TED ANKARA COLLEGE FOUNDATION PRIVATE HIGH SCHOOL

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Physics – Standard Level

Extended Essay

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1. ABSTRACT

This essay studies the friction phenomenon to answer the question: "*how does kinetic friction depend on the contact surface area of a solid?"* The object of research, kinetic friction, has been modified from the sole term "friction" to narrow down the scope of investigation and get accurate results about the factor investigated. Since it is a mechanical subject and it is rather practical to build a setup, an experimental approach is chosen to investigate the topic. The experiment is done in several steps by changing the setup which is a block released from an inclined plane. The angle, distance and mass of the solid is changed for blocks with five different surface areas and the acceleration is measured. Depending on the theoretical correlations between the kinetic friction and the distance, mass and angle of the position of the solid, data for five different surface areas have been obtained.

According to data and graphs, it is seen that, there is no significant relationship between the surface area and the kinetic friction. My hypothesis is concluded to be wrong, however, theoretical works are in coherence with the result of the experiment. Thus, the experiment is done without major errors and the aim is attained.

Word Count: 202

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3. INTRODUCTION

Friction” is a word that we encounter a lot both in our daily lives and school. We hear the “frictionless steel of Gillette” or “tyre-to-road friction of Goodyear” [1] in commercials. We have been also taught about the effect of friction on motion on our physics class. The coefficient of friction is widely used in calculations of the motion which means that there are some factors affecting this force. I wondered what are the factors that changes the magnitude of the friction.

3.1.Background Information

3.1.1 Friction as a General Concept

Friction as a term is “*a force that resists the relative motion or tendency to such motion of two bodies in contact.”* [2] It is understood that there has to be a force acting on a body so as to friction to resist the motion of the force. Another point is that there has to be two bodies in contact. This may seem as two rigid bodies but there are drag forces between flying objects and air as a matter or fluid resistance.

It is important to distinguish the point of view when the friction is investigated because there is the friction in microscopic scale between the molecules and macroscopic friction that can be calculated via the variables of the motion (Persson,1)[3]. In this essay friction will be examined on a macroscopic level.

1http://www.goodyear.eu/uk_en/tire-advice/eu-tire-label/tire-performance/index.jsp
2http://www.merriam-webster.com/dictionary/friction
3Persson, B.N.J., Sliding Friction: Physical Principles and Applications. Germany: Springer, 2000. Print.P09.01.2013. <http://books.google.com.tr/books?id=1jb-nZMnRGYC&printsec=frontcover&dq=friction&hl=tr&sa=X&ei=U-PtUPDvH42yhAeww4G4Aw&redir_esc=y#v=onepage&q=friction&f=fals

3.1.2 Static and Kinetic Friction

The word "tendency" is also significant in the definition. This leads to the conclusion that there is a static friction where there is no apparent motion. "When a force is applied on a body and there is no motion on the same direction, the opposite force of static friction keeps it from moving."[4] For body to move, the force applied must exceed the maximum force of friction which can be found with the formula:

$$F_{fr} \leq \mu_s.N$$ [5]

Where F_{fr} is the force of friction, μ_s is the coefficient of static friction and N is the normal force. Normal force is the reactant force to the weight of the body according to Newton's Third Law Of Motion.

Right after the body moves, kinetic friction takes place of the static friction on the opposite direction of the applied force. Kinetic friction on the other hand, does not vary like static friction. Kinetic friction basically is the concern of the sliding motion and depends on the nature of both surfaces in contact and can be found using the formula:

$$F_{fr} = \mu_k.N$$ [6]

Where $_{fr}$ is the force of friction, μ_k is the coefficient of kinetic friction and N is the normal force. When the formula is investigated, it can be seen that kinetic friction depends on the normal force and coefficient of friction. Coefficient of friction may depend on many factors such as surface area -since there is a contact between two bodies-, type of the materials and temperature etc.

[4] p.96,97, Physics Principles with Applications, Douglas c. Giancoli, Fifth Edition, Print.

[5] p.31, Addison - Wesley Publishing Company: College Physics, Sixth Edition, Print.

[6] p.32, Addison - Wesley Publishing Company: College Physics, Sixth Edition, Print.

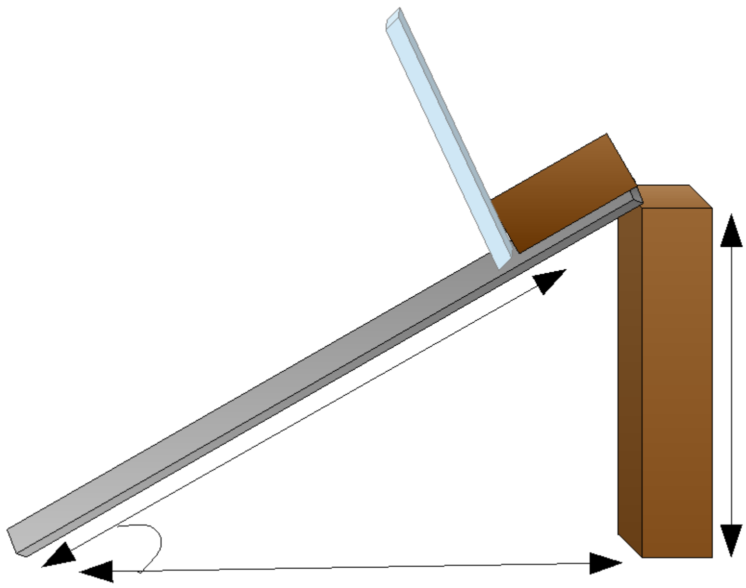


Image 1: *Prototype of the experiment where the angle is 30 degrees*

In this essay, the aim is to investigate the effect of changing contact surface area on kinetic friction of a body. To do this, wooden blocks with different surface areas but having the same mass and density are released from an inclined plane and distance is measured. Using the formula:

$$x = \frac{1}{2}at^2$$ [7]

Where x is the distance of the motion, t refers to time and a is the acceleration, we can find acceleration of the body in motion. By comparing the acceleration of the body in different conditions with different surface areas, we can distinguish the effect of surface area on the kinetic friction.

To create different conditions, inclined plane is set up in several positions *(how it is done is mentioned in the methods part.)* This way, angle is changed. According to

[7] P.52, Cambridge University Press, Physics for the IB Diploma, K. A. Tsokos, Fifth Edition, Print.

theoretical information, as angle increases normal force and surface friction decreases. Hence, acceleration is expected to increase as angle increases.

When the mass is doubled, normal force of the solid and the surface friction increases so it is expected to decrease as the masses of the objects are doubled.

3.2. Research Question

How is surface area of a body in contact related to the force of kinetic friction on an inclined plane?

3.3. Hypothesis

Increasing the surface area also increases the kinetic friction force since the contact area of two bodies increase.

3.4.Variables

3.4.1. Controlled Variables

3.4.1.1.General Controlled Variables for All Parts

- Type of the material of the body: Wood
- Type of the material of the inclined plane: Aluminum
- Initial push: Wooden block is held with a cardboard and when cardboard is removed block slides without any other external force exerted.

3.4.1.2 Controlled Variables For Each Surface Area

- The mass of the body: Mass is approximately 0.6 kg for trials where mass does not change.

3.4.2. Independent Variables

- Surface Area of the blocks changing from 28.80, 39.69, 41.00, 59.78 and 60.00 cm^2.
  - All blocks have been made by a carpenter and they all have the same

volume approximately 120 cm^3. Thus, their masses are same. The values above have been obtained by multiplication of the two verges of the blocks which are in contact with the surface of the inclined plane :

- For 28.80 cm^2: The verges with a length of 6.0 and 4.8 cm were multiplicated.
- For 39.69 cm^2: The verges with a length of 4.9 and 8.1 cm were multiplicated.
- For 41.00 cm^2: The verges with a length of 10.0 and 4.1 cm were multiplicated.
- For 59.78 cm^2: The verges with a length of 4.9 and 12.2 cm were multiplicated.
- For 60.00 cm^2: The verges with a length of 4.0 and 15.0 cm were multiplicated.

- Angle of the inclined plane from plane from 30, 45, and 60 degrees.
- The distance of the motion changing from 0.600 m, 0.700 m, 0.800 m, 0.900 m and 1.000 m.

3.4.3. Dependent Variables

- Time for the motion of the body released from an inclined plane (in seconds)

3.5. Materials

1. Two of Each Wooden Block

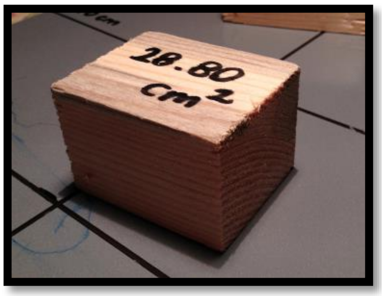


Image 2: *The wooden block with surface area in contact with inclined plane of 28.8 cm² that is used in the experiment*

- For 28.8 cm^2: The edges of the wooden block are $6.0 \pm 0.1\ cm$, $4.8 \pm 0.1\ cm$ and $4.1 \pm 0.1\ cm$.

Image 3: *The wooden block with surface area in contact with inclined plane of 39.7 cm² that is used in the experiment*

- For 39.7 cm^2: The edges of the wooden block are $8.1 \pm 0.1\ cm$, $4.9 \pm 0.1\ cm$ and $3.0 \pm 0.1\ cm$.

Image 4: *The wooden block with surface area in contact with inclined plane of 41.0 cm² that is used in the experiment*

- For 41.0 cm^2: The edges of the wooden block are $4.1 \pm 0.1\ cm$, $10.0 \pm 0.1\ cm$ and $2.9 \pm 0.1\ cm$.

Image 5: *The wooden block with surface area in contact with inclined plane of 59.8 cm² that is used in the experiment*

- For 59.8 cm^2: The edges of the wooden block are $4.9 \pm 0.1\ cm$, $12.2 \pm 0.1\ cm$ and $2.0 \pm 0.1\ cm$.

Image 6: *The wooden block with surface area in contact with inclined plane of 60.0 cm² that is used in the experiment*

- For 60.0 cm^2: The edges of the wooden block are $4.0 \pm 0.1\ cm$, $15.0 \pm 0.1\ cm$ and $2.0 \pm 0.1\ cm$.

2. Ruler (±0.1 cm)

3. Meter (±0.001 m)

4. An emery paper

5. Electronic Scale (±0.001 g)

6. Tape

7. Camera

8. Scissors

9. Chronometer (±0.1s)

10. Weighing Machine (±0.001 kg)

11. A cardboard plane for letting go of the block.

12. A sheet aluminum used for the inclined plane with the length $1.500 \pm 0.001\ m$ and the width $0.010 \pm 0.001\ m$

13. A block with a height of $0.650 \pm 0.001\ m$.

3.6. Method

Pre Experiment

1. To do the setup, first inclined plane is needed to be built. The inclined plane has two parts: Sheet aluminum as a contact area – the hypotenuse if the inclined plane is regarded as a triangle – and the block with 0.65m height which is the base where the aluminum is placed. The width of the aluminum sheet crosswise is ten centimeters. Hence when the aluminum sheet is placed on the block with a height

of 0.65 meters, total height is 0.75 meters. To illustrate, the red line in the image below indicates the real height of the setup:

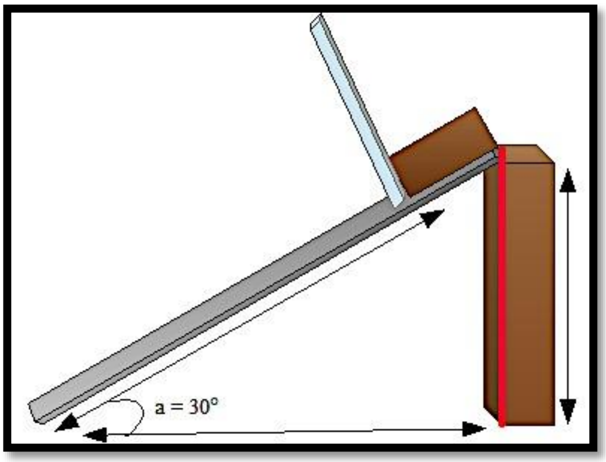


Image 7: *Experimental setup*

Since we change the distance of the motion in one of the parts in the experiment, we have to mark the places where the blocks are released. By putting the 0 of the ruler at the beginning of the aluminum plane, distances of 0.6, 0.7, 0.8, 0.86, 0.9, 1 and 1.3 m is marked via marker – values should be indicated to avoid confusion–

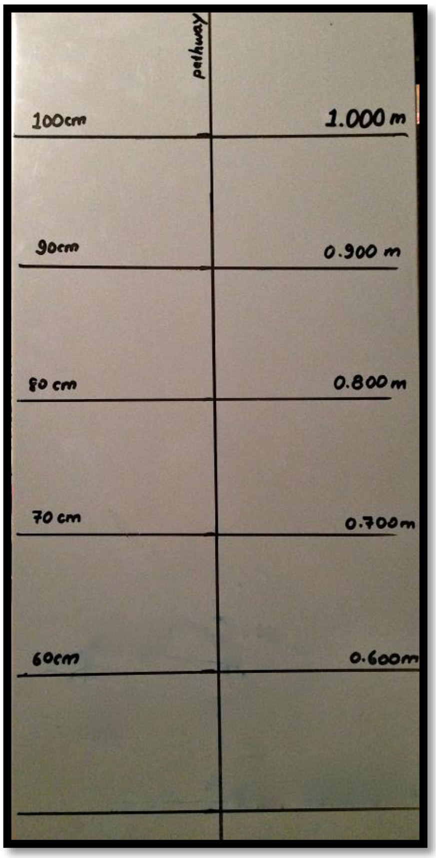


Image 8: *The sheet aluminum used as inclined plane used (The marked points on that sheet is shown.)*

2. Aluminum sheet's tip is placed on the block. Since the height of the setup which is the sum of the height of the block holding the aluminum and the crosswise width of the aluminum is 0.75 meters and the aluminum sheet's total length is 1.5 meters, the angle between the surface and the aluminum plane is calculated to be 30° using the trigonometric formula:

$\sin(a) = y/x$

Where a is the angle between the surface and the aluminum plane, y is and x is the height of the wood block plus width of the aluminum plane the length of the projection of the aluminum plane on the surface.

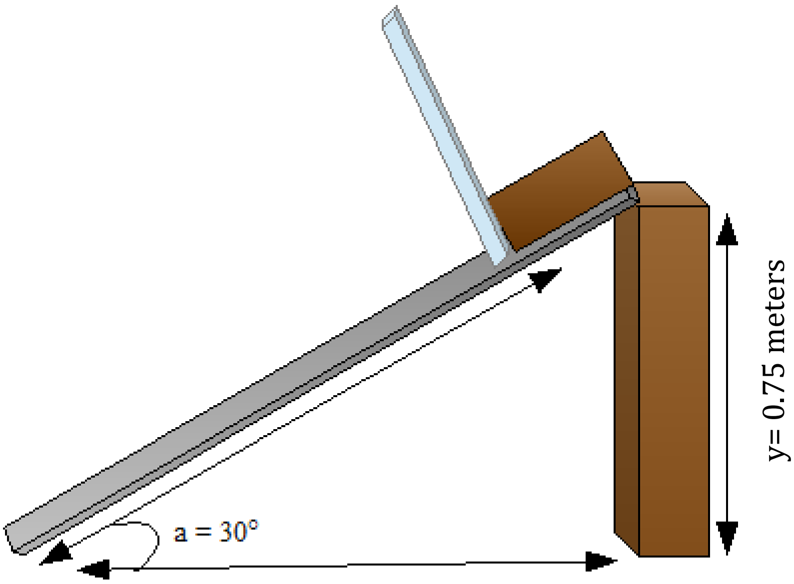


Image 9: *Experimental Setup*

3. A flat plane is needed to hold the blocks so when the experiment begins there are not going to be a force exerted by the student, since all needs to be done is to simply removing the plane. In this case, a cupboard plane with a size of a5 paper is cut out to be used as a holder.

