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EXPERIMENT 1

ANALYSIS OF DATA

a

LAB REPORT

Date: ..6./.2./.2019..................

Name: ..Khaled....Al-Naser.... Partner's Name: .Ibrahim..ghosheh

Registration No: Registration No. ......

Section: ....14................. Instructor's Name: Essam...dossi..

PURPOSE

To learn basic data analysis and use it to uncover correlations and empirical relationships between experimental variables.

Note: For this lab, a thorough reading of the Introduction and Appendix B is required.

I. INTRODUCTION

The data for this lab have been collected from an experiment that has already been performed. The basic procedure of the experiment consists of filling a cylindrical container with water to a certain height (h) and measuring the time (t) it takes to drain the container by allowing the water to escape through a circular hole with diameter (d) at the bottom of the container. The height and diameter (h and d) are the independent variables of the experiment, and time, t, is the dependent variable.

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The objective of the experiment and the analysis that you will carry out is to find an empirical relation $t(d,h)$, *i.e.* one that is based on the data, relating the time to the height of the water and diameter of the hole.

The relation being sought has the form $t = A\, h^{\alpha}\, d^{\beta}$, where A, α, and β are constants. You will determine

- α and β,
- the empirical relationship between t and h when d is fixed, and
- the empirical relationship between t and d when h is fixed.

You will use graphical representation of the data in order to visualize the correlation between the variables.

II. PROCEDURE

In order to arrive at the empirical relation $t(d,h)$, the height and diameter, h and d, were varied and the resulting variation of the time t was observed.

The standard way to carry out such an experiment is to fix one independent variable, d for example, and vary the other independent variable (h in this case) and measure the time (for each value of h). Then one repeats the procedure for a different d but the same values of h. In this manner Table 1.1 is obtained.

It is clear that at fixed d, larger h (more water) should result in larger t (more time is needed to empty the container). On the other hand, for a given h, t is expected to decrease when d is increased (a larger diameter allows for a higher flow rate of water).

Note that in a row in the table, h is constant and d is varied, while for a column, d is constant and h is varied. For example, the first row has the following time values for h = 30.0 cm: 73.0 s for d = 1.5 mm, 41.2 s for d = 2.0 mm, etc.

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Table 1.1

	t (s)			
h (cm)	d = 1.5 mm	d = 2.0 mm	d = 3.0 mm	d = 5.0 mm
30.0	73.0	41.2	18.4	6.80
10.0	43.5	23.7	10.5	3.90
4.0	26.7	15.0	6.80	2.20
1.0	13.5	7.20	3.70	1.50

III. Data

8. Use the data in Table 1.1 to fill in Table 1.2

Table 1.2

	t (s)			
d (mm)	h = 1.0 cm	h = 4.0 cm	h = 10.0 cm	h = 30.0 cm
1.5	13.5	26.7	43.5	73.0
2.0	7.20	15.0	23.7	41.2
3.0	3.70	6.80	10.5	18.4
5.0	1.50	2.20	3.90	6.80

9. For h = 30 cm, use Tables 1.1 and 1.2 and fill in Table 1.3.

Table 1.3

t (s)	d (mm)	$1/d^2$ (mm^{-2})
6.80	5.0	0.04
18.4	3.0	0.11
41.2	2.0	0.25
73.0	1.5	0.44

10. For d = 2.0 mm, fill in Table 1.4 below:

Table 1.4

t (s)	h (cm)	$Log_{10}\, t$	$Log_{10}\, h$
7.20	1.0	0.857	0
15.0	4.0	1.176	0.602
23.7	10.0	1.374	1
41.2	30.0	1.614	1.47

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V. ANALYSIS OF DATA

1. Plot your results.

Using a scale that utilizes at least 2/3 of the sheet of graph paper, plot on the *same graph paper* (using the same axes) the function $t(h)$ (*i.e.*, t *vs.* h) for each diameter (d) used. Connect the data points from each case with a smooth curve, and label each curve with the corresponding d.

Similarly, on a second sheet of graph paper, plot the function $d(t)$ (*i.e.*, d *vs.* t) for each value of the height (h). Connect the points corresponding to each value of h with a smooth curve and label each curve with the appropriate value of h.

- Plot t versus $1/d^2$ for $h = 30$ cm.
- Plot $\text{Log}_{10}t$ versus $\text{Log}_{10}h$ for $d = 2$ mm.

Use your graphs to answer the following questions:

2. From your graph of (h) versus (t) for d = 1.5 mm, extrapolate the curve toward the origin. Does it pass through it? Would you expect it to do so? Explain.

yes, by the relation between h, t ⇒ $t = A h^{\alpha} d^{b}$
If we use the value ($h = 0$) then the value of t will be zero.

3. What type of relationship (direct or inverse) do you see between the time t and diameter d for a fixed value of h? Why?

Inverse, because by the graph when the value of the diameter (d) increases, the ~~value~~ of the time (t) decreases.

4. From the graph of t versus $1/d^2$, determine the empirical relationship between time t and hole diameter d for h = 30 cm.

~~t = md~~ $t = m \frac{1}{d^2} + a$

$t = 166.6 * \frac{1}{d^2}$

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5. Do you expect the empirical relationship from above (between time t and hole diameter d) to be different for h = 50 cm, for example? Explain.

no yes, because the value of the diameter (d) and time (t) will change, so the slope will slope.

-0.25

6. From the previous relation, calculate the time needed to empty the container if the diameter of the hole is 4 mm.

$y = ax + b$

$\log(t) = m\log(h) + 0.857$

$\log(t) = 0.53\log(h) + 0.857$

$\log(t) = \log(h)^{0.53} + 0.857$

$\log(t) - \log(H)^{0.53} = 0.857$

$\log\left(\frac{t}{h^{0.53}}\right) = 0.857$

$\frac{t}{h^{0.53}} = 10^{0.857}$

$t = 10^{0.857} * h^{0.53}$

(7) السؤال

7. From the Log$_{10}t$ versus Log$_{10}h$ graph, find the empirical relationship between the time t and height h for d = 2 mm.

(6) السؤال: $t = \frac{166.6}{4^2} = \frac{166.6}{16} = 10.412$ s

8. From the previous relation, calculate the time needed to empty the container if the height of water was 25 cm.

$t = 10^{0.857} * h^{0.53}$

$t = 10^{0.857} * 25^{0.53} = 39.61$ s

unit -0.25

9. What is meant by an empirical relationship?

A relationship between two variables that depends on each other.

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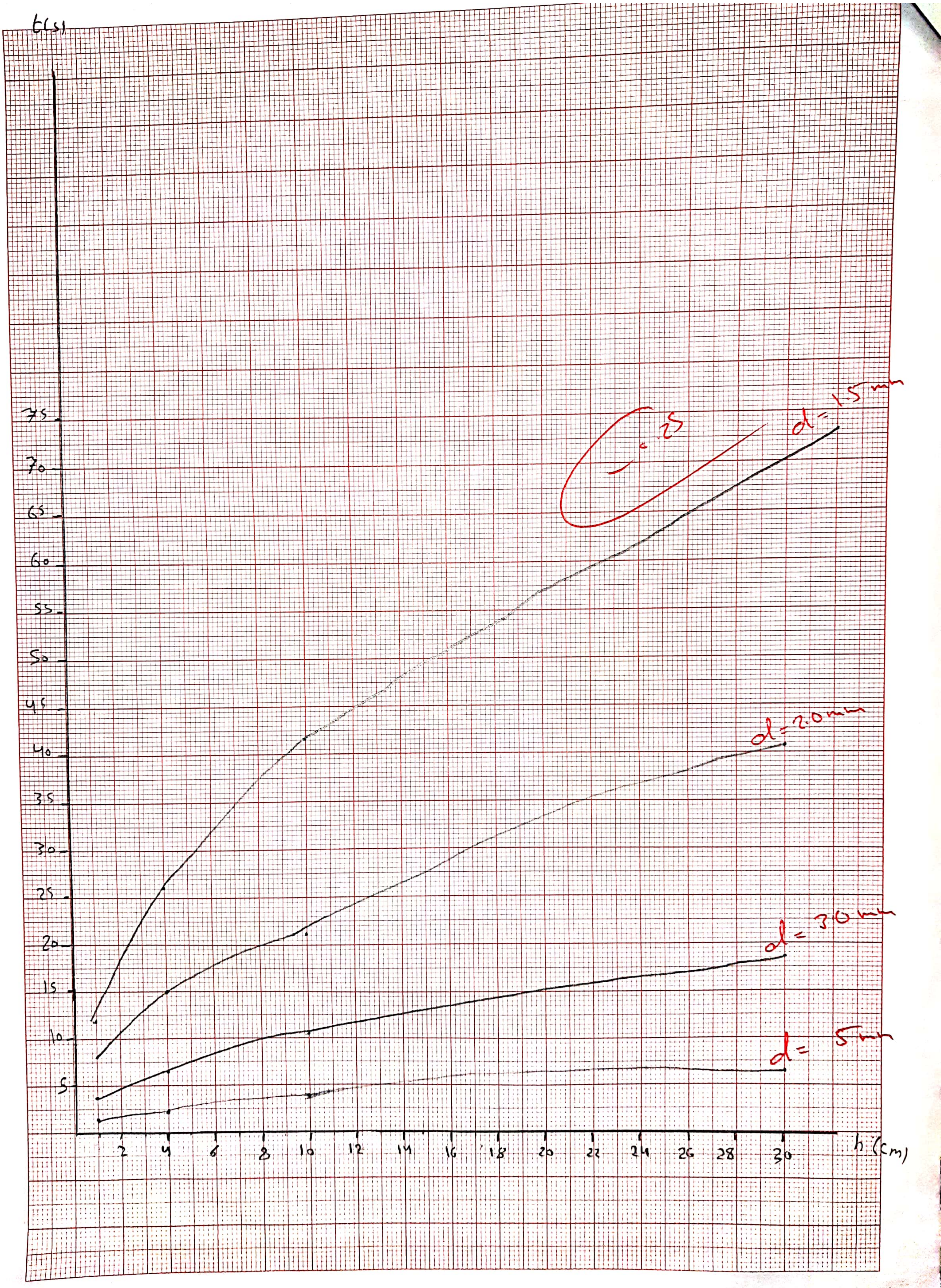

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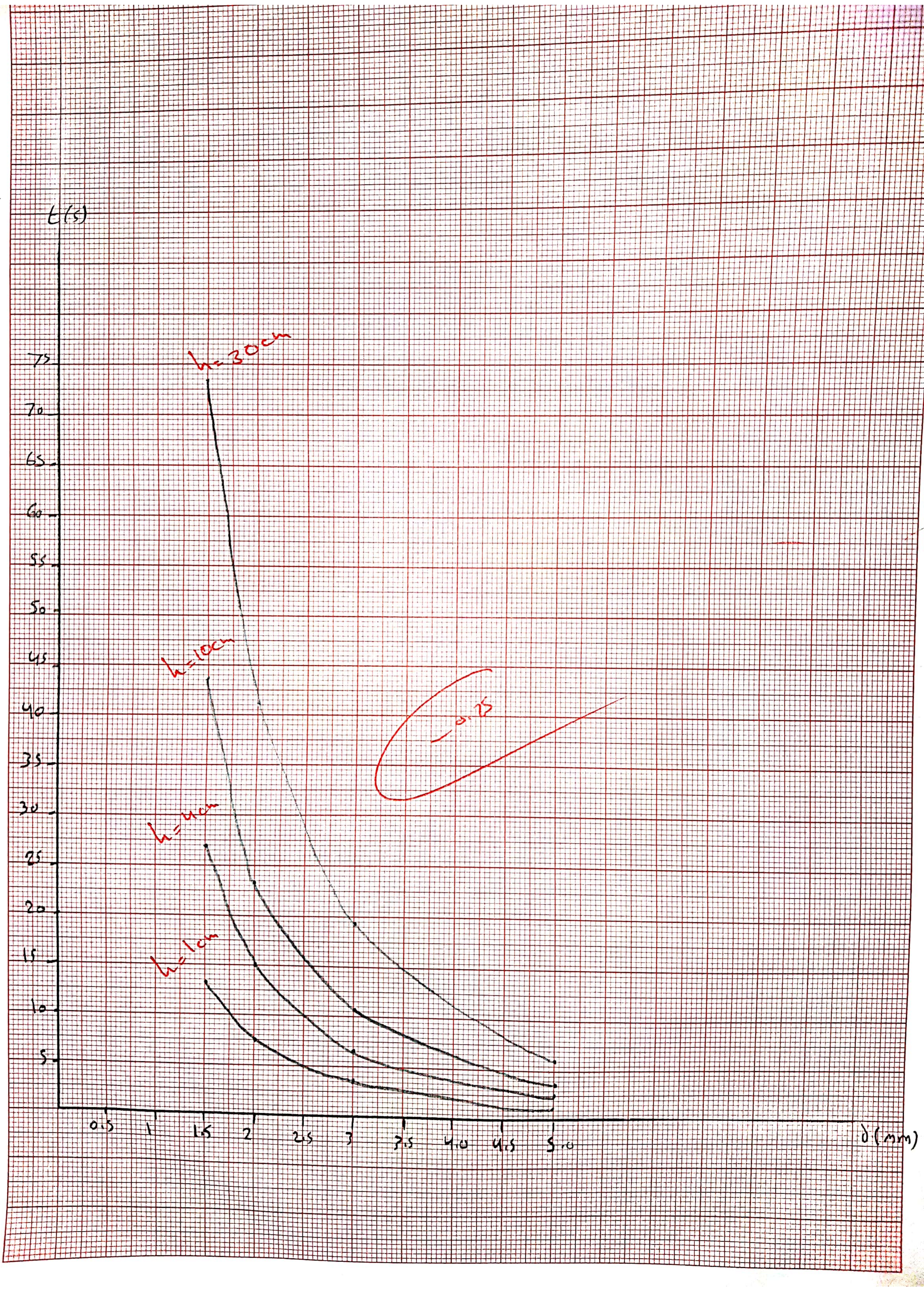

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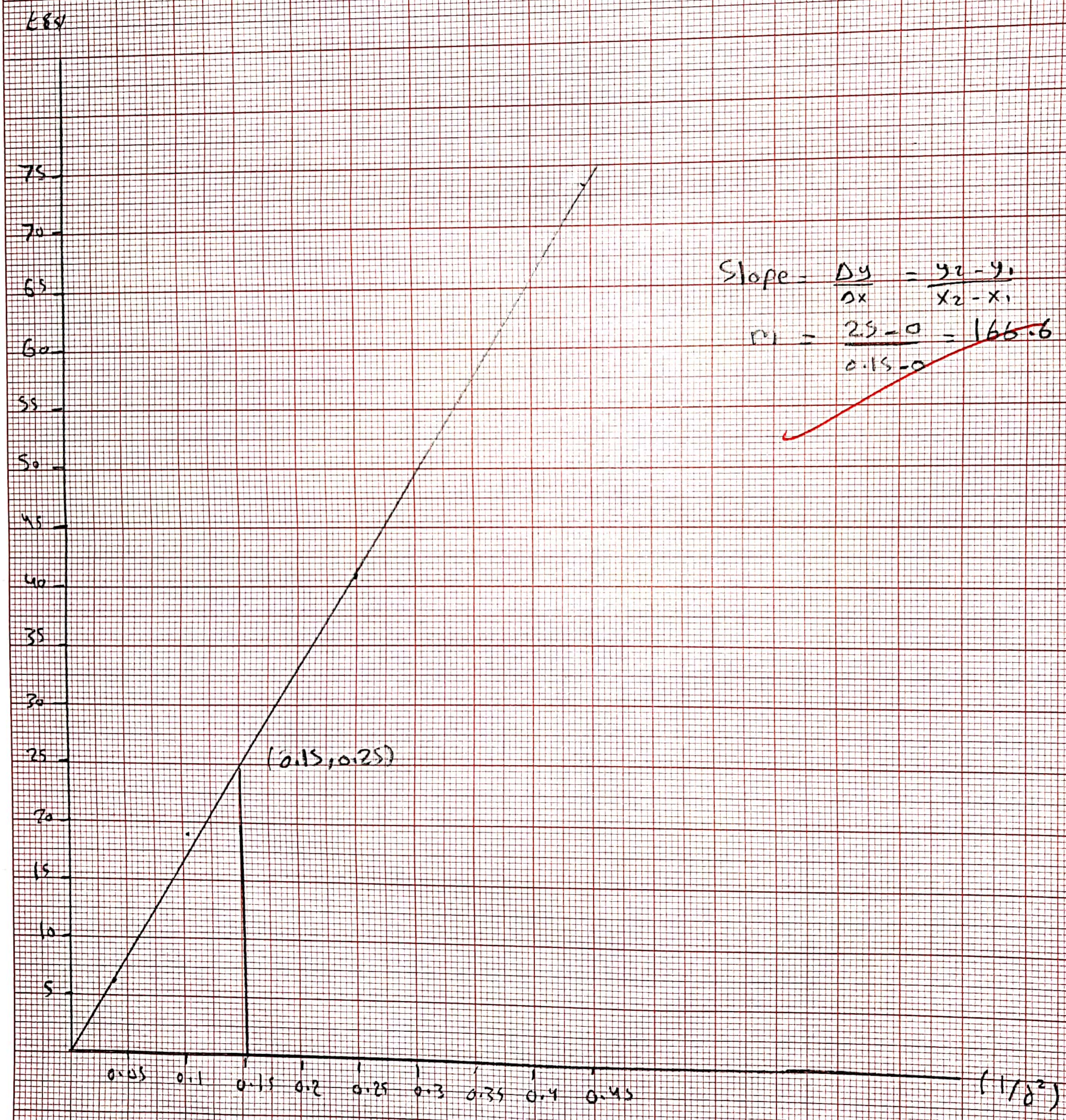
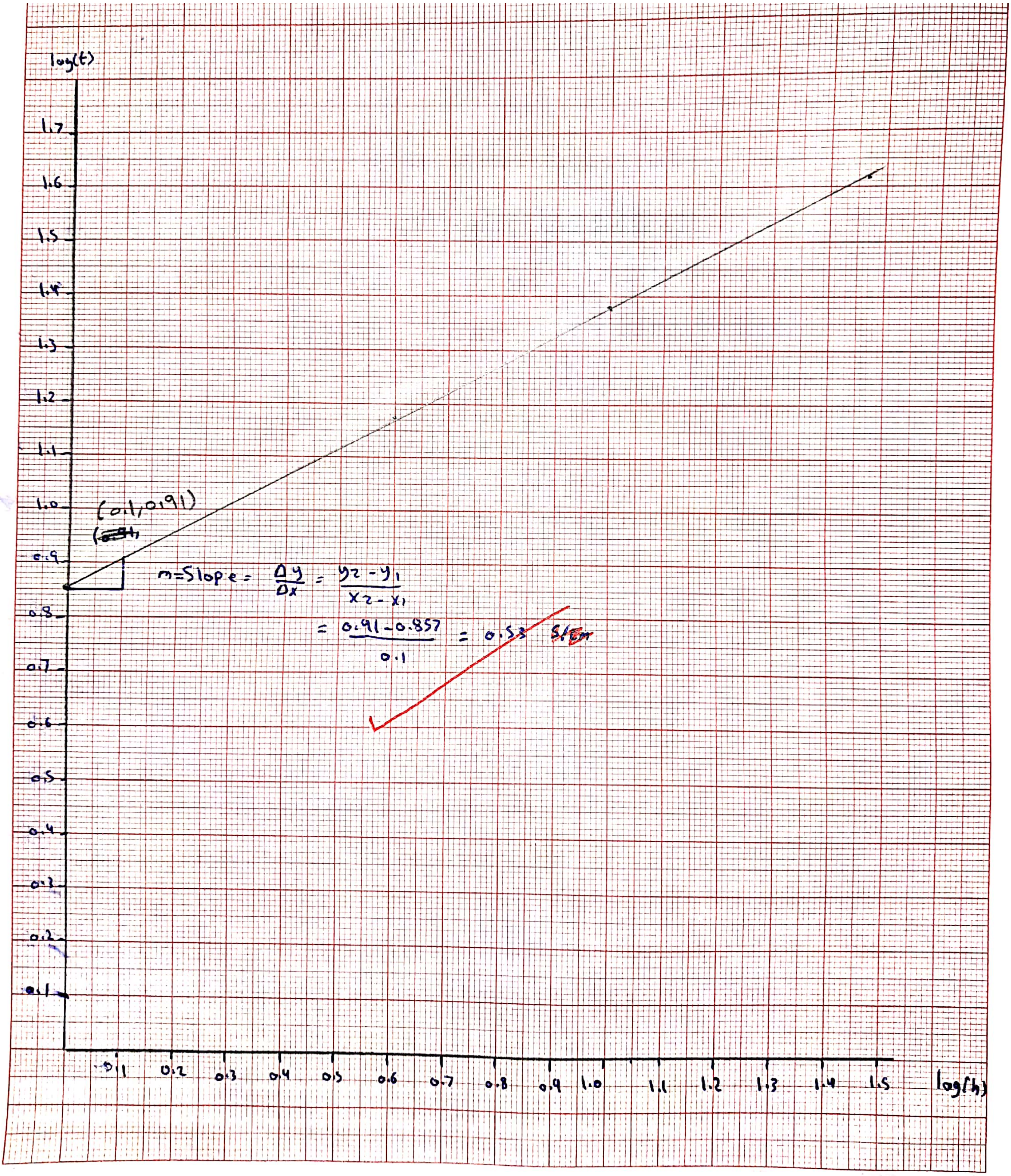


$$Slope = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$m = \frac{25 - 0}{0.15 - 0} = 166.6 \ S.mm^2$$



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EXPERIMENT 2

MEASUREMENTS AND UNCERTAINTIES

LAB REPORT

Date .....13/..2/.2019...............

Name ..Khaled....al-naser.........

Partner's Name ..Ibrahim..ghosheh

Registration No. .

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Section ......14.......................

Instructor's Name ..Eman...daar

I. PURPOSE:

To learn how to estimate errors in experimental measurements.

II. INTRODUCTION

In this lab you will estimate the density of a cylindrical piece of brass using measurements of its mass, diameter, and height. You will estimate the error in your measurements and the resulting error in your density estimate.

III. EQUIPMENT

- Pan balance
- Vernier caliper (Figures 2.1, 2.2)
- Brass rod
- Piece of paper tape
- Meter stick
- Micrometer (Figure 2.3)
- Wooden or plastic disc

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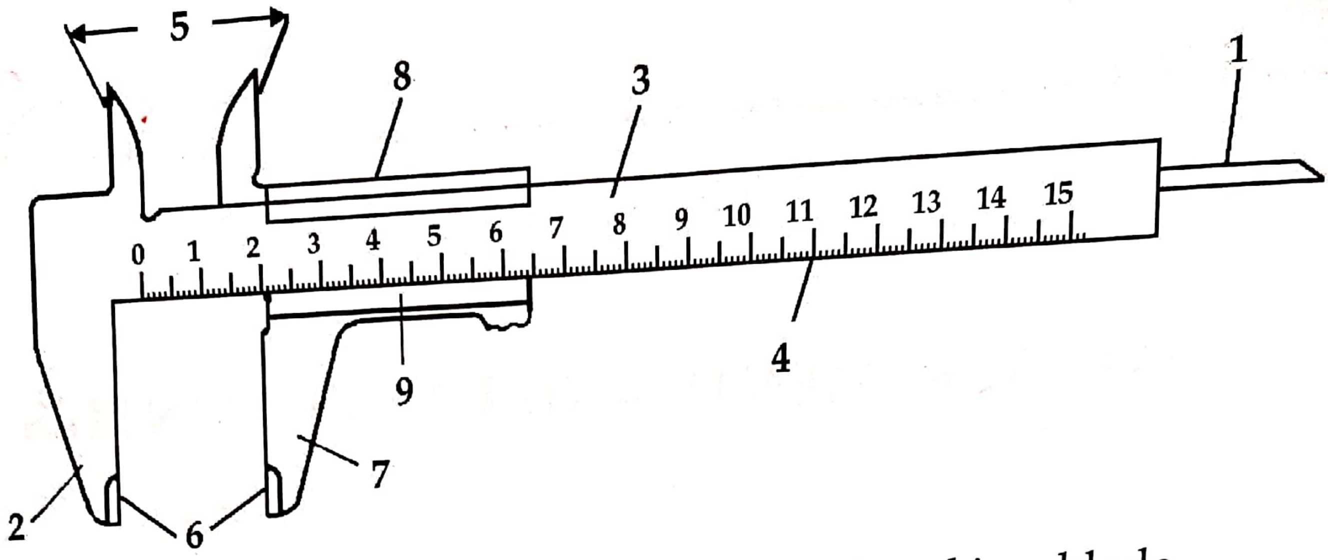

(1) Depth measuring

(2) Fixed jaw blade

(3) Guide bar

(4) Graduated scale

(5) Knife-edge measuring faces for interior measurement

(6) Measuring faces for exterior measurement

(7) Movable jaw blade

(8) Slide

(9) Vernier scale

Figure 2.1: Vernier caliper.

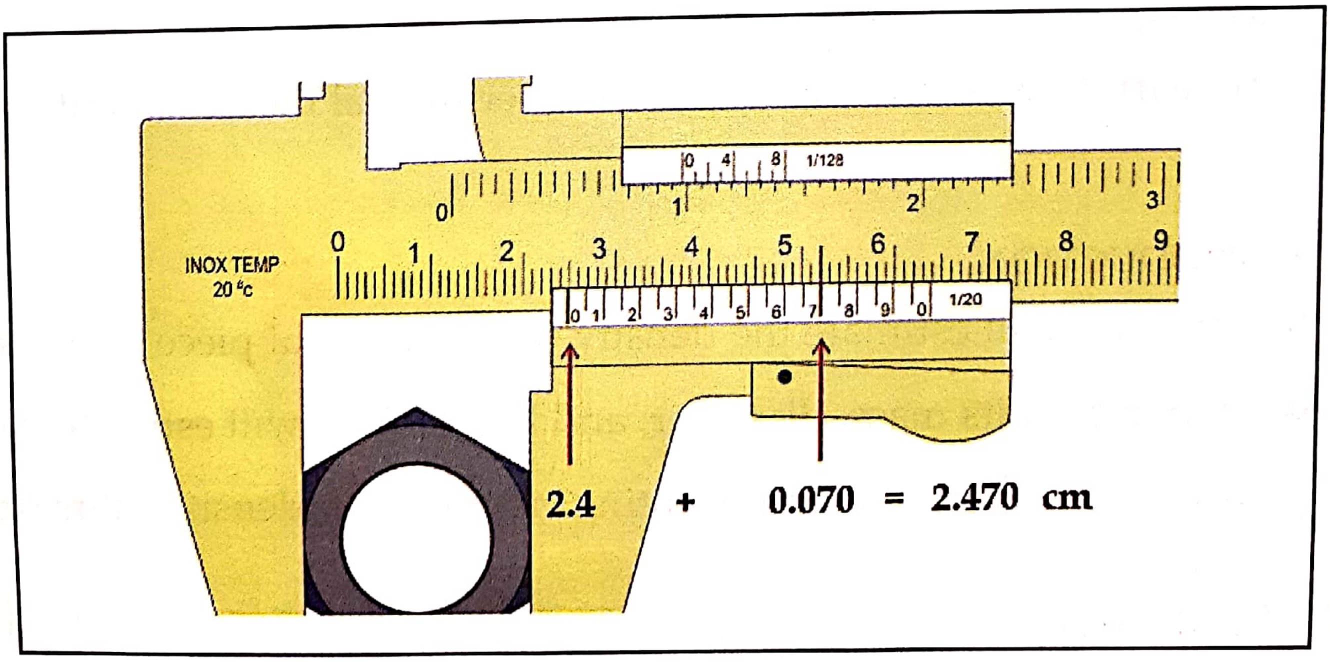

Figure 2.2: Reading off 2.4 on the graduated scale and 0.070 on the vernier scale gives 2.470 cm.

