are how the calculations were done.

We first recorded the various weights displayed by the weighing machine at various points of time. Then we compute the change in weight and the corresponding change in time. To compute acceleration in various time segments, as acceleration is different in different time segments, we use the below methodology.

Case a: Acceleration: $a = g*\{(x-w)/w\}$

In this case $x>w$ and hence a is positive

Where a is the acceleration, g is the acceleration due to gravity, x is the weight reading and w is the weight at rest.

Case b: Acceleration: $a = g*\{(x-w)/w\}$

In this case $x<w$ and hence a is negative

Case c: Acceleration: $a = g*\{(x-w)/w\}$

In this case $x<w$ and hence a is negative

Case d: Acceleration: $a = g*\{(x-w)/w\}$

In this case $x>w$ and hence a is positive

Case e: Acceleration: $a = g*\{(x-w)/w\}$

In this case $x=w$ and hence $a=0$. No change in weight.

Once we have acceleration for various time segments of the elevator ride, we can compute the velocity of that time segment using the formula

$v = u + at$

where v is the final velocity at the end of the time segment, u is the initial velocity at the beginning of that time segment (starts with u= 0m/s when the experiment begins), a is the acceleration for that time segment and t is the time elapsed in that time segment. We then arrive at the final velocity for each time segment.

We need to be careful with the signs of acceleration with acceleration being positive in cases a and d while being negative in cases b and c.

We can further take this information of initial velocity of every time segment, the length of the time segment, the acceleration in that time segment to compute the distance the elevator traveled in that time segment.

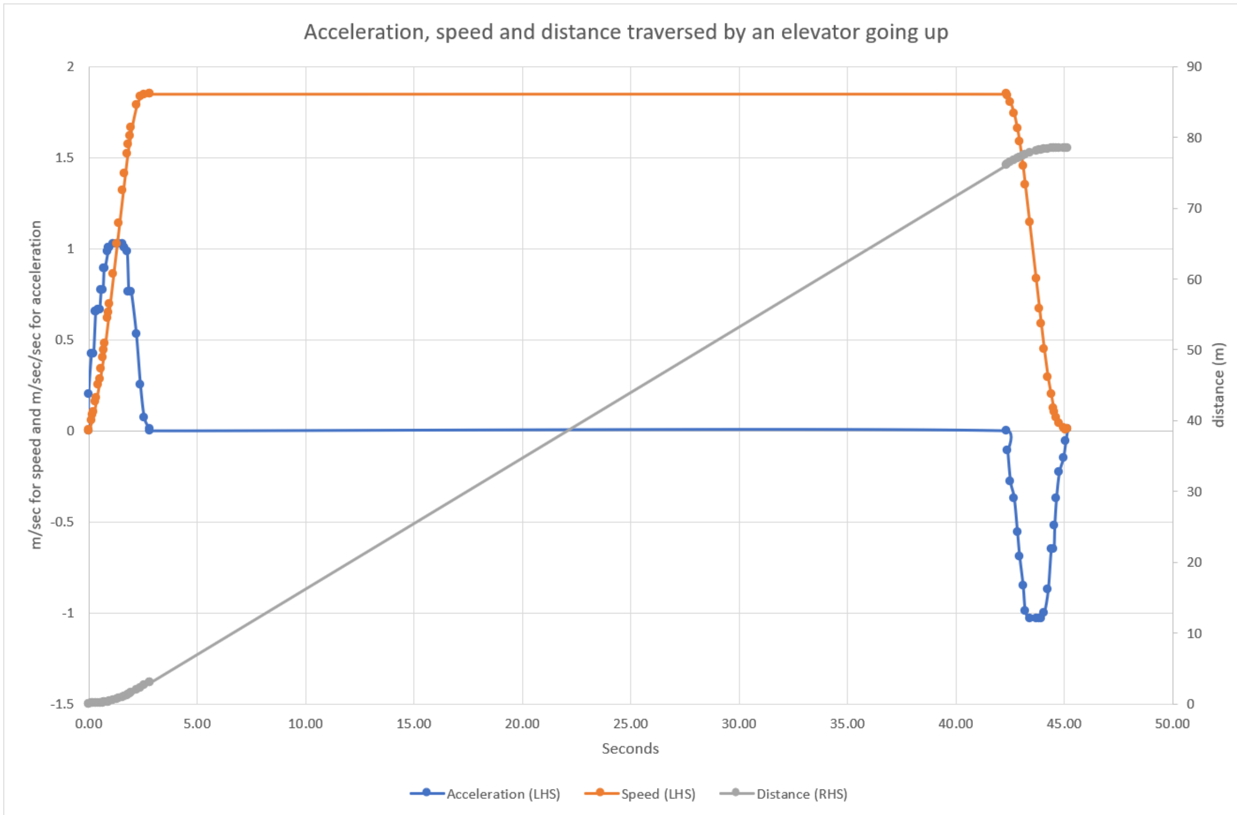
$S = ut+(1/2)at^2$.