4. The blocks that have been made by the carpenter are weighed using an electronic scale. Using the emery paper, overweight blocks have been fixed. For instance, if a block is 0.65 kilograms, it is emeried until it is 0.60 grams. After that, their surface areas are calculated using their dimensions and noted.

5. All twenty five blocks are gathered and grouped according to their surface areas.

6. Since the blocks have two sides with the same surface areas, one of each of them are marked so as to use the same surface each time and decrease uncertainties.

7. The clockwatch is initialized to zero.

The Experiment

8. One of the blocks with a surface area of 28.80 cm^2 is placed on the aluminum sheet positioned at the mark of 0.6 meters. It is hold by the cupboard plane.

9. The clockwatch is started when the cupboard plane is removed. When the wooden block reaches the end, the watch is stopped and data obtained is recorded.

10. This process from the steps six to eight is repeated for nine other trials, on the same marked surface.

11. Same block is placed on the block on the marked position of 0.7 meters. Chronometer is initialized.

12. The process of removing cardboard, freeing the block and recording the time interval is repeated for ten trials and the data is recorded.

13. This process is done for 0.8, 0.9 and 1 meters on the aluminum plane for ten trials each.

14. After it's finished, using Pythogorian theorem, to make the angle 45°, both projection of the inclined plane and the height is arranged to be 0.75 meters by moving the block underneath the aluminum sheet.

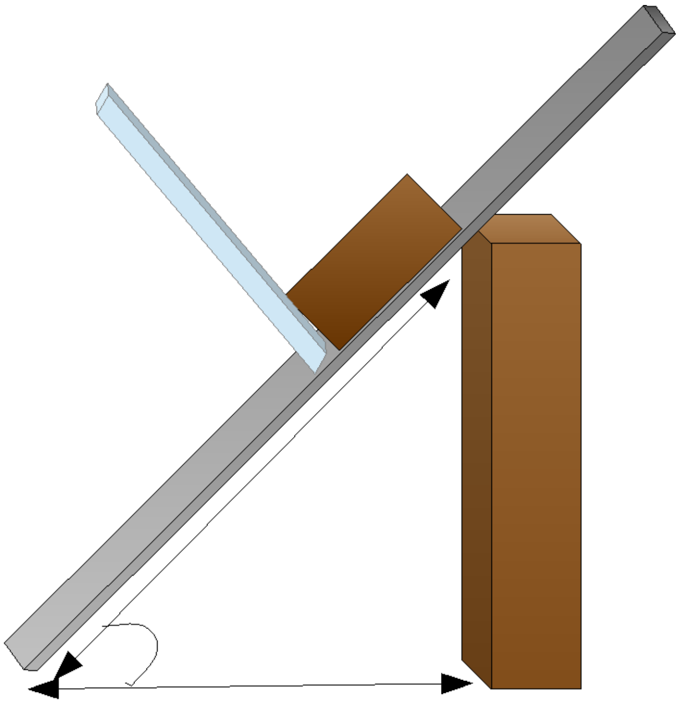


Image 10: Drawing of the experiment where angle is changed by moving wood block underneath the aluminum plane.

11. At the angle of 45˚, the same process for different surfaces of 28.80, 39.69, 41.00, 59.78 and 61.50 cm^2 is done from steps seven to twelve.

12. Up to this point one hundred data should be recorded. To change angle to 60 degrees, the block under the aluminum sheet is positioned right under the mark at 0.86 meters. That way the projection is 0.43 and height is 0.75 meters and the angle is sixty degrees. The same procedure is done from steps seven to twelve.

13. After that, mass is changed by uniting two blocks with same surface area using a duct tape and the same process is done from steps seven to twelve for each of the surface areas.

4. DATA COLLECTION AND PROCESSING:

4.1 Raw Data:

- *For 30 Degrees:*

In this part of the experiment, the wooden blocks with the same mass of $0.600 \pm 0.001\ kg$ is released from different distances such as 0.600, 0.700, 0.800, 0.900 and 1.000 m on the inclined plane with an angle of 30˚.

Initially, the wooden block with a contact surface area of 28.8 ± 1.0 cm^2 is released from the various distances as mentioned above.

Let name the edges of the wooden block as "a" and "b" which is in contact with the surface of the inclined plane. "a" is equal to 6.0 ± 0.1 cm and "b" is equal to 4.8 ± 0.1 cm.

The surface area of the wooden block that contact with the inclined plane is equal to $(a \times b)$. Therefore the contact surface area is:

$$(a \times b) = 6.0 \times 4.8 = 28.8\ cm^2$$

To find out the uncertainty of this surface area, the following equation is used.

$$(6.0 \pm 0.1) \times (4.8 \pm 0.1)$$

$$= \left(\frac{unc. of\ a}{a} + \frac{unc. of\ b}{b}\right) \times (a \times b)$$

$$= \left(\frac{0.1}{6.0} + \frac{0.1}{4.8}\right) \times (6.0 \times 4.8)$$

$$= 1.08$$

$$\approx 1.0$$

As a result, the surface area of the wooden block that is used in the first experiment is 28.8 ± 1.0 cm^2.

	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.6	1.6	1.6	1.5	1.5	1.5	1.6	1.6	1.5	1.6
0.700	1.9	1.8	1.8	1.8	1.9	1.8	1.9	1.9	1.9	1.9
0.800	2.2	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.3	2.3
0.900	2.7	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.7	2.6
1.000	2.9	2.9	2.9	2.9	2.8	2.8	2.8	2.8	2.9	2.9

Table 1: *Time required (s) for the object with a surface area of* 28.8 ± 1.0 *cm^2 and mass of* 0.600 ± 0.001 kg *to slide down from an inclined surface with an angle of 30° with differing distances (m)*

This experiment is repeated with different wooden blocks which have same masses but different surface areas such as 39.7 ± 1.0 cm^2, 41.0 ± 1.0 cm^2, 59.8 ± 2.0 cm^2, 60.0 ± 2.0 cm^2. The processing part is done with the same method as displayed in *Appendix 6.2.*

- *For 45 Degrees:*

The wooden blocks with the same mass of $0.600 \pm 0.001\ kg$ that are used in the previous part of the experiment is released from different distances such as 0.600, 0.700, 0.800, 0.900 and 1.000 m on the inclined plane with an angle of 45˚. As in the previous part, the experiment is repeated with different contact surface areas such as 28.8 ± 1.0 cm^2, 39.7 ± 1.0 cm^2, 41.0 ± 1.0 cm^2, 59.8 ± 2.0 cm^2 and 60.0 ± 2.0 cm^2.

	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.2	1.2	1.2	1.1	1.1	1.1	1.2	1.2	1.2	1.1
0.700	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.7	1.5	1.5
0.800	1.8	1.8	2.0	1.9	2.0	1.8	1.8	1.8	1.7	1.8
0.900	2.0	1.9	1.9	2.0	2.0	2.0	2.0	2.0	1.9	2.0
1.000	2.3	2.3	2.3	2.2	2.3	2.3	2.3	2.3	2.2	2.2

Table 6: *Time required (s) for the object with a surface area of* 28.8 ± 1.0 *cm*^{2} *and mass of* $0.600 \pm 0.001\ kg$ *to slide down from an inclined surface with an angle of 45˚ with differing distances (m)*

This experiment is repeated with using wooden blocks which have different contact surface area and these data are shown in *Appendix 6.2.*

- *For 60 Degrees:*

In this section, the wooden blocks with the same mass of $0.600 \pm 0.001\ kg$ is released from various distances such as 0.600, 0.700, 0.800, 0.900 and 1.000 m on the inclined plane with an angle of 60˚. As in the previous part, the experiment is repeated with different contact surface areas such as 28.8 ± 1.0 cm^2, 39.7 ± 1.0 cm^2, 41.0 ± 1.0 cm^2, 59.8 ± 2.0 cm^2 and 60.0 ± 2.0 cm^2.

	Time Interval (s) $(\pm\mathbf{0.1})$									
Distance (m) $(\pm\mathbf{0.001})$	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	0.4	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.5	0.5
0.700	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.8	0.8
0.800	1.1	1.1	1.0	1.0	1.1	1.0	1.1	1.0	1.0	1.1
0.900	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.3	1.3
1.000	1.5	1.5	1.5	1.6	1.6	1.6	1.5	1.5	1.5	1.6

Table 11: *Time required (s) for the object with a surface area of* 28.8 ± 1.0 *cm*^{2} *and mass of* $0.600 \pm 0.001\ kg$ *to slide down from an inclined surface with an angle of 60˚ with differing distances (m)*

This experiment is repeated with using wooden blocks which have different contact surface area and these data are shown in *Appendix 6.2*.

- *For Doubled Masses:*

In the last part of the experiment, the mass of the wooden blocks are doubled and it is equal to $1.200 \pm 0.001\ kg$. These blocks are released from various distances such as 0.600, 0.700, 0.800, 0.900 and 1.000 m on the inclined plane with an angle of 60˚. As in the previous part, the experiment is repeated with different contact surface areas such as 28.8 ± 1.0 cm^2, 39.7 ± 1.0 cm^2, 41.0 ± 1.0 cm^2, 59.8 ± 2.0 cm^2 and 60.0 ± 2.0 cm^2. To sum up, the contact surface area of the blocks are remained constant but their masses is doubled.

	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.2	1.2	1.2	1.3	1.3	1.4	1.3	1.4	1.2	1.2
0.700	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.7	1.5	1.5
0.800	1.9	1.9	2.0	1.9	2.0	1.8	1.9	1.9	1.8	1.8
0.900	2.0	1.9	1.9	2.0	2.0	2.0	2.0	2.0	1.9	2.0
1.000	2.3	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.2

Table 16: *Time required (s) for the object with a surface area of* 28.8 ± 1.0 *cm^2 and mass of* $1.200 \pm 0.001\ kg$ *to slide down from an inclined surface with an angle of 45˚ with differing distances (m)*

This experiment is repeated with using wooden blocks which have different contact surface area and these data are shown in *Appendix 6.2.*

2.1 Processing Data:

As it seen in *Raw Data* part, all of the experiments is repeated for 10 times to get more reliable results. In this section, the square of the mean of the time intervals are processed with reference to these data.

According to the first row of the *Table 1*, the mean value of time interval can be calculated as shown below:

$$\frac{sum\ of\ time\ intervals}{number\ of\ trials}$$

$$= \frac{(1.6 + 1.6 + 1.6 + 1.5 + 1.5 + 1.5 + 1.6 + 1.6 + 1.5 + 1.6)}{10} = 1.56$$

To find its uncertainty value:

$$uncertainty = \frac{|max - min|}{2}$$

$$= \frac{|1.6 - 1.5|}{2} = 0.05$$

At:	S.Area (cm) / Distance (±0.001m)	Time Interval (s)				
		$\mathbf{28.8 \pm 1.0}$	$\mathbf{39.7 \pm 1.0}$	$\mathbf{41.0 \pm 1.0}$	$\mathbf{59.8 \pm 2.0}$	$\mathbf{60.0 \pm 2.0}$
30°	0,600	1.56 ± 0.05	1.52 ± 0.10	1.54 ± 0.05	1.55 ± 0.05	1.54 ± 0.05
	0,700	1.86 ± 0.05	1.88 ± 0.10	1.84 ± 0.05	1.85 ± 0.05	1.87 ± 0.05
	0,800	2.25 ± 0.05	2.27 ± 0.10	2.32 ± 0.10	2.26 ± 0.05	2.34 ± 0.05
	0,900	2.59 ± 0.10	2.58 ± 0.15	2.57 ± 0.15	2.58 ± 0.15	2.54 ± 0.05
	1,000	2.86 ± 0.05	2.90 ± 0.10	2.92 ± 0.10	2.90 ± 0.10	2.86 ± 0.10
45°	0,600	1.16 ± 0.05	1.17 ± 0.10	1.14 ± 0.05	1.15 ± 0.05	1.12 ± 0.10
	0,700	1.56 ± 0.10	1.53 ± 0.05	1.54 ± 0.05	1.63 ± 0.05	1.43 ± 0.05
	0,800	1.84 ± 0.15	1.76 ± 0.20	1.73 ± 0.05	1.74 ± 0.05	1.75 ± 0.05
	0,900	1.97 ± 0.05	1.95 ± 0.05	1.94 ± 0.05	1.93 ± 0.05	1.93 ± 0.05
	1,000	2.27 ± 0.05	2.23 ± 0.05	2.25 ± 0.05	2.25 ± 0.05	2.25 ± 0.05
60°	0,600	0.54 ± 0.10	0.57 ± 0.05	0.57 ± 0.05	0.55 ± 0.05	0.52 ± 0.10
	0,700	0.85 ± 0.05	0.85 ± 0.05	0.85 ± 0.05	0.84 ± 0.05	0.83 ± 0.10
	0,800	1.05 ± 0.05	1.05 ± 0.05	1.05 ± 0.05	1.05 ± 0.05	1.04 ± 0.05
	0,900	1.25 ± 0.05	1.27 ± 0.10	1.27 ± 0.10	1.25 ± 0.05	1.25 ± 0.05
	1,000	1.54 ± 0.05	1.53 ± 0.10	1.53 ± 0.10	1.57 ± 0.10	1.54 ± 0.05
Doubled Masses	0,600	1.27 ± 0.10	1.26 ± 0.05	1.30 ± 0.10	1.28 ± 0.10	1.21 ± 0.15
	0,700	1.56 ± 0.10	1.55 ± 0.05	1.51 ± 0.10	1.63 ± 0.05	1.50 ± 0.10
	0,800	1.89 ± 0.10	1.78 ± 0.20	1.71 ± 0.10	1.74 ± 0.05	1.76 ± 0.05
	0,900	1.97 ± 0.05	1.95 ± 0.05	1.94 ± 0.05	1.94 ± 0.05	1.95 ± 0.05
	1,000	2.27 ± 0.05	2.25 ± 0.05	2.26 ± 0.05	2.25 ± 0.05	2.25 ± 0.05

Table 21: *Mean values of the time required for the wooden blocks which has different surface area in contact to slide on the inclined plane*

To use the formula $x = \frac{1}{2}at^2$, the square of the mean of time values is have to be taken.

$$(1.56 \pm 0.05) \times (1.56 \pm 0.05) = 2.434$$

To find its uncertainty, the following equation is required.

$$\left(\frac{unc. of\ time\ taken}{time\ taken} + \frac{unc. of\ time\ taken}{time\ taken}\right) \times (time\ taken)^2$$