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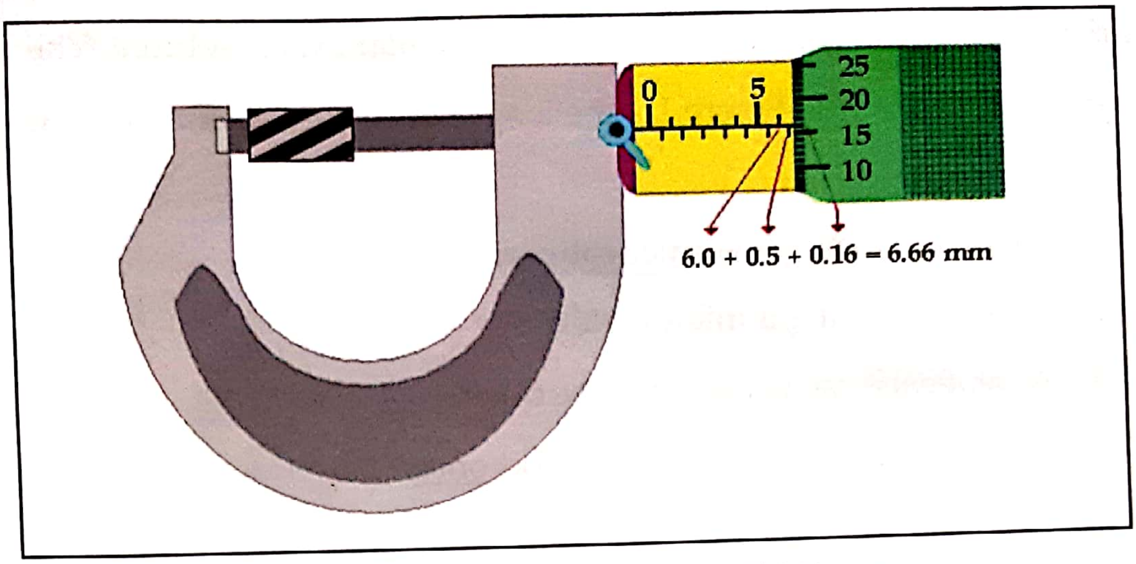

Figure 2.3: Micrometer, reading off 6.66 mm.

IV. Procedure

Part 1: Estimating π

1. Measure the diameter (D) of the wooden disc using a vernier caliper (one trial). Record the result and uncertainty (ΔD) in Table 2.1.
2. Wrap a piece of paper tape around the circumference of the wooden disc and measure the length (C, circumference) of the tape using a meter stick (one trial). Record the result and the uncertainty (ΔC) in Table 2.1.
3. Calculate the fractional errors in the diameter ($\frac{\Delta D}{D}$) and the circumference ($\frac{\Delta C}{C}$). Record the result in Table 2.1.

Part 2: Determination of Density

The density ρ is defined as the ratio of mass m to the volume V of an object; $\rho = m/V$. In other words it is the mass per unit volume. In MKS, the unit of ρ is $kg.m^{-3}$. The density of water is 1.0 g/cm^3 which is equivalent to 1000 kg/m^3.

In this part you will determine the density of brass by measuring the mass

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of a brass rod using a pan balance, and calculating its volume. The latter is given by $V=\pi\,(d/2)^2L$, where L is the length of the rod and d its diameter. For this:

4. Measure L using a vernier caliper.
5. Measure d using a micrometer.
6. Repeat each measurement five times.
7. Measure the mass of the brass rod <u>once</u>.

V. DATA ANALYSIS

PART 1: ESTIMATING π

1. Record your data in Table 2.1 below:

Table 2.1

بالورقة

D = 37.65 mm	ΔD = ± 0.025 mm	$\frac{\Delta D}{D}$ = 6.64 × 10^{-4}
C = 11.9 cm	ΔC = ± 0.05 cm	$\frac{\Delta C}{C}$ = 4.2 × 10^{-3}

2. Using the measured values of (D) and (C), calculate an estimate of π.

$\pi = \frac{C}{d} = \frac{11.9\ cm}{3.765\ cm} = 3.16$

3. Calculate the error, Δπ, in your estimate of π. Show your calculations in detail.

Remember: $$\Delta\pi = \pi\cdot\sqrt{\left(\frac{\Delta D}{D}\right)^2+\left(\frac{\Delta C}{C}\right)^2}$$

$\Delta\pi = 3.16\sqrt{(6.64\times10^{-4})^2 + (4.2\times10^{-3})^2}$

$= 3.16 \times 42.521 \times 10^{-4}$

$= 134.368 \times 10^{-4}$

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$P.E = \frac{|E-A|}{A} * 100$

4. Compare your estimate of π with the accepted value ($\pi_{accepted}$=3.14159).

$P.E = \frac{|E - A|}{A} * 100$

$P.E = \frac{|3.16 - 3.14159|}{3.14159} * 100 \%$

$P.E = 5.86 * 10^{-1} = 0.586$

5. Which error contributes most to π? Explain your answer in detail.

$\frac{\Delta C}{C} = 4.2 * 10^{-3}$ because $\frac{\Delta C}{C}$ contributes the most to π.

PART 2: DETERMINATION OF DENSITY

1. Record your measured values of L in Table 2.2 below.
2. Calculate the error, $\Delta\bar{L}$, in the average measured length and enter the result in Table 2.2. $\Delta\bar{L} = \sqrt{\frac{\Sigma(L_i - \bar{L})^2}{n(n-1)}}$

Table 2.2

Trial No.	L_i(cm)	$(L_i - \bar{L})^2$ (cm²)	$\bar{L}$ = 8.43 (cm)
1	8.43 cm	0 cm²	
2	8.425 cm	$2.5 * 10^{-5}$ cm²	$\sum_{i=1}^{5}(L_i - \bar{L})^2 = 5 * 10^{-5}$ cm²
3	8.435 cm	$2.5 * 10^{-5}$ cm²	
4			
5			
$\Delta\bar{L} = \pm\sqrt{\frac{5*10^{-5}}{6}} = 2.88*10^{-3}$		$\frac{\Delta\bar{L}}{L} = 3.416 * 10^{-4}$	

3. Record your measured values of d in Table 2.3 below.
4. Calculate the error, $\Delta\bar{d}$, in the average measured diameter and enter the result in Table 2.3.

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Table 2.3

Trial No.	d_i (cm)	$(d_i - \bar{d})^2$ (cm²)	$\bar{d} =$ 0.519 (cm)
1	0.5	3.61 * 10⁻⁴	
2	0.51	8.1 * 10⁻⁵	$\sum_{i=1}^{5}(d_i - \bar{d})^2 =$ 1.283 * 10⁻³
3	0.548	8.41 * 10⁻⁴	
4			
5			
$\Delta\bar{d} = \pm \sqrt{\frac{1.283 * 10^{-3}}{6}}$ = 0.0146			$\frac{\Delta\bar{d}}{\bar{d}} =$ 0.0281

5. Record your measured value of m in Table 2.4 below. Estimate the error Δm and calculate the ratio $\frac{\Delta m}{m}$.

Table 2.4

$m =$	14.21	g
$\Delta m =$	0.01	g
$\frac{\Delta m}{m} =$	7.04 * 10⁻⁴	

Remember: $|\Delta m|$ is the smallest division of the balance used.

6. Calculate ρ, the density of the rod, using the value of π, determined in part 1, and the measured values of $\bar{h}$, $\bar{d}$, and mass m, determined in part 2.

$\rho = \frac{M}{V}$

$V = A L$

$= \pi (\frac{D}{2})^2 \bar{L}$

ρ = $\frac{M}{V}$ = $\frac{14.21}{1.793}$ V = AL

V = $\pi (\frac{\bar{D}}{2})^2 \bar{L}$

= 7.925 g/cm³ V = 3.14 * 0.067 * 8.43

V = 1.793

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7. Calculate $\Delta\rho$ using $\Delta\rho = \rho \cdot \sqrt{\left(\frac{\Delta m}{m}\right)^2 + \left(\frac{\Delta \pi}{\pi}\right)^2 + \left(\frac{2\Delta \bar{d}}{\bar{d}}\right)^2 + \left(\frac{\Delta \bar{L}}{\bar{L}}\right)^2}$.

Show the details of your calculation.

$\Delta\rho$ = 7.92 * $\sqrt{(7.04\times10^{-4})^2 + \left(\frac{134.36\times10^{-4}}{3.16}\right)^2 + (2\times0.0281)^2 + (3.416\times10^{-4})^2}$

7.92 × 0.0563

= 0.4464 g/cm³ (— .25) unit

8. Order the errors $\Delta\pi$, $\Delta\bar{d}$, $\Delta\bar{L}$, and Δm according to their contribution to the error in ρ.

$\frac{\Delta\pi}{\pi} = \frac{134.36\times10^{-4}}{3.16} = 42.51\times10^{-4}$

$\frac{\Delta \bar{d}}{\bar{d}}$ = 0.0281 =

$\frac{\Delta \bar{L}}{L}$ = 3.416×10^{-4}

$\frac{\Delta m}{m}$ = 7.04×10^{-4}

$\frac{\Delta\bar{d}}{d} > \frac{\Delta\pi}{\pi} > \frac{\Delta m}{m} > \frac{\Delta \bar{L}}{L}$

9. The accepted value of ρ is: $\rho_{accepted}$ = 8.3 g/cm³. Your measured value is in the range $[\bar{\rho}-\Delta\bar{\rho}, \bar{\rho}+\Delta\bar{\rho}]$. Is $\rho_{accepted}$ within the range?

[7.925 − 0.4464 , 7.925 + 0.4464]

[7.478 g/cm³ , 8.37 g/cm³] it is in the range

10. Justify your answer in step 9.

because the value ρ accepted = 8.3 g/cm³ is in the range [7.478 , 8.37]

11. State and discuss three sources of error in this experiment.

1) Uncertain micrometer

2) Uncertain Vernier caliper

3) Unexpected value of ρ out of the range

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EXPERIMENT 4

KINEMATICS OF RECTILINEAR MOTION

LAB REPORT

Date ..20/2/2019......................

Name ..Khaled....al-naser.

Partner's Name ..Ibrahim....ghoshe

Registration No. ..

Registration No. ....

Section ......14..............

Instructor's Name .Eman..Dase...

I. PURPOSE:

To study and analyze motion with variable acceleration in one dimension.

II. INTRODUCTION - THEORETICAL BACKGROUND

Kinematics is the study of the purely geometrical aspects of the motion of an object or particle, such as its trajectory in space, its displacement, velocity, and acceleration, and how they vary with time, without reference to its mass or the forces acting on it.

Motion of a particle or an object is described by measuring its position with respect to a coordinate system as a function of time. In this experiment, you will analyze motion along a straight line, also called rectilinear or one-dimensional motion.

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If the object's positions at different times (preferably at regularly spaced time intervals, Δt) are recorded, one can then obtain the displacements made during the time intervals, which are used to calculate velocities and accelerations.

Assuming the object is moving along the x-axis, the displacement Δx it makes during a time interval Δt, when it moves from an initial position with coordinate x_i, to a final position with coordinate x_f, is defined as:

$$\Delta x = x_f - x_i \tag{4.1}$$

The average velocity of the object during this time interval is defined by:

$$\overline{v} = \frac{\Delta x}{\Delta t} \tag{4.2}$$

If, during the same time interval, the velocity of the object changes from an initial value v_i to a final value v_f, then the average acceleration of the object during this interval is defined by:

$$\overline{a} = \frac{\Delta v}{\Delta t} \tag{4.3}$$

In this experiment, you will pull a ~ 1.0-m long paper tape along a straight line, such that its acceleration is variable both in magnitude and direction, and you will analyze the resulting motion. A record of the tape's motion as a function of time is obtained with the help of a device for measuring time called a *ticker timer*, shown in Figure 4.1 below. It is an electrical device that has a little screw-shaped hammer that vibrates vertically at a rate of 50 Hz. The tape is threaded through the device and under a carbon disc placed right below the hammer. As the tape is pulled through while the ticker timer is on, the hammer strikes the carbon disc at a rate of 50 times each second, leaving a dot on the tape with each strike. The distance between two dots on the tape is the distance covered by the tape in 0.02 s.

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Note that Δx is always positive in our experiment, because motion is always in the same (positive) direction. This means that the velocities are also positive in this experiment.

Since the tape moves as one unit, all points on it have the same velocity and acceleration at each instant during the motion. Therefore, the motion of any dot on the tape is representative of the tape's motion. Let us choose one of the first few dots left on the tape by the ticker timer, and analyze its subsequent motion by measuring its position with respect to its initial position (directly under the timer's hammer). In what follows we will refer to this dot as the 0^{th} point.

Let the initial time $t_0 = 0$, and the initial x-coordinate and velocity of the 0^{th} point be $X_0 = 0$ and $V_0 = 0$, respectively. At a later time t_i ($i = 1, 2, 3, \ldots$), the dot's position and velocity will be denoted by X_i and V_i, respectively. The dots on the tape will be used to analyze the motion of the 0^{th} point.

Table 4.1 shows the definitions of quantities, their symbols, and the equations used in the analysis.

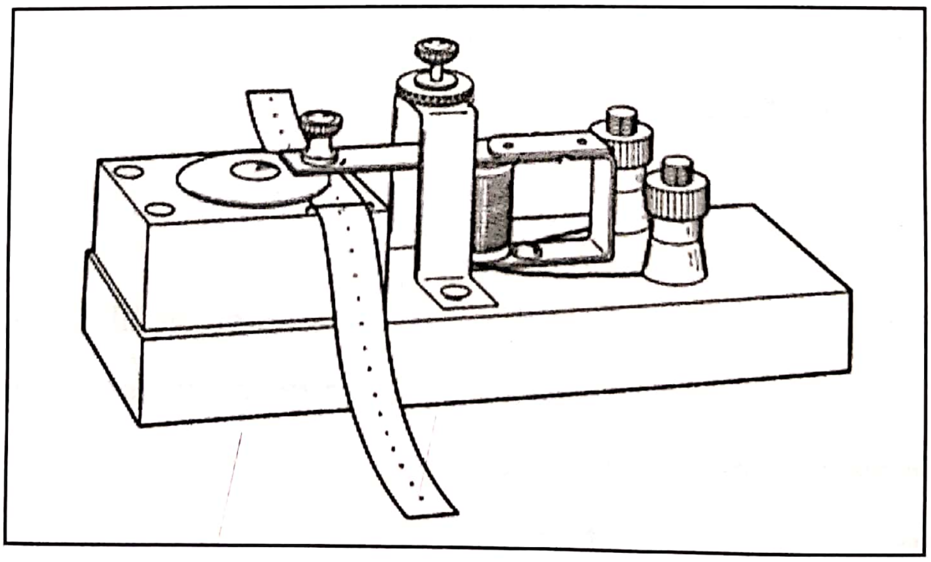

Figure 4.1: Ticker Timer.

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III. PROCEDURE

SEE TABLE 4.1 FOR THE USED VARIABLES

1. Thread a ~1.0 m tape through the ticker timer and under the carbon disc. See Figure 4.1.
2. Connect the ticker timer to the electrical power source.
3. While the ticker timer is turned on, pull the tape while simultaneously swinging your hand in a random fashion to ensure that the resulting acceleration of the tape is varying in magnitude and direction.
4. Make sure you have at least 50 clearly defined dots on the tape before starting the analysis.
5. Usually the first few dots on the tape are not well defined and you can neglect them. Draw a circle around the first clearly defined dot; this will be your reference 0 point ($X_0 = 0$, $t_0 = 0$). See Figure 4.2.
6. Count five dots after the 0^{th} point and circle the last one. At this point $t_1 = 0.1$ s. See Figure 4.2.
7. Repeat the above step for $t_2 = 0.2$ s, $t_3 = 0.3$ s, …, $t_{10} = 1.0$ s.
8. Measure X_i by a ruler. Record the measurements in Table 4.2.
9. Calculate ΔX_i. Record the results in Table 4.2.

Note:

The displacements ΔX_1, ΔX_2, ΔX_3 etc.., are covered in equal time intervals, $\Delta t = 0.10$ s, and their values should be filled in squares in Table 4.2 corresponding to the center of the appropriate time interval. For example, the values of ΔX_1, ΔX_2, ΔX_3, etc. should be filled in the squares corresponding to $t = 0.05$ s, $t = 0.15$ s, $t = 0.25$ s, etc. This is because we will approximate the instantaneous velocity at the center of a time interval by its average over the interval.

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Table 4.1

Note that all quantities (position, displacement, velocity, and acceleration) in the table are those of the 0th point

Symbol	Definition and Notes
t_i	Time taken by the 0th point to reach position X_i.
X_i	Position of the 0th point with respect to X_0 at t_i.
Δt	Regular spaced time intervals to study the motion. $\Delta t = t_{i+1} - t_i$ *For this experiment* Δt= 0.10 s.
ΔX_i	Displacement made by the 0th point during Δt. $\Delta X_i = X_i - X_{i-1}$ In this experiment, ΔX_i *is always a positive quantity*
$\bar{V}_i$	Average velocity $\bar{V}_i = \frac{\Delta X_i}{\Delta t}$ $\bar{V}_i$ *has the same sign as* ΔX_i. *Therefore,* $\bar{V}_i$ *is always a positive quantity.*
$\Delta \bar{V}_i$	Velocity difference due to change of average velocity during Δt. $\Delta \bar{V}_i = \bar{V}_{i+1} - \bar{V}_i$ $\Delta \bar{V}_i$ may be positive or negative.
$\bar{a}_i$	Average acceleration, and defined as the velocity difference per unit time interval Δt, $\bar{a}_i = \frac{\Delta \bar{V}_i}{\Delta t}$ $\bar{a}_i$ has the same sign as $\Delta \bar{V}_i$. Therefore, it can be positive, negative, or zero. A negative sign indicates a decrease in velocity with respect to the previous one. Its absolute value will determine the maximum and minimum accelerations.

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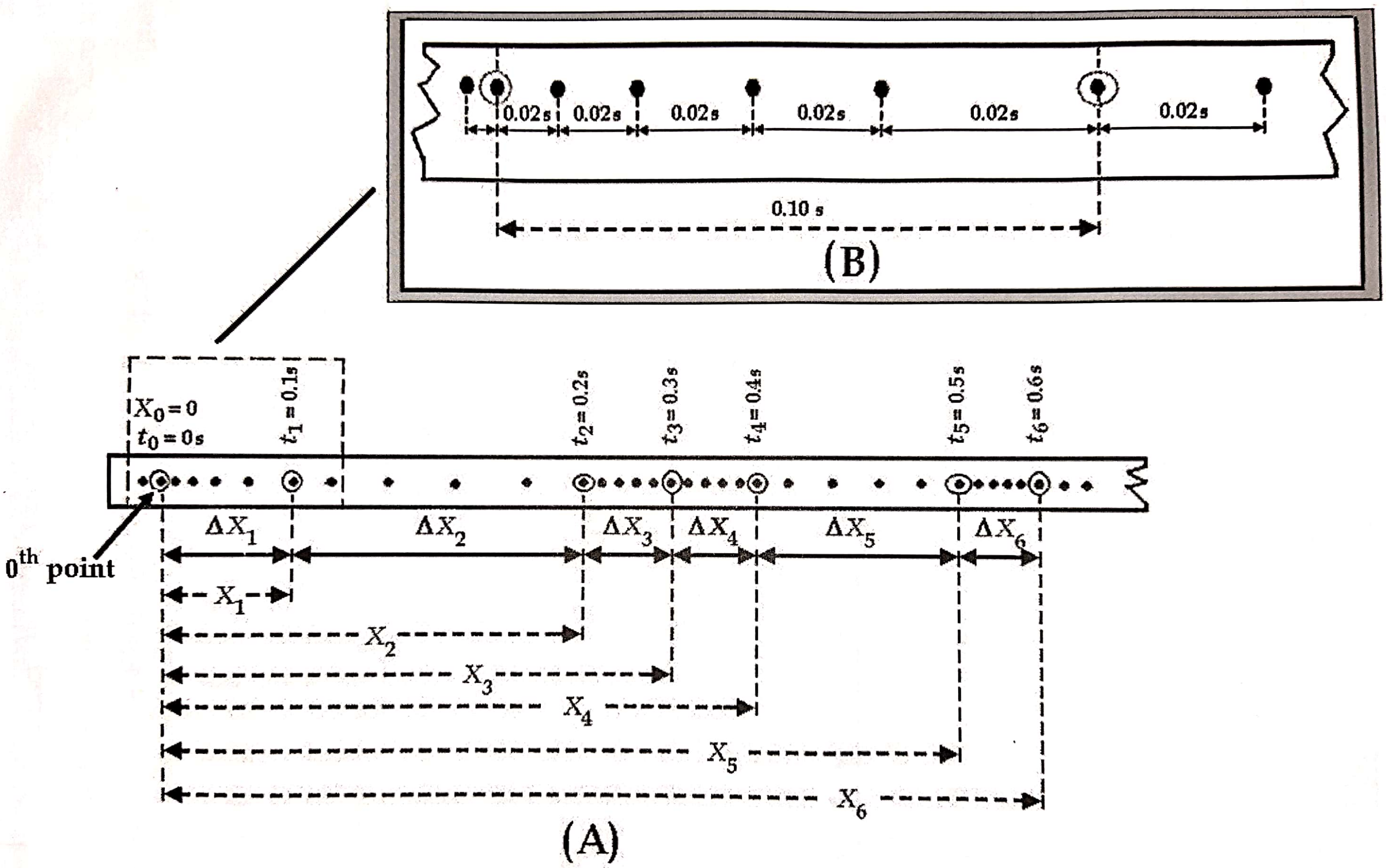

Figure 4.2: A) A typical Ticker Timer tape. B) A blow-up to of the rectangle enclosed by dashed lines (in A).

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IV. Data Analysis

A) Average Velocities and Accelerations

▶ Answer the following questions

From your recorded measurements in Table 4.2, can you determine during which time intervals the average velocities and accelerations are maximum? minimum?

Velocity
Time interval during which the velocity is maximum:
Time interval during at which the velocity is minimum:

Acceleration
Time interval during which the average acceleration is maximum: ....
Time interval during which the average acceleration is minimum: ....

1. Calculate $\overline{V_i}$, $\Delta\overline{V_i}$, and $\bar{a}_i$.
2. Record the calculations in Table 4.2.

Table 4.2 - Useful Notes $\overline{V_i}$

- The average velocities ( ) are computed for equal time intervals of Δt = 0.10 s and entered in the squares corresponding to the centers of the appropriate intervals (similar to the ΔX_i's).
- The successive velocity differences $\Delta\overline{V_1}$, $\Delta\overline{V_2}$, $\Delta\overline{V_3}$ etc. occur over equal time intervals of Δt = 0.10 s.
- The velocity differences $\Delta\overline{V_i}$ and the corresponding average accelerations are entered at times 0.1 s, 0.2 s, 0.3 s, etc.

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Note:

To determine maximum and minimum average velocities we know that $\bar{V} = \frac{\Delta X}{\Delta t}$ and Δt is constant for all displacements. Therefore, $\bar{V} \propto \Delta X$. That is, maximum (minimum) average velocity occurs in the interval in which the maximum (minimum) displacement was made.

Average acceleration, $\bar{a} = \frac{\Delta \bar{V}}{\Delta t}$, is a function of velocity difference. Hence, to determine maximum and minimum accelerations we should look for two successive time intervals:

Acceleration is maximum when $|\Delta V_i|$ is the largest.

Acceleration is minimum when $|\Delta V_i|$ is the smallest.

Acceleration is zero when ΔV_i is zero.

50 Hz

$\frac{1}{50} = 0.02$

$\Delta t = 0.1$ s

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Table 4.2

Index (i)	t_i (s)	X_i (cm)	ΔX_i (cm)	$\bar{V}_i$ (cm/s)	$\Delta\bar{V}_i$ (cm/s)	$\bar{a}_i$ (cm/s²)
0	0.00	0 cm				
	0.05		1.1 cm	11 cm/s		
1	0.10	1.1 cm			5 cm/s	50 cm/s²
	0.15		1.6 cm	16 cm/s		
2	0.20	2.7 cm			6 cm/s	60 cm/s²
	0.25		2.2 cm	22 cm/s		
3	0.30	4.9 cm			8 cm/s	80 cm/s²
	0.35		3 cm	30 cm/s		
4	0.40	7.9 cm			12 cm/s	120 cm/s²
	0.45		4.2 cm	42 cm/s		
5	0.50	12.1 cm			12 cm/s	120 cm/s²
	0.55		5.4 cm	54 cm/s		
6	0.60	17.5 cm			14 cm/s	140 cm/s²
	0.65		6.8 cm	68 cm/s		
7	0.70	24.3 cm			18 cm/s	180 cm/s²
	0.75		8.6 cm	86 cm		
8	0.80	32.9 cm			13 cm/s	130 cm/s²
	0.85		9.9 cm	99 cm		
9	0.90	42.8 cm			-7 cm/s	-70 cm/s²
	0.95		9.2 cm	92 cm		
10	1.00	52 cm				

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B) Estimating The Instantaneous Velocity From The Approximation of Average Velocity.

1. Compute the instantaneous velocity at $t = 0.6$ s.
2. Record the data of X in Table 4.3 as listed in Table 4.2.
3. For each time interval (3rd column in Table 4.3), calculate $\overline{V}$ and record your result in the last column of the table.

Table 4.3

t (s)	X (cm)	Δt (s)	ΔX (cm)	$\overline{V}$ (cm/s)
$T_5 = 0.5$ $T_7 = 0.7$	$X_5 =$ 12.1 cm $X_7 =$ 24.3 cm	0.2 s	12.2 cm	61 cm/s
$t_4 = 0.4$ $t_8 = 0.8$	$X_4 =$ 7.9 cm $X_8 =$ 32.9 cm	0.4 s	25 cm	62.5 cm/s
$t_3 = 0.3$ $t_9 = 0.9$	$X_3 =$ 4.9 cm $X_9 =$ 42.8 cm	0.6 s	37.9 cm	63.17 cm/s

▶ *Answer the Following questions:*

Considering your data analysis from your paper tape and the calculations in Table 4.3, can you shrink the interval $\Delta t'$ to less than 0.2 s (keeping t_i at the center of the time interval of the calculation)? Explain.

yes because the instantaneous velocity is equal to the limit that is calculated by the slope between (X, t)

What is your estimate of the instantaneous velocity at t_i?

$V_{inst}(t_i) = V_{inst}(t_i) =$ 61 cm/s

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C) X-*t* GRAPH

Using the data in Table 4.2, plot X versus *t*. Label your axes and include their units. Connect the points with a smooth curve (Don't use a ruler). The slope of the tangent to the X-*t* curve at a given instant represents the instantaneous velocity at that instant. The X-*t* graph can be used to determine:

- The instantaneous velocity at any time during the motion.
- The average velocity for any time interval during the motion.
- Time intervals during which the moving object is stationary, speeding up, or slowing down.

▶ *Answer the following*

a) Calculate the instantaneous velocity at t = 0.6 s from the slope of the tangent (Figure 4.3) to your X versus t graph at t = 0.6 s. Show your calculations in detail on your graph.

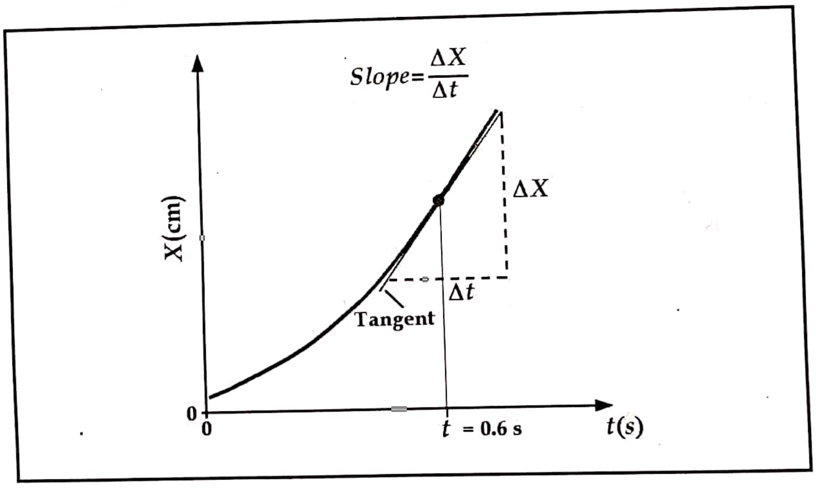

Figure 4.3: Displacement versus time (non-uniform motion):

t_i = ...0.6......... s.

V_{inst} (t_i) = ...66.67........ cm/s.

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Compare the calculated instantaneous velocities with the value from Table 4.3.

..from.....table...4.3.....the....instantaneons...velocity...equl=..61cm/s.

..and..from.....the...graph...between(x,t)....V.ins.=..66.67..cm/s..........