We need to be careful with the signs of acceleration with acceleration being positive in cases a and d while being negative in cases b and c.

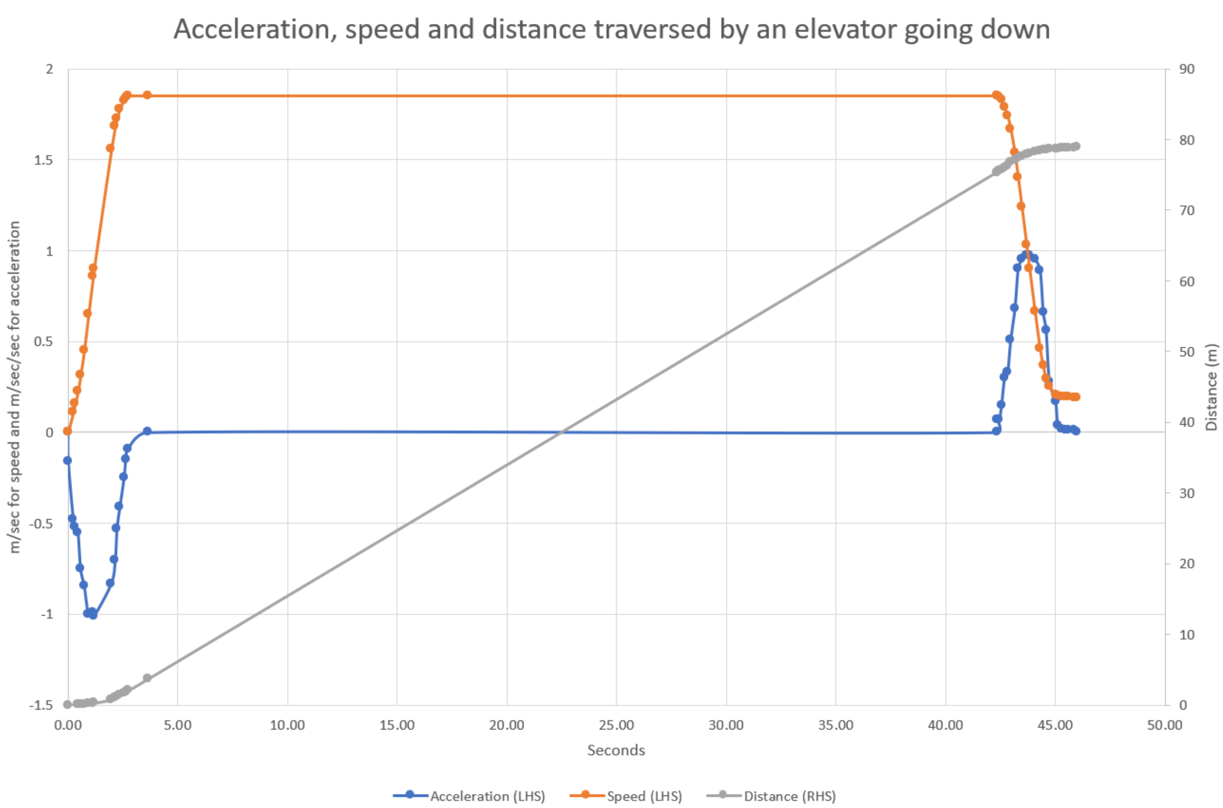
By adding the distance traveled by the elevator in various time segments, we then get the cumulative distance the elevator has traveled during the ride.