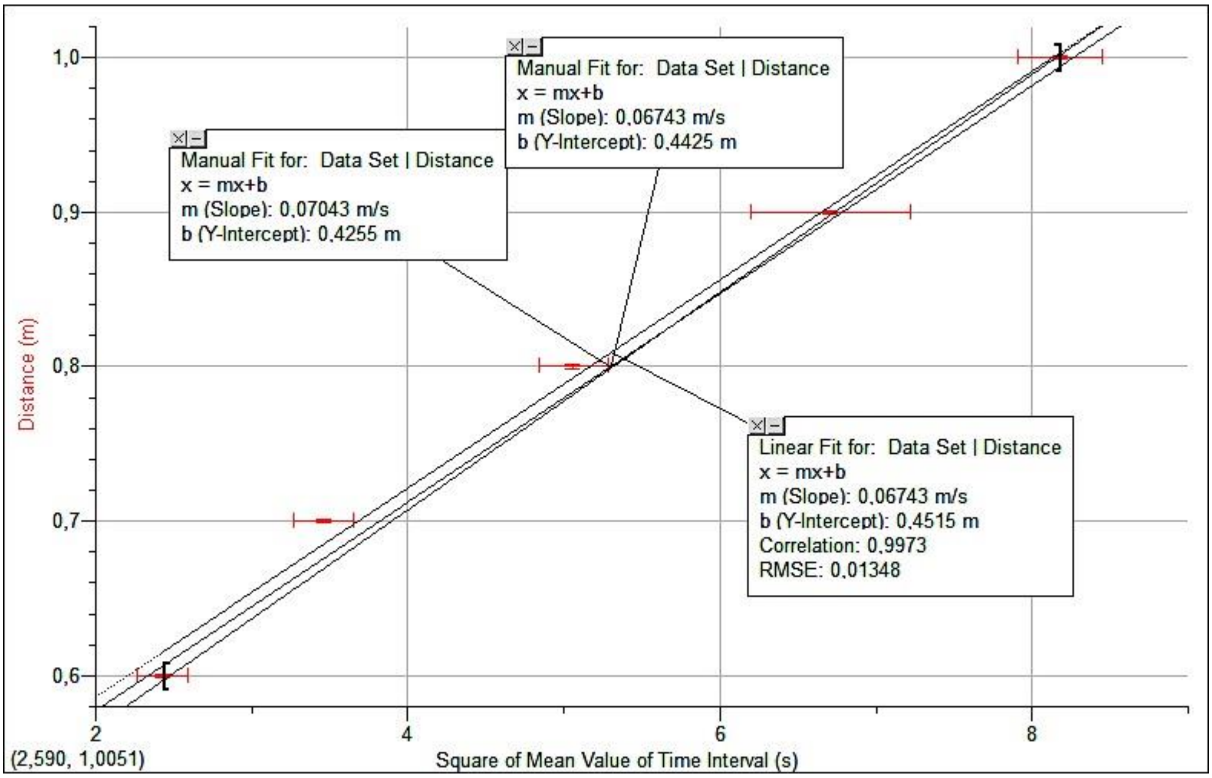
$$\left(\frac{0.05}{1.56} + \frac{0.05}{1.56}\right) \times (1.56 \times 1.56) = 0.156 \approx 0.1$$

Therefore, t^2 value is equal to $2.4 \pm 0.1\ s^2$.

		Square of Time Interval (s^2)				
At:	S.Area (cm) / Distance(±0.001m)	28.80 ± 1.08	39.69 ± 1.30	41.00 ± 1.41	59.78 ± 1.71	60.00 ± 1.90
30°	0,600	2.4 ± 0.2	3.3 ± 0.3	2.4 ± 0.2	2.4 ± 0.1	2.4 ± 0.2
	0,700	3.5 ± 0.2	3.5 ± 0.4	3.4 ± 0.2	3.4 ± 0.2	3.5 ± 0.2
	0,800	5.1 ± 0.2	5.1 ± 0.5	5.4 ± 0.5	5.1 ± 0.2	5.5 ± 0.2
	0,900	6.7 ± 0.5	6.7 ± 0.8	6.6 ± 0.8	6.7 ± 0.8	6.5 ± 0.3
	1,000	8.18 ± 0.05	8.4 ± 0.6	8.5 ± 0.6	8.4 ± 0.6	8.2 ± 0.6
45°	0,600	1.3 ± 0.1	1.4 ± 0.2	1.3 ± 0.1	1.3 ± 0.1	1.3 ± 0.2
	0,700	2.4 ± 0.3	2.3 ± 0.1	2.4 ± 0.1	2.7 ± 0.2	2.0 ± 0.1
	0,800	3.4 ± 0.5	3.1 ± 0.7	3.0 ± 0.2	3.0 ± 0.2	3.1 ± 0.2
	0,900	3.9 ± 0.2	3.8 ± 0.2	3.8 ± 0.2	3.7 ± 0.2	3.7 ± 0.2
	1,000	5.1 ± 0.2	5.0 ± 0.2	5.1 ± 0.2	5.1 ± 0.2	5.1 ± 0.2
60°	0,600	0.29 ± 0.03	0.32 ± 0.05	0.32 ± 0.06	0.30 ± 0.06	0.27 ± 0.30
	0,700	0.72 ± 0.08	0.72 ± 0.09	0.72 ± 0.09	0.70 ± 0.08	0.64 ± 0.04
	0,800	1.1 ± 0.1	1.1 ± 0.1	1.1 ± 0.1	1.1 ± 0.1	1.1 ± 0.1
	0,900	1.6 ± 0.1	1.6 ± 0.3	1.6 ± 0.3	1.6 ± 0.1	1.6 ± 0.1
	1,000	2.4 ± 0.1	1.3 ± 0.3	1.3 ± 0.3	1.5 ± 0.3	2.4 ± 0.1
Doubled Masses	0,600	1.6 ± 0.3	1.6 ± 0.1	1.7 ± 0.3	1.6 ± 0.3	1.5 ± 0.4
	0,700	2.4 ± 0.3	2.4 ± 0.1	2.3 ± 0.3	2.7 ± 0.2	2.3 ± 0.3
	0,800	3.6 ± 0.4	3.2 ± 0.7	2.9 ± 0.3	3.0 ± 0.2	3.1 ± 0.2
	0,900	3.9 ± 0.2	3.8 ± 0.2	3.8 ± 0.2	3.8 ± 0.2	3.8 ± 0.2
	1,000	5.1 ± 0.2	5.1 ± 0.2	5.1 ± 0.2	5.1 ± 0.2	5.1 ± 0.2

Table 22: *Square of the mean values of the time required for the wooden blocks which has different surface area in contact to slide on the inclined plane*

Using the slope of the distance vs. square of time graphs, acceleration can be found since $a = 2\frac{x}{t^2}$.



Graph 1: *Distance vs. square of mean value of time interval of the block with a surface area of 28,8±1.0 cm^2 where the angle is 30 degrees.*

Sample graph for the wooden block with a contact surface area of *28,8±1.0 cm^2* slide down from inclined plane is shown. The graphs of other experiment is displayed on *Appendix 6.3.*

By using the slope of graphs, the acceleration of the wooden blocks in each experiment can be processed according to the formula as stated below.

$$x = \frac{1}{2}at^2$$

If the equation solved for acceleration (a);

$$a = 2\frac{x}{t^2}$$

Since the slope of the graph gives $x/_{t^2}$, acceleration of the wooden blocks can be found by multiplying the slopes of the graphs by 2.

The calculations as showed below is done by using the data of the wooden blocks whose surface area is equal to 28.8±1.0 cm^2.

$$Slope\ of\ the\ graph: 0.067$$

$$Acceleration\ of\ the\ object = 2 \times (0.067) = 0.134$$

To find its uncertainty, the slope of the steepest and the least steep line are used which are drawn on the graph manually.

The slope of the steepest line is 0.07043

The slope of the least steep line is 0.06743.

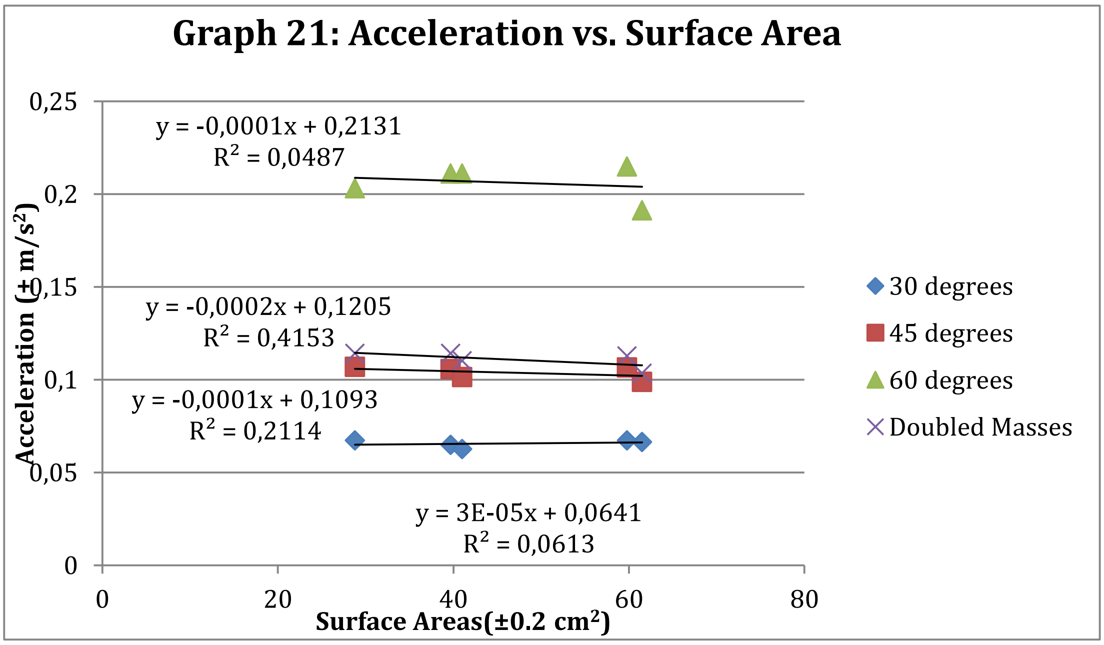
$$unc = \frac{\left|slope_{the\ steepest\ line} - slope_{the\ least\ steep\ line}\right|}{2}$$

$$unc = \frac{|0.07043 - 0.06743|}{2} = 0.003$$

As a result, the acceleration of the wooden block with a surface area in contact 28.8±1.0 cm^2 is equal to $0.134 \pm 0.003\ ms^{-2}$.

Surface Areas	At:	Slope of Graph (ms^{-2})	Accelaration (ms^{-2})
28.8±1.0 cm²	30°	0.067	0.134 ± 0.003
	45°	0.109	0.218 ± 0.006
	60°	0.195	0.39 ± 0.013
	Doubled Mass	0.115	0.230 ± 0.006
39.7 ±0.2 cm²	30°	0.072	0.144 ± 0.004
	45°	0.106	0.212 ± 0.004
	60°	0.199	0.40 ± 0.01
	Doubled Mass	0.118	0.236 ± 0.007
41.0 ±1.0 cm²	30°	0.064	0.128 ± 0.003
	45°	0.111	0.222 ± 0.003
	60°	0.199	0.40 ± 0.01
	Doubled Mass	0.116	0.232 ± 0.006
59.8 ±2.0 cm²	30°	0.065	0.130 ± 0.003
	45°	0.113	0.226 ± 0.005
	60°	0.186	0.37 ± 0.01
	Doubled Mass	0.122	0.244 ± 0.006
60.0±2.0 cm²	30°	0.068	0.136 ± 0.004
	45°	0.106	0.106 ± 0.006
	60°	0.190	0.190 ± 0.010
	Doubled Mass	0.113	0.113 ± 0.006

Table 23: *Slopes of the best lines of the graphs 1-20 and the acceleration of the blocks which is found by multiplying the slope by two due to the formula* $a = 2\frac{x}{t^2}$.



Graph 21*: In this graph, acceleration of the blocks for different conditions of 30, 45, 60 ° and doubled masses and change in surface area from 28.80, 39.69, 41.00, 59.78 and 61.50 cm² is shown.*

5.CONCLUSION AND EVALUATION:

Conclusion

In this experiment the aim is to investigate whether surface area is related to the kinetic friction of the body in motion. This factor is chosen because there is a contact between the surfaces of the body in motion and plane of the motion.

To do that, a mechanism of an inclined plane is set up. Block at the top of the inclined plane has a potential energy due to height. As it moves downwards, this potential energy transforms into kinetic energy and acceleration occurs. However, since there is surface friction regarding non ideal environment, kinetic energy is not equal to potential energy. Force of friction in this case, can be correlated with acceleration regarding the bigger the force of friction gets, the lower the acceleration becomes.

The experiment is actually done in several parts. Five blocks with five different surface areas but with same masses are taken and released from differing heights from 1 meter to 0.5 meter. This process is done for three different angles and doubled masses so as to see the effect of factors affiliated with kinetic friction.

As the data obtained observed, it can be said that the expectations about the relation between the angle and mass are correct because as the angle grows, acceleration increases.

When the mean values of the data obtained is investigated in table 21, the significant resemblance can be seen between the values of time intervals of the block with different surfaces.

When the graph 21 is analyzed where the acceleration of the blocks due to the increase in surface area is shown, it can clearly be seen that slopes of the best lines of the data are approximately zero which means, acceleration does not change when the surface area changes. Since we have related the acceleration of the body inverse proportionally to the kinetic friction it can be concluded that*, there is no significant correlation between the surface area of a body in motion and the kinetic friction force.*

To compare it with a literary work, in Physics for Scientists and Engineers it is stated that:

"The coefficients of friction are nearly independent of the area of contact between the surfaces."[8]

Thus, both the experiment and the literature disprove the hypothesis of the relation between the area and kinetic friction. Kinetic friction of a solid object does not depend on the surface area on the macroscopic point of view.

Evaluation

When the graphs are investigated thoroughly it can be said that there are minor errors in the experiments. This may be due to several reasons following:

- The experiment is done on macroscopic scale, however on the microscopic level there are some researches that surface area affects kinetic friction due to the adhesion of molecules in contact. [9]This seem as a minor difference, however it may have affected the results.
- Although a cardboard is used, there must be still a force acting on the block because of the experimenter.
- Due to friction, there may be some deformation on both of the contact areas this may have changed the independent variables on a minor level.

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8 http://books.google.com.tr/books?id=XgweHqlvtiUC&printsec=frontcover&dq=physics+for+scientists+and+engineers+vol+1&hl=tr&sa=X&ei=_GEIUe2MMsO3hQeehYGQBg&redir_esc=y#v=onepage&q&f=false

- There was a minor change in the direction of the block as it was released since it moved freely on the flat surface. Due to this change in direction, the distance, consequently the time interval may have changed. This affects the whole data obtained.
- The time interval is measured by the student using a chronometer. Reflex time of the student should be taken into account which may have lead to different results.
- The time interval measured can be considered as too short. The average human reflex time is 225 milliseconds[10]. When compared, reflex time becomes a tremendous uncertainty according to the data obtained.