..the...values.....are...close...to...each.....others...............................

b) During which intervals does the velocity increase, decrease, or remain constant? Mark the correct answer for each time interval by a (✓) in Table 4.4.

Table 4.4

t (s)	0.0 - 0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	0.9 - 1.0
Increase	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Decrease										
Constant										

D) $\bar{V}$ -t GRAPH

Refer to Table 4.2 and plot a *histogram* of $\bar{V}$ versus time. See Figure 4.4 below. Label your axes and include their units.

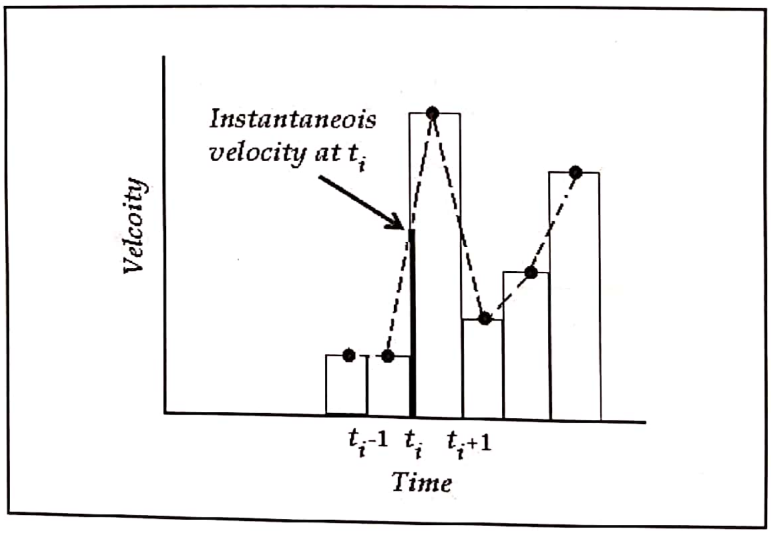

Figure 4.4: Histogram of $\bar{V}$ versus time.
The height of the darkened line represents the value of the instantaneous velocity at t_i.

A velocity-vs-time graph can be used to determine:

- The instantaneous velocity at any time.

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- The total displacement from the area under the curve.
- The acceleration from the slope of the graph.
- The intervals during which the velocity is constant, increasing, or decreasing.

In your histogram, connect the successive mid-points of the horizontal segments with straight lines.

By joining two successive mid-points with straight lines we are assuming that the acceleration is constant during the intervals separating the points. Therefore, the calculated average velocity for the time interval $[t_{i-1}, t_{i+1}]$ will equal the instantaneous velocity at the middle of this interval, at t_i. See Figure 4.4.

▶ **Answer the following:**

a) Use the graph to determine the value of the instantaneous velocity at t = 0.6 s. Show your work on the graph.

V_{inst} (t = 0.6 s) = ...61............. cm/s.

Compare with the instantaneous velocity from Table 4.3 above. Discuss.

.....V.inst......from.....table....4.3.=..61.cm/s..and...........................

...V..ist........From.......histogram...=..61...cm/s.....So...they....are..........

........equal......to...each...other..

b) Determine where the velocity is increasing, decreasing, or constant. Indicate the correct answer for each time interval by a ✓ in Table 4.5.

Table 4.6

t (s)	0.05 - 0.15	0.15 - 0.25	0.25 - 0.35	0.35 - 0.45	0.4 5- 0.55	0.55 - 0.65	0.65- 0.75	0.75 - 0.85	0.85 - 0.95
Increase	✓	✓	✓	✓	✓	✓	✓	✓	
Decrease									✓
Constant									

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c) Ask your instructor for which time interval $[t_i, t_f]$ to use for calculating the area under the $\bar{V}$-T curve; see Figure 4.5 below. Record the area in Table 4.6. This area represents the displacement made by the 0th point during the chosen time interval.

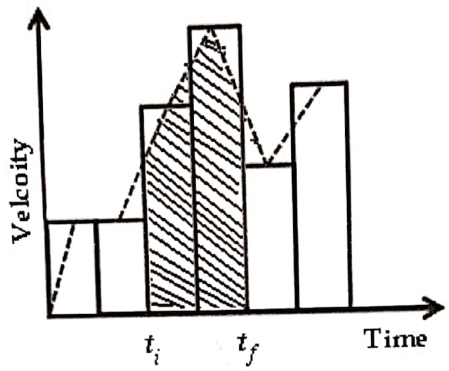

Figure 4.5: Finding the displacement from the area under the Velocity-Time graph.

Table 4.6

t_i = 0.2 s	t_f= 0.4 s
Area under the curve from *V-t* graph = 2.2 + 3 = 5.2 cm	
Displacement from the paper tape = 5.2cm	
Do the two measurements agree? Discuss. Yes, because the area under the curve is equal to the integration of the velocity ($\bar{v}$) that is cavl to the displacement.	

E) *a-t* GRAPH

Refer to Table 4.2 and plot *a* versus *t*. Label your axes. The *a-t* graph can be used to determine the maximum and minimum accelerations.

Record your results in Table 4.7.

Table 4.7

Maximum Acceleration	Minimum Acceleration
a_{max} = 180 cm/s²	a_{min} = −70 cm/s²
$t(a_{max})$ = 0.7 s	$t(a_{min})$ = 0.9 s

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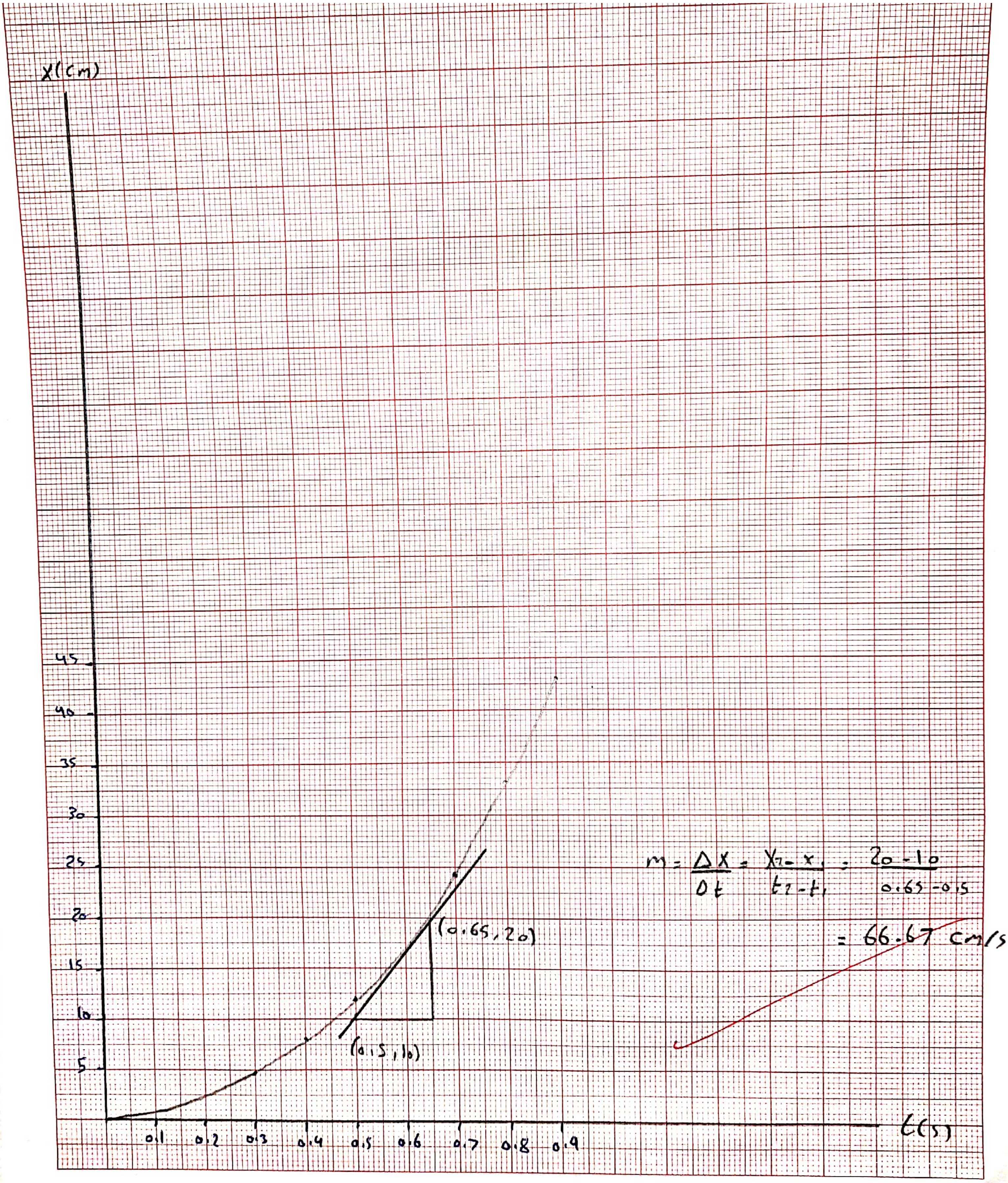

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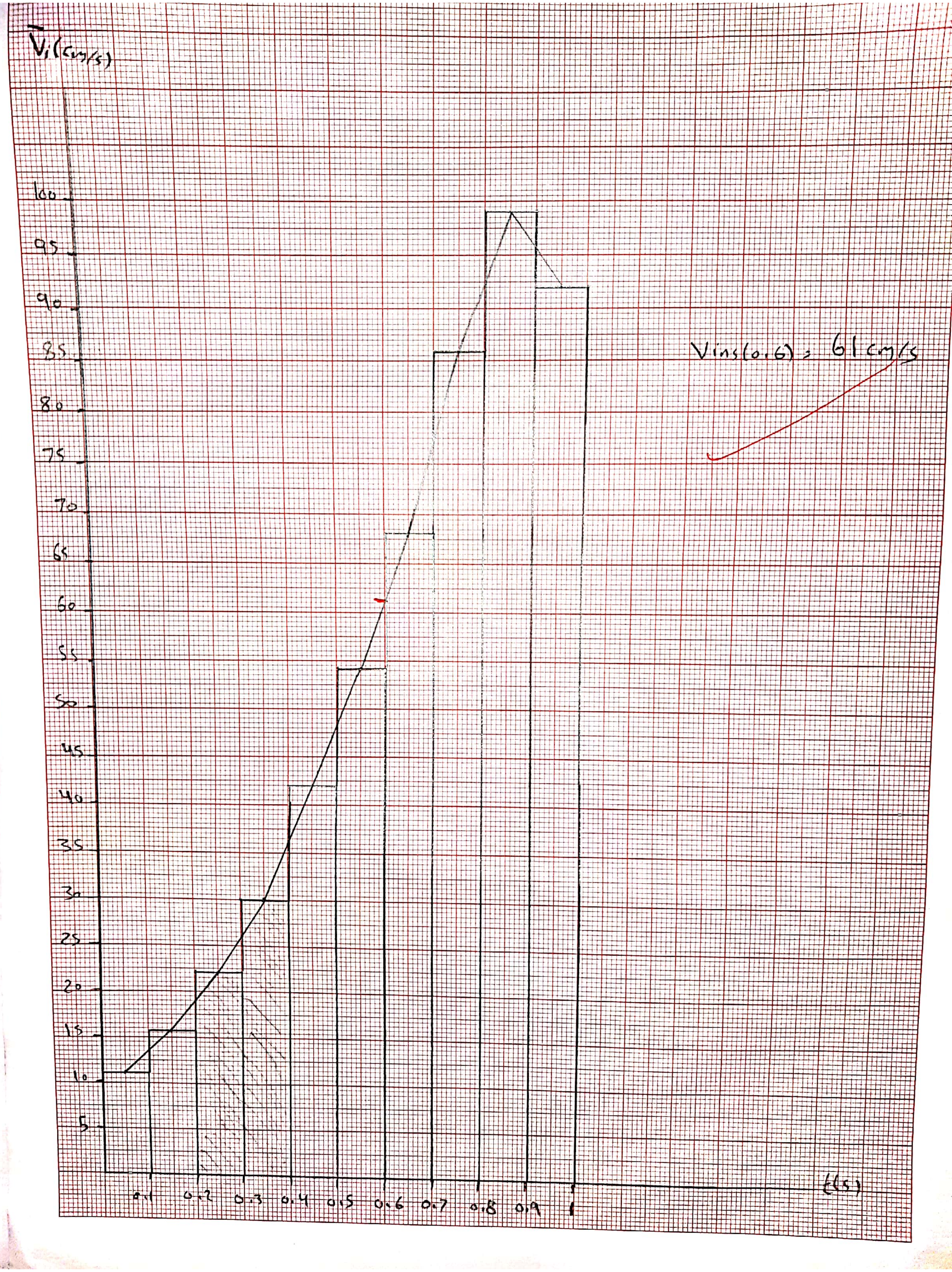

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10

EXPERIMENT 11

SPECIFIC HEAT CAPACITY OF METALS

LAB REPORT

Date ...27/11/2019...............

Name ...Khaled.....al-naser.........

Partner's Name .Ibrahim....ghasheh

Registration No.

Registration No

Section ....14........................

Instructor's Name .Eman..Dar'...

I. PURPOSE

To determine the specific heat capacity of a metal sample using a simple calorimeter.

II. INTRODUCTION:

Heat is a form of energy. When two objects at different temperatures exchange heat in isolation from their surroundings, one observes that the two objects reach a common final temperature, a condition called thermal equilibrium. We say that heat flowed from the hotter object to the colder one.

In thermodynamics *temperature* is a relative measure of the hotness (or coldness) of an object or a thermodynamic system.

If a system in a given phase, at initial temperature T_i, absorbs (loses) an amount of heat Q and does not undergo a phase change, its temperature

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increases (decreases) to a final value T_f. Experiments show that for a wide range of materials and temperatures, Q is proportional to the temperature difference $\Delta T = T_f - T_i$.

The proportionality constant is called the *heat capacity* C. We thus write

$$Q = C\Delta T \tag{11.1}$$

That is, the heat capacity of a given quantity of a substance (at a given pressure *or* volume, in a given phase) is the heat flow to the substance required to raise its temperature by one degree Celsius (without changing its phase).

In MKS the unit of heat flow is joule (J)

The calorie (cal) is another unit for measuring heat flow, defined as the amount of heat necessary to raise the temperature of 1 g of water from 14.5 °C to 15.5 °C at a pressure of one atmosphere (1 atm). 1 cal = 4.18 J

Thus, the MKS unit for heat capacity is J/°C or cal/°C.

For a substance in a given phase, at a given temperature and pressure or volume, we define its *specific heat capacity*, denoted by c, as the heat flow needed to raise the temperature of 1 g of the substance by 1 °C. The MKS unit for heat capacity is J/g.°C or cal/g.°C.

For example The specific heat capacity of water, at constant volume, is c_w = 1 cal/g.°C

Clearly, the heat capacity C of M grams of the substance is related to the specific heat capacity of the substance by:

$$c = \frac{C}{M} \tag{11.2}$$

Therefore, Equation 11.1 can be written as:

$$Q = cM\Delta T \tag{11.3}$$

In physics, the process of measuring heat transfer is called calorimetry and is employed, among other things, for the experimental determination of

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specific heat capacities of substances.

In this experiment, a metallic container, with known mass (M_1) and known specific heat capacity (c_1), is filled with water (mass M_W). This is our calorimeter. The calorimeter (container + water) is initially at a given temperature, T_1, usually room temperature. A piece of the substance (a metal here) for which we want to measure the specific heat capacity is heated to a temperature $T_2 > T_1$, and then immersed in the water. The metal loses heat to the calorimeter and the metal-calorimeter attains a state of thermodynamic equilibrium, reaching a common temperature T_f.

Assuming that heat losses out of the metal-calorimeter system are negligible, the zeroth law of thermodynamics states that the heat gained by the (container + water) is equal to the heat lost by the other part of the system (the metal piece).

Measuring the final equilibrium temperature, T_f, the specific heat capacity of the metal can be calculated.

The calculations are simple and detailed in the following:

Heat flow to the calorimeter = Heat flow from the piece of metal

$$Q_{gained}\text{ (by calorimeter)} = - Q_{lost}\text{(by metal)} \tag{11.4}$$

Using Equation 11.3, we can write

$$(M_1c_1 + M_wc_w)\,(T_f - T_1) = M_2c_2\,(T_2 - T_f) \tag{11.5}$$

where M_1, M_w, and M_2 are the masses of the container, water, and piece of metal, respectively. c_1, c_w, and c_2 are the corresponding specific heat capacities.

Defining the variables:

$$X = M_1\,c_1 + M_wc_w,\ Y = T_f - T_1,\text{ and } Z = T_2 - T_f. \tag{11.6}$$

We have

$$c_2 = \frac{XY}{M_2\,Z} \tag{11.7}$$

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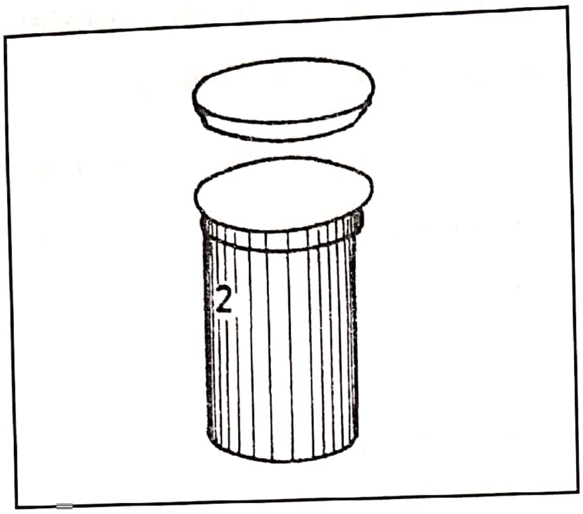
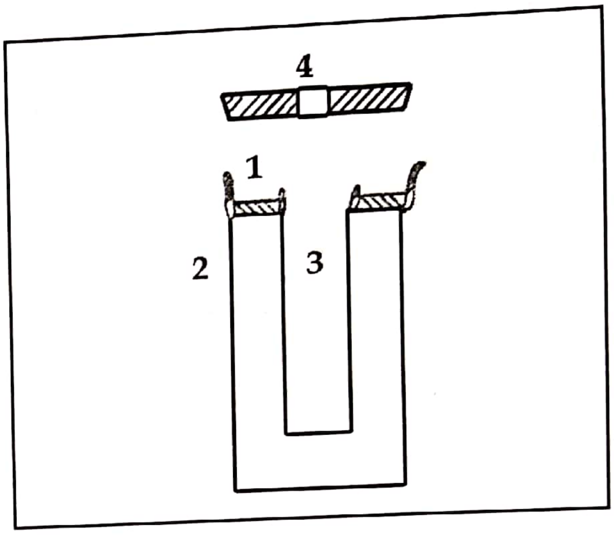
III. EQUIPMENT

A double-walled calorimeter (made of Aluminum) (Figure 11.1)

- Thermometer
- Metal piece
- Balance
- Water
- Beaker
- Heater





1. Insulator 2. Outer cup 3. Inner cup 4. Wooden cap

Figure 11.1: Double-walled calorimeter.

IV. PROCEDURE

- The metal samples to be used in the following procedure have been immersed in a pot containing boiling water for a sufficient time, prior to the start of the lab.
- Record all your measurements in Table 11.1 below.

1. Weigh the mass M_1 of the inner cup. Pour about 50-60 g of tap water (mass M_w) into the cup. Allow the cup and water to reach thermal equilibrium.
2. Measure the common temperature of the water and cup (T_1).
3. Measure the temperature of the boiling water (T_2), which is also the temperature of the metal sample.
4. *Quickly* Transfer the metal sample from the boiling water into the calorimeter cup. Stir well.
5. Measure the final temperature (T_f) of the metal-calorimeter system;

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this is the maximum temperature reached by the thermometer within a few seconds after the transfer.

6. Remove the metal sample from the calorimeter, dry it, and weigh it (M_2).

IV. DATA ANALYSIS

1. Using equations 11.6 and 11.7, calculate the specific heat capacity of the metal (c_2). Record your calculations in Table 11.2.

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Table 11.1

Symbol	Definition	Measurements	Units	Errors
c_1	Specific Heat Capacity of Calorimeter	0.22	cal/g °C	-
c_w	Specific Heat Capacity of Water	1.00	cal/g °C	-
M_1	Mass of Calorimeter	45.77	g	$\Delta M_1 =$ 0.01 g
M_{cw}	Mass of Calorimeter + Water ($M_{cw}= M_1+M_w$)	123.19	g	$\Delta M_{cw} =$ 0.01 g
M_w	Mass of Water ($M_{cw} - M_1$)	77.42	g	$\Delta M_w =$ 0.0141 g
T_1	Initial Temperature of Calorimeter	17.5	°C	$\Delta T_1 =$ 0.25 C°
T_2	Initial Temperature of Metal	91	°C	$\Delta T_2 =$ 0.25 C°
T_f	Final Equilibrium Temperature for Calorimeter + Water + Metal	24	°C	$\Delta T_f =$ 0.25 C°
M_2	Mass of Metal	99.9	g	$\Delta M_2 =$ 0.01 g

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$(m_w c_w + m_1 c_1)(T_F - T_1) = m_2 c_2 (T_2 - T_F)$

$X: (m_w c_w + m_1 c_1)$

$X = (77.42 \times 1) + (45.77 \times 0.22)$ $C = \frac{XY}{m_2 Z}$

$X = 87.4894$ cal/c°

$Y = (T_F - T_1) = (24 - 17.5)$, $Y = 6.5$ c°

$Z = T_2 - T_F = 91 - 24$, $Z = 67$ c°

Table 11.2

X = 87.4894 Cal/c°	$c_2 = \frac{XY}{m_2 Z} = \frac{87.4894 \times 6.5}{99.9 \times 67} = 0.085$ Cal/g.c°	
Y = 6.5 c°		
Z = 67 c°		

2. Use the relations in the table below and calculate the error Δc_2, and express your final result as $c_2 \pm \Delta c_2$.

3. Record your calculations in Table 11.3 below.

$\Delta c_2 = \sqrt{\left(\frac{0.01427}{87.4894}\right)^2 + \left(\frac{0.3535}{6.5}\right)^2 + \left(\frac{0.3535}{67}\right)^2 + \left(\frac{0.01}{99.9}\right)^2}$

$$\Delta c_2 = c_2\sqrt{\left(\frac{\Delta X}{X}\right)^2+\left(\frac{\Delta Y}{Y}\right)^2+\left(\frac{\Delta Z}{Z}\right)^2+\left(\frac{\Delta M_2}{M_2}\right)^2} =$$
$$\Delta X = \sqrt{(c_w \Delta M_w)^2+(c_1 \Delta M_1)^2} = \sqrt{(1 \times 0.0141)^2 + (0.22 \times 0.01)^2}$$
$$\Delta Y = \sqrt{(\Delta T_1)^2+(\Delta T_f)^2} = \sqrt{(0.25)^2 + (0.25)^2}$$
$$\Delta Z = \sqrt{(\Delta T_2)^2+(\Delta T_f)^2} = \sqrt{(0.25)^2 + (0.25)^2}$$

Table 11.3

ΔX = 0.01427 Cal/c°	Δc_2 = 0.0546 Cal/g.c°
ΔY = 0.3535 c°	
ΔZ = 0.3535 c°	
$c_2 \pm \Delta c_2$ = (0.085 - 0.0546, 0.085 + 0.0546) → (0.0304, 0.1396)	

4. Referring to Table 11.4, what is your metal sample? (Show your calculations in detail)

$C_2 = 0.085$ cal/g.c° × 4.18 J/cal

$C_2 = 0.3553$ J/g.c°

∴ the metal sample is copper (Cu).

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Table 11.4

Metal	Symbol	Specific heat (J/g °C)
Iron	Fe	0.449
Lead	Pb	0.129
Magnesium	Mg	1.023
Copper	Cu	0.387
Aluminum	Al	0.900
Silver	Ag	0.235
Silicon	Si	0.703
Tin	Sn	0.540

5. What will happen to the heat capacity and specific heat capacity of your metal sample if its mass is changed by a factor (...2....)? Record your answers in Table 11.5.

Table 11.5

$C = mc$

Change Factor = 2		
Physical Quantity	Effect	Value
Specific Heat Capacity	Constant	0.085 cal/g.°C
Heat Capacity	Double	C = mc = 2 (8.5) = 17 cal/°C

before: $C = mc$

99.9 × 0.085 = 8.5 cal/°C

6. Discuss the possible sources of errors in this experiment.

1) lost of heat

2) errors in reading by the observe

7. How much heat is gained or lost for the given metal under the conditions specified in Table 11.6 below. Use the information from Table 11.4.

$H = m_2 c_2 \Delta T$

Table 11.6

Metal	Copper	Initial temperature	91 °C
Mass	99.9 g	Final Temperature	24 °C

$H = m_2 c_2 \Delta T$

$= 99.9 \times 0.085 (24 - 91)$

$= -568.93$ cal (lost)

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EXPERIMENT 3

VECTORS – FORCE TABLE

10

LAB REPORT

Date ..6/3/.2019.....................

Name .Khaled....Al-naser...........

Partner's Name ....

Registration No.

Registration No. ....

Section ....14..........................

Instructor's Name .Enan...Dar'.....

I. PURPOSE:

In this experiment, you will subject an object (a ring) to two (three) horizontal forces whose resultant is not zero, and experimentally determine the third (fourth) force that will balance them. You will also determine this force (magnitude and direction) computationally and graphically and compare your answers. Thus, you will apply your knowledge of vector addition in a practical setting.

II. INTRODUCTION - THEORETICAL BACKGROUND:

Physical quantities can be classified into either: (i) scalar quantities, or (ii) vector quantities. A scalar quantity is defined by its magnitude only. Mass, length, and time are scalars. On the other hand, a vector quantity is defined by both magnitude and direction. Displacement, velocity, acceleration, and force are vector quantities.

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Addition of scalar quantities is done algebraically. But in vector addition, we have to take directions into consideration. A vector quantity is represented by an arrow pointing in the direction of the vector, with its length proportional to the magnitude of the vector.

When multiple forces act on an object, they may be replaced by a single force called the resultant ($\vec{R}$), which is their vector sum. The effect of the resultant is equivalent to the combined effects of the forces.

Vector Addition

Graphical Methods

To represent a vector in two dimensions on graph paper, two perpendicular axes are set up on the paper. Each axis represents a direction in actual two dimensional space. The length scales for each axis are chosen such that the arrow representing the vector fits within the graph paper (see Figure 3.2).

If the scales of the two axes are the same, then the angles made by the arrow on the graph paper with the two axes are the same as the corresponding angles of the actual vector in real space. Otherwise, the actual angles of the vector cannot be determined from the graph and must be calculated from the vector's components.

To find the sum or resultant of two vectors $\vec{A}$ and $\vec{B}$, two graphical methods, the parallelogram method and the triangle method, are used to

- **Parallelogram Method**

In this method we draw $\vec{A}$ on the graph paper. Then, from the tail of $\vec{A}$, we draw a vector equal to $\vec{B}$. Next, we complete the parallelogram formed by these two vectors. The resultant, $\vec{R} = \vec{A} + \vec{B}$, is represented by the arrow pointing along the diagonal of the parallelogram (Figure 3.1a), beginning at the tails of $\vec{A}$ and $\vec{B}$ (vertex a) and ending at the vertex c (*i.e.* vector $\vec{Oc}$).