The data has been plotted below. Each point represents the time segment when the weight and time data was recorded. As can be seen, in the first case when the elevator is riding up, the initial segment of the graph shows acceleration is positive. It increases and then decreases but is always positive in the initial part of the ride. It then becomes zero. Finally, it becomes negative and comes back to zero. Correspondingly, in the initial part of the ride, the speed increases till acceleration does not become zero (when it attains maximum speed). It then travels with constant speed. At the end of the ride as acceleration turns negative, speed drops till it becomes zero and the elevator stops. When we observe the distance graph, given that the elevator is accelerating, the initial part of the ride shows the distance covered to rise exponentially ($S = ut +(1/2)at^2$) then it increases in a straight line (when acceleration is zero) and finally it starts increasing slowly (when acceleration turns negative).

The same approach can be used to observe the second graph, when the elevator is descending, too.



Graph1: Acceleration, speed and distance of an ascending elevator.



Graph2: Acceleration, speed and distance of a descending elevator.

Observations

	Elevator going up	Elevator going down
Peak acceleration	1.022 m/sec/sec	1.012 m/sec/sec
Peak deceleration	-1.032 m/sec/sec	-0.972 m/sec/sec
Peak speed	1.848 m/sec	1.844 m/sec
Duration of travel (seconds)	45.18	45.91
Distance traveled (meters)	78.42	78.57

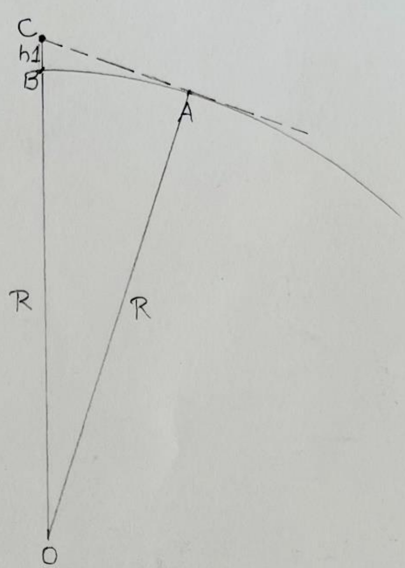
By using laws of dynamics, we computed the acceleration from weight changes during the elevator ride. Then using acceleration and the time duration of each segment, we use kinematics equations to calculate the final velocity of the time segment (initial velocity for the first time segment is zero and for subsequent time segments, it is the final velocity of the previous time segment). We then use the velocity, acceleration and time period of each segment to determine the distance traveled during that time period.

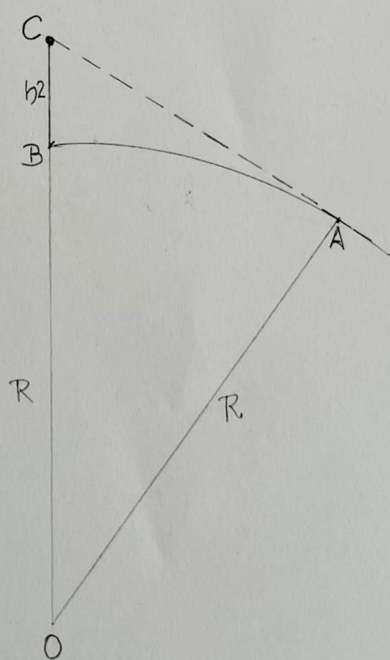
Within the error range of instruments used, we find that the distance the elevator travels is nearly the same, which it should be, during ascension and descension.