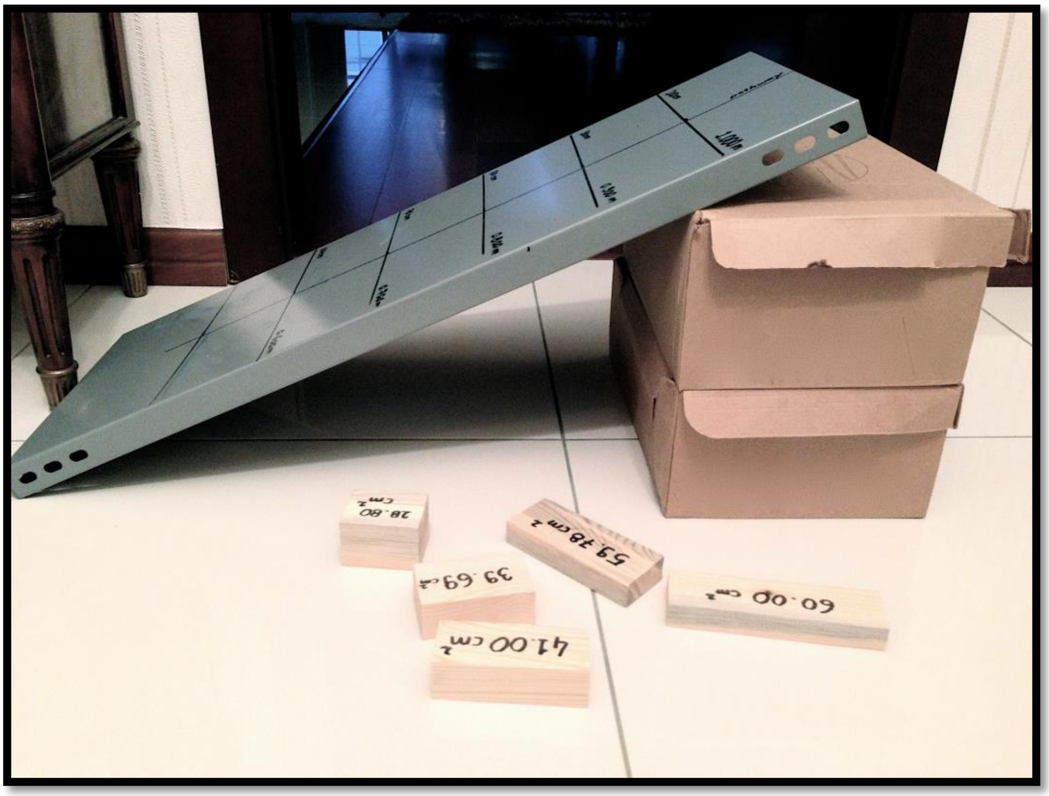
To decrease these limitations, several improvements can be suggested such as:

- A basic pulley mechanism can be used instead of releasing the block using a cardboard, this way force exerted by the student can be minimized.
- For each trial, a separate but identical block can be used to decrease the deformation of the block.
- To avoid the change in direction a rail or a riffled system could be set up regarding their constants of friction.
- The length of the aluminum sheet, consequently the distance of the motion of the solid could be increased so as to get more valid and accurate data.
- Whole experiment can be recorded. Thus, instead of using a chronometer and a person to measure time, time intervals in the recording can be trimmed after the experiment is finished. This way, reflex time of the person doing the experiment is eliminated and the observation process can be done in details.

[10] http://www.humanbenchmark.com/tests/reactiontime/stats.php

6. APPENDIX:

6.1.Appendix:



During the experiment, the photo of the experimental setup is taken and displayed below.

6.2.Appendix:

- *For 30 Degrees:*

	Time Interval (s) $(\pm\mathbf{0.1})$									
Distance (m) $(\pm\mathbf{0.001})$	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.5	1.6	1.6	1.4	1.5	1.5	1.5	1.5	1.6	1.5
0.700	1.8	1.9	1.9	1.8	2.0	1.9	1.9	1.8	1.9	1.9
0.800	2.2	2.2	2.4	2.3	2.3	2.3	2.3	2.2	2.3	2.2
0.900	2.6	2.6	2.6	2.5	2.6	2.5	2.6	2.5	2.8	2.5
1.000	2.9	2.9	3.0	2.9	2.9	2.9	2.8	2.9	2.9	2.9

Table 2: *Time required (s) for the object with a surface area of* 39.7 ± 1.0 *cm²* *and mass of* $0.600\ \pm 0.001\ kg$ *to slides down from an inclined surface with an angle of 30° with differing distances (m)*

	Time Interval (s) $(\pm\mathbf{0.1})$									
Distance (m) $(\pm\mathbf{0.001})$	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.5	1.5	1.5	1.6	1.6	1.5	1.5	1.6	1.6	1.5
0.700	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.8	1.8	1.8
0.800	2.3	2.3	2.4	2.4	2.4	2.3	2.2	2.3	2.3	2.3
0.900	2.5	2.6	2.5	2.6	2.6	2.6	2.5	2.5	2.8	2.5
1.000	3.0	3.0	3.0	2.9	2.9	2.9	2.8	2.9	2.9	2.9

Table 3: *Time required (s) for the object with a surface area of* 41.0 ± 1.0 *cm²* *and mass of* $0.600\ \pm 0.001\ kg$ *to slides down from an inclined surface with an angle of 30° with differing distances (m)*

	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.6	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.6	1.6
0.700	1.8	1.9	1.9	1.8	1.9	1.9	1.9	1.8	1.8	1.8
0.800	2.2	2.3	2.3	2.3	2.2	2.2	2.2	2.3	2.3	2.3
0.900	2.6	2.6	2.6	2.5	2.6	2.5	2.6	2.5	2.8	2.5
1.000	2.9	2.9	3.0	2.9	2.9	2.9	2.8	2.9	2.9	2.9

Table 4: *Time required (s) for the object with a surface area of* 59.78 ± 2.0 *cm² and mass of* 0.600 ± 0.001 *kg to slides down from an inclined surface with an angle of 30˚ with differing distances (m)*

	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.6	1.6	1.6	1.5	1.5	1.6	1.5	1.5	1.5	1.5
0.700	1.9	1.9	1.9	1.9	1.8	1.8	1.9	1.8	1.9	1.9
0.800	2.3	2.3	2.3	2.4	2.4	2.3	2.3	2.3	2.4	2.4
0.900	2.5	2.5	2.5	2.6	2.6	2.5	2.6	2.5	2.6	2.5
1.000	2.8	2.8	2.9	2.9	3.0	2.9	2.8	2.8	2.8	2.9

Table 5: *Time required (s) for the object with a surface area of* 60.0 ± 2.0 *cm² and mass of* 0.600 ± 0.001 *kg to slides down from an inclined surface with an angle of 30˚ with differing distances (m)*

- *For 45 Degrees:*

	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.1	1.2	1.3	1.2	1.2	1.2	1.2	1.1	1.1	1.1
0.700	1.5	1.6	1.5	1.5	1.6	1.5	1.6	1.5	1.5	1.5
0.800	1.7	1.7	1.7	2.1	1.7	1.8	1.7	1.8	1.7	1.7
0.900	1.9	1.9	1.9	2.0	2.0	1.9	1.9	2.0	2.0	2.0
1.000	2.2	2.3	2.2	2.2	2.3	2.2	2.3	2.2	2.2	2.2

Table 7: *Time required (s) for the object with a surface area of* 39.7 ± 1.0 *cm²* *and mass of* $0.600 \pm 0.001\ kg$ *to slides down from an inclined surface with an angle of 45*$^\circ$ *with differing distances (m)*

	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.1	1.1
0.700	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.5	1.5
0.800	1.8	1.7	1.6	1.7	1.7	1.8	1.8	1.8	1.7	1.7
0.900	2.0	2.0	1.9	2.0	2.0	1.9	1.9	1.9	1.9	1.9
1.000	2.3	2.3	2.3	2.2	2.2	2.2	2.3	2.3	2.2	2.2

Table 8: *Time required (s) for the object with a surface area of* 41.0 ± 1.0 *cm²* *and mass of* $0.600 \pm 0.001\ kg$ *to slides down from an inclined surface with an angle of 45*$^\circ$ *with differing distances (m)*

	Time Interval (s) $(\pm\mathbf{0.1})$									
Distance (m) $(\pm\mathbf{0.001})$	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.2	1.2	1.1	1.1	1.1	1.2	1.2	1.1	1.2	1.1
0.700	1.7	1.6	1.6	1.7	1.6	1.6	1.7	1.6	1.6	1.6
0.800	1.8	1.8	1.7	1.7	1.7	1.8	1.7	1.8	1.7	1.7
0.900	2.0	2.0	1.9	1.9	1.9	1.9	1.9	2.0	1.9	1.9
1.000	2.2	2.3	2.2	2.3	2.3	2.2	2.3	2.3	2.2	2.2

Table 9: *Time required (s) for the object with a surface area of* 59.78 ± 2.0 *cm² and mass of* 0.600 ± 0.001 kg *to slides down from an inclined surface with an angle of 45˚ with differing distances (m)*

	Time Interval (s) $(\pm\mathbf{0.1})$									
Distance (m) $(\pm\mathbf{0.001})$	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.0	1.1	1.1	1.2	1.1	1.1	1.1	1.2	1.2	1.1
0.700	1.4	1.4	1.4	1.5	1.4	1.5	1.4	1.5	1.4	1.4
0.800	1.7	1.7	1.7	1.8	1.8	1.7	1.8	1.7	1.8	1.8
0.900	2.0	2.0	1.9	1.9	2.0	1.9	1.9	1.9	1.9	1.9
1.000	2.3	2.3	2.2	2.2	2.2	2.2	2.3	2.2	2.3	2.3

Table 10: *Time required (s) for the object with a surface area of* 60.0 ± 2.0 *cm² and mass of* 0.600 ± 0.001 kg *to slides down from an inclined surface with an angle of 45˚ with differing distances (m)*

- *For 60 Degrees:*

	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	0.6	0.6	0.5	0.6	0.5	0.5	0.6	0.6	0.6	0.6
0.700	0.8	0.9	0.8	0.8	0.9	0.8	0.9	0.9	0.9	0.8
0.800	1.0	1.0	1.0	1.1	1.1	1.0	1.1	1.1	1.0	1.1
0.900	1.2	1.3	1.3	1.4	1.2	1.2	1.3	1.2	1.3	1.3
1.000	1.5	1.6	1.6	1.6	1.5	1.6	1.5	1.4	1.5	1.5

Table 12: *Time required (s) for the object with a surface area of* 39.7 ± 1.0 *cm² and mass of* 0.600 ± 0.001 kg *to slides down from an inclined surface with an angle of 60° with differing distances (m)*

	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	0.6	0.6	0.5	0.6	0.5	0.5	0.6	0.6	0.6	0.6
0.700	0.8	0.9	0.8	0.8	0.9	0.8	0.9	0.9	0.9	0.8
0.800	1.0	1.0	1.0	1.1	1.1	1.0	1.1	1.1	1.0	1.1
0.900	1.2	1.3	1.3	1.4	1.2	1.2	1.3	1.2	1.3	1.3
1.000	1.5	1.6	1.6	1.6	1.5	1.6	1.5	1.4	1.5	1.5

Table 13: *Time required (s) for the object with a surface area of* 41.0 ± 1.0 *cm² and mass of* 0.600 ± 0.001 kg *to slides down from an inclined surface with an angle of 60° with differing distances (m)*

	Time Interval (s) ($\pm\mathbf{0.1}$)									
Distance (m) ($\pm\mathbf{0.001}$)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	0.6	0.5	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.6
0.700	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.8
0.800	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.0	1.1
0.900	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.3	1.3
1.000	1.7	1.7	1.6	1.6	1.5	1.6	1.5	1.5	1.5	1.5

Table 14: *Time required (s) for the object with a surface area of* 59.78 ± 2.0 *cm² and mass of* 0.600 ± 0.001 kg *to slides down from an inclined surface with an angle of 60° with differing distances (m)*

	Time Interval (s) ($\pm\mathbf{0.1}$)									
Distance (m) ($\pm\mathbf{0.001}$)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	0.5	0.5	0.4	0.6	0.6	0.5	0.5	0.5	0.5	0.6
0.700	0.9	0.9	0.9	0.7	0.8	0.8	0.8	0.8	0.9	0.8
0.800	1.1	1.0	1.0	1.0	1.1	1.1	1.1	1.0	1.0	1.0
0.900	1.3	1.2	1.2	1.3	1.3	1.2	1.3	1.3	1.2	1.2
1.000	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.5	1.6	1.5

Table 15: *Time required (s) for the object with a surface area of* 60.0 ± 2.0 *cm² and mass of* 0.600 ± 0.001 kg *to slides down from an inclined surface with an angle of 60° with differing distances (m)*

- *For Doubled Mass:*

	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.2	1.3	1.3
0.700	1.6	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.6	1.6
0.800	1.8	1.8	1.7	2.1	1.7	1.8	1.7	1.8	1.7	1.7
0.900	1.9	1.9	2.0	2.0	2.0	2.0	1.9	2.0	1.9	1.9
1.000	2.3	2.3	2.3	2.2	2.3	2.2	2.3	2.2	2.2	2.2

Table 17: *Time required (s) for the object with a surface area of* 39.7 ± 1.0 *cm² and mass of* $1.200 \pm 0.001\ kg$ *to slides down from an inclined surface with an angle of 45˚ with differing distances (m)*

	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.2	1.2	1.3	1.4	1.4	1.3	1.4	1.2	1.3	1.3
0.700	1.4	1.4	1.5	1.5	1.6	1.6	1.6	1.5	1.5	1.5
0.800	1.7	1.7	1.7	1.6	1.6	1.7	1.8	1.8	1.8	1.7
0.900	2.0	1.9	1.9	2.0	2.0	2.0	1.9	1.9	1.9	1.9
1.000	2.3	2.3	2.2	2.2	2.2	2.2	2.3	2.3	2.3	2.3

Table 18: *Time required (s) for the object with a surface area of* 41.0 ± 1.0 *cm² and mass of* $1.200 \pm 0.001\ kg$ *to slides down from an inclined surface with an angle of 45˚ with differing distances (m)*