Thus, the magnitude R and direction, respectively, of the resultant can be

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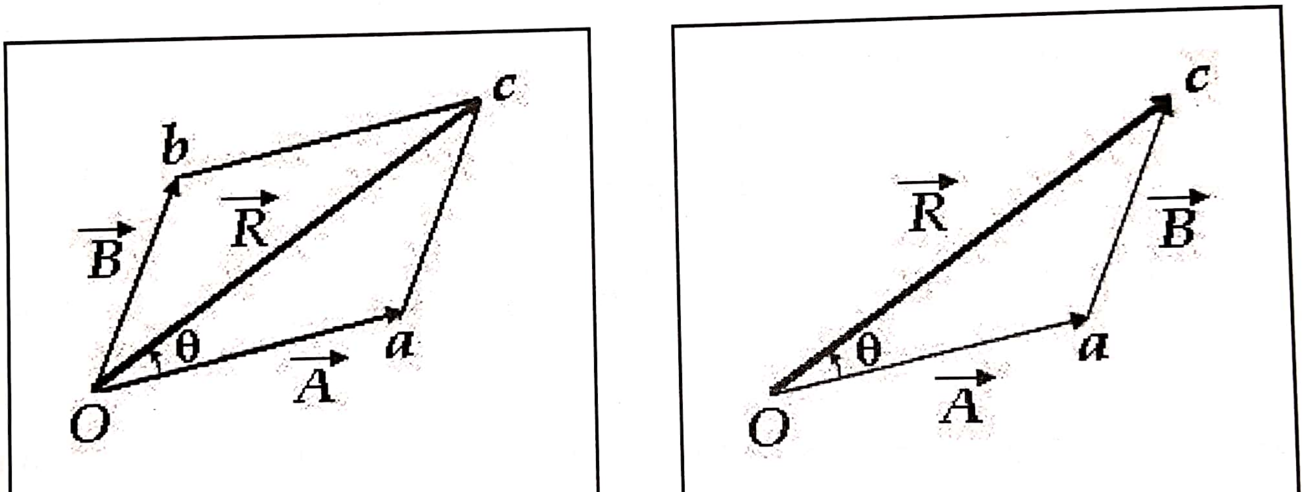
determined directly from the length of the diagonal arrow and the angle θ it makes with $\vec{A}$.

- Triangle Method

An equivalent method of finding $\vec{R}$ is to place the vectors to be added "head to tail" (head of $\vec{A}$ to tail of $\vec{B}$, or vice versa, Figure 3.1b). We can move a vector around on a graph sheet as long as it retains the same magnitude and direction. The resultant is this case is represented by the arrow pointing from the tail of $\vec{A}$ to the head of $\vec{B}$ (Figure 3.1b). Just like in the method above, the magnitude and direction of the resultant can be found directly from the arrow $\vec{Ob}$ in the triangle.



a) Parallelogram method b) Triangle method

Figure 3.1: Addition of vectors.

- Polygon Method (Three or more vectors)

If more than two vectors are to be added, the head-to-tail method forms a polygon (Figure 3.2). Figure 3.2 shows addition of four vectors; the resultant $\vec{R} = \vec{A} + \vec{B} + \vec{C} + \vec{D}$ is the vector arrow from the tail of the vector $\vec{A}$ to the head of the vector $\vec{D}$. The length (magnitude) and the direction of $\vec{R}$ can be determined from the figure.

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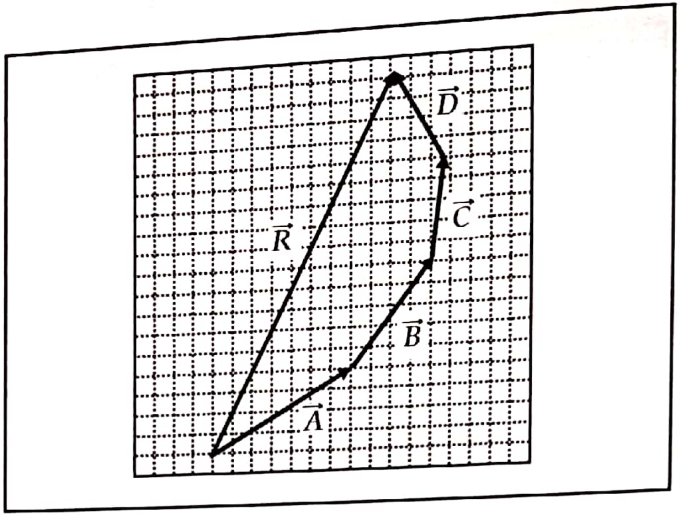

Figure 3.2: Polygon Method. Addition of more than two vectors.

Analytical Method (Method of components)

Let $\vec{A}$ be a vector that lies in the *xy* plane (*i.e.*, has no component along the *z*-direction), with *x* and *y* components A_x and A_y, respectively, as shown in Figure 3.3 below. We have:

$$A_x = A\cos\theta$$
$$A_y = A\sin\theta \qquad (3.1)$$

where θ is the angle that $\vec{A}$ makes with the positive *x–axis*, measured counterclockwise (θ> 0).

Denoting the unit vectors in the positive *x* and *y* directions by $\hat{i}$ and $\hat{j}$, respectively, we have:

$$\vec{A} = A\cos\theta\,\hat{i} + A\sin\theta\,\hat{j} \qquad (3.2)$$

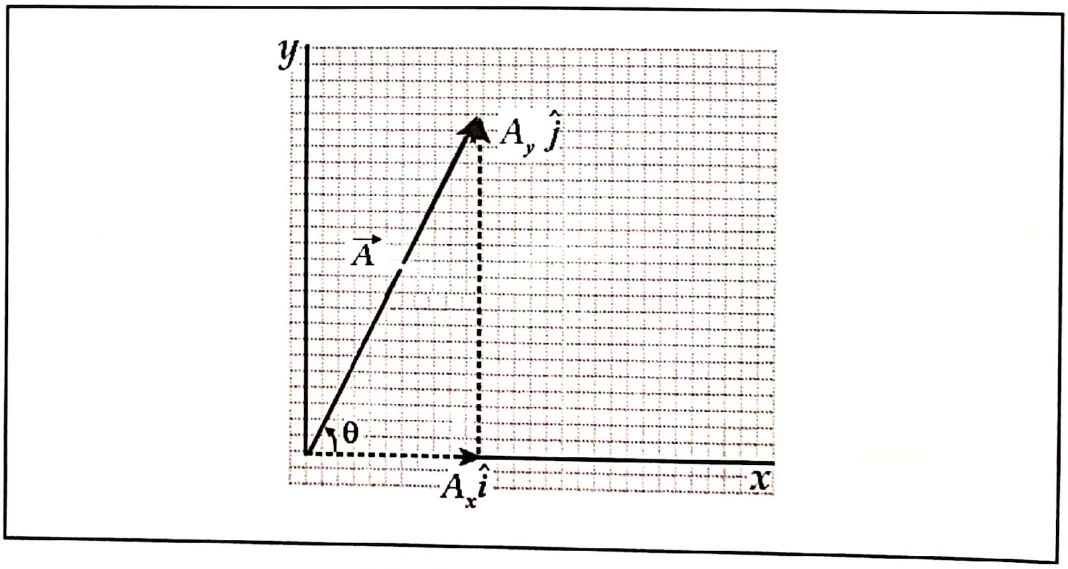

Figure 3.3: Components of a vector.

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In order to find the vector sum $\vec{R}$ of a set of vectors $\vec{A}$, $\vec{B}$, $\vec{C}$, etc... in two dimensions, we follow the following steps:

c) Find the x and y components A_x, B_x, C_x ... and A_y, B_y, C_y ..., for each vector using the above equations.

d) The components can be positive or negative depending on their direction.

e) Add up the x and y components, respectively, to get the x component (R_x) and y component (R_y) of the resultant:

$$\begin{aligned} R_x &= A_x + B_x + C_x + \cdots \\ R_y &= A_y + B_y + C_y + \cdots \end{aligned} \tag{3.3}$$

Now, the magnitude of $\vec{R}$, denoted simply R, is: $R = \left(R_x^2 + R_y^2\right)^{1/2} \left(R_x^2 + R_y^2\right)^{1/2}$

and the direction of $\vec{R}$ is defined by the angle θ it makes with the positive *x-axis*, measured counterclockwise.

$$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right) \tag{3.4}$$

III. EQUIPMENT

1- Force table - Figure 3.4

2- Four weight holders

3- Four pulleys

4- Different weights

5- Different strings

6- A ring

7- A protractor

The force table, Figure 3.4, consists of a horizontal disc whose rim is graduated in degrees from 0° to 360°. The pulley clamp has an indexing mark to indicate the angle at which the pulley is clamped.

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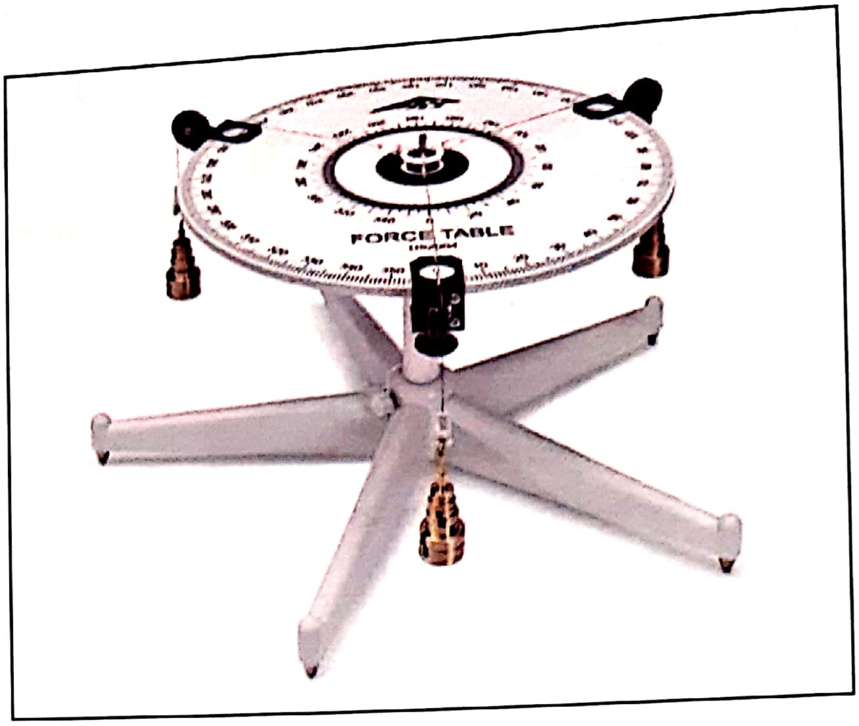

Figure 3.4: Force Table.

IV. PROCEDURE - PART 1

1. On the force table:

- Clamp two pulleys at the rim of the force table such that one is at an angle of 30° and the other one at an angle of 120°. Hang from the former a mass m_1 and at the latter a mass m_2. The values of m_1 and m_2 will be provided by your instructor. Fill in the table below.

$F_1 = w_1 = m_1 g$ = $\frac{100}{1000}$ x 9.8 = 0.98 N	θ_1 = 30°
$F_2 = w_2 = m_2 g$ = $\frac{150}{1000}$ x 9.8 = 1.47 N	θ_2 = 120°

g is the acceleration of gravity and is approximately equal to 9.80 m/s^2 near the Earth's surface. The force diagram in Figure 3.5 shows the forces.

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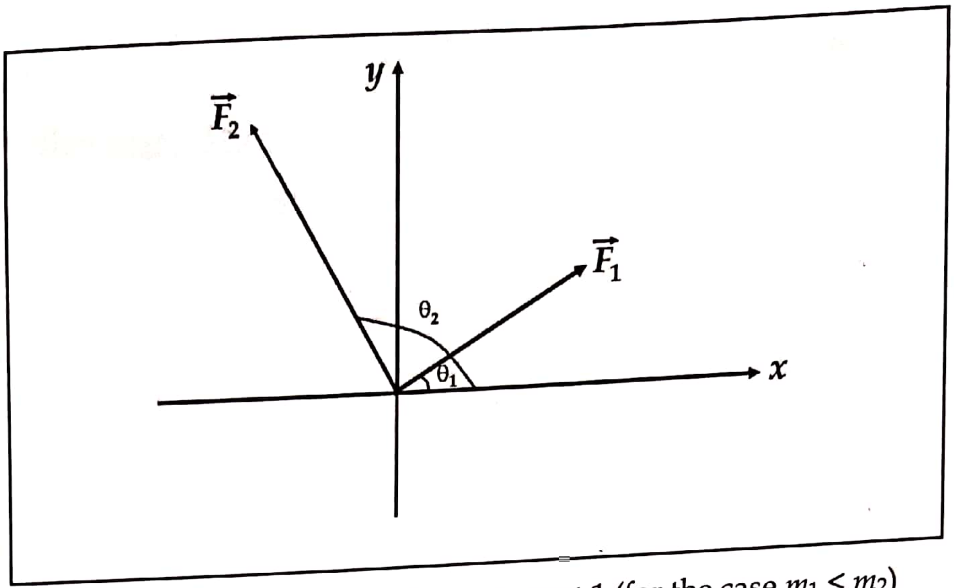

Figure 3.5: Schematic setup of forces in part 1 (for the case $m_1 < m_2$)

- With the use of a third pulley and a third hanging mass find the magnitude and direction of the equilibrium force that returns the ring to the equilibrium position. This third force is called the balance force; it is equal in magnitude and opposite in direction to the resultant of the two forces.

V. Data Analysis – Part 1

Find the resultant of the above two forces (magnitude, R and direction, θ_R) by:

a) Experimental method (Force Table)

Balance force (B)=	180 ×g= $\frac{180}{1000}$ × 9.8 = 1.764 N	θ_B = 267°
Resultant (R)=	180 ×g= $\frac{180}{1000}$ × 9.8 = 1.764 N	θ_R = θ_B − 180 = 267 − 180 = 87°

b) Method of Components

$\vec{F_1} = F_1x + F_1y$

$\vec{F_1} = F_1\cos\theta_1 + F_1\sin\theta_1$

$\vec{F_1} = 0.98 * \frac{\sqrt{3}}{2} + 0.98 * \frac{1}{2}$

$\vec{F_1} = 0.849 + 0.49$

$\vec{F_1} = 1.339\ N$

$\vec{F_2} = F_2x + F_2y$

$\vec{F_2} = F_2\cos\theta_2 + F_2\sin\theta_2$

$\vec{F_2} = 1.47 * -\frac{1}{2} + 1.47 * \frac{\sqrt{3}}{3}$

$\vec{F_2} = -0.735 + 1.273$

$\vec{F_2} = 0.538\ N$

$\Sigma F_x = F_1\cos\theta_1 + F_2\cos\theta_2$

$\Sigma F_x = 0.849 + -0.735$

$\Sigma F_x = 0.114\ N$

$\Sigma F_y = F_1\sin\theta_1 + F_2\sin\theta_2$

$\Sigma F_y = 0.49 + 1.273$

$\Sigma F_y = 1.763\ N$

$F_R = \sqrt{(\Sigma F_x)^2 + (\Sigma F_y)^2}$

$F_R = \sqrt{(0.114)^2 + (1.763)^2}$

$F_R = 1.767\ N$

$\theta_R = \tan^{-1}\left(\frac{\Sigma F_y}{\Sigma F_x}\right) = \tan^{-1}\left(\frac{1.763}{.114}\right)$

$\theta_R = 86.3$

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c) Graphical Method

For this section, use the plot sheet in the next page. Follow the rules explained in the introduction of this manual.

R = ...FR = 1.763 N..

θ_R = ...86.3°...

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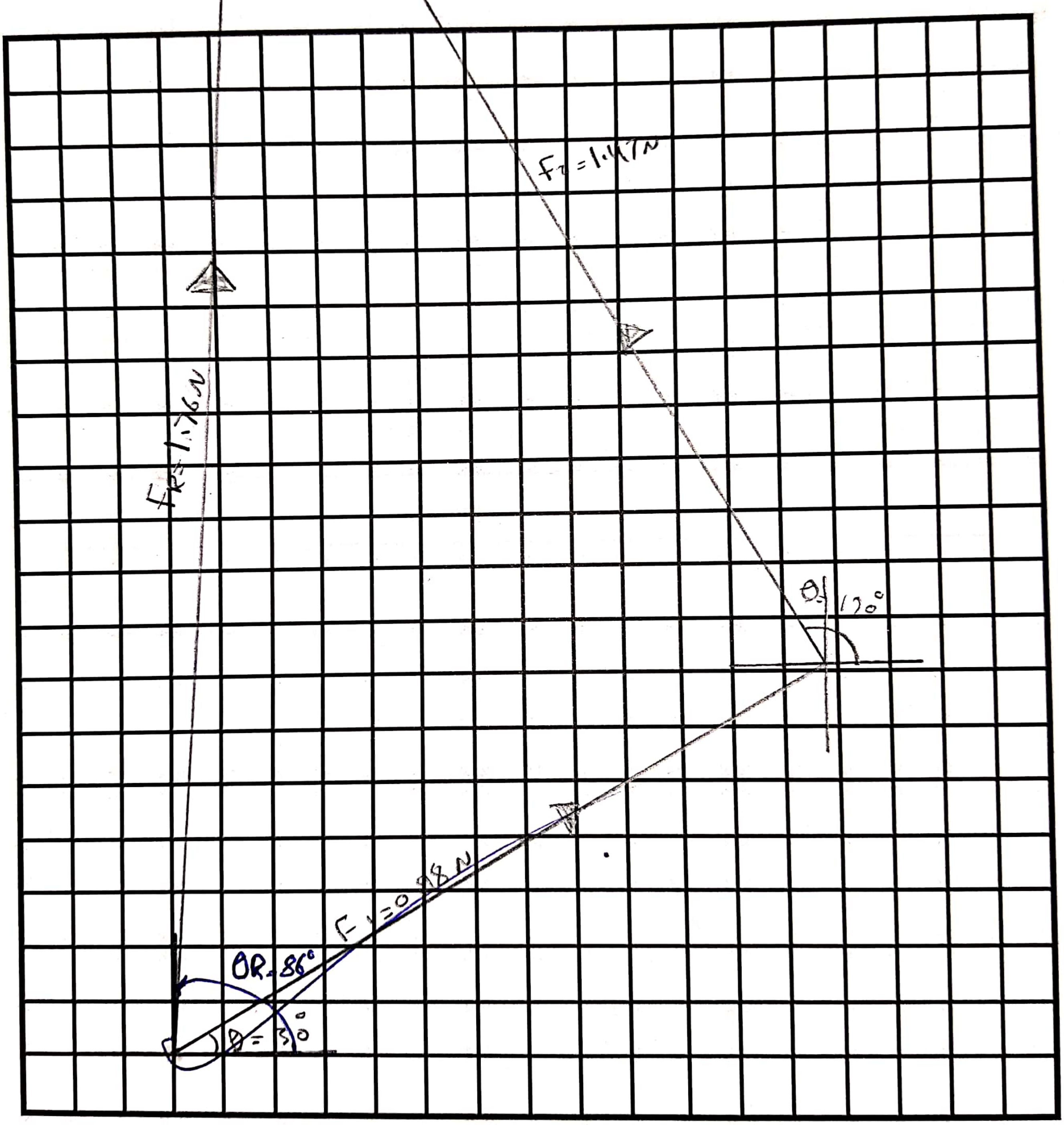
Scale: 1 cm = ...0.1 N.... N

R = ...1.763 N......... (N)

θ_R = ...86.3°..................



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VI. PROCEDURE - PART 2

1. Follow the procedure in part 1 above to find the resultant of the three forces with directions as shown in Figure 3.6.

Use the masses m_1, m_2, and m_3 (provided by your instructor).

Fill in the table below.

$F_1 = w_1 = m_1 g$ = 100/1000 × 9.8 = 0.98 N	θ_1 = 30°
$F_2 = w_2 = m_2 g$ = 150/1000 × 9.8 = 1.47 N	θ_2 = 240°
$F_3 = w_3 = m_3 g$ = 180/1000 × 9.8 = 1.764 N	θ_3 = 315°

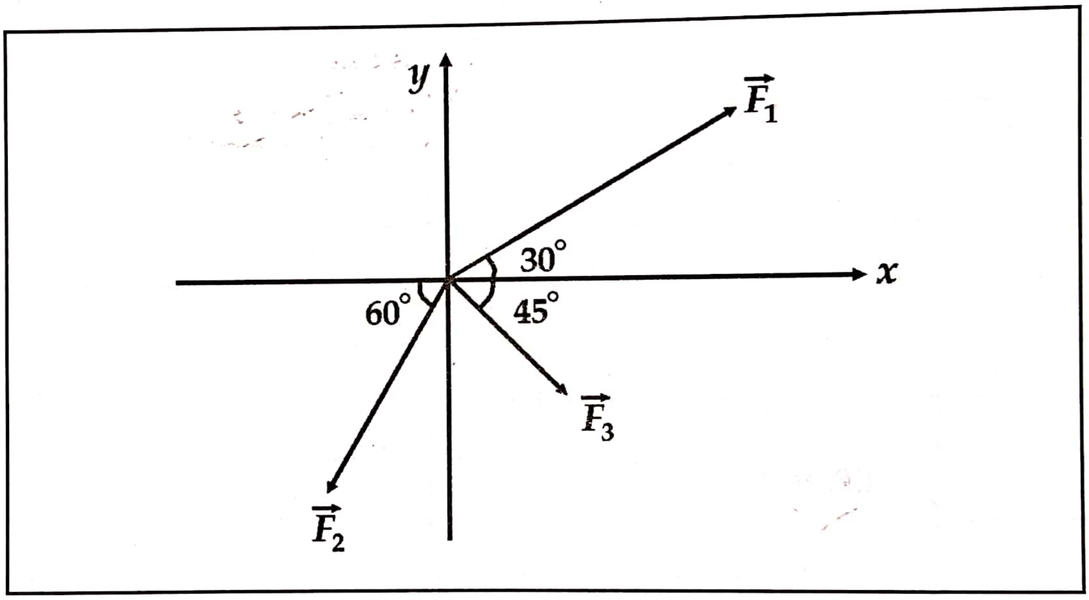

Figure 3.6: Setup of forces in part 2.

VII. Data Analysis – Part 2

1. Find the resultant of the above three forces (magnitude, R, and direction, θR)

a) Experimental method (Force Table)

Balance force (B)=	.250. × g= 250 × 9.8 / 1000 = 2.45.... N	θ_B = 125°
Resultant (R)=	.250. × g= ..2.45..N......... N	θ_R = 180 - 125° = 55°

b) Method of Components

....

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$\vec{F_1} = F_{1x} + F_{1y}$

$\vec{F_1} = F_1\cos\theta_1 + F_1\sin\theta_1$

$\vec{F_1} = 0.98 \times \frac{\sqrt{3}}{2} + 0.98 \times 0.5$

$\vec{F_1} = 0.85N\hat{i} + 0.49\hat{j}$

$\vec{F_2} = F_{2x} + F_{2y}$

$\vec{F_2} = F_2\cos\theta_2 + F_2\sin\theta_2$

$\vec{F_2} = 1.47 \times -0.5 + 1.47 \times -\frac{\sqrt{3}}{2}$

$\vec{F_2} = -0.735\hat{i} + -1.273\hat{j}$

$\vec{F_3} = F_3\cos\theta_3 + F_3\sin\theta_3$

$\vec{F_3} = 1.764 \times \frac{\sqrt{2}}{2} + 1.764 \times -\frac{\sqrt{2}}{2}$

$\vec{F_3} = 1.247\hat{i} + -1.247\hat{j}$

$\Sigma F_x = F_1\cos\theta_1 + F_2\cos\theta_2 + F_3\cos\theta_3$

$\Sigma F_x = 0.849 + -0.735 + 1.247$

$\Sigma F_x = 1.361\ N$

$\Sigma F_y = F_1\sin\theta_1 + F_2\sin\theta_2 + F_3\sin\theta_3$

$\Sigma F_y = 0.49 + -1.273 + -1.247$

$\Sigma F_y = -2.03$

$F_R = \sqrt{(\Sigma F_x)^2 + (F_y)^2}$

$F_R = \sqrt{(1.361)^2 + (-2.03)^2}$

$F_R = 2.44\ N$

$\theta = \tan^{-1}\left(\frac{\Sigma F_y}{\Sigma F_x}\right) = \tan^{-1}\left(\frac{-2.03}{1.361}\right)$

$\theta = -56.16°$

c) Graphical Method

Use the graph sheet on the next page. Follow the rules explained in the introduction of this manual.

R = $F_R = 2.44\ N$

θ_R = $-56.16°$

2. State and discuss three sources of error in this experiment.

① Weight errors

② personal errors

③ exerimental errors

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Scale: 1 cm = 0.2 N

F_1 = 0.98 N N

F_2 = 1.47 N N

F_3 = 1.764 N N

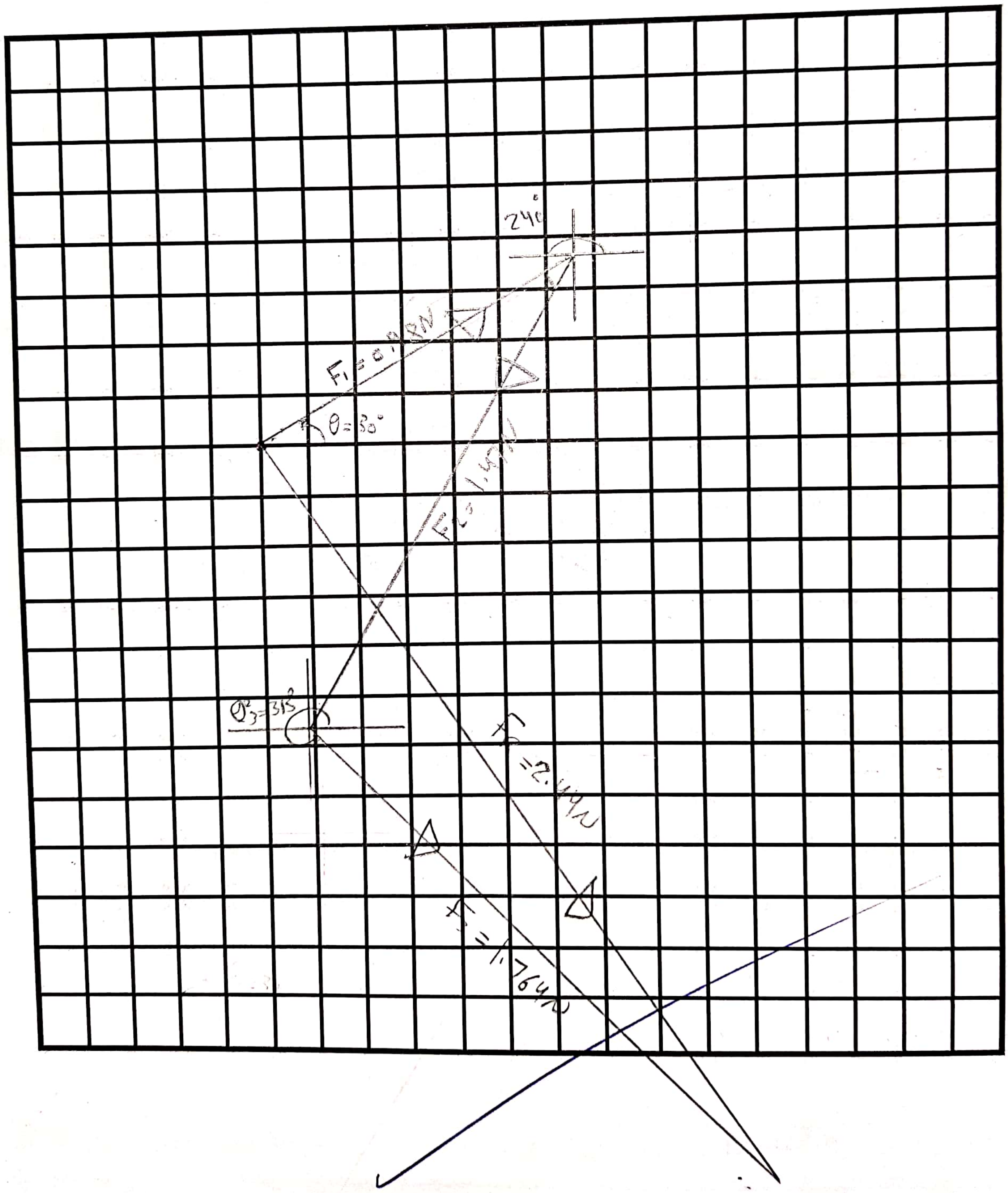
R = 2.44 N (N)

θ_1 = 30°

θ_2 = 240°

θ_3 = 315°

θ_R = -56.16° = 304°



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EXPERIMENT 10

BOYLE'S LAW

10

LAB REPORT

Date ...13./.3./.2019..................

Name ..Khaled....Al-Naser... | Partner's Name .IBrahim...ghosheh

Registration Nc | Registration No.

Section .....19.................... | Instructor's Name ..Emam...Dase.

I. PURPOSE:

To verify Boyle's law for a trapped gas at room temperature.

II. Introduction

According to Boyle's law, the pressure of a trapped gas at constant temperature is inversely proportional to its volume.

A force F acting perpendicularly to a surface with area A exerts a pressure given:

$$P = F/A \tag{10.1}$$

In MKS the unit of pressure is the Pascal or Pa = N/m^2.