Distance to horizon

Once we know the height of the building, we can also find out how far is the horizon (one can see) from the upper floor of the building and compare it with how far it is at sea level.

Below is the illustration


C
h1
B
A
R
R
O


C
h2
B
A
R
R
O

Given that the earth is spherical (nearly), a person standing at sea level can see the horizon to a distance before the curvature comes along. To compute how far the person can see, let us assume the person is of a height of 1.65 m (h1). His line of sight meets the curvature at the horizon and this line is a tangent to the radius drawn from the point of horizon to the center of the earth. Therefore, the triangle formed between the center of earth (point O), the point of horizon (point A) and the person's eye (point C) is a right triangle as the line of sight is perpendicular to the radius of earth at the horizon. The linear distance to the horizon will be the length of the shorter side of the right triangle.

The triangle sides will be

R = radius of earth = 6,371,000 meters

h = height of the observer at sea level

R+h = 6,371,001.65 meters.

Line of sight linear distance = ((R+h)^2 – R^2)^0.5 (Using Pythagoras theorem)

In the above case this distance comes out to be 4.59 km, which is the linear distance. To find the actual distance (on the curved surface of earth), we need to compute the acute angle of the triangle at the center of the earth. This can be computed by inverse cosine of (r/(r+h)).

That comes to 0.00072 radians.

The curved distance will then be the radius of earth multiplied by the radian measure = 4.59km which is like the linear distance (not surprising because the angle is very small).

From the top of my building which is around 78.5m (h2) high the distance to horizon will be 31.63 km.

Here the angle of the triangle is 0.0050 radians, and the curved distance is similar to the linear distance at 31.63 km (given the angle is very small).

Error analysis

It is important to know the errors which impacted the experiment and conclusions.

1. The electronic scale while it shows readings of up to 0.1gm, may have an inbuilt error of 1 gm. This was observed when the body weighing 489 gm even when stationary was showing a reading between 488 gm and 490 gm. Error due to electronic scale is 0.2%
2. The sensitivity of the electronic scale may have an error of 10 gm. Given the elevator is accelerating/decelerating continuously, the electronic scale moves in steps and therefore its sensitivity maybe low and latency (reaction time) may not be as instantaneous as one would like. Combine the two and the error should be around 10 gm for every reading. Error could be 2%.
3. Video recording and replay. Windows Media Player allows 0.125x speed and even at that 1 sec of playback time it shows 1/8th of a second of real time. This compared to the stopwatch which has a clock speed of 0.01 sec makes reading values error prone. I estimate this error would be around 1/10th of a second. Error could be 1%.

4. Finally, acceleration due to gravity which is used is the value at equator. Mumbai being at a latitude of 19 degrees has a slightly lower acceleration due to gravity by 0.32%.
5. If we look at both experiments, elevator going up and going down, the distance traversed should be the same. In one case the result was 78.42m and in the other case it was 78.88m. That is a difference of 0.19% which is well within the tolerance limits of the instruments used to conduct the experiment.

Conclusion

The experiment uses simple instruments, electronic balance, phone and a home computer, available in any household. Using these commonly available instruments we first demonstrated the law of dynamics. Then we used the same data and applied principles of force and kinematics equation to determine the acceleration experienced by the body during each time segment, velocity of the body and the distance it traveled. We used principles of integration to add up various time segments and the data pertaining to each segment. Finally, we used the distance traveled as the height of the observer to compute the distance to the horizon using the geometry of earth and basic trigonometric calculations.

The experiment demonstrates how physical data is linked and by knowing the basic principles of physics, one can use data to compute various physical quantities.

The experiment is not very accurate because of the errors induced due to the choice of instruments and the manual reading of the output. Nevertheless, the error in the final figure is within tolerable limits.