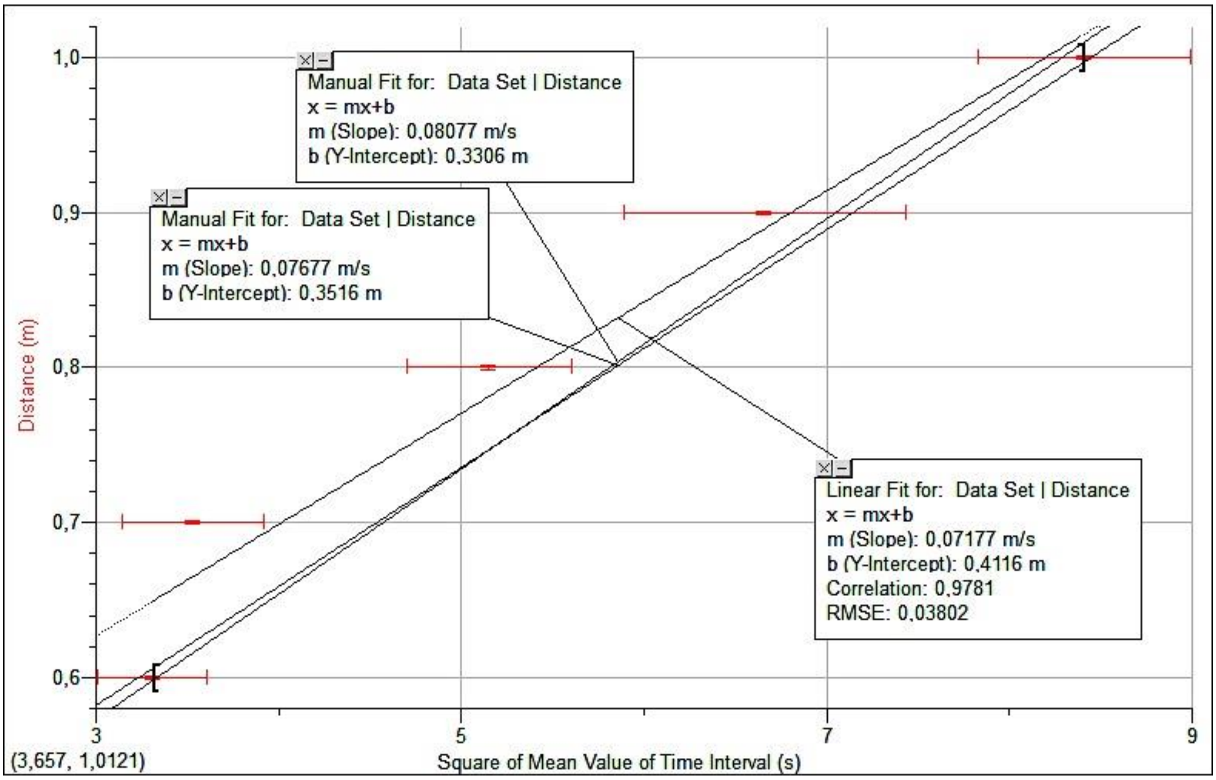
	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.4	1.3	1.2	1.2	1.3	1.2	1.3	1.3	1.3	1.3
0.700	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7
0.800	1.8	1.8	1.7	1.7	1.7	1.8	1.7	1.8	1.7	1.7
0.900	2.0	1.9	1.9	1.9	1.9	1.9	1.9	2.0	2.0	2.0
1.000	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.2	2.2

Table 19: *Time required (s) for the object with a surface area of* 59.78 ± 2.0 *cm² and mass of* $1.200 \pm 0.001\ kg$ *to slides down from an inclined surface with an angle of 45° with differing distances (m)*

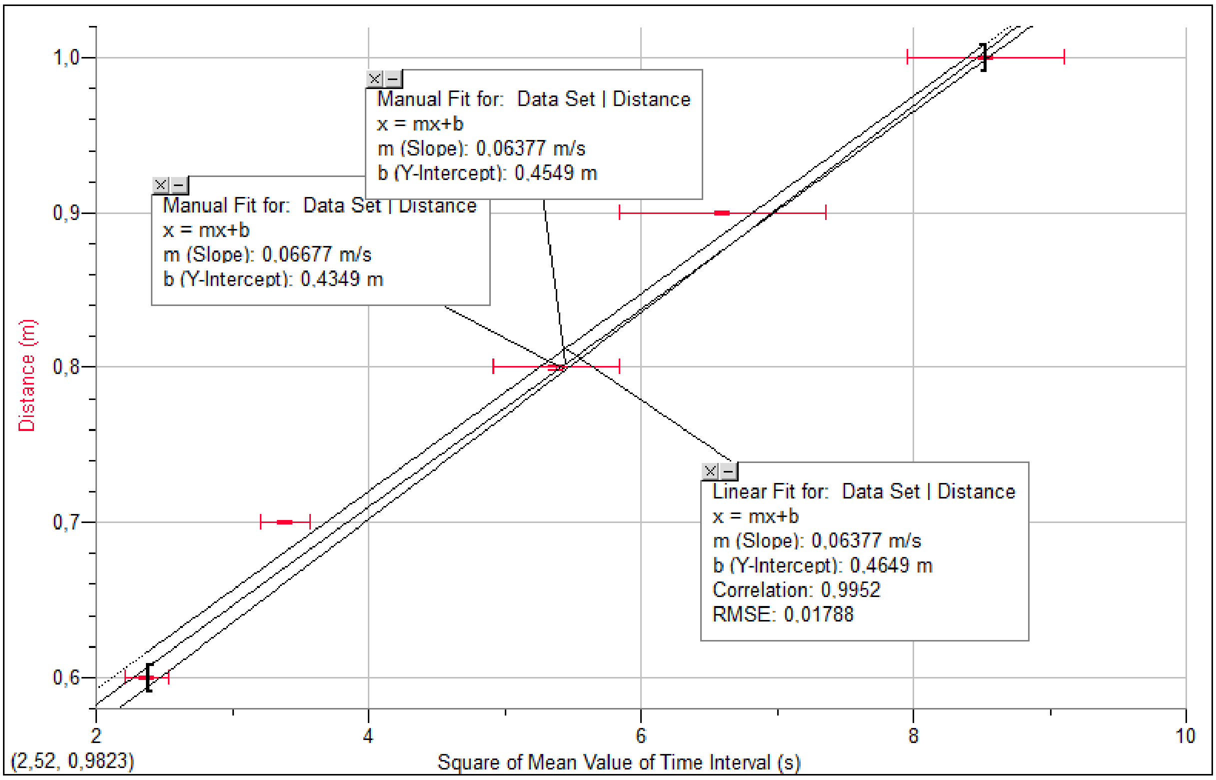
	Time Interval (s) (± 0.1)									
Distance (m) (± 0.001)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**	**Trial 8**	**Trial 9**	**Trial 10**
0.600	1.2	1.2	1.1	1.2	1.2	1.4	1.3	1.2	1.2	1.1
0.700	1.4	1.5	1.5	1.6	1.5	1.6	1.4	1.5	1.5	1.5
0.800	1.8	1.8	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8
0.900	2.0	1.9	1.9	1.9	2.0	1.9	1.9	2.0	2.0	2.0
1.000	2.2	2.2	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3

Table 20: *Time required (s) for the object with a surface area of* 60.0 ± 2.0 *cm² and mass of* $1.200 \pm 0.001\ kg$ *to slides down from an inclined surface with an angle of 45° with differing distances (m)*

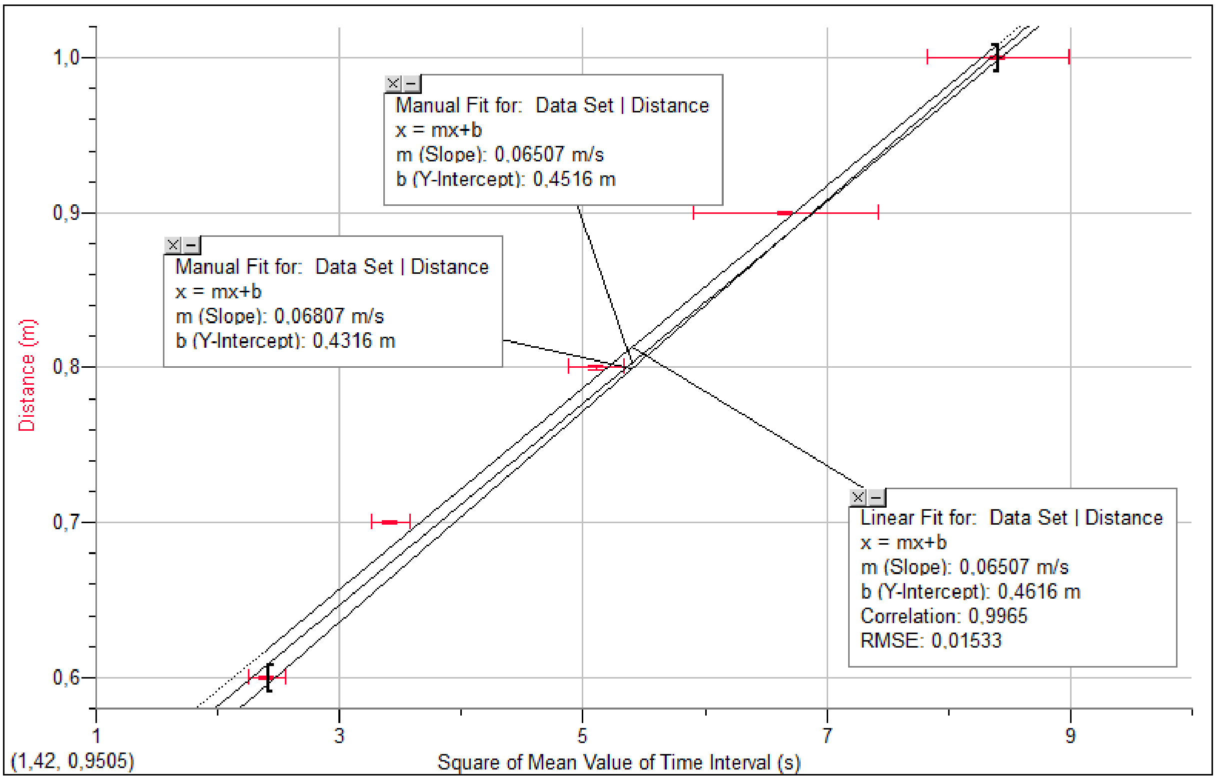
6.3.Appendix:



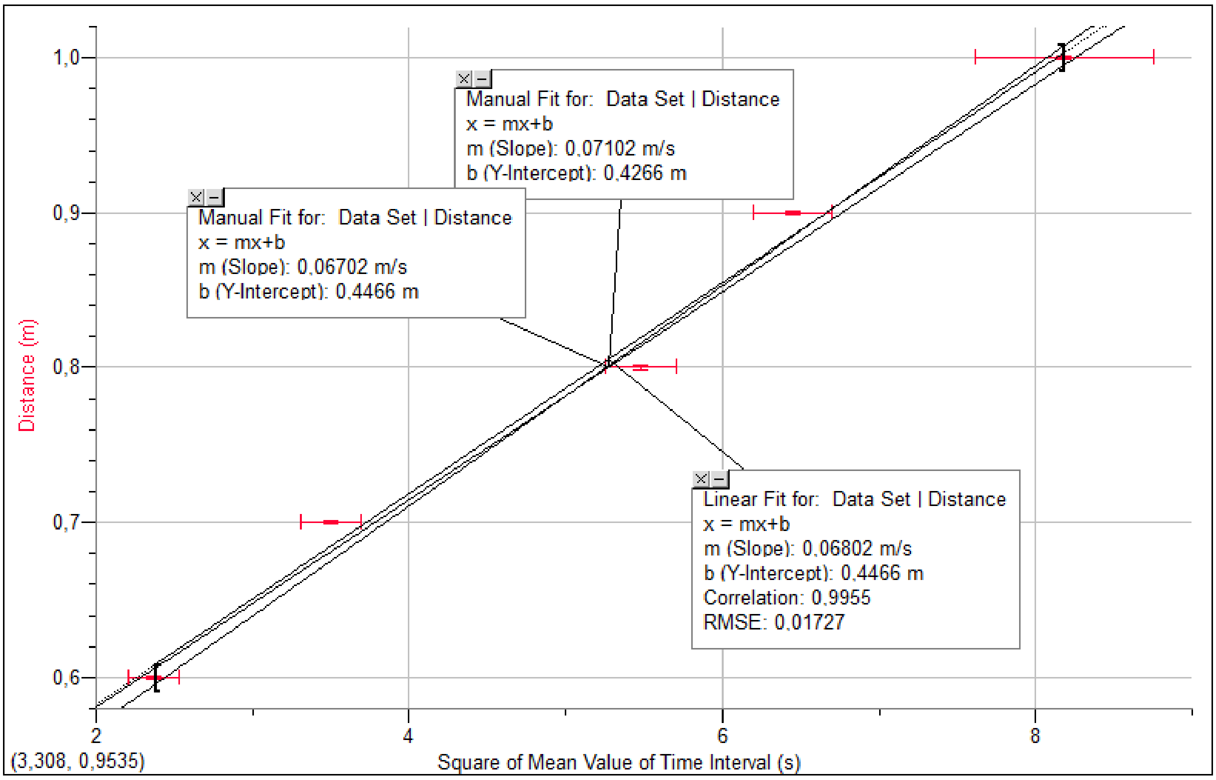
Graph 2: *Distance vs. square of mean value of time interval of the block with a surface area of 39.7±1.0 cm^2 where the angle is 30 degrees.*



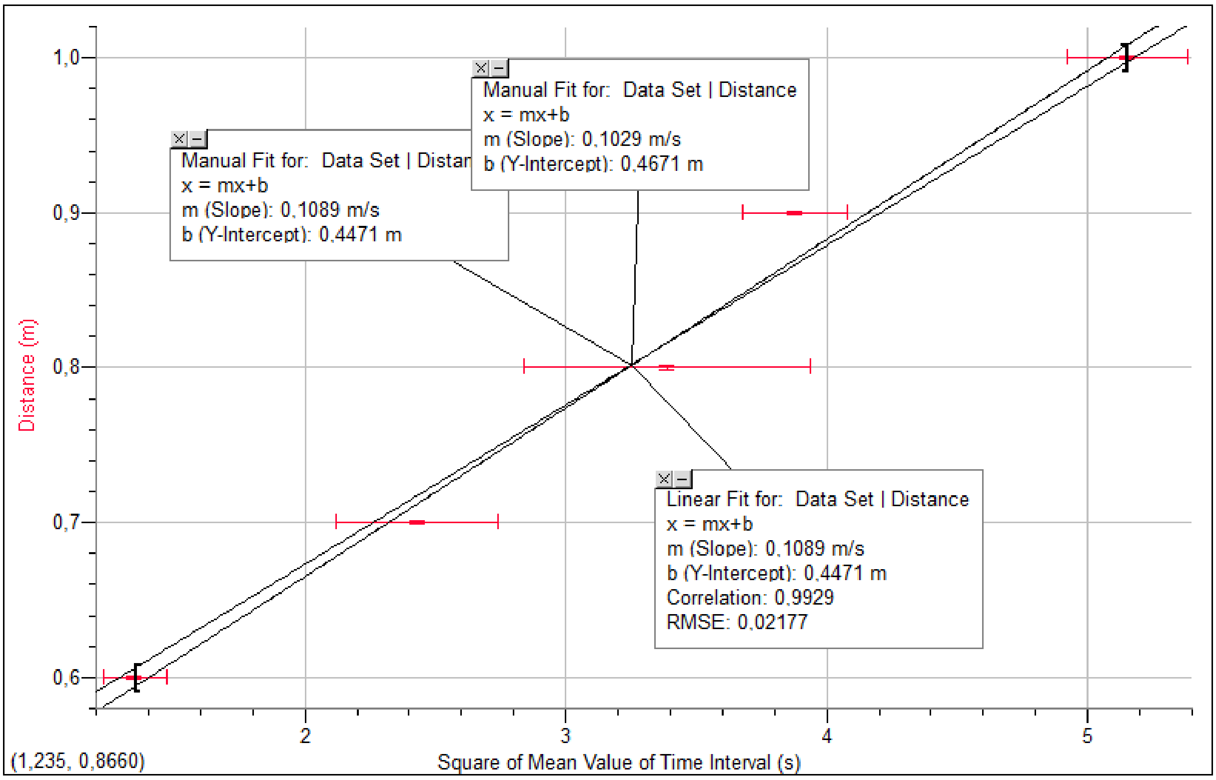
Graph 3: *Distance vs. square of mean value of time interval of the block with a surface area of 41.0±1.0 cm^2 where the angle is 30 degrees.*