It can be shown that the pressure exerted on a surface by a column of fluid of density ρ and height h is given by:

$$P = \rho g h \tag{10.2}$$

The atmospheric pressure at a given location is due to the column of air

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above that location and its value at sea level, at T = 20 °C, is 101 325 *Pa* [NIST]. It is equivalent to the pressure of a column of mercury 760 mm high.

$$1 \text{ atm} = 101\ 325 \text{ Pa} = 760 \text{ mmHg} \tag{10.3}$$

The molecules (or atoms) of a gas are in continuous motion. When a gas is trapped in a container, the incessant and huge number of collisions each second between its molecules (or atoms) and the container's walls will exert pressure on the walls of the container. Boyle's law expresses the empirical relationship, valid for gases at low densities, between pressure and volume for a trapped gas at constant temperature, as follows:

$$P\,V = \text{constant} \tag{10.4}$$

The standard apparatus to investigate Boyle's law is shown in Figure 10.1. It consists of a glass tube BC, of uniform cross-sectional area A, closed at the upper end B and open at the lower end C. The lower end is connected by a length of rubber tubing CE to an open glass tube DE. When mercury is poured into the tube, air is trapped in the closed segment BX of length L of the left tube. A fixed meter stick, placed between the two tubes, is used to read the mercury levels in both tubes.

- The volume of the trapped air is $V = AL$.
- The pressure of the trapped gas P, measured in units of mmHg, is $P_a + h$, where P_a is the atmospheric pressure in mmHg, and $h = Y - X$ is the difference of the mercury levels X and Y in the two tubes.

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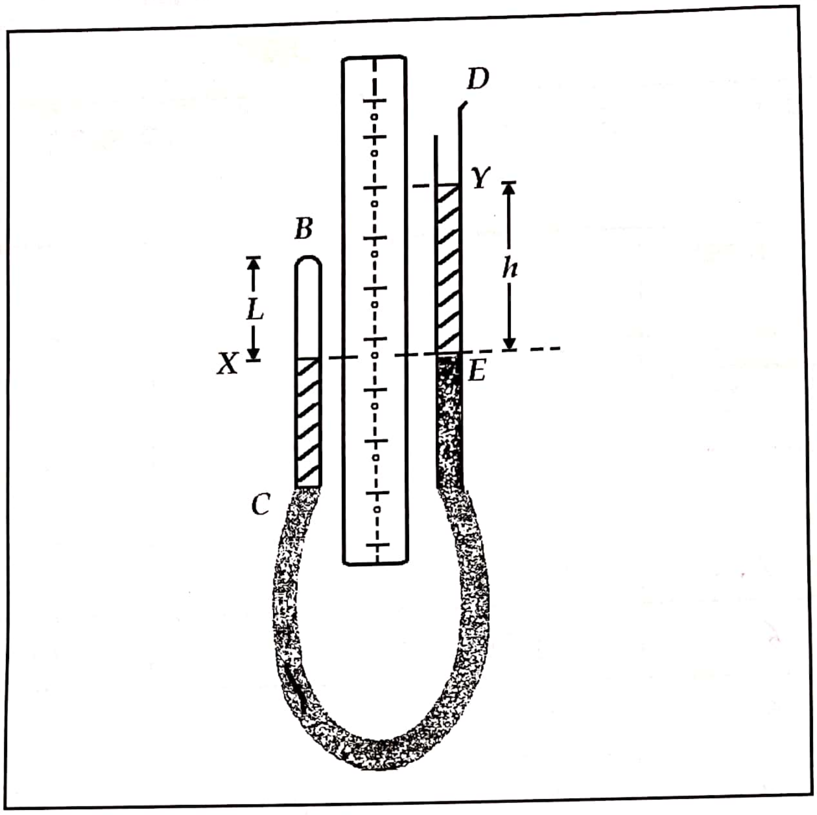

Figure 10.1: Boyle's law apparatus.

III. EQUIPMENT

Boyle's Law Apparatus, thermometer.

IV. PROCEDURE

Notes: a) The tube BC is held fixed throughout the experiment.

b) Start with the right-hand tube DE at maximum height.

1. Record the position of the closed end B of the tube BC.
2. Measure room temperature using a thermometer.
3. Record this temperature in Table 10.1 below.
4. Change the volume of the trapped air in the BX segment by lowering the tube DE.
5. Record the scale readings X and Y in Table 10.1
6. Calculate $L = B - X$ (the length of the trapped gas column) and $h = Y - X$ (the difference of mercury levels).
7. Repeat steps 3-4 for a total of eight times.

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Table 10.1

Average Room Temperature = 20 °C

B = 350 mm

Scale Readings (mm)		$h = Y - X$ (mm)	$L = B - X$ (mm)	$1/L$ ~ 10^{-3} (mm^{-1})
X	Y			
281	800	519.	69	14.5 × 10^{-3}
276	700	424	74	13.5 × 10^{-3}
271	600	329	79	12.6 × 10^{-3}
262	500	238	88	11.3 × 10^{-3}
253	400	147	97	10.3 × 10^{-3}
241	300	59	109	9.1 × 10^{-3}

V. Data Analysis

1. Plot h versus $1/L$. Use the graph to find the value of the atmospheric pressure $P_a \pm \Delta P_a$ in units of mmHg.

....

P_a = 700 mmHg ....

....

....

2. With the value of the atmospheric pressure known, you can now calculate the pressure P of the trapped air for each value of h, using the relation: $P = P_a + h$. Calculate the quantity PL for each (h,L) pair and enter the values in Table 10.2 below:

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Table 10.2

L (mm)	h (mm)	$P = P_a + h$ (mmHg)	PL (mmHg . mm)
69	519	= 700 + 519 = 1219	= 1219 × 69 = 8.4 × 10^4
74	424	= 700 + 424 = 1124	= 1124 × 74 = 8.3 × 10^4
79	329	= 700 + 329 = 1029	= 1029 × 79 = 8.1 × 10^4
88	238	= 700 + 238 = 938	= 938 × 88 = 8.2 × 10^4
97	147	= 700 + 147 = 847	= 847 × 97 = 8.2 × 10^4
109	59	= 700 + 59 = 759	= 759 × 109 = 8.2 × 10^4

3. Plot L versus $P = (P_a + h)$. What do you conclude from the graph?

The relation between L and P is inverse from the graph.

4. Plot a third graph of L versus $P\,L$. What do you conclude?

the relation between PL and L is constant because PL is constant from the graph.

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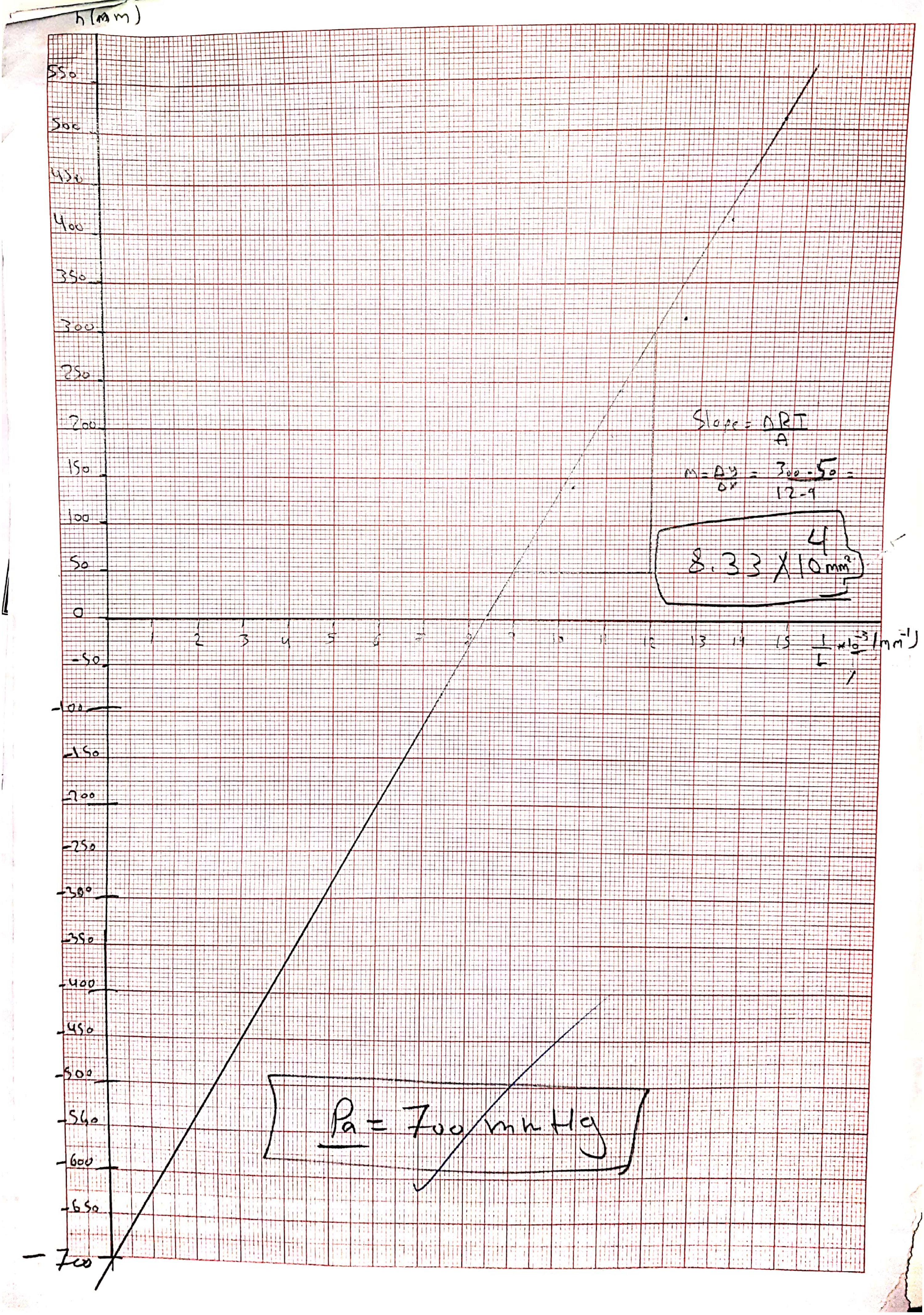

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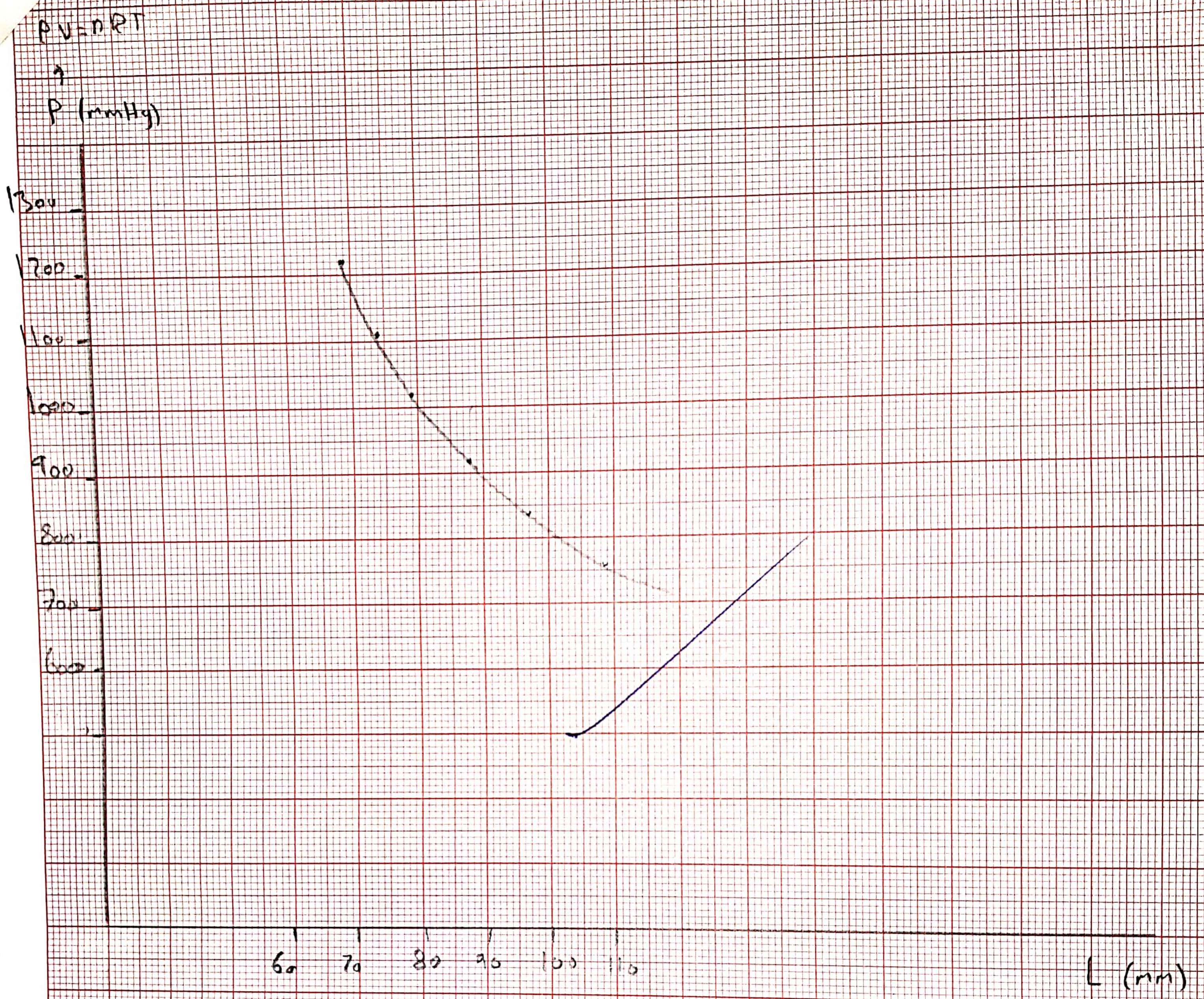

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EXPERIMENT 5

FORCE AND MOTION

10

LAB REPORT

Date ......27/3/2019..................

Name ..Khaled.....al-Naser.........

Partner's Name .Ibrahim..ghosheh

Registration No. ....

Registration No. ....

Section ......14.........................

Instructor's Name .Eman..Daar....

I. PURPOSE

To verify Newton's second law for a mechanical system moving in one dimension, specifically, the relationship between the acceleration of the mechanical system, its mass, and the net force, acting on it. Two cases will be studied:

1- The net force is kept constant.

2- The mass is kept constant.

II. INTRODUCTION - THEORETICAL BACKGROUND

Newton's second law of motion gives the relationship between the mass of a mechanical system (m), its acceleration $\vec{a}$, and the net (resultant) force, $\vec{F}_{net}$ acting on it:

$$\vec{F}_{net} = m\,\vec{a} \qquad (5.1)$$

where $\vec{F}_{net} = \sum \vec{F}_{ext}$, is the vector sum of all external forces acting on the object.

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Equation 5.1 shows that the acceleration of a given mass is directly proportional to the net force and for a given force it is inversely proportional to the mass of the object.

In this experiment, the mechanical system consists of a cart on a horizontal surface, connected by a light string passing over a pulley to a vertically hanging mass (Figure 5.1). A pin on the top of the cart can be used to add mass to it using slotted weights.

In order to minimize the effect of friction between the cart and the surface, an air track is used to provide a cushion of air above the surface, rendering it essentially frictionless.

The air track is an aluminum surface with many tiny holes punched regularly through it. An electric air blower continuously blows air through these holes to form the cushion of air.

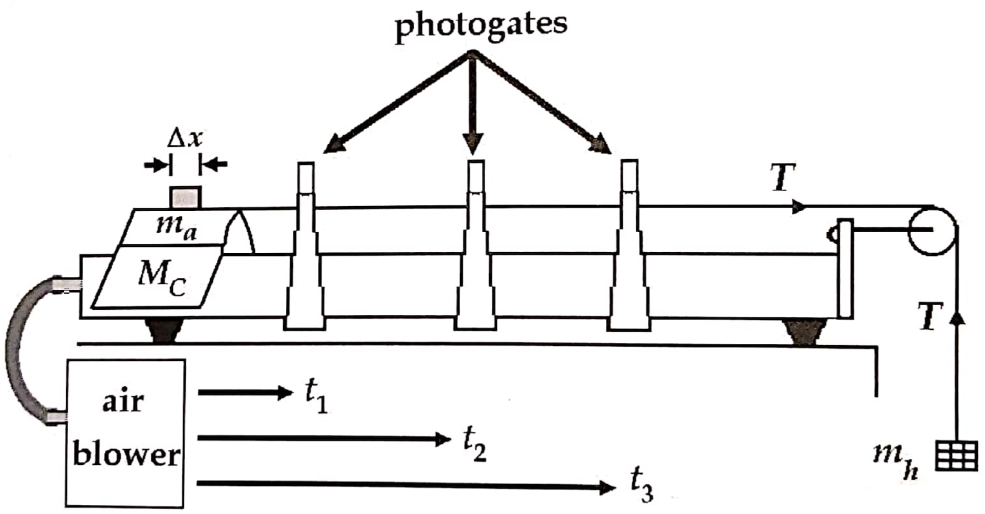

Figure 5.1: Air Track - Experimental Setup.

Let m_c, m_a, and m_h denote the masses of the cart, the added slotted weight, and the hanging mass, respectively.

All parts of the system move together with the same velocity and acceleration at every instant.

Applying Newton's second law to the cart (with the added mass) and the

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hanging mass, respectively, gives:

$$T = (m_c + m_a)\, a \qquad (5.3)$$

$$m_h\, g - T = m_h\, a \qquad (5.4)$$

Where g is the acceleration of gravity, and T is the tension in the string. Note that the tension on both sides of the pulley has the same value, because we consider the pulley as massless and frictionless.

Adding Equation 5.3 to Equation 5.4 gives

$$m_h\, g = (m_c + m_a + m_h)\, a. \qquad (5.5)$$

Equation 5.5 can be thought of as Newton's second law for a system in which the string and the masses m_1 and m_h are thought of as one single object with a mass equal to the total mass of the system, $(m_c + m_a + m_h)$. The only external force is the weight of the hanging mass: $F_{net} = m_h g$, and the tension *does not appear in this equation because it* is an internal force.

Since the acceleration is constant with time, its instantaneous magnitude is the same as its average value, and we have:

$$a = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1} \qquad (5.6)$$

where v_1 and v_2 are the instantaneous velocities at two different positions along the path of motion, and Δt is the time it takes the cart to move between the two positions.

The velocities v_1 and v_2, are determined with the help of two photogates located at the two positions.

When the cart passes between the two arms of the photogate, a metal flag of width Δx attached to it blocks the infrared light beam. A digital counter registers the starting time of the blocking t and its duration Δt.

The instantaneous velocity v of the cart at the location of the photogate can be approximated by:

$$v = \frac{\Delta x}{\Delta t} \qquad (5.7)$$

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III. EQUIPMENT

Air track apparatus:

- Photogates
- Timer
- Air blower
- Cart

The air track will be assembled and leveled by the laboratory technician. Please do not attempt any adjustments of the air track. If you have any concerns, then please ask the instructor for assistance.

The operation of the system is controlled with the following buttons:

- START: starts the timer and simultaneously releases the cart by deactivating the magnet holding it in its initial position.
- STOP: stops the timer.
- RESET: resets the timer before starting a new count.
- SELECT: allows to select the desired photogates.

IV. PROCEDURE - PART 1: ACCELERATION WITH VARIABLE SYSTEM MASS AND CONSTANT NET FORCE

1. Measure the flag's width Δx of the cart to be used in this experiment, and record its value in the appropriate tables.
2. Set up the system as shown in Figure 5.1 and note that
    - The value of the hanging mass (m_h) is kept constant at 20 g during this part to ensure a constant net force.
    - No mass is added to the cart for the first run.
3. Press the RESET button.
4. Start the motion by pressing the START button.
5. Do not attempt to move the cart if the air supply is not turned on.
6. After the cart passes the third photogate, press the STOP button.
7. Press the SELECT button to choose the first photogate.
8. Press the t-button and read off the t value for that photogate.
9. Next press the Δt-button and read off the corresponding Δt value.
10. Record these values in Table 5.1 below.
11. Repeat step (3) for the other two photogates.

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12. Press the RESET button and set up the system for a new run.
13. Repeat steps 2 through 6 three times, adding 25 g to the cart each time, thus varying the system's mass.

V. Analysis of Data – Part 1

1. For each value of m_a, use Equation 5.7 and Table 5.1 to calculate the cart's velocity at each of the three photogate positions.
2. Record your results in the appropriate cells in the table.

Table 5.1

Δx = ...4........ cm $\qquad$ m_h = 20 g

$m_a = 0$			$m_a = 25$ g			$m_a = 50$ g			$m_a = 75$ g		
t (s)	Δt (s)	v (cm/s)	t (s)	Δt (s)	v (cm/s)	t (s)	Δt (s)	v (cm/s)	t (s)	Δt (s)	v (cm/s)
0	0	0	0	0	0	0	0	0	0	0	0
0.757	0.46	86.95	0.837	0.05	80	1.126	0.052	76.92	0.94	0.056	71.4
1.067	0.03	117.64	1.171	0.038	105.2	1.397	0.039	102.56	1.314	0.041	97.5
1.302	0.028	142.8	1.426	0.03	133.3	1.748	0.031	129.03	1.599	0.033	121.2

3. On one graph sheet, v *versus* t for each value of the added mass and draw the best fit line through the data points.
4. Label each line with the corresponding value of the added mass m_a.
5. Determine the acceleration (a) for each case from the slope of the corresponding line, and enter your values in Table 5.2 below:

Table 5.2

m_a (g)	a (cm/s^2)	$1/a$ (s^2/cm)
0	116.6 cm/s^2	8.6×10^{-3}
25	91 cm/s^2	10.9×10^{-3}
50	80 cm/s^2	12.5×10^{-3}
75	77 cm/s^2	13.0×10^{-3}

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6. Plot m_a versus $1/a$.

7. From the graph, what conclusion can you make about the way the acceleration of the cart depends on the system's total mass?

the relationship between the acceleration of the cart and the system's total mass is an inverse relationship.

8. From your graph, find the mass of the cart, m_C.

b = mc + mh

93.5 = mc + 20

mc = 93.5 - 20 = 73.5 g

VI. Procedure - Part 2: Acceleration under Variable Net Force and constant System Mass

In this part, you will use two photogates.

1. Set up the system as indicated in Figure 5.1, starting with $m_a = 30$ g and $m_h = 10$ g.
2. Reset the photogates by pressing the RESET button.
3. Press the START button to start the motion.
4. Read off the times t_1, t_2, Δt_1, and Δt_2 following the same procedure from part 1. Record your results in Table 5.3.
5. Repeat steps 2 through 4 three more times, reducing m_a by 10 g and increasing m_h by the same amount.

VII. Analysis of Data – Part 2

1. For each run, use Equation 5.7 and Table 5.1 to calculate the cart's velocity at each of the two photogate positions. Record your results in the appropriate cells in the table.

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Table 5.3

Δx = ...4cm.... cm

	Time (s)		$v = \frac{\Delta x}{\Delta t}$ (cm/s)	$v_2 - v_1$ (cm/s)	$a = \frac{v_2 - v_1}{t_2 - t_1}$ (cm/s²)
m_a = 30 g, m_h = 10 g	t_1= 1.196	Δt_1= 0.071	56.33		
				19.14	40.29
	t_2= 1.671	Δt_2= 0.053	75.47		
	Time (s)		$v = \frac{\Delta x}{\Delta t}$ (cm/s)	$v_2 - v_1$ (cm/s)	$a = \frac{v_2 - v_1}{t_2 - t_1}$ (cm/s²)
m_a = 20 g, m_h = 20 g	t_1= 0.934	Δt_1= 0.56	71.43		
				23.82	63.52
	t_2= 1.309	Δt_2= 0.042	95.24		
	Time (s)		$v = \frac{\Delta x}{\Delta t}$ (cm/s)	$v_2 - v_1$ (cm/s)	$a = \frac{v_2 - v_1}{t_2 - t_1}$ (cm/s²)
m_a = 10 g, m_h = 30 g	t_1= 0.897	Δt_1= 0.039	102.56		
				30.77	116.11
	t_2= 1.162	Δt_2= 0.03	133.33		
	Time (s)		$v = \frac{\Delta x}{\Delta t}$ (cm/s)	$v_2 - v_1$ (cm/s)	$a = \frac{v_2 - v_1}{t_2 - t_1}$ (cm/s²)
m_a = 0 g, m_h = 40 g	t_1= 0.572	Δt_1= 0.33	121.21		
				38.87	170.88
	t_2= 0.799	Δt_2= 0.025	160		

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2. For each run, calculate the average acceleration (a), where $a = (v_2 - v_1)/(t_2 - t_1)$.

3. Enter your data for the hanging weight ($m_h g$) and the corresponding acceleration (a) in Table 5.4. (Take $g = 980\ cm/s^2$).