I would also like to mention that when I conceptualized the experiment, I thought it would be very easy to execute. First, I took a bathroom weighing scale and tried to record the weight changes with a phone. It did not work as a bathroom scale does not fluctuate with change in acceleration. I then used a kitchen scale with a dial but it was very hard to read the fluctuations off the dial. I then went to Crawford market and found a weights and measures store and asked them if they had an electronic scale which changes as weight changes. Finally, I zeroed in on the electronic scale. Similarly, to record time accurately, after many tries, I came up with the idea of recording time in the video too. The experiment made me appreciate the nuances of physics and how with a good understanding of the basics, one can observe the laws of physics and get a better understanding of the world around us.

Data Tables

Table 1: Data for the graph 1

S. No.	Stopwatch reading (seconds)	Weight reading (gm)	Time interval (t) (seconds)	Change in weight (gms) (w)	Acceleration (m/sec/sec) (9.82*w/489) (a)	Initial Velocity (u)	Final Velocity (v =u+at)	Segment Distance (ut+0.5at^2) meters	Cumulative distance (meters)
1	5.24	489.0						0.00000	0.00000
2	5.25	499.0	0.01	10.0	0.20041	0.00000	0.00200	0.00001	0.00001
3	5.38	510.0	0.13	21.0	0.42086	0.00200	0.05672	0.00382	0.00383
4	5.45	510.0	0.07	21.0	0.42086	0.05672	0.08618	0.00500	0.00883
5	5.48	510.0	0.03	21.0	0.42086	0.08618	0.09880	0.00277	0.01160
6	5.57	521.5	0.09	32.5	0.65133	0.09880	0.15742	0.01153	0.02313
7	5.60	521.5	0.03	32.5	0.65133	0.15742	0.17696	0.00502	0.02815
8	5.71	522.0	0.11	33.0	0.66135	0.17696	0.24971	0.02347	0.05162
9	5.76	522.0	0.05	33.0	0.66135	0.24971	0.28278	0.01331	0.06493
10	5.83	527.5	0.07	38.5	0.77157	0.28278	0.33679	0.02168	0.08661
11	5.91	527.5	0.08	38.5	0.77157	0.33679	0.39851	0.02941	0.11602
12	5.96	533.5	0.05	44.5	0.89182	0.39851	0.44310	0.02104	0.13706
13	6.00	533.5	0.04	44.5	0.89182	0.44310	0.47878	0.01844	0.15550
14	6.14	538.0	0.14	49.0	0.98200	0.47878	0.61626	0.07665	0.23215
15	6.17	539.0	0.03	50.0	1.00204	0.61626	0.64632	0.01894	0.25109
16	6.22	539.0	0.05	50.0	1.00204	0.64632	0.69642	0.03357	0.28466
17	6.38	540.0	0.16	51.0	1.02209	0.69642	0.85996	0.12451	0.40917
18	6.54	540.0	0.16	51.0	1.02209	0.85996	1.02349	0.15068	0.55985
19	6.65	540.0	0.11	51.0	1.02209	1.02349	1.13592	0.11877	0.67861
20	6.83	540.0	0.18	51.0	1.02209	1.13592	1.31989	0.22102	0.89964
21	6.92	539.0	0.09	50.0	1.00204	1.31989	1.41008	0.12285	1.02249
22	7.03	538.0	0.11	49.0	0.98200	1.41008	1.51810	0.16105	1.18354
23	7.10	527.0	0.07	38.0	0.76155	1.51810	1.57141	0.10813	1.29167
24	7.16	527.0	0.06	38.0	0.76155	1.57141	1.61710	0.09566	1.38732
25	7.22	527.0	0.06	38.0	0.76155	1.61710	1.66279	0.09840	1.48572
26	7.45	515.5	0.23	26.5	0.53108	1.66279	1.78494	0.39649	1.88221
27	7.64	501.5	0.19	12.5	0.25051	1.78494	1.83254	0.34366	2.22587
28	7.82	492.5	0.18	3.5	0.07014	1.83254	1.84517	0.33099	2.55687
29	8.06	489.5	0.24	0.5	0.01002	1.84517	1.84757	0.44313	2.99999
30	8.08	489.0	0.02	0.0	0.00000	1.84757	1.84757	0.03695	3.03694
31	47.58	489.0	39.50	0.0	0.00000	1.84757	1.84757	72.97904	76.01598
32	47.65	483.5	0.07	-5.5	-0.11022	1.84757	1.83985	0.12906	76.14504
33	47.78	475.0	0.13	-14.0	-0.28057	1.83985	1.80338	0.23681	76.38185
34	47.95	470.5	0.17	-18.5	-0.37076	1.80338	1.74035	0.30122	76.68307