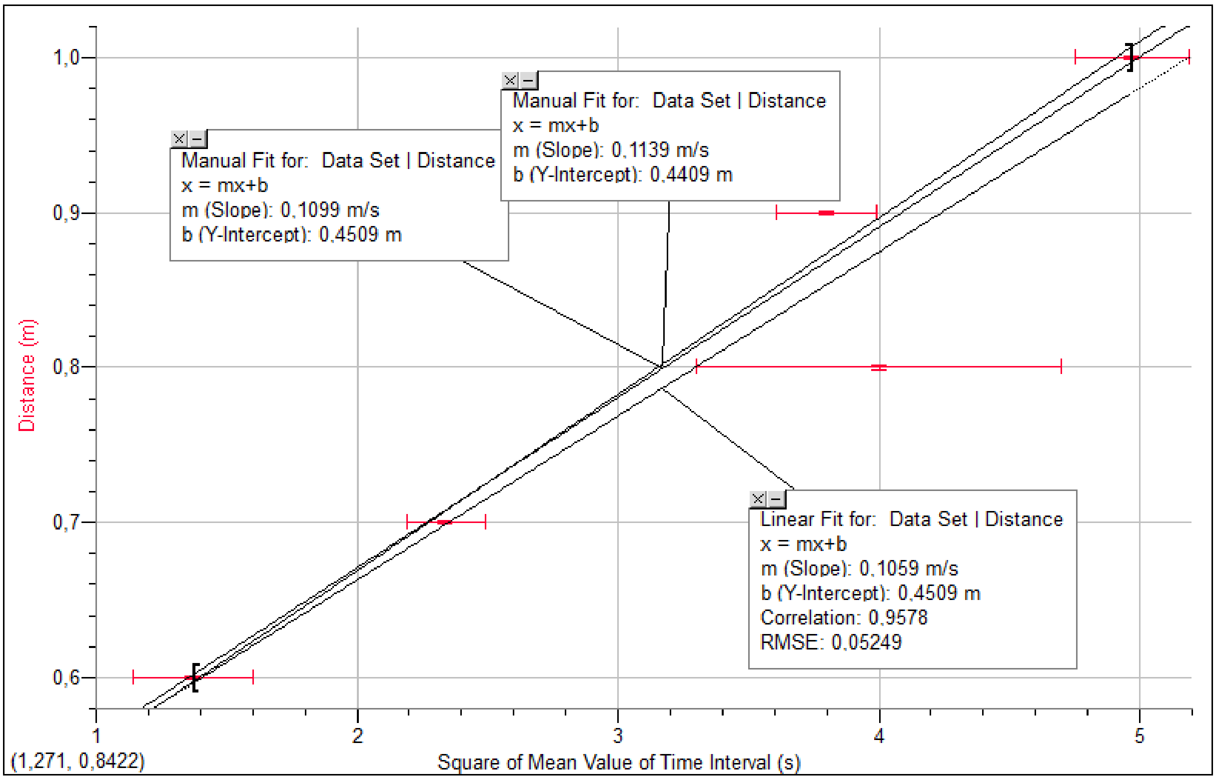
Graph 4: *Distance vs. square of mean value of time interval of the block with a surface area of 59.8±2.0 cm^2 where the angle is 30 degrees.*



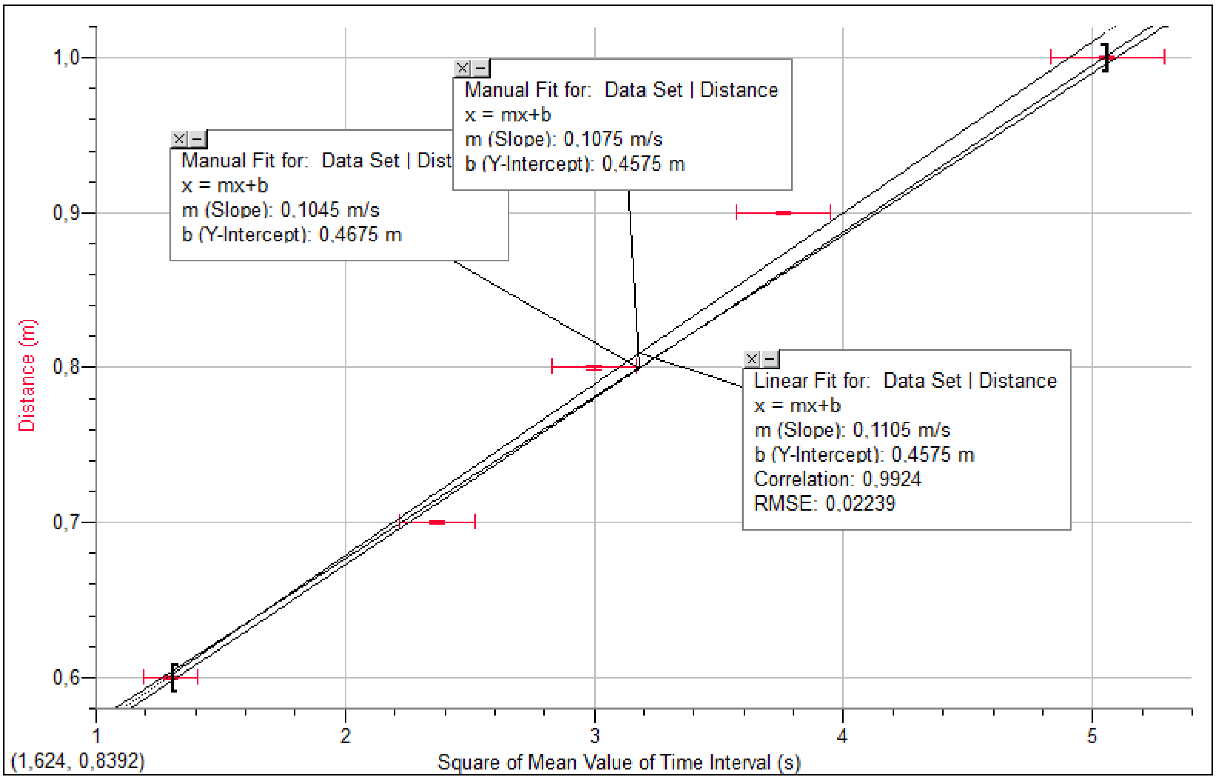
Graph 5: *Distance vs. square of mean value of time interval of the block with a surface area of 60.00±0.2 cm^2 where the angle is 30 degrees.*



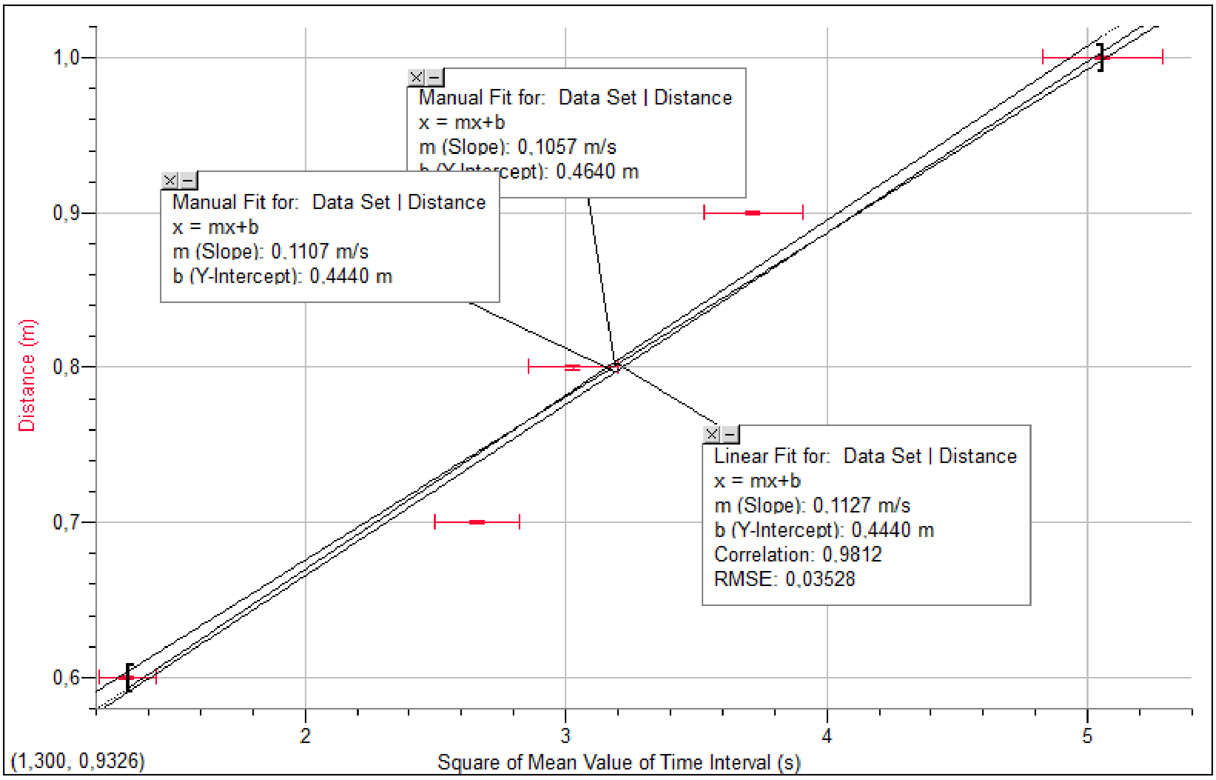
Graph 6: *Distance vs. square of mean value of time interval of the block with a surface area of 28.8 ±1.0 cm^2 where the angle is 45 degrees.*



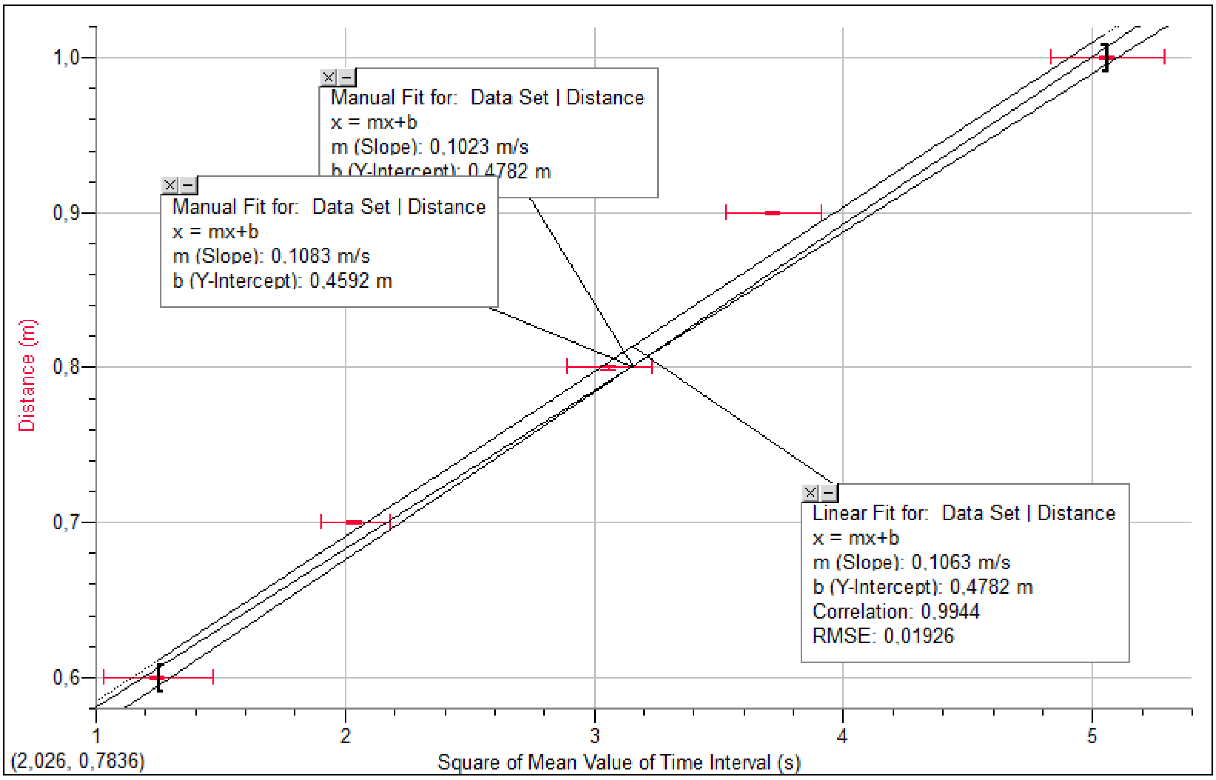
Graph 7: *Distance vs. square of mean value of time interval of the block with a surface area of 39.7 ±1.0 cm² where the angle is 45 degrees.*



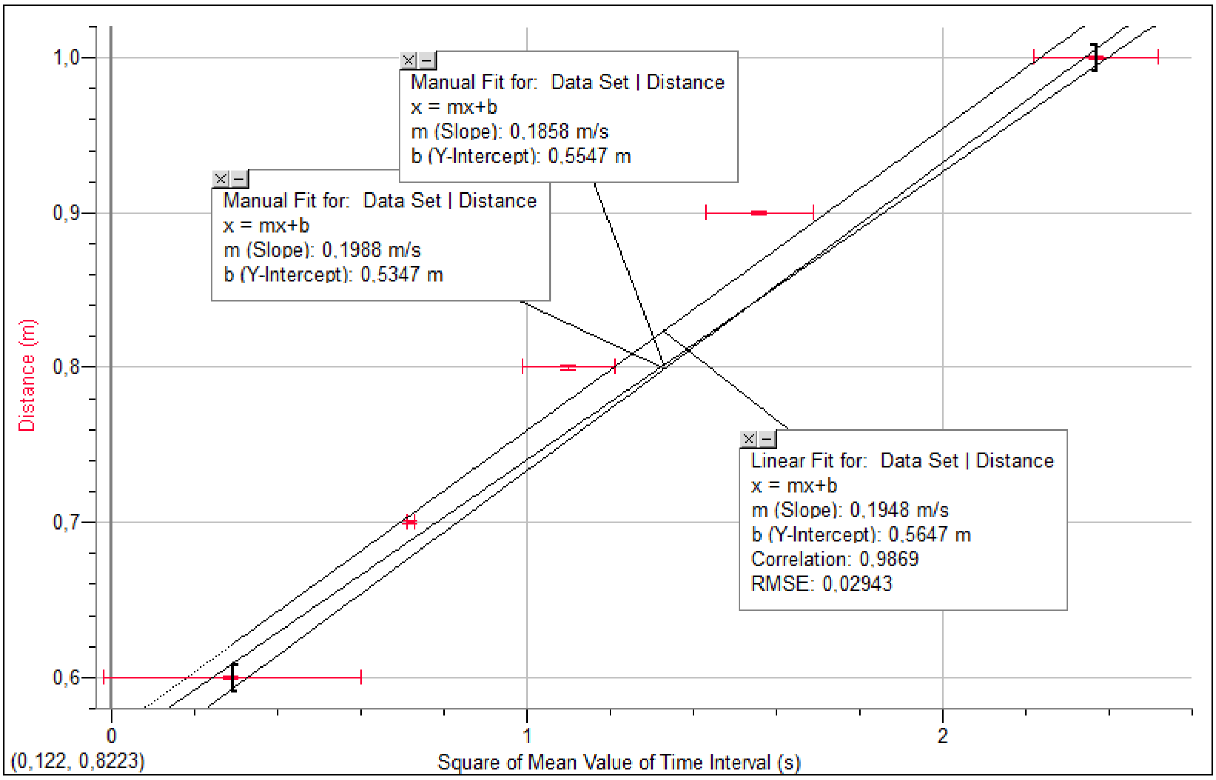
Graph 8: *Distance vs. square of mean value of time interval of the block with a surface area of 41.0 ±1.0 cm² where the angle is 45 degrees.*