Table 5.4

Hanging weight $m_h g$ (dyne)	Acceleration a (cm/s^2)
10 * 980	40.29
20 * 980	63.52
30 * 980	116.11
40 * 980	170.88
1 dyne = 1 g cm s^{-2} = 10^{-5} N	

4. Plot a graph of the hanging weight ($m_h g$) against the acceleration (a).
5. Calculate the slope of your graph. What does the slope of your graph represent?

the Slop = 196 gram
it represent Mg+Ma Mh

6. State and discuss three sources of error in this experiment.

① Systematic errors
② Calculations errors
③ Personal errors

See also:

http://www.phywe-es.com/index.php/fuseaction/download/lrn_file/versuchsanleitungen/p1199705/e/p1199705e.pdf

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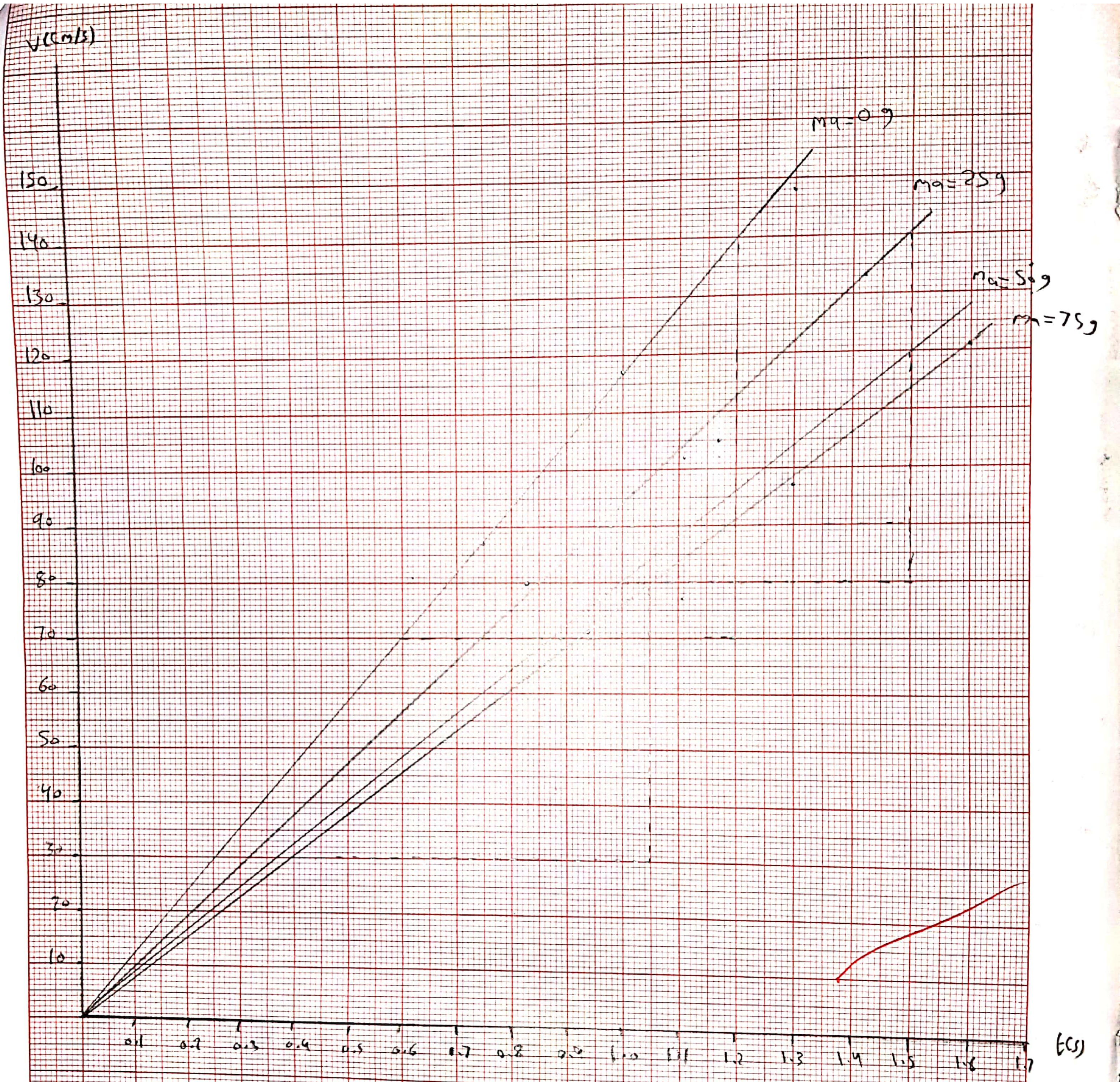

Slope $ma = 0\,g$

$$m = \frac{140 - 70}{1.2 - 0.6}$$

$$m = 116.6\ cm/s^2$$

$ma = 25\,g$

$$m = \frac{140 - 90}{1.5 - 0.95}$$

$$M = 91\ cm/s^2$$

$ma = 75\,g$

$$m = \frac{120 - 80}{1.5 - 1.0}$$

$$m = 80\ cm/s^2$$

$ma = 75\,g$

$$m = \frac{80 - 30}{1.05 - 0.4}$$

$$m = 77\ cm/s^2$$

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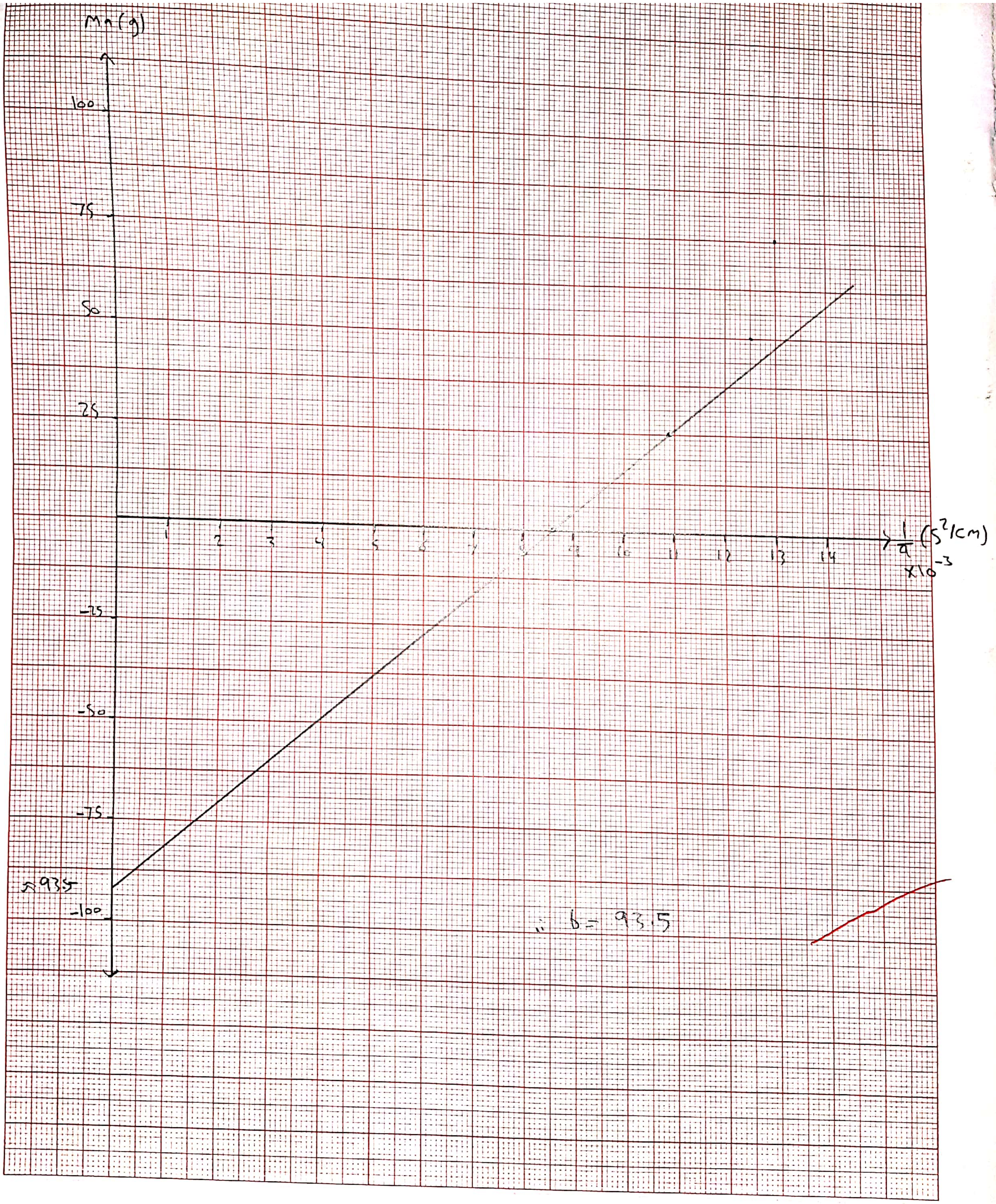

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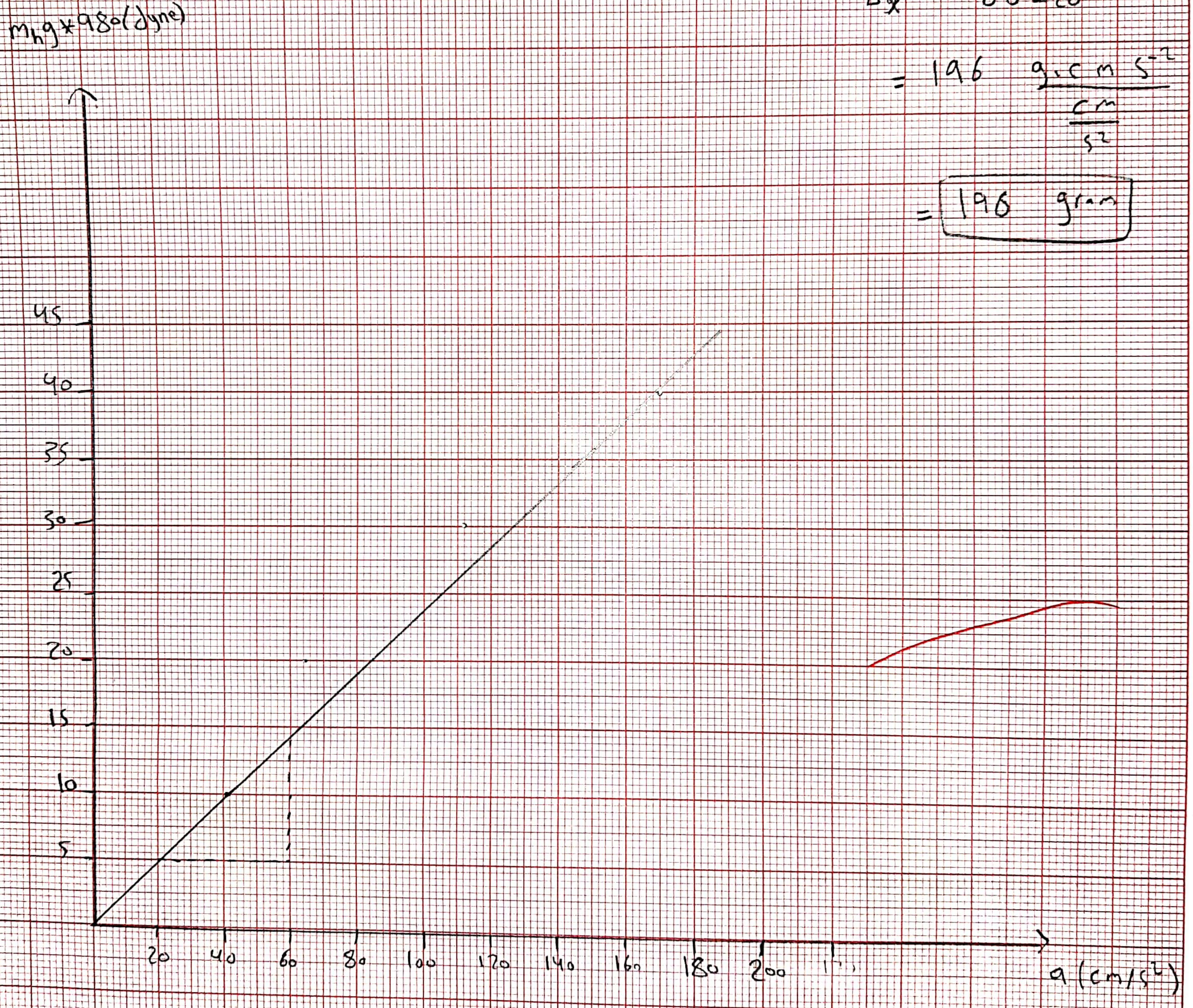
$$\text{Slope} = m = \frac{\Delta y}{\Delta x} = \frac{13-5(980)}{60-20}$$

$$= 196 \ \frac{g \cdot cm\, s^{-2}}{\frac{cm}{s^2}}$$

$$= \boxed{196 \ \text{gram}}$$



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18

EXPERIMENT 7

SIMPLE HARMONIC MOTION

THE SIMPLE PENDULUM

LAB REPORT

Date ...27/3/2019..................

Name ...Khaled...Al-Naser........ Partner's Name ..Ibrahim...Shahab

Registration No. Registration No.

Section ....14............................ Instructor's Name ..Eman..Asar....

I. PURPOSE

To study simple harmonic motion of a simple pendulum and verify the relationship between its length and period.

You will also calculate g, the acceleration of gravity.

II. INTRODUCTION - THEORETICAL BACKGROUND

Oscillatory motion is a type of motion in which a particle moves back and forth over the same path. If the oscillatory motion repeats itself in regular time intervals (periods), then it is called a harmonic motion There are several types of oscillatory harmonic motions, *simple harmonic motion* (SHM) being the simplest.

Two important characteristics of periodic motion are its *amplitude* and *period*. Amplitude refers to the maximum size of the quantity whose magnitude is oscillating with time, while period refers to the time interval

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this quantity takes to return to a given value again.

There are several types of oscillatory motions, among which *simple harmonic motion* (SHM) is the simplest because its oscillatory behavior has the simplest mathematical form (a sine or cosine function of time).

In this type of motion, the moving particle or object moves back and forth about an equilibrium position, under the influence of a "restoring" force whose magnitude is proportional to the displacement of the particle or object from its equilibrium position.

Two common examples of SHM are:

(1) the vibration of a spring that has been displaced from its equilibrium position, and

(2) the oscillation of a simple pendulum about its (vertical) equilibrium position, which is the subject of the present experiment.

Simple Harmonic Motion of a Spring

Consider the horizontal spring, with spring constant k, shown in Figure 7.1a. Its left end is fixed to a vertical wall and its right end is attached to a block of mass m sitting on a smooth, horizontal surface.

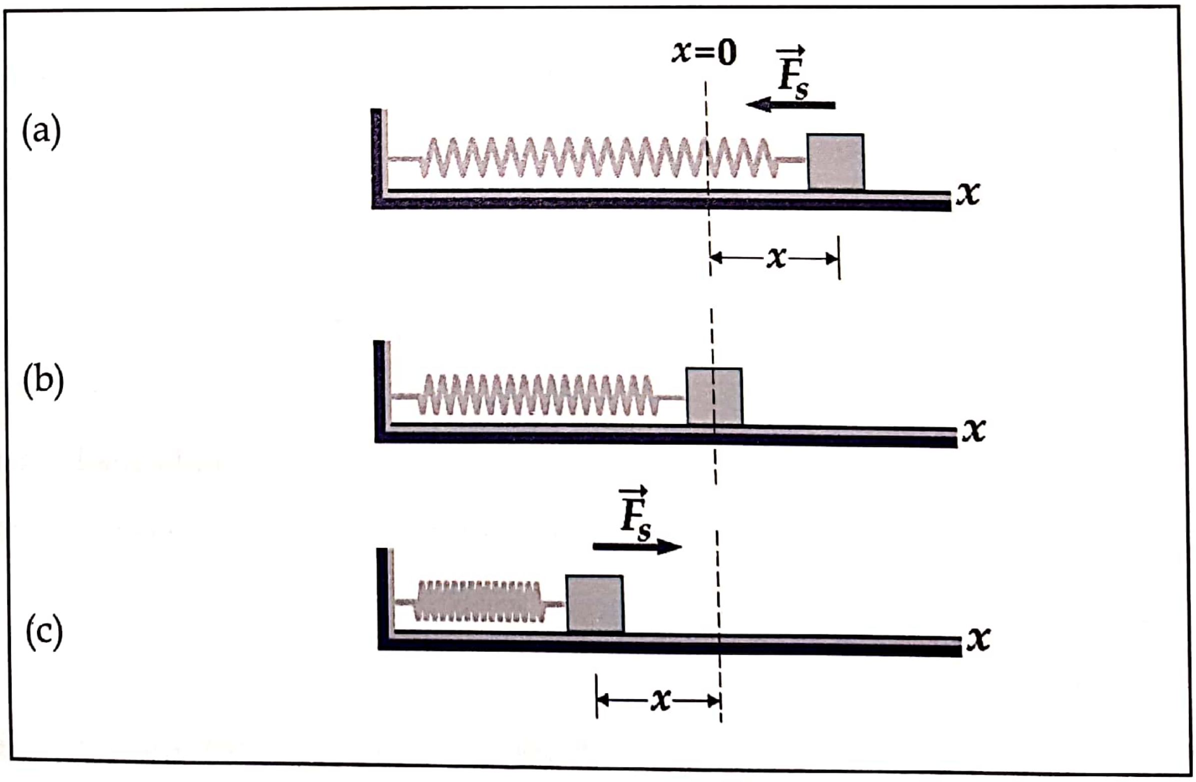

Figure 7.1: A block with mass m is attached to a horizontal spring. a) the spring is stretched a distance x from equilibrium, b) the spring is relaxed, and c) the spring is compressed a distance x from equilibrium.

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We call the position at which the spring is relaxed the "equilibrium position". If we stretch or compress the spring (while the block is attached to it) a distance x from its equilibrium position and release it, the spring-block system starts to *oscillate* about the equilibrium position. If we ignore friction and air resistance, the system will continue in its oscillatory motion forever. When we release the block, it will move under the action of the spring force (F_s) which tends to restore the spring to its equilibrium position. This force, also called a restoring force, is directly proportional to the displacement (x) of the block from the equilibrium position ($x = 0$) and is given by the well-known Hooke's law:

$$F_s = -k\,x \qquad (7.1)$$

The minus sign indicates that the force and the displacement are always in opposite directions.

Applying Newton's second law, we have

$$-kx = ma = m\frac{dv}{dt} = m\frac{d^2x}{dt^2} \qquad (7.2)$$

Equation 7.2 is the characteristic equation of simple harmonic motion: The acceleration $\vec{a}$ of a body in a simple harmonic motion is proportional to the displacement " $\vec{x}$ "and they have opposite directions.

Rearranging the above equation gives:

$$\frac{d^2x}{dt^2} + \frac{k}{m}x = 0\,. \qquad (7.3)$$

We define the angular frequency of this SHM by:

$$\omega = \sqrt{\frac{k}{m}} \qquad (7.4)$$

Equation 7.3 can be rewritten as:

$$\frac{d^2x}{dt^2} + \omega^2 x = 0\,. \qquad (7.5)$$

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This type of equation is of special interest in physics and is called *homogenous linear second order differential equation*. Its general solution is given by:

$$x(t) = A\cos(\omega t + \phi) \qquad (7.6)$$

where A and ϕ are two integration constants. $x(t)$ represents the position of the block at time t. It is clear that the position oscillates sinusoidally about the equilibrium position.

You can verify that the function $x(t)$ is a solution of Equation 7.5 by plugging it into the left-hand side of Equation 7.5 to check that it gives zero. The constant A is called the amplitude, which is the maximum displacement of the block from the equilibrium position. The angle ϕ is called the phase constant. The term $(\omega t + \phi)$ is called the phase of the simple harmonic motion. ϕ is zero if at $t = 0$ the displacement is maximum.

A plot of $x(t)$ versus t is shown in Figure 7.2 ($\phi = 0$) below.

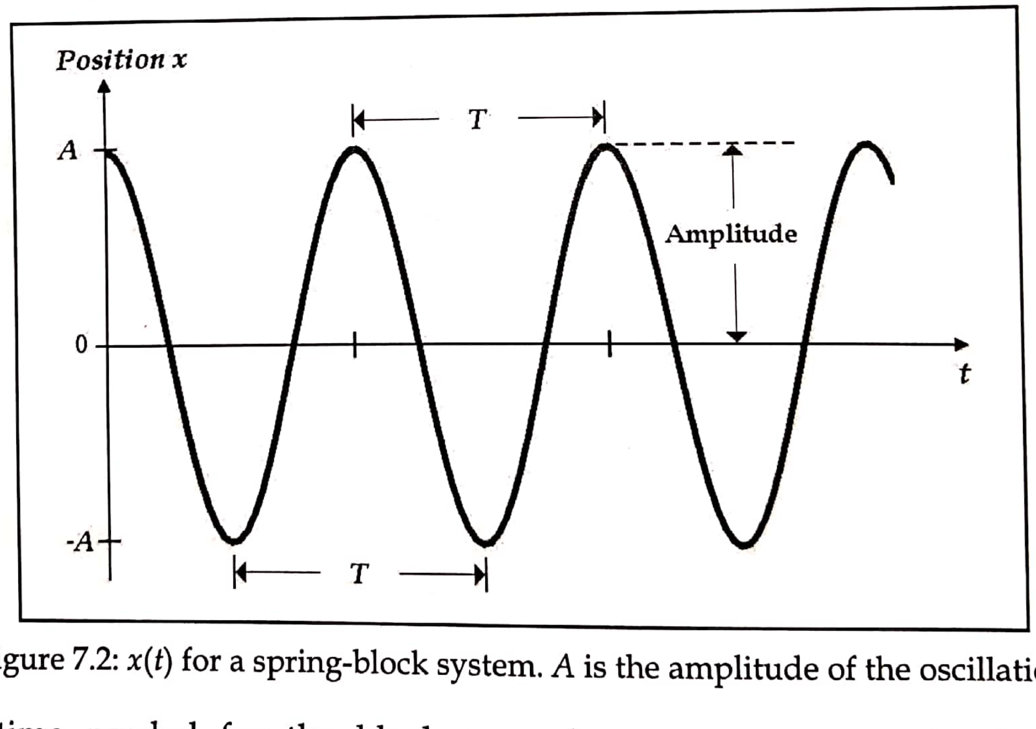

Figure 7.2: $x(t)$ for a spring-block system. A is the amplitude of the oscillation.

The time needed for the block to make one complete cycle (go from maximum compression to maximum stretching and then back to maximum compression) is called the *period* and is denoted by (T). The number of

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oscillations (complete cycles) that the block performs in one second is called the *frequency* and is denoted by (f). Obviously, $f = 1/T$.

f is related to ω by the following equation:

$$\omega = 2\pi f = 2\pi/T \qquad (7.6)$$

In MKS, the units of ω are *rad/s*.

Simple Harmonic Motion of a Simple Pendulum

The motion of a simple pendulum is another example of simple harmonic motion.

A simple pendulum consists of a mass m (also called the bob) that is attached to a string or to a massless rod of length L. The string or the massless rod is fastened to a frictionless pivot. When we displace the bob by an angle θ from the equilibrium position ($\theta = 0°$) and release it, the bob will start to oscillate (move back and forth) in the vertical plane about the equilibrium position, as illustrated in Figure 7.3.

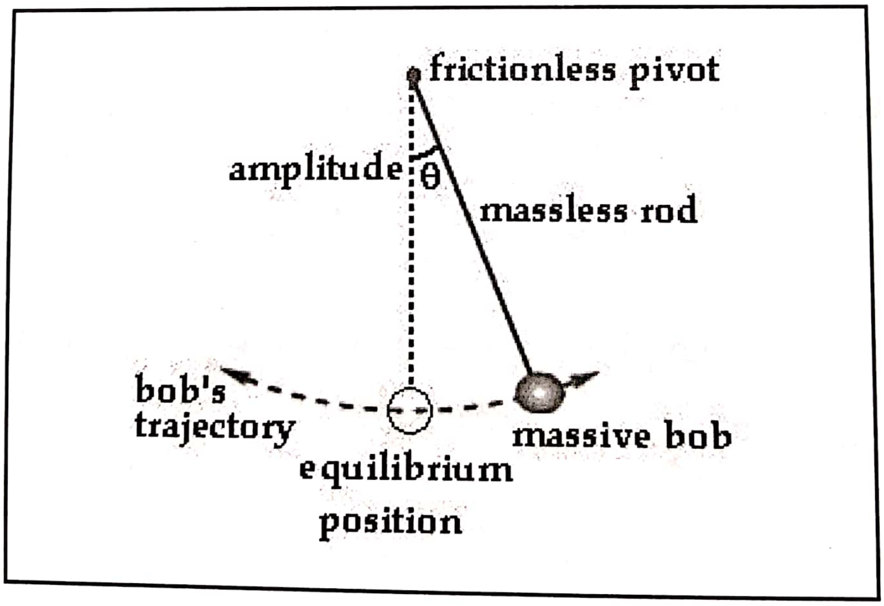

Figure 7.3: A simple pendulum.

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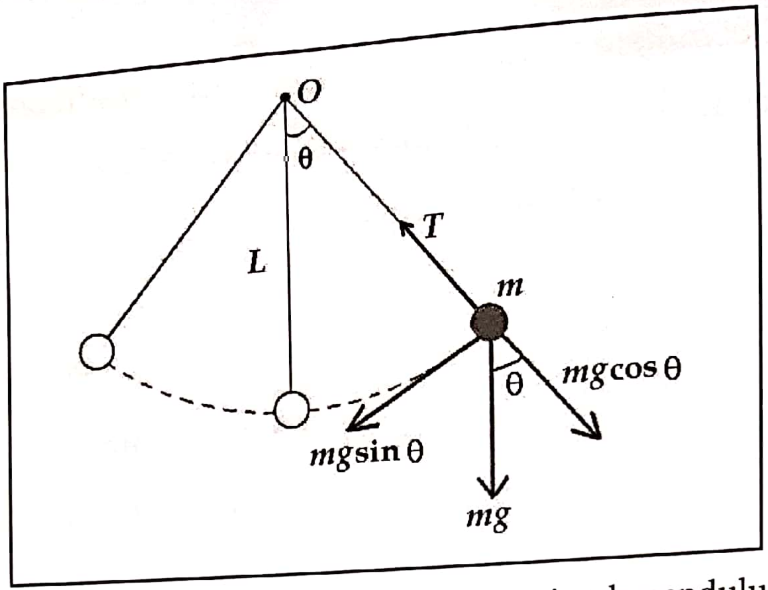

Figure 7.4: Analysis of forces acting on a simple pendulum.

When the bob is displaced by an angle θ, as shown in Figure 7.4, two forces act on it, namely, the tension in the string T and the weight mg. Applying Newton's second law along the tangential direction:

$$\sum F_t = m a_t \Rightarrow -m g \sin\theta = m\frac{d^2 s}{dt^2} \tag{7.7}$$

where s is the length of the arc subtended by the angle θ, and is given by:

$$s = L\theta ; \theta \text{ in radians.} \tag{7.8}$$

The first and second derivatives, ds/dt and d^2s/dt^2, are:

$$\frac{ds}{dt} = L\frac{d\theta}{dt}, \quad \frac{d^2 s}{dt^2} = L\frac{d^2\theta}{dt^2}. \tag{7.9}$$

If θ is small (*i.e.*, for small displacement of the pendulum), then $\sin\theta \approx \theta$. In this case Equation 7.7 can be rewritten as:

$$L\frac{d^2\theta}{dt^2} = -g\theta \tag{7.10}$$

Defining the constant $\omega = \sqrt{\frac{g}{L}}$, Equation 7.10 can be rewritten as follows:

$$\frac{d^2\theta}{dt^2} + \omega^2\theta = 0 \tag{7.11}$$

Equation 7.11 has the same form as Equation 7.5 above. Again this is a

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homogeneous linear second order differential equation and its solution is:

$$\theta(t) = \theta_0 \cos(\omega t + \phi) \quad (7.12)$$

where θ_0 and ϕ are two integration constants. $\theta(t)$ is the angular displacement of the pendulum from the equilibrium (vertical) position at time t. The constant ω is the angular frequency of oscillation.

You can verify that the function $\theta(t)$ is a solution of Equation 7.11 by plugging it into the left-hand side of Equation 7.11 to check that it gives zero.

Here θ_0 is the angular amplitude of the harmonic motion, $(\omega t + \phi)$ is the phase, and ϕ is the phase constant. ϕ is zero if at $t = 0$ the angular displacement is maximum.

The angular displacement θ varies with time, taking $\phi = 0$, as illustrated in Figure 7.5 below.

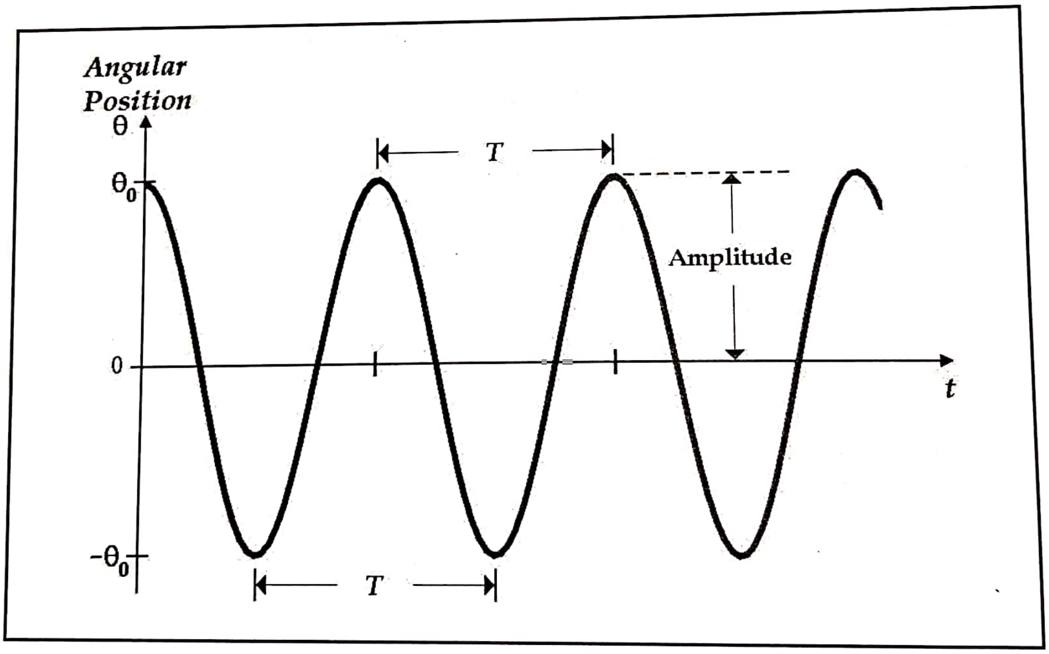

Figure 7.5: Angular displacement $\theta(t)$ for a simple pendulum.

The period, $T = 1/f = 2\pi/\omega$ is given by:

$$T = 2\pi\sqrt{\frac{L}{g}} \quad (7.14)$$

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Note that the period T does not depend on the pendulum's mass. It only depends on the length of the string and the acceleration due to gravity at the location of the experiment.

III. EQUIPMENT

- Simple pendulum apparatus
- Stopwatch
- Meter stick

IV. PROCEDURE

1. The length of the pendulum (L) is the distance between the point of support to the center of mass of the hanging bob. For the length in the first trial use a value L_1 (to be given to you by your instructor).
2. Now displace the bob by a small angle θ (not greater than 15°) and release it. Measure the time (t) required for 10 complete oscillations using the stopwatch. Record your measurement in Table 7.1 below.
3. Repeat step 2 above three more times.
4. Note: Make sure that the plane of oscillations remains fixed and vertical during the pendulum's motion, otherwise the motion is no longer simple harmonic.
5. Repeat steps 2 and 3 above for five more lengths, reducing the length L each time by 10 cm.