35	48.10	461.0	0.15	-28.0	-0.56115	1.74035	1.65618	0.25474	76.93781
36	48.20	454.5	0.10	-34.5	-0.69141	1.65618	1.58704	0.16216	77.09997
37	48.36	446.5	0.16	-42.5	-0.85174	1.58704	1.45076	0.24302	77.34299
38	48.46	439.5	0.10	-49.5	-0.99202	1.45076	1.35156	0.14012	77.48311
39	48.66	437.5	0.20	-51.5	-1.03211	1.35156	1.14514	0.24967	77.73278
40	48.96	437.5	0.30	-51.5	-1.03211	1.14514	0.83551	0.29710	78.02988
41	49.12	437.5	0.16	-51.5	-1.03211	0.83551	0.67037	0.12047	78.15035
42	49.20	437.5	0.08	-51.5	-1.03211	0.67037	0.58780	0.05033	78.20067
43	49.34	439.0	0.14	-50.0	-1.00204	0.58780	0.44751	0.07247	78.27314
44	49.52	445.5	0.18	-43.5	-0.87178	0.44751	0.29059	0.06643	78.33957
45	49.66	456.5	0.14	-32.5	-0.65133	0.29059	0.19941	0.03430	78.37387
46	49.78	456.5	0.12	-32.5	-0.65133	0.19941	0.12125	0.01924	78.39311
47	49.82	463.0	0.04	-26.0	-0.52106	0.12125	0.10040	0.00443	78.39755
48	49.90	470.5	0.08	-18.5	-0.37076	0.10040	0.07074	0.00685	78.40439
49	50.03	477.5	0.13	-11.5	-0.23047	0.07074	0.04078	0.00725	78.41164
50	50.22	481.5	0.19	-7.5	-0.15031	0.04078	0.01222	0.00504	78.41668
51	50.33	486.0	0.11	-3.0	-0.06012	0.01222	0.00561	0.00098	78.41766
52	50.42	489.5	0.09	0.5	0.01002	0.00561	0.00651	0.00055	78.41820