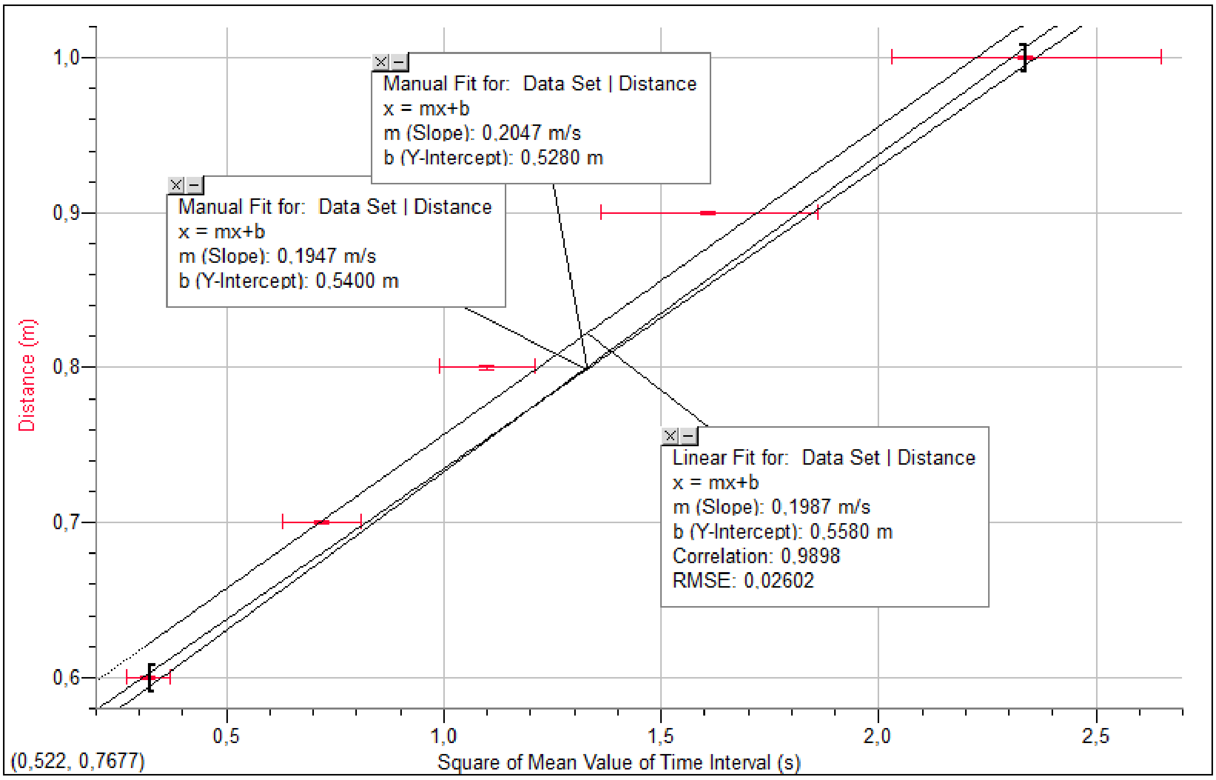
Graph 9: *Distance vs. square of mean value of time interval of the block with a surface area of 59.8±2.0 cm^2 where the angle is 45 degrees.*



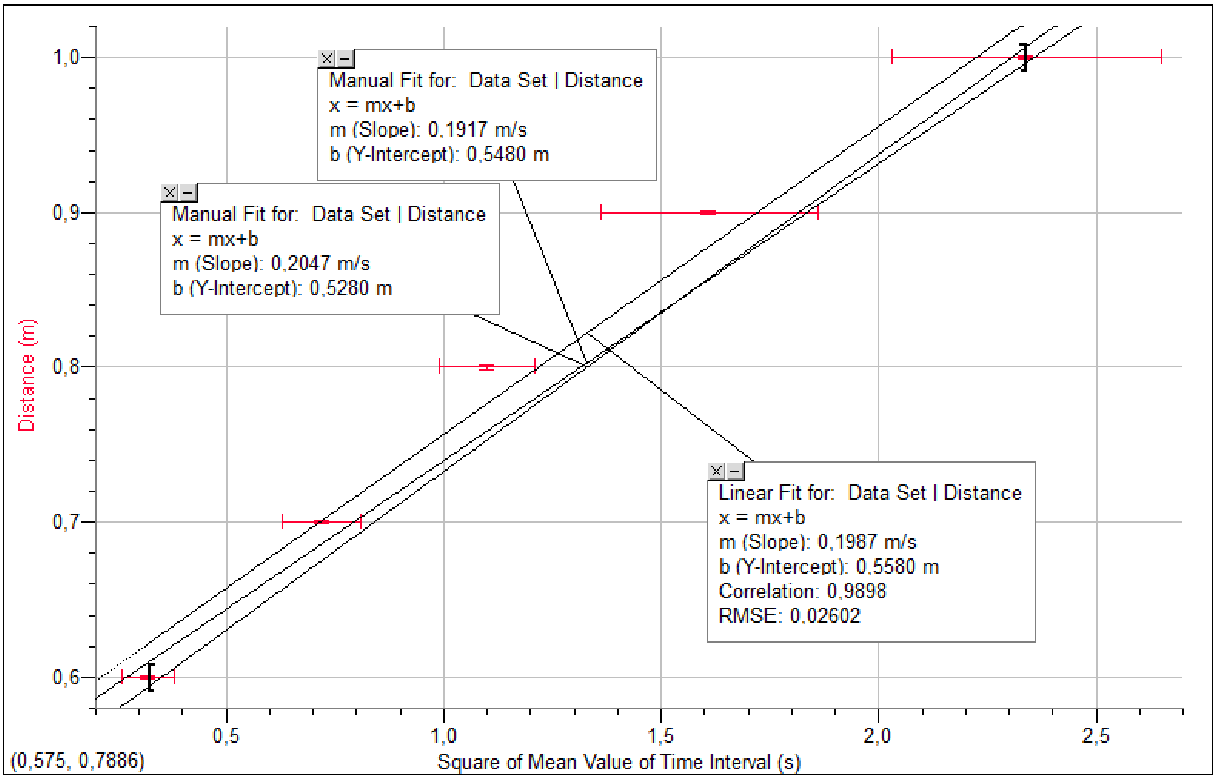
Graph 10: *Distance vs. square of mean value of time interval of the block with a surface area of 60.0±2.0 cm^2 where the angle is 45 degrees.*



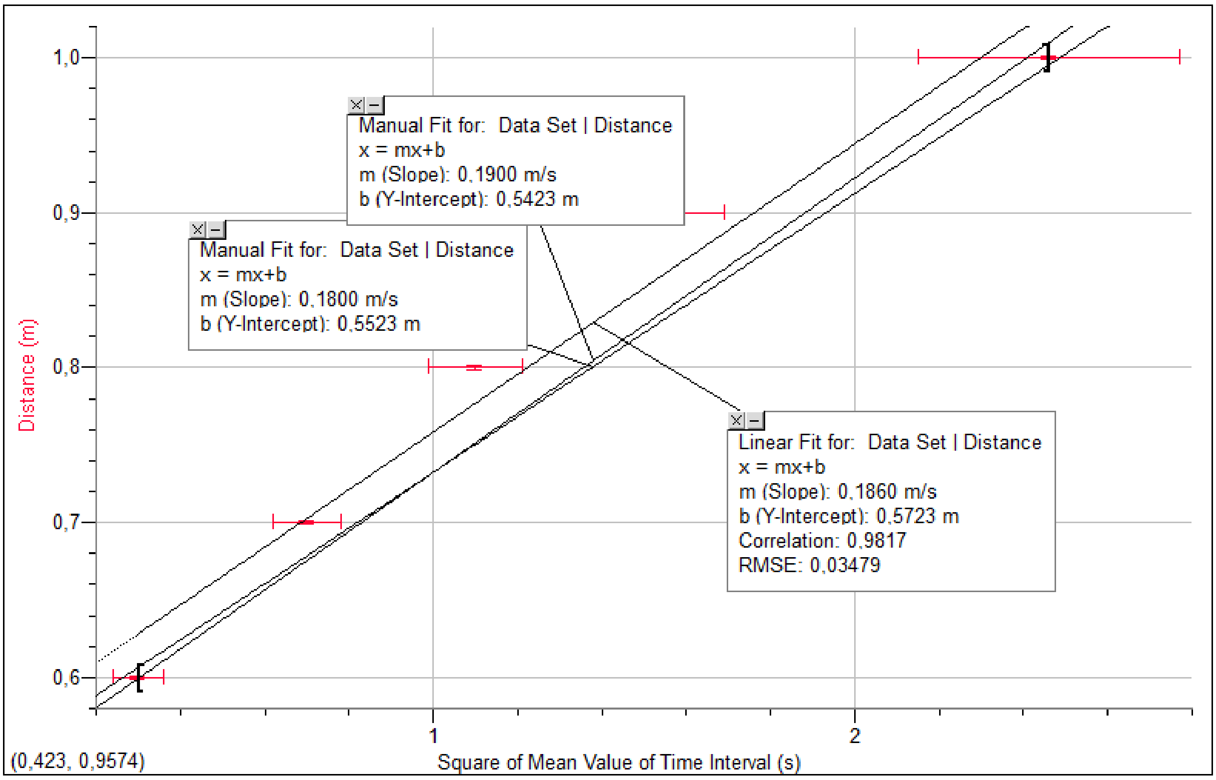
Graph 11: *Distance vs. square of mean value of time interval of the block with a surface area of 28.8±1.0 cm*^{2} *where the angle is 60 degrees.*



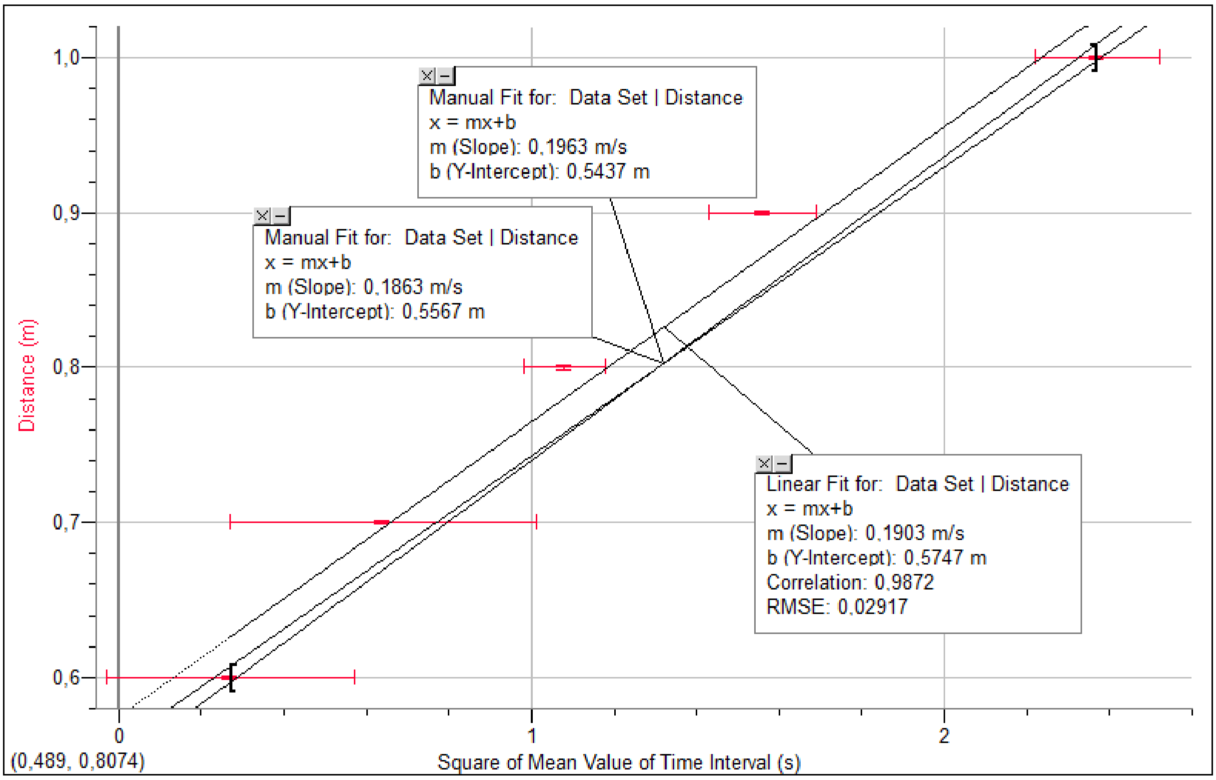
Graph 12: *Distance vs. square of mean value of time interval of the block with a surface area of 39.7±1.0 cm*^{2} *where the angle is 60 degrees.*