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Table 7.1

L = Length of pendulum $T^{(10)}$ = Average time for 10 cycles (s)							
L (m)	Trial 1	Trial 2	Trial 3	Trial 4	$\bar{T}^{(10)}$	$\bar{T} = \frac{\bar{T}^{(10)}}{10}$ (s)	$\bar{T}^2$ (s^2)
L_1 = 80×10^{-2}					18.25 s	1.82 s	3.31 s
L_2 = 65×10^{-2}					16.27	1.62 s	2.62 s
L_3 = 50×10^{-2}					14.21	1.42 s	2.01 s
L_4 = 35×10^{-2}					12 s	1.2 s	1.44 s
L_5 = 20×10^{-2}					9.07 s	0.9 s	0.81 s
L_6 = 5×10^{-2}					5 s	0.5 s	0.25 s

V. Data Analysis

In the following, for simplicity of notation, we will replace $\bar{T}$ and $\bar{T}^2$ by T and T^2, respectively.

1. Using the data in Table 7.1, make a plot of T (vertical axis) versus L (horizontal axis).

2. What type of relationship do you observe between T and L? Is it linear? Is it consistent with Equation 7.14?

   direct relationship between T and L. No it is not linear, yes it is consistent with $T = 2\pi\sqrt{\frac{L}{g}}$

3. Using the data presented in Table 7.1, make a plot of T^2 (vertical axis) versus L (horizontal axis).

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4. What type of relationship do you observe in the previous graph? Is it consistent with the theoretical predictions of Equation 7.14?

Linear relationship , yes it is consistent with the

$T^2 = \frac{4\pi^2}{g} L$

5. Draw the best-fit line for the data presented in the T^2 versus L graph.

6. What is the slope of the best fit line found in 5 obtained above?

0.04×10^2

7. What does this slope represent?

Slope $= \frac{T^2}{L} = \frac{4\pi^2}{g}$

8. Using the value of the slope that you obtained in 6, calculate the acceleration due to gravity (g) at the University of Jordan.

$g = \frac{4\pi^2}{slope} = \frac{4\pi^2}{0.04 \times 10^2} = \pi^2 = 9.87$ m/s^2 ✓

9. Calculate the percentage error in your experimentally found g.

$PE = \left| \frac{A - E}{A} \right| \times 100\% = \left| \frac{9.8 - 9.87}{9.8} \right| \times 100\%$

$P.E. = 0.7\ \%$

10. State and discuss three sources of error in this experiment.

① Personal errors

② Movment of pendulum

③ Angle of view

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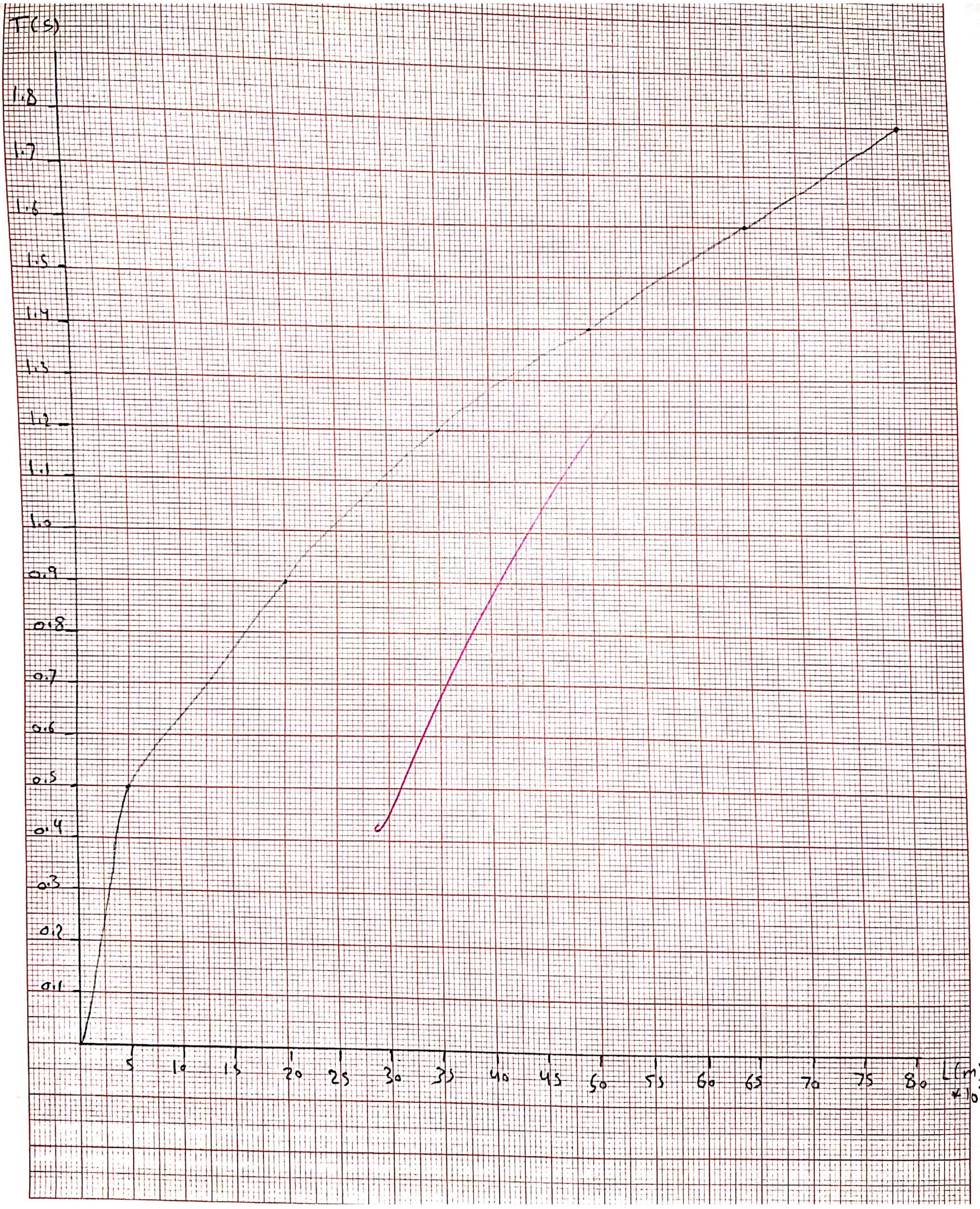

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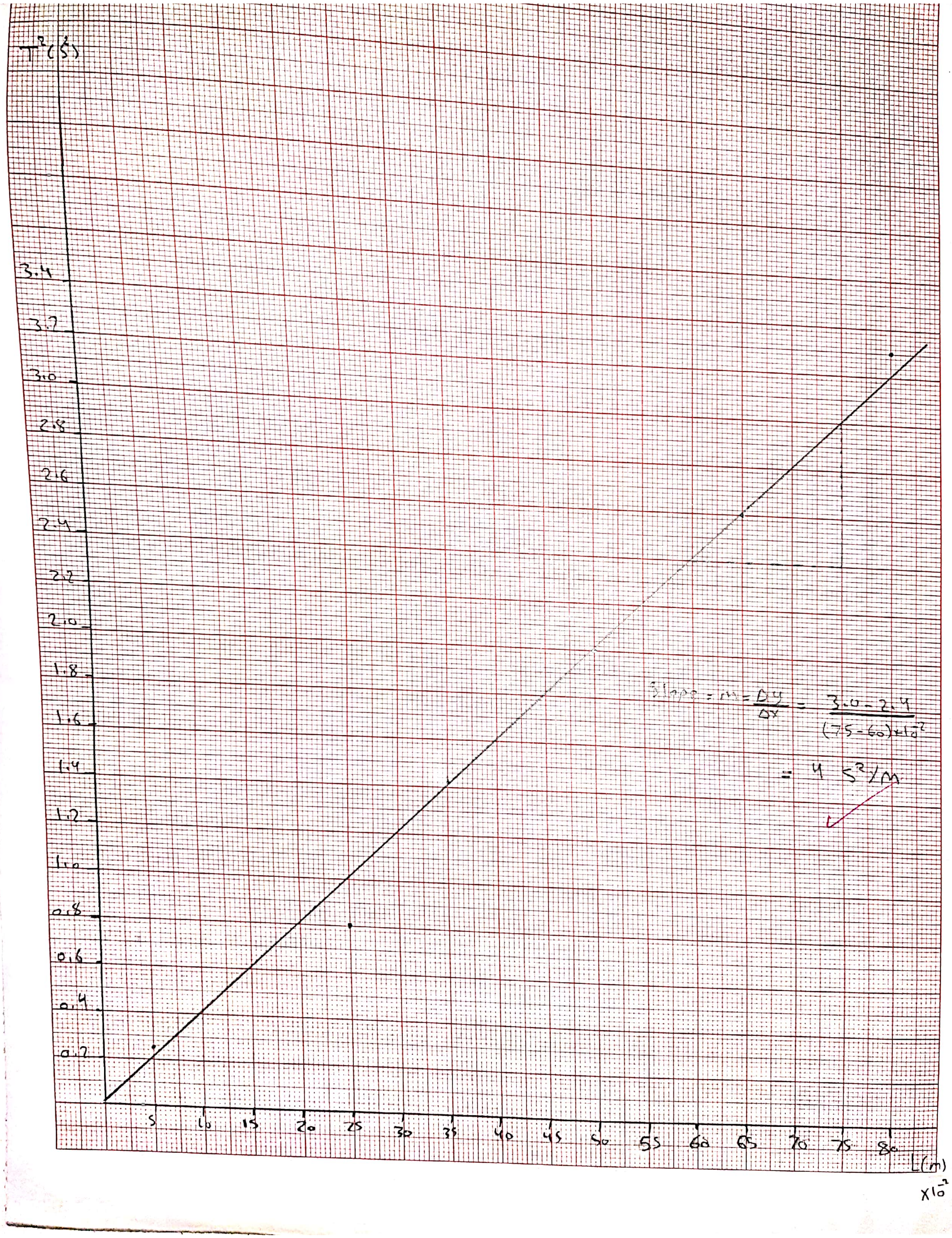

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EXPERIMENT 6

COLLISIONS IN ONE DIMENSION

(CONSERVATION OF LINEAR MOMENTUM)

LAB REPORT

8

Date ....3/4/2019...................

Name ..Khaled.....al-naser.........

Partner's Name ..IBrahim....ghesheh

Registration No.

Registration No.

Section ...14..................................

Instructor's Name ..Emam...Daas..

I. PURPOSE:

To study conservation of linear momentum and kinetic energy in elastic and inelastic collisions in one dimension.

II. INTRODUCTION - THEORETICAL BACKGROUND

The linear momentum and kinetic energy of a object or particle of mass m moving with velocity $\vec{v}$ are defined as follows:

$$\vec{p} = m\vec{v} \tag{6.1a}$$

$$K = \frac{1}{2}mv^2 = \frac{p^2}{2m} \tag{6.1b}$$

When two objects collide in the absence of external forces (or,

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equivalently, when the resultant external force is zero), then their *total momentum* is conserved. This means that the total initial momentum after collision is the same as that before collision:

$$\vec{p}_1 + \vec{p}_2 = \vec{p}_1' + \vec{p}_2' \quad (6.2)$$

or

$$m_1 \vec{v}_1 + m_2 \vec{v}_2 = m_1 \vec{v}_1' + m_2 \vec{v}_2' \quad (6.3)$$

where m_1 and m_2 are the masses, $\vec{v}_1$ and $\vec{v}_2$ are the velocities before collision, $\vec{v}_1'$ and $\vec{v}_2'$ are the velocities after collision.

If no kinetic energy is lost during the collision, then the collision is said to be elastic; otherwise it is inelastic. Therefore, in an elastic collision:

$$\left(\sum K\right)_{\text{before collisions}} = \left(\sum K\right)_{\text{after collisions}} \quad (6.4)$$

$$\frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 = \frac{1}{2} m_1 v_1'^2 + \frac{1}{2} m_2 v_2'^2 \quad (6.5)$$

The ratio

$$r = \left(\sum K\right)_{after} / \left(\sum K\right)_{before} \quad (6.6)$$

is called the rebound coefficient and is equal to 1 for elastic collisions.

Collisions in One Dimension

Figure 6.1 shows a collision between two objects in one dimension, with the masses and velocities as indicated.

a) Before collision b) After collision

Figure 6.1: One-dimensional elastic collision.

Generally the magnitudes of the initial velocities are known. Using equations 6.3 and 6.4, the final velocities can be found and we have:

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$$v_1' = \frac{m_1 - m_2}{m_1 + m_2} v_1 + \frac{2m_2}{m_1 + m_2} v_2$$
$$v_2' = \frac{2m_1}{m_1 + m_2} v_1 + \frac{m_2 - m_1}{m_1 + m_2} v_2 \qquad (6.7)$$

This experiment is divided in three parts, described below. The experimental setup consists of carts moving on a horizontal, frictionless (air) track. In part 1, we study an elastic collision of a cart with one of the fixed ends of the track. In parts 2 and 3, we study elastic and inelastic collisions between two carts.

The velocities are determined with the help of photogates installed at predefined positions along the track.

When a cart passes between the two arms of a photogate, a metal flag of width Δx attached to it blocks the infrared light beam. A digital counter registers the starting time of the blocking t and its duration Δt.

The velocity v of the cart at the location of the photogate can be approximated by:

$$v = \frac{\Delta x}{\Delta t} \qquad (6.8)$$

1. Elastic Collision with a Fixed Barrier

Here, you will investigate conservation of linear momentum and kinetic energy when a cart collides with the spring attached to one end of the track.

For the small cart speeds used in this experiment, the force acting on the track during the collision with the cart is not sufficient to overcome the static force of friction between the track and the surface under it. As a result, the track acts a fixed barrier and remains stationary relative to the surface under it after the collision.

Effectively, then, the track forms one system with Earth and its effective

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mass, m_2, in this case is the Earth's mass. Denoting the cart's mass by m_1, we have $m_1 << m_2$. Using Equations 6.6 with $m_1 << m_2$ and $v_2 = 0$, we get:

$$v_1' = -v_1 \ , \ v_2' = 0$$

that is, the cart bounces back with the same speed it had before the collision. Therefore, the collision is elastic. Note that the track-Earth system does exchange momentum with the cart, but the resulting velocity after collision, $2\ m_1\ v_1/m_2$, is extremely small and may be set to zero for all practical purposes.

Similarly, the cart does not bounce back with exactly the same speed as before collision, but the difference is so small they can be assumed exactly equal.

2. Elastic Collision Between Two Carts

In this part, you will allow two carts to collide elastically in one dimension. The first cart will have a fixed mass m_1 and initial nonzero velocity, while the second cart will have a variable mass m_2 and will initially be at rest. The two empty carts (without masses added to either) have equal masses. The mass of the second cart will be varied by adding extra weights to it. A spring attached to one cart on the end facing the other cart will ensure that the collision is elastic. You will measure the initial velocity of cart 1 and the final velocities of the two carts to verify conservation of linear momentum and kinetic energy.

3. Completely Inelastic Collision Between two Carts

In this part, you will allow two carts to collide completely inelastically in one dimension, by allowing them to stick together after collision. The first cart will have a fixed mass m_1 and initial nonzero velocity, while the second cart will have a variable mass m_2 and will initially be at rest. The mass of the second cart will be varied by adding extra weights to it.

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You will measure the initial velocity v of cart 1 and the final common velocity v' of the two carts to verify conservation of linear momentum. That is, you will be verifying whether the equation below holds:

$$m_1 v_1 = (m_1 + m_2)v' \qquad (6.9)$$

III. EQUIPMENT

Air track apparatus:

-Photogates -Timer -Air blower -A set of carts

In this experiment we will use the same air track system of experiment 5. It will be assembled and leveled by the laboratory technician. Please do not attempt any adjustments of the air track. If you have any concerns, please ask your instructor for assistance.

Make sure that each cart to be used has a vertical metallic flag installed at its center. The time taken by the flag to cross a photogate is used to calculate the velocity of the cart as it passes the photogate.

The operation of the air track system is controlled with the following buttons:

- START: starts the timer manually.
- STOP: stops the timer manually.
- RESET: resets the timer before starting a new count.
- SELECT: allows to select a photogate in order to read the time Δt taken by a cart to pass the photogate.

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IV. PROCEDURE – PART 1: ELASTIC COLLISION AGAINST A FIXED BARRIER

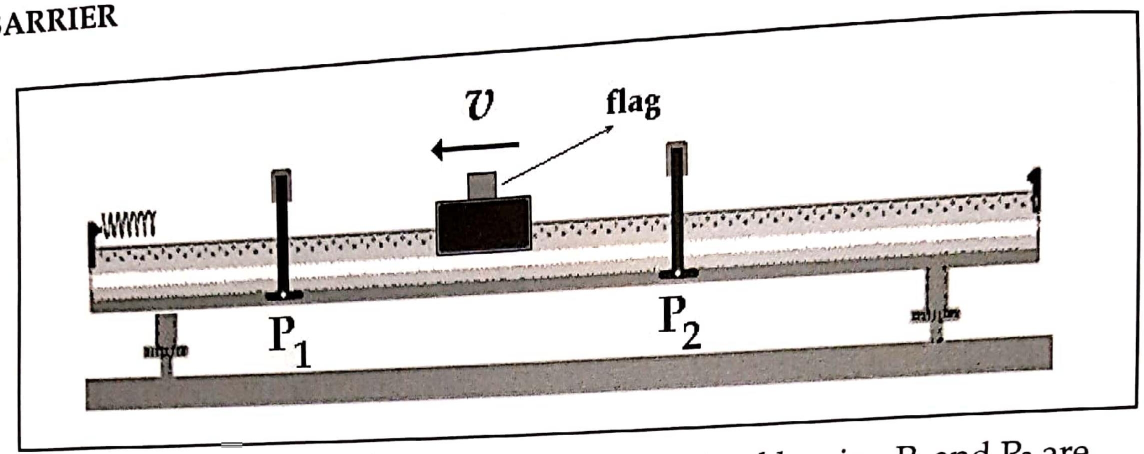

Figure 6.2: Elastic collision of cart 1 against a fixed barrier. P_1 and P_2 are photogates.

1. Measure the flag's width Δx for one of the carts to be used in this experiment, and record its value in the appropriate tables.
2. Connect photogate P_1 to a power outlet, and place it about 20 cm from the spring attached to the end of the track as in Figure 6.2.
3. Connect a second photogate P_2 to a power outlet, and place it about 40 cm from the spring.
4. Turn on the air blower.
5. Press the RESET button on the timer.
6. Place a cart between the two photogates on the track, immediately next to photogate 1.
7. Press the START button on the timer.
8. Push the cart towards photogate 1 and the spring.
9. After the cart passes both photogates, press the STOP button.
10. Press the SELECT button to read the times Δt_1 and Δt_2.
11. Record your readings from above in Table 6.1.
12. Repeat steps 5 through 11 two more times, each time adding an additional mass (the value of which will be provided by your instructor) to the cart.

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V_1 , V_2' من الجهاز
V_1' من المعادلة

V. DATA ANALYSIS – PART 1

1. Calculate the initial and final velocities of the cart, $v_1 = \Delta x/\Delta t_1$ and $v_1' = \Delta x/\Delta t_2$. Record your results in Table 6.1.

2. the rebound coefficient $r = \frac{|v_1'|}{|v_1|}$. Record your results in Table 6.1.

Table 6.1

Δx = ..4.......... cm

Mass of cart (g)	Δt_1 (s)	Δt_2 (s)	v_1 (cm/s) $\frac{\Delta x}{\Delta t_1}$	v_1' (cm/s) $\frac{\Delta x}{\Delta t_2}$	$r = \frac{\lvert v_1' \rvert}{\lvert v_1 \rvert}$
100 g	0.058	0.059	69	67.8	0.983
125 g	0.074	0.075	54	53.3	0.987
150 g	0.127	0.129	31.5	31	0.984

3. Answer the following:

If r = 1 this means that

...the...velocity.......before....and after....collisions..............

.......are....equal...(elastic....collision).:...............................

If r< 1 this means that

.......the....velocity.........before....the....collision.........is.........

........greater...than....the....velocity.....after......the..collision..

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VI. PROCEDURE – PART 2: ELASTIC COLLISION BETWEEN TWO CARTS

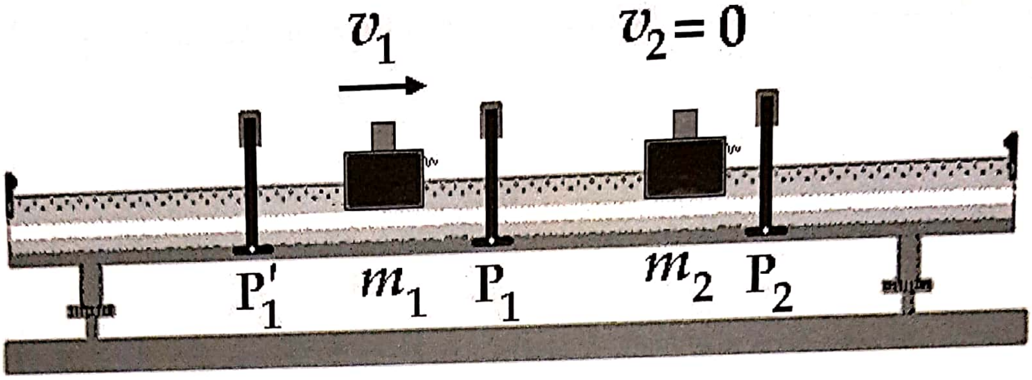

Figure 6.3: Elastic collision between two carts.

1. Place photogates P_1, P_2, P'_1 at approximately 20 cm, 40 cm, and 60 cm, respectively, from the left end of the track. Do not change their positions during this part.
2. Turn on the air blower.
3. Record the mass m_1 of cart 1 in Tables 6.2., 6.3, and 6.4.
   During this part, m_1 is kept fixed.
4. Place cart 1 on the track, between photogates P_1 and P'_1.
5. Record the mass m_2 of cart 2 in Tables 6.2., 6.3, and 6.4.
   Place cart 2 on the track between photogates P_1 and P_2.
   Make sure it is at rest.
6. Press the RESET button on the timer.
7. Press the START button on the timer.
8. With cart 2 at rest, push cart 1 toward it.
9. After cart 1 has passed through photogate P_1' and cart 2 has passed photogate P_2, press the STOP button on the timer.
10. Press the SELECT button on the timer to obtain Δt_1, Δt_2, and $\Delta t'_1$ from photogates P_1, P_2, and P'_1, respectively.
    Record the readings in Table 6.2.
11. Repeat steps 4 through 10 three more times, each time increasing the mass of cart 2 by an amount determined by your instructor.

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VII. DATA ANALYSIS – PART 2

1. Calculate the initial and final velocities of the two carts (initial velocity of cart 2 is zero) and record the results in Table 6.2.

Table 6.2

m_1 = ...150.......... g $\qquad$ $v_2 = 0$

	Before collision		After collision (من القانون)			
m_2 (g)	Δt_1 (s)	v_1 (cm/s)	$\Delta t'_1$ (s)	v'_1 (cm/s)	Δt_2 (s)	v'_2 (cm/s)
100	0.148	27		7.4	0.136	29.4
125	0.074	54		7.08	0.071	56.3
150	0.117	22.6		-7.9	0.131	30.5
200	0.097	41.2		-4.8	0.116	34.5

In the following,

- p_i, K_i are the initial momentum and kinetic energy of cart i (i=1,2).
- p'_i, K'_i are the final momentum and kinetic energy of cart i.
- $p_{tot} = p_1 + p_2$ and $K_{tot} = K_1 + K_2$ are the total initial momentum and kinetic energy.
- $p'_{tot} = p'_1 + p'_2$ and $K'_{tot} = K'_1 + K'_2$ are the total final momentum and kinetic energy.

2. Calculate the following and record the results in Table 6.3.
   - p_1, p_2, p'_1, and p'_2
   - p_{tot} and p'_{tot}.

3. Calculate the following and record the results in Table 6.4.
   - K_1, K_2, K'_1, and K'_2
   - K_{tot} and K'_{tot}

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Table 6.3

$v_2 = 0$

$m_1 =$ 150 g

m_2 (g)	p_1 (g cm/s)	p_2 (g cm/s)	p'_1 (g cm/s)	p'_2 (g cm/s)	p_{tot} (g cm/s)	p'_{tot} (g cm/s)	$\frac{\lvert p'_{tot} - p_{tot}\rvert}{p_{tot}} \times 100\%$
					4050	4050	0 %
100	4050	0	1110	2940	8100	8100	0 %
125	8100	0	1062	7037.5	3390	3390	0 %
150	3390	0	-1185	4575	6180	6180	0 %
200	6180	0	-720	6900			

Table 6.4

m_2 (g)	K_1 (erg)	K_2 (erg)	K'_1 (erg)	K'_2 (erg)	K_{tot} (erg)	K'_{tot} (erg)	$r = \frac{K'_{tot}}{K_{tot}}$
100	54675	0	2738	43218	54675	45956	0.84
125	218700	0	3133	198105.6	218700	201238.6	0.92
150	38307	0	468.75	69768.7	38307	74449.4	1.94
200	127308	0	2304	119025	127308	121329	0.953

1 erg = 1 dyne. 1 cm = 10^{-5} N 10^{-2} m = 10^{-7} J

4. Within experimental error, was linear momentum conserved in each of the four collisions? Hint: Use the last column in Table 6.3.

yes, because experimental error is zero

5. For each of the four collisions, was kinetic energy, within experimental error, conserved (*i.e.* was the collision elastic)? Justify your answer. Hint: Use the last column in Table 6.4.

yes it was, the value of r close to 1 (elastic collision).

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VIII. PROCEDURE – PART 3: INELASTIC COLLISION

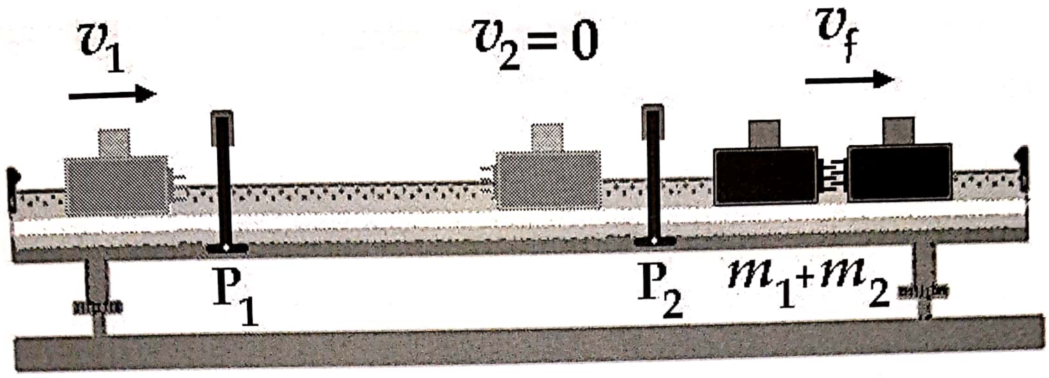

Figure 6.4: Completely inelastic collision between two carts.

1. Place photogates P_1 and P_2 at approximately 20 cm and 40 cm, respectively, from the left end of the track. See Figure 6.4 above. Do not change their positions during this part.
2. Turn on the air blower.
3. Record the mass m_1 of cart 1 in Tables 6.5 and 6.6.
   During this part, m_1 is kept fixed.
4. Place cart 1 on the track, to the left of photogate P_1.
5. Record the mass m_2 of cart 2 in Tables 6.5 and 6.6.
   Place cart 2 on the track between photogates P_1 and P_2.
   Make sure it is at rest.
6. Press the RESET button on the timer.
7. Press the START button on the timer.
8. With cart 2 at rest, push cart 1 toward it.
9. After the two carts stick together and pass photogate 2, press the STOP button.
10. Press the SELECT button on the timer to obtain Δt_1 and Δt_2 from photogates P_1 and P_2, respectively.
    Record the results in Table 6.5.
11. Repeat steps 4 through 10 three more times, each time increasing the mass of cart 2 by an amount determined by your instructor.

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IX. DATA ANALYSIS – PART 3

1. Calculate the initial and final velocities, v and v', respectively, and record the results in Table 6.5.

   In the following:

- p and K are the initial momentum and kinetic energy of cart 1. Since cart 2 is initially at rest they are equal to the total initial momentum and kinetic energy of the system.
- p' and K' are the final momentum and kinetic energy of the system composed of cart 1 and cart 2 stuck together.

2. Calculate p and K and record the results in Table 6.5.
3. Calculate p' and K' and record the results in Table 6.6.

Table 6.5

m_1 = ...15.0.......... g $\qquad$ $v_2 = 0$

m_2 (g)	Δt_1 (s)	v_1 (cm/s)	Δt_2 (s)	v' (cm/s)	p (g cm/s)	p' (g cm/s)	$\frac{\lvert p'_{tot} - p_{tot} \rvert}{p_{tot}} \times 100\%$
100	0.076	52.63	0.129	31	7894.5	3100	60.7 %
125	0.115	34.78	0.212	18.86	5217	2357.5	54.8 %
150	0.140	28.57	0.285	14	4285.5	2100	51 %
200	0.107	37.4	0.265	15.1	5607	3020	46.1 %

Table 6.6

m_2 (g)	K (erg)	K' (erg)	$r = \frac{K'}{K}$
100	138495.8	48050	0.35
125	75603	22231.2	0.3
150	61218.3	14700	0.24
200	139876	22801	0.16

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4. Within experimental error, was linear momentum conserved in each of the four collisions? Justify your answer.

   Hint: Use the last column in Table 6.5.

   .....yes...it was....because....the....linear...momentum.......
   ....is.....conserved.....within.....experimantal....error........
   ....which....is....small...
   ....

5. For each of the four collisions, was kinetic energy conserved (*i.e.* was the collision elastic) within experimental error? Justify your answer.

   Hint: Use the last column in Table 6.6.

   ....yes....because.......r.sl.......b....kinetic....energy.....is.......
   ....not....conserved.......and.......it.....is.......inelastic.............
   ....collision...
   ....

6. State and discuss three sources of error in this experiment.

   ....1)..personal....errors...
   ....2).....mistakes......by...usingtools..............................
   ....3)....calculation....errors.....................................
   ....

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EXPERIMENT 8

BALLISTIC PENDULUM

10

LAB REPORT

Date ..10/4/2019..................

Name ..Khaled....al-Naser........ Partner's Name .IBrahim..ghosheh

Registration No. . Registration No.

Section ......14........................ Instructor's Name Eman...Dahir..

I. PURPOSE:

To investigate the principles of conservation of mechanical energy and linear momentum as they apply to a spring-ball system and a ball-ballistic-pendulum systems.

II. INTRODUCTION - THEORETICAL BACKGROUND

An isolated mechanical system is one that does not interact with its environment. Conservation of the total energy and the total linear momentum of an isolated system are two fundamental conservation laws in physics. These laws, together with the law of conservation of angular momentum in rotational motion of isolated systems, play an important role in physics and are widely used to explain many phenomena.

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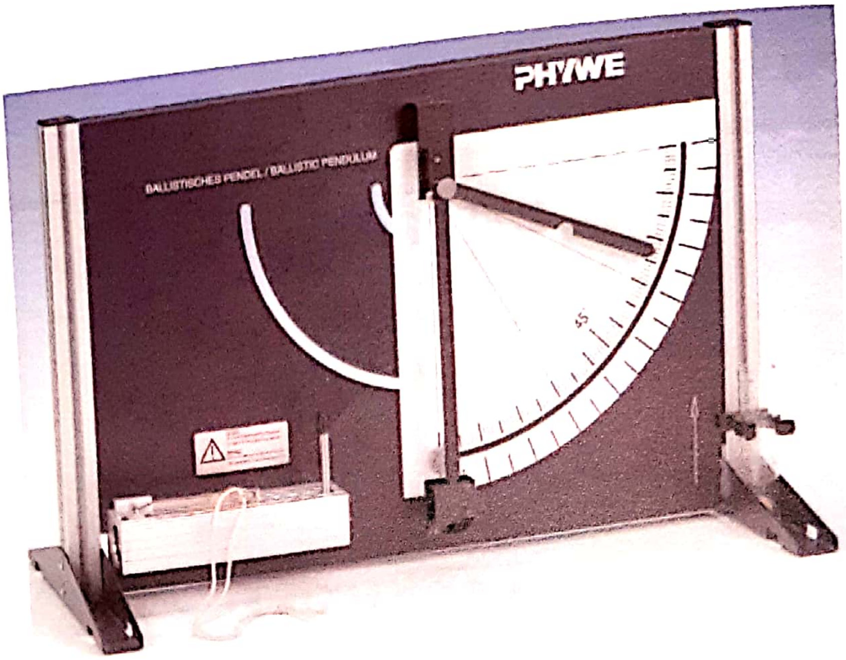

Figure 8.1: Ballistic Pendulum apparatus

The Ballistic Pendulum apparatus

The ballistic pendulum apparatus used in this experiment is shown in Figure 8.1 above.

It consists of the following main components:

1. Ballistic unit: it has the following components:
   - A spring (housed inside the unit) that can be compressed by three different distances: $x_1 = 2.0$ cm, $x_2 = 3.5$ cm, and $x_3 = 5.0$ cm.
   - A tension lever, which can be used to lock the spring in the desired compressed position.
   - A trigger arm, which can be pulled by the ring attached at its end to trigger the shot.
   - A magnet which can hold steel balls provided with the apparatus.
2. A ballistic pendulum, composed of a rigid metallic rod with a catcher at the bottom. The catcher has a conical aperture through which a steel ball ejected by the spring gun can enter. The catcher is provided with a screw which can be used to add additional masses to it.
3. A *trailing* pointer for indicating the angular displacements of the pendulum.

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4. An angle scale which can be used to read the angular position of the pointer.

The spring has a magnet which can be used to hold a steel ball of mass m. When the spring-ball system is compressed by a distance x, elastic potential energy stored in the system is $U_s = \frac{1}{2}kx^2$, where k is the spring constant.

When the gun is fired, the ball exits the gun with horizontal velocity v and collides with the catcher. The ball is embedded in the catcher forming a new system. As a result of the collision, the ball+catcher swings by an angle θ, as illustrated in Figure 8.2 below.

The mechanical energy of the spring-ball system is conserved because it can be considered be an isolated system. Therefore the elastic potential energy, U_S, initially stored in the spring-ball system is converted to kinetic energy K of the ball as it exits the gun with speed v. That is:

$$U_s = K \Rightarrow \frac{1}{2}kx^2 = \frac{1}{2}mv^2 \qquad (8.1)$$

Thus

$$v = \sqrt{\frac{k}{m}}\,x \qquad (8.2)$$

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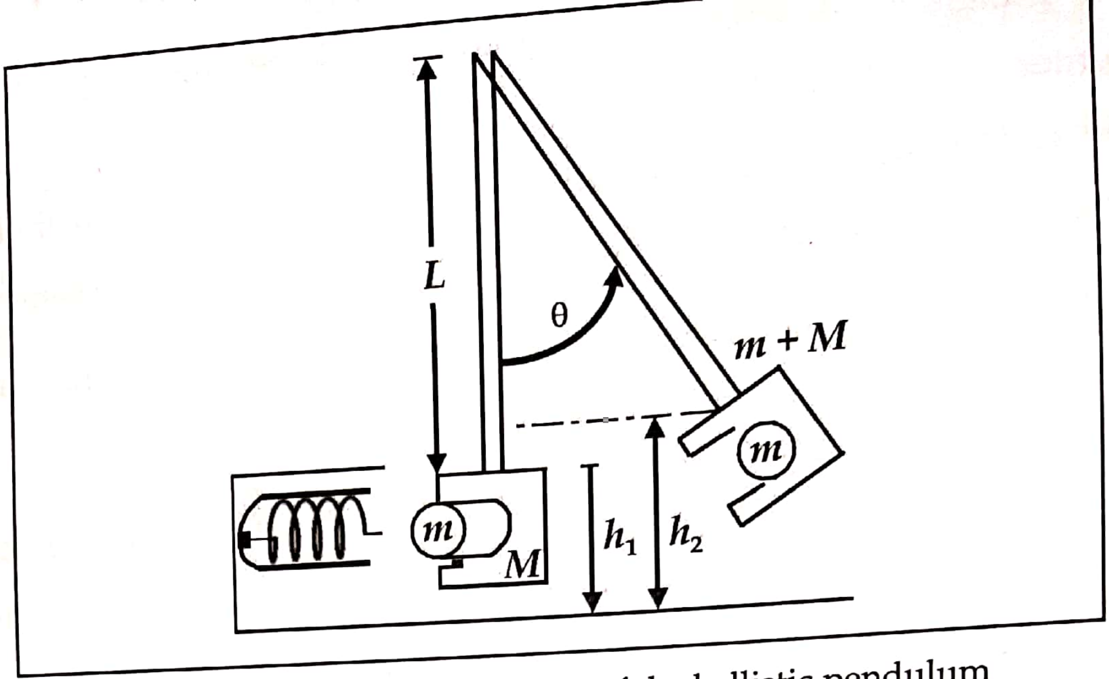

Figure 8.2: Variables of the motion of the ballistic pendulum

Let us denote the mass of the catcher and any added mass (m_a) as:

$$M_{tot} = M + m_a \tag{8.3}$$

Immediately after the collision, the ball+catcher move with velocity V, which can be determined using the law of conservation of total linear momentum:

$$mv = (m+M_{tot})V \tag{8.4}$$

From which we get

$$V = \frac{m}{m+M_{tot}}v \tag{8.5}$$

Neglecting friction and air resistance, the ball+catcher system is acted upon by two forces, namely, the gravitational force $(m + M_{tot})\,g$ and the tension T in the rod.

The tension does zero work on the pendulum as it is perpendicular to the direction of the displacement. Thus, here, only the gravitational force, which is a conservative force, does work. Consequently, the mechanical energy of the ball+catcher, *i.e.* the sum of kinetic energy K and gravitational potential energy U is conserved.

If K_i and U_i are the initial kinetic and potential energies, respectively, and K_f

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and U_f are their final values, then we have:

$$K_i + U_i = K_f + U_f \tag{8.6}$$

If we set the gravitational potential energy of the pendulum (U) at its initial position to zero (*i.e.* $U_i = 0$), then U_f at the highest point of the displacement (where the velocity is zero) is given by:

$$U_f = (m + M_{tot}) g \Delta h \tag{8.7}$$

where $\Delta h = h_2 - h_1$, is the maximum height to which the center of gravity of the ball+catcher rises (see Figure 8.2).

Equation 8.6 can be written as:

$$\frac{1}{2}(m + M_{tot})V^2 + 0 = 0 + (m + M_{tot}) g \Delta h \tag{8.8}$$

Dividing both sides in Equation 8.8 by $(m + M_{tot})$ we have:

$$\frac{1}{2}V^2 = g \Delta h \tag{8.9}$$

Defining θ as in Figure 8.2 we have $\cos\theta = \frac{L - \Delta h}{L} = 1 - \frac{\Delta h}{L}$ and

$$\Delta h = L(1 - \cos\theta) \tag{8.10}$$

where L is the length of the pendulum. Equation 8.9 can now be rewritten as

$$\frac{1}{2}V^2 = gL(1 - \cos\theta) \tag{8.11}$$

and we have:

$$V = \sqrt{2gL(1 - \cos\theta)} \tag{8.12}$$

Using Equation 8.5, we can calculate the velocity v:

$$v = \frac{m + M_{tot}}{m}\sqrt{2gL(1 - \cos\theta)} \tag{8.13}$$

We can rearrange the previous equation (a form adapted to the procedure) as follows:

$$1 - \cos\theta = \frac{v^2}{2gL}\left(\frac{m}{m + M_{tot}}\right)^2 \tag{8.14}$$

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III. Procedure

Part 1:

1. Calculate the magnitude of the exit velocity for each compression distance x of the spring using Equation 8.2 and fill in Table 8.1

Part 2:

1. With the tension lever at its rightmost position (*i.e.*, with the spring uncompressed), affix the steel ball to the holding magnet as in Figure 8.3 A below.
2. Pull the tension lever back until the second lock-in position has been reached.
3. Ensure that the pendulum is at rest and that the pointer points to zero.

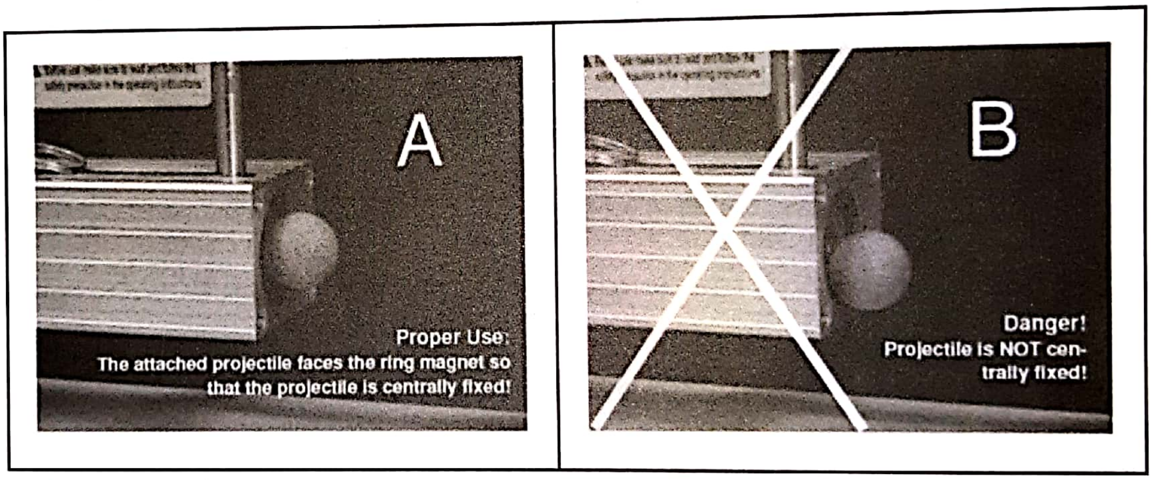

Figure 8.3: Proper and improper affixing of the steel ball to the magnet*.

* http://repository.phywe.de/files/bedanl.pdf/11229.00/e/1122900e.pdf

4. Trigger the shot by pulling the trigger lever.
5. In order to minimize the effect of friction between the trialing pointer and its point of support, you may repeat this step two or three times without resetting the trailing pointer. When the trailing pointer is not moved any further, one can assume that the indicated angle is not affected by friction.

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6. Read the maximum angular displacement θ made by the pendulum from the angular position of the pointer. Record in Table 8.2 below.
7. Reset the trailing pointer to zero, and repeat steps 1 to 5 five more times, each time adding a 10-g mass to the pendulum using the screw at the bottom. The total added mass is denoted by m_a. Make sure that you always compress the spring to the second lock-in position.

IV. Data Analysis

Part 1: Calculation of the magnitude of exit velocities of the steel ball for the three possible tension energies.

1. Using Equation 8.2, calculate the magnitude of exit velocity of the ball at the three settings and record your calculations in Table 8.1 below.

Table 8.1

$k = 750$ N/m $m = 35 \pm 0.01$ g (28) $V = \sqrt{\frac{k}{m}}\, x$

x(m)	x^2(m²)	kx^2 (N.m)	v (m/s)
0.020	4×10^{-4}	0.3	3.273
0.035	1.225×10^{-3}	0.918	5.73
0.050	2.5×10^{-3}	1.875	6.28

Part 2:

1. Using the data you obtained in part 2 of the experimental procedure, fill in Table 8.2 below:

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Table 8.2

$M = \sout{85}$ 95 ± 0.01 g $L = 24.00 \pm 0.05$ cm

m_a (kg)	θ (degrees)	(1 – cosθ)	$M_{tot}+m$ (kg)	$M_{tot} = M + m_a$ (kg)	$[m/(M_{tot}+m)]^2$
0	37°	0.201	0.123	0.095	0.05
0.01	30°	0.134	0.133	0.105	0.044
0.02	27°	0.11	0.143	0.115	0.038
0.03	25°	0.09	0.153	0.125	0.033
0.04	23°	0.08	0.163	0.135	0.029
0.05					

2. Once you have filled Table 8.2, plot on a linear graph paper (1 - cos θ) versus $[m/(m + M_{tot})]^2$.

3. Draw the best fit line through your data points and compute its slope.

Slope = m = $\frac{\Delta y}{\Delta x}$ = $\frac{(17-14)\times10^{-2}}{(45-40)\times10^{-3}}$ = 6 kg⁻¹

4. What does this slope represent? What is its unit?

The slope represents $\frac{V^2}{2gL}$ no unit

5. Calculate g, the acceleration due to gravity, using the slope you obtained in 3 above.

Slope = $\frac{V^2}{2gL}$

$6 = \frac{(5.73)^2}{2g \times 24\times10^{-2}}$ = 11.4 m/s²

6. State and discuss three sources of error in this experiment.

1) personal error

2) experimental error

3) Calculations error

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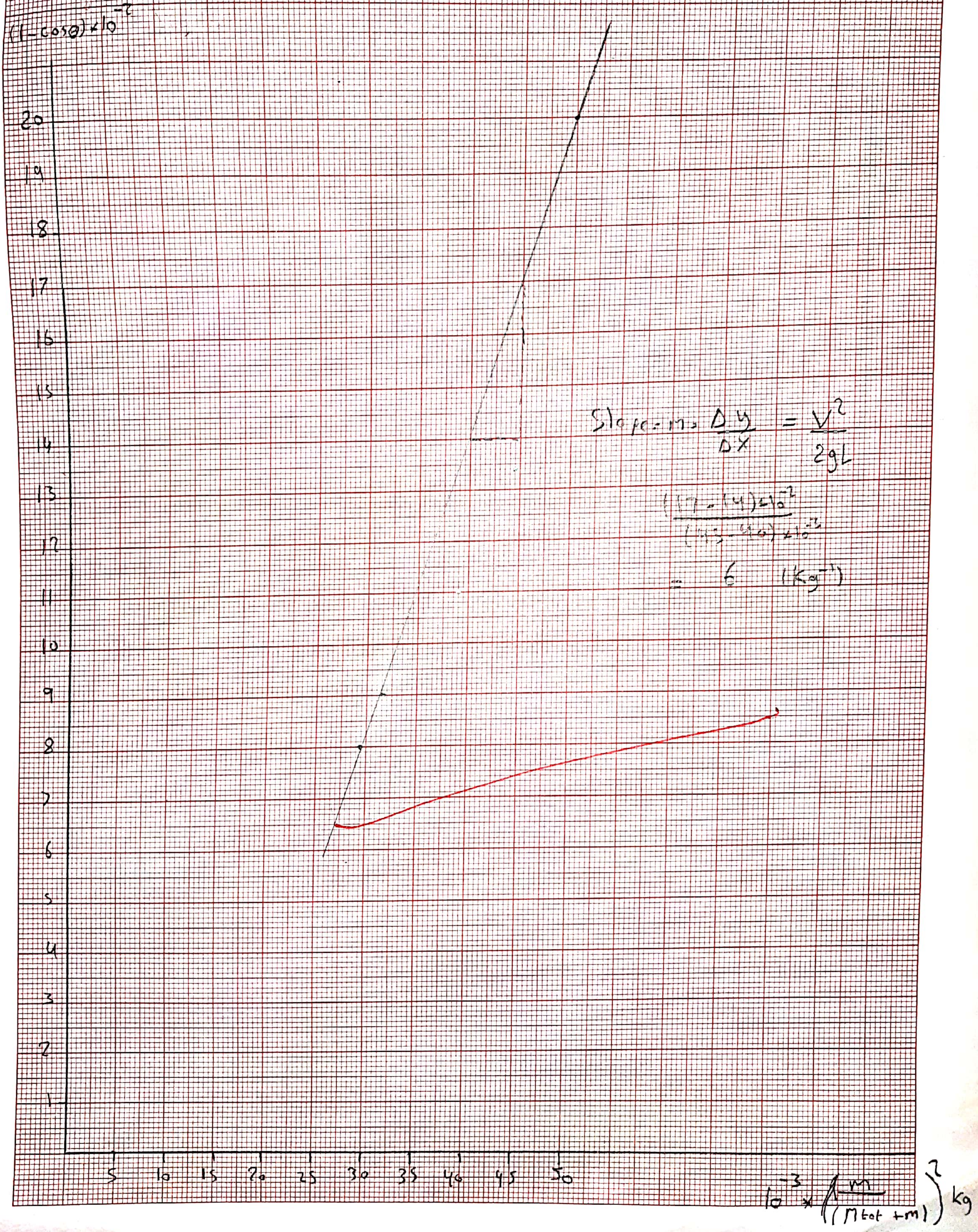
(1 - cosθ) × 10^-2
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
5
10
15
20
25
30
35
40
45
50
10^-3 × (m / (Mtot + m))^2 kg
Slope = m = Δy / Δx = V^2 / 2gL
((17 - 14) × 10^-2) / ((45 - 40) × 10^-2)
= 6 (Kg^-1)

LAB REPORT FOR EXPERIMENT 7

Date: ------------------------------

Name:------------------------------ Partner's Name:--------------

Registration No:-------------- Registration No:--------------

Physics Section:-------------- Instructor's Name:-----------

PHYSICS LAB EXPERIMENT 7: ROTATIONAL MOTION

I. PURPOSE :

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II. DATA AND DATA ANALYSIS :

A. Acceleration and Moment of Inertia with Constant Applied Torque.

1. Enter your computed data of v versus t in Table 7.1 shown below:

Table 7.1

	Added mass to the turntable					
	M = 0 g		M = 100 g		M = 200 g	
Time (s)	v cm/s	ω = v/R rad/s	v cm/s	ω = v/R rad/s	v cm/s	ω = v/R rad/s
0.05	20	1.7	14	1.2	11	0.9
0.15	28	2.3	25	2.1	20	1.7
0.25	41	3.4	35	2.9	28	2.3
0.35	52	4.3	41	3.4	38	3.2
0.45	65	5.4	54	4.5	47	3.9
0.55	75	6.3	64	5.3	55	4.6
0.65	90	7.5	74	6.2	62	5.2
Radius of the turntable (R) = 12 cm						

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2. For each value of the added mass, plot a graph of ω versus t. Plot them all on the **same sheet of graph paper**. Label each graph with the corresponding value of the added mass for identification.

3. What conclusions can you draw from your graphs about the angular acceleration of the empty and loaded turntable under a constant applied torque?

The slope of the graph represents the angular Acceleration (α)

4. From your graphs determine the angular acceleration (α) of the turntable in each case, and enter your data in Table 7.2 below:

Table 7.2

$I = \overset{50}{m} \underset{17}{R} \left(\frac{\overset{980}{g}}{\alpha} - R \right)$

Added mass M (g)	Angular Acceleration α (rad/s²)	Moment of Ineria I (g .cm²)
0	9.2	56713
100	8.3	63643.4
200	7.5	71200

5. Calculate the moment of inertia (I) of the turntable with and without the added masses using the following equation:

$$I = mR\left(\frac{g}{\alpha} - R\right)$$

where m is the mass of the falling weight and R is the radius of the turning wheel

6. From your table, how does the moment of inertia of the turntable (I) changes with the added mass?

It increases when the added mass increase So it is a direct relation between them

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Acceleration and Torque with Constant Moment of Inertia :

1. Compute the translational and angular velocities v and ω, for each recorded tape, and enter your data in Table 7.3 below:

Table 7.3

	Total Hanging Mass					
	m = 50 g		m = 100 g		m = 150 g	
Time (s)	v cm/s	ω = v/R rad/s	v cm/s	ω = v/R rad/s	v cm/s	ω = v/R rad/s
0.05	20	1.7	23	1.9	27	2.25
0.15	28	2.3	42	3.5	58	4.8
0.25	41	3.4	66	5.5	90	7.5
0.35	52	4.3	88	7.3	120	10
0.45	65	5.4	111	9.3	152	12.7
0.55	75	6.3	134	11.2	180	15
0.65	90	7.5	157	13.1	210	17.5

2. Use Table 7.3 to plot, on the **same sheet of paper**, the graphs of ω versus **t.**

3. What do you conclude from your graphs?

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4. Determine the angular acceleration (α) in each case.

5. Enter your results in Table 7.4 below:

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Table (7.4)

Total Hanging Mass m (g)	Angular Acceleration α (rad/s 2)	Torque (τ) = Rm(g-αR) (dyne.cm)
50	9.2	521760
100	20	888000
150	25	1224000

6. Plot a graph of (τ) the **applied torque** against **angular acceleration** (α).

7. What do you conclude from your graph?

the slope = I

8. Determine the moment of inertia of the empty turntable.

I = 0.6 x 10^5

9. Do the values obtained in part A & part B for the moment of inertia of the empty turntable (I_o) agree ?

yes. it's agree

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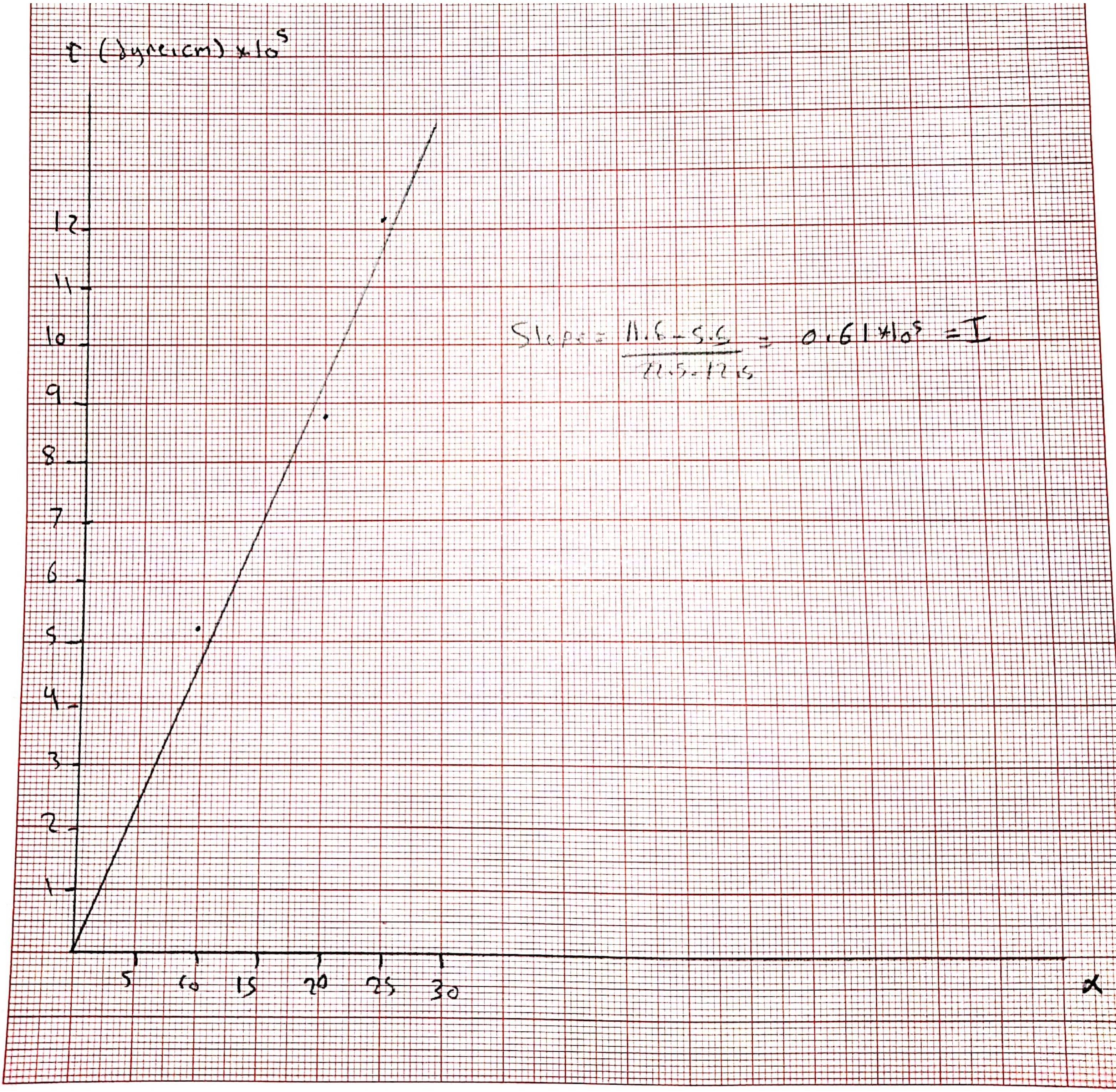

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