Table 2: Data for the graph 2

S. No.	Stopwatch reading (seconds)	Weight reading (gm)	Time interval (t) (seconds)	Change in weight (gms) (w)	Acceleration (m/sec/sec) (9.82*w/489) (a)	Initial Velocity (u)	Final Velocity (v =u+at)	Segment Distance (ut+0.5at^2) meters	Cumulative distance (meters)
1	2.26	489							
2	2.28	481	0.02	-8.0	-0.16033	0.00000	0.00321	-0.00003	-0.00003
3	2.51	465	0.23	-24.0	-0.48098	0.00321	0.11383	-0.01198	-0.01202
4	2.6	463	0.09	-26.0	-0.52106	0.11383	0.16073	0.00813	-0.00388
5	2.72	461.5	0.12	-27.5	-0.55112	0.16073	0.22686	0.01532	0.01144
6	2.84	451.5	0.12	-37.5	-0.75153	0.22686	0.31705	0.02181	0.03325
7	3	447	0.16	-42.0	-0.84172	0.31705	0.45172	0.03995	0.07320
8	3.2	439	0.20	-50.0	-1.00204	0.45172	0.65213	0.07030	0.14351
9	3.41	438.5	0.21	-50.5	-1.01207	0.65213	0.86466	0.11463	0.25814
10	3.45	438.5	0.04	-50.5	-1.01207	0.86466	0.90515	0.03378	0.29192
11	4.24	447.5	0.79	-41.5	-0.83170	0.90515	1.56219	0.45554	0.74745
12	4.42	454	0.18	-35.0	-0.70143	1.56219	1.68845	0.26983	1.01728
13	4.5	462.5	0.08	-26.5	-0.53108	1.68845	1.73093	0.13338	1.15066
14	4.63	468.5	0.13	-20.5	-0.41084	1.73093	1.78434	0.22155	1.37221
15	4.82	476.5	0.19	-12.5	-0.25051	1.78434	1.83194	0.33450	1.70671
16	4.9	481.5	0.08	-7.5	-0.15031	1.83194	1.84396	0.14607	1.85278
17	5.02	489	0.12	0.0	0.00000	1.84396	1.84396	0.22128	2.07406
18	5.9	489	0.88	0.0	0.00000	1.84396	1.84396	1.62269	3.69675
19	44.63	489	38.73	0.0	0.00000	1.84396	1.84396	71.41669	75.11344
20	44.63	489	0.00	0.0	0.00000	1.84396	1.84396	0.00000	75.11344
21	44.72	492.5	0.09	3.5	0.07014	1.84396	1.83765	0.16624	75.27968
22	44.82	496.5	0.10	7.5	0.15031	1.83765	1.82262	0.18452	75.46420
23	44.96	504	0.14	15.0	0.30061	1.82262	1.78053	0.25811	75.72231
24	45.1	505.5	0.14	16.5	0.33067	1.78053	1.73424	0.25252	75.97483
25	45.24	514.5	0.28	25.5	0.51104	1.73424	1.66269	0.50562	76.48045
26	45.43	523	0.19	34.0	0.68139	1.66269	1.53323	0.32821	76.80866
27	45.58	534	0.15	45.0	0.90184	1.53323	1.39795	0.24013	77.04879
28	45.75	536.5	0.17	47.5	0.95194	1.39795	1.23612	0.25141	77.30020
29	45.93	537.5	0.18	48.5	0.97198	1.23612	1.06117	0.23825	77.53844
30	46.1	537.5	0.17	48.5	0.97198	1.06117	0.89593	0.19444	77.73289
31	46.35	536.5	0.25	47.5	0.95194	0.89593	0.65794	0.25373	77.98662
32	46.58	533.5	0.23	44.5	0.89182	0.65794	0.45282	0.17492	78.16153
33	46.72	522	0.14	33.0	0.66135	0.45282	0.36024	0.06988	78.23141
34	46.85	517	0.13	28.0	0.56115	0.36024	0.28729	0.05157	78.28298
35	47	503	0.15	14.0	0.28057	0.28729	0.24520	0.04625	78.32923

36	47.28	497.5	0.28	8.5	0.17035	0.24520	0.19750	0.07533	78.40456
37	47.38	491	0.10	2.0	0.04008	0.19750	0.19349	0.01995	78.42452
38	47.55	490	0.17	1.0	0.02004	0.19349	0.19009	0.03318	78.45770
39	47.75	489.5	0.20	0.5	0.01002	0.19009	0.18808	0.03822	78.49592
40	47.87	489.5	0.12	0.5	0.01002	0.18808	0.18688	0.02264	78.51856
41	48.12	489.5	0.25	0.5	0.01002	0.18688	0.18438	0.04703	78.56559
42	48.17	489	0.05	0.0	0.00000	0.18438	0.18438	0.00922	78.57481

Bibliography

1. Fundamentals of Physics (1975) by B M Yavorsky and A A Pinsky.

Software used

1. Windows Media Player
2. Microsoft Excel
3. Microsoft Word

Flowchart of the project and steps involved