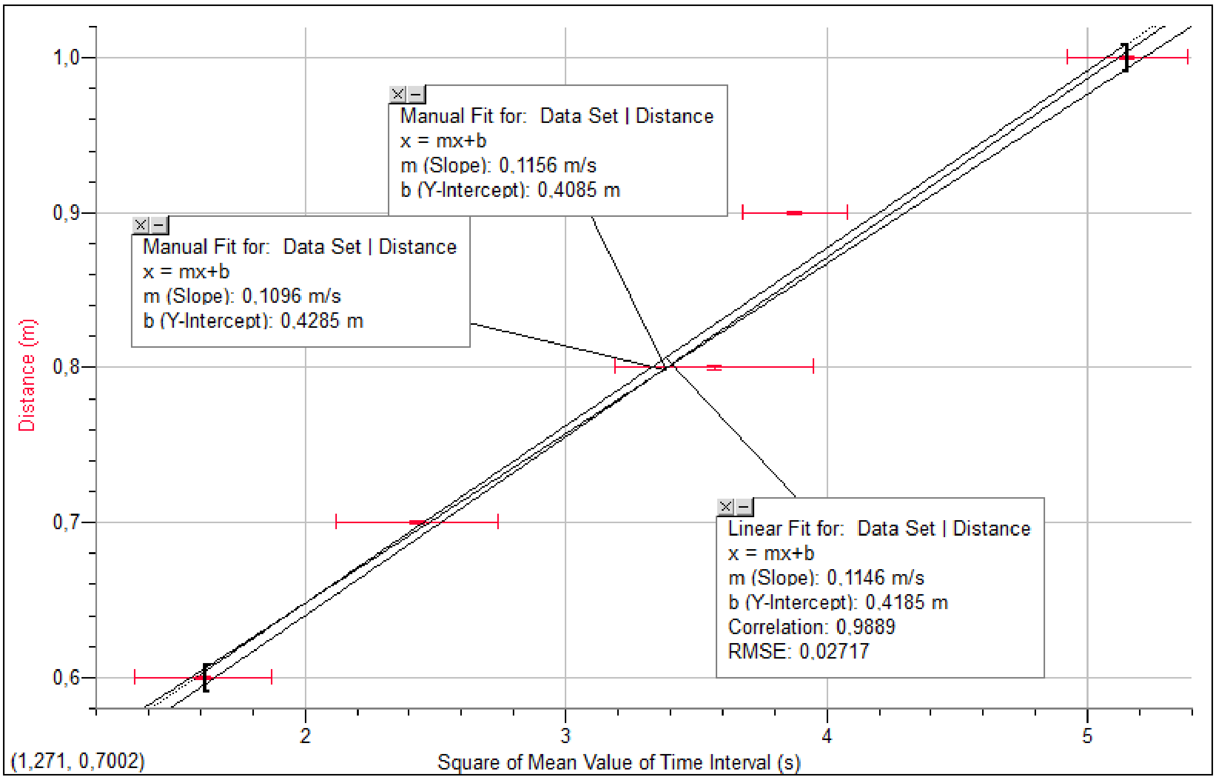
Graph 13: *Distance vs. square of mean value of time interval of the block with a surface area of 41.0±1.0 cm^2 where the angle is 60 degrees*



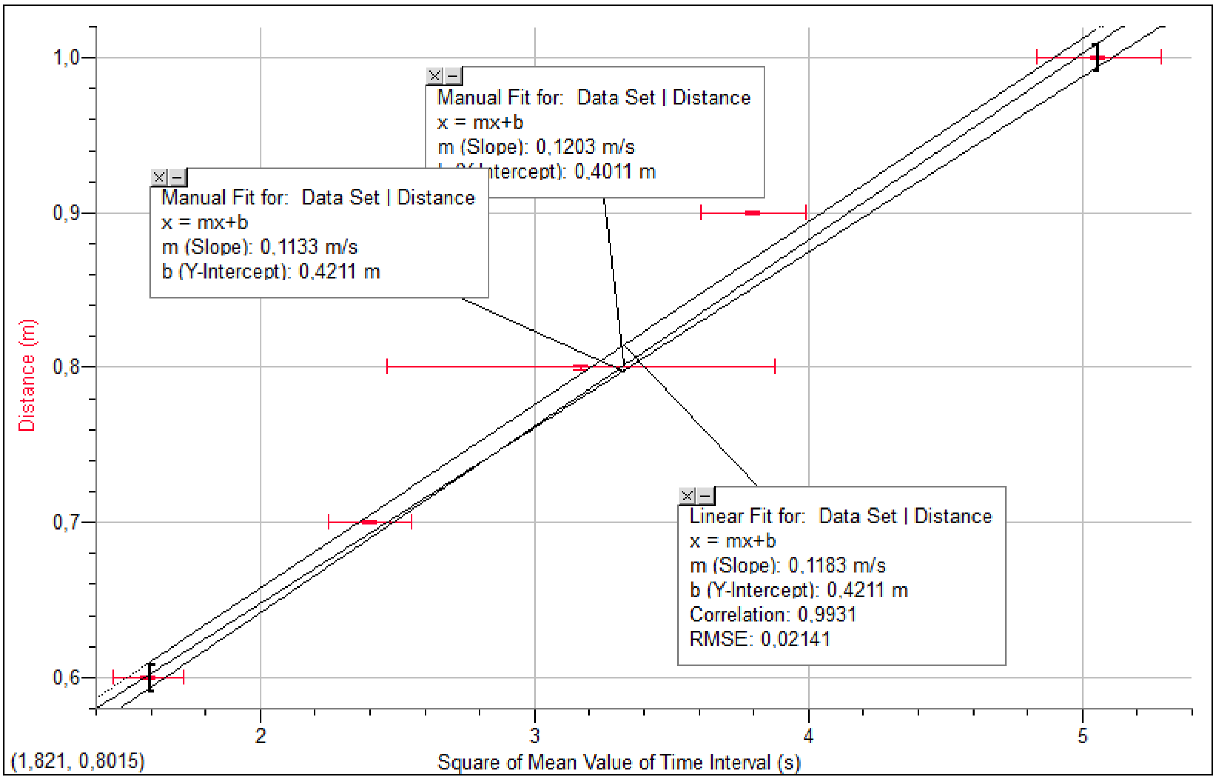
Graph 14: *Distance vs. square of mean value of time interval of the block with a surface area of 59.8±2.0 cm^2 where the angle is 60 degrees.*



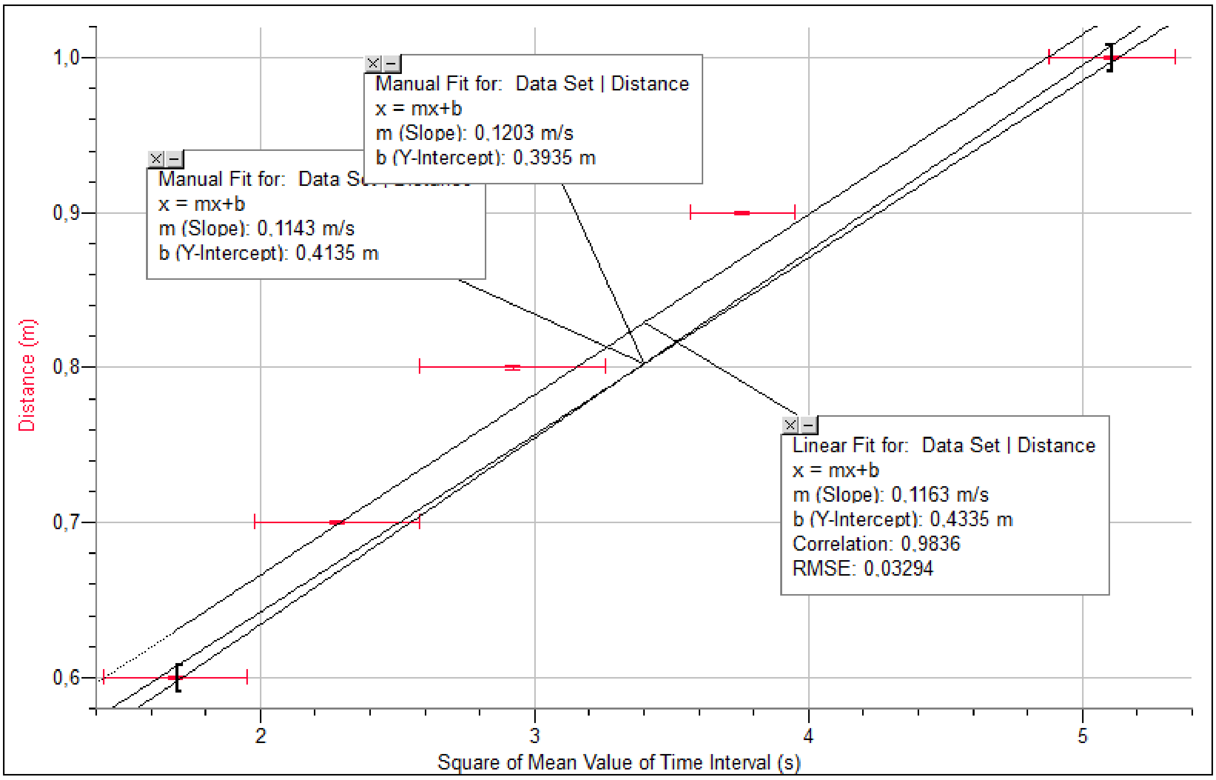
Graph 15: *Distance vs. square of mean value of time interval of the block with a surface area of 60.0±2.0 cm² where the angle is 60 degrees.*



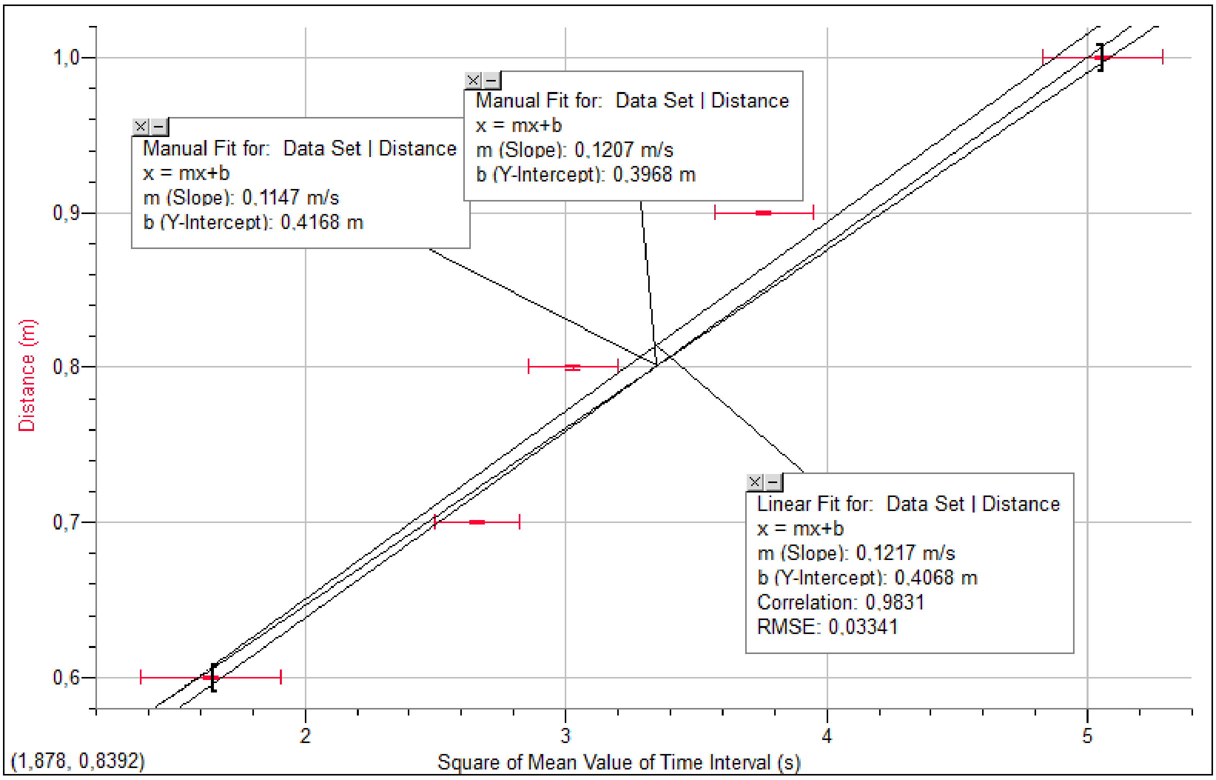
Graph 16: *Distance vs. square of mean value of time interval of the block with a surface area of 28.8±1.0 cm² where the angle is 45 degrees and mass is the twice the weight of a one block.*



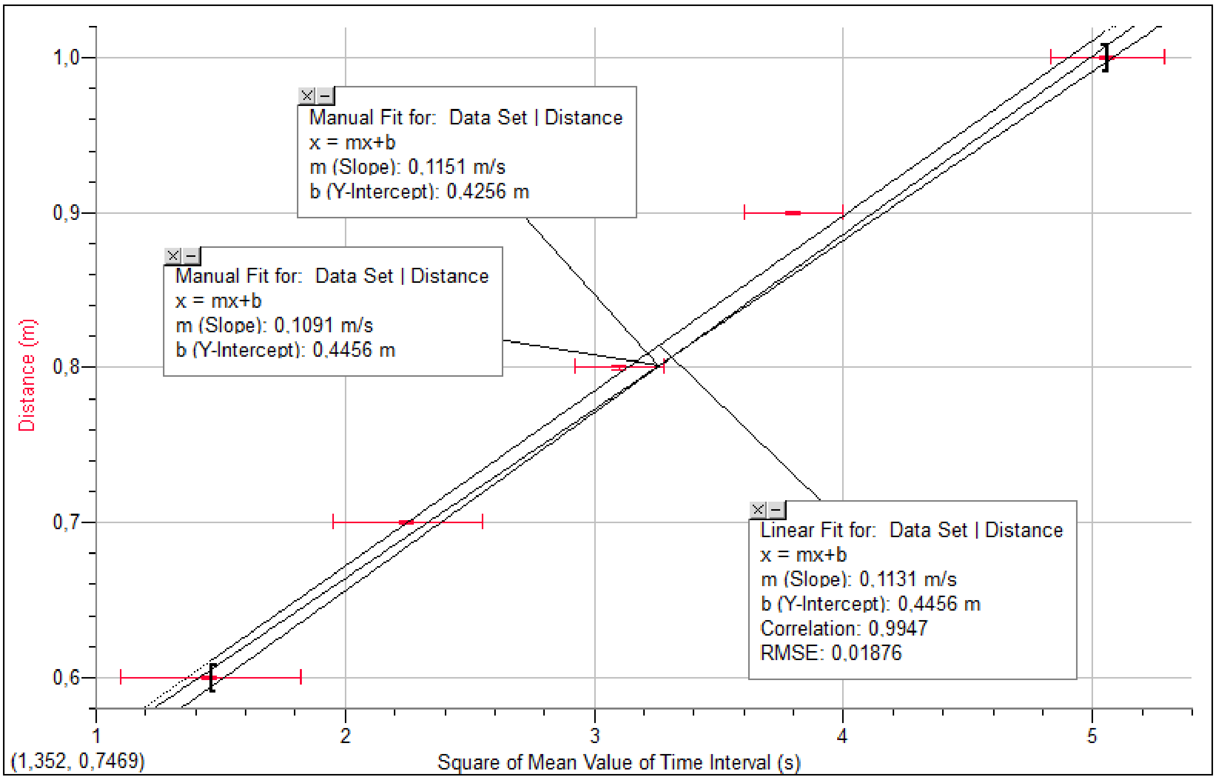
***Graph 17:** Distance vs. square of mean value of time interval of the block with a surface area of 39.7±1.0 cm^2 where the angle is 45 degrees and mass is the twice the weight of a one block.*



***Graph 18 :** Distance vs. square of mean value of time interval of the block with a surface area of 41.0±1.0 cm^2 where the angle is 45 degrees and mass is the twice the weight of a one block.*



Graph 19 : *Distance vs. square of mean value of time interval of the block with a surface area of 59.8±2.0 cm^2 where the angle is 45 degrees and mass is the twice the weight of a one block.*



Graph 20 : *Distance vs. square of mean value of time interval of the block with a surface area of 60.0±2.0 cm^2 where the angle is 45 degrees and mass is the twice the weight of a one block.*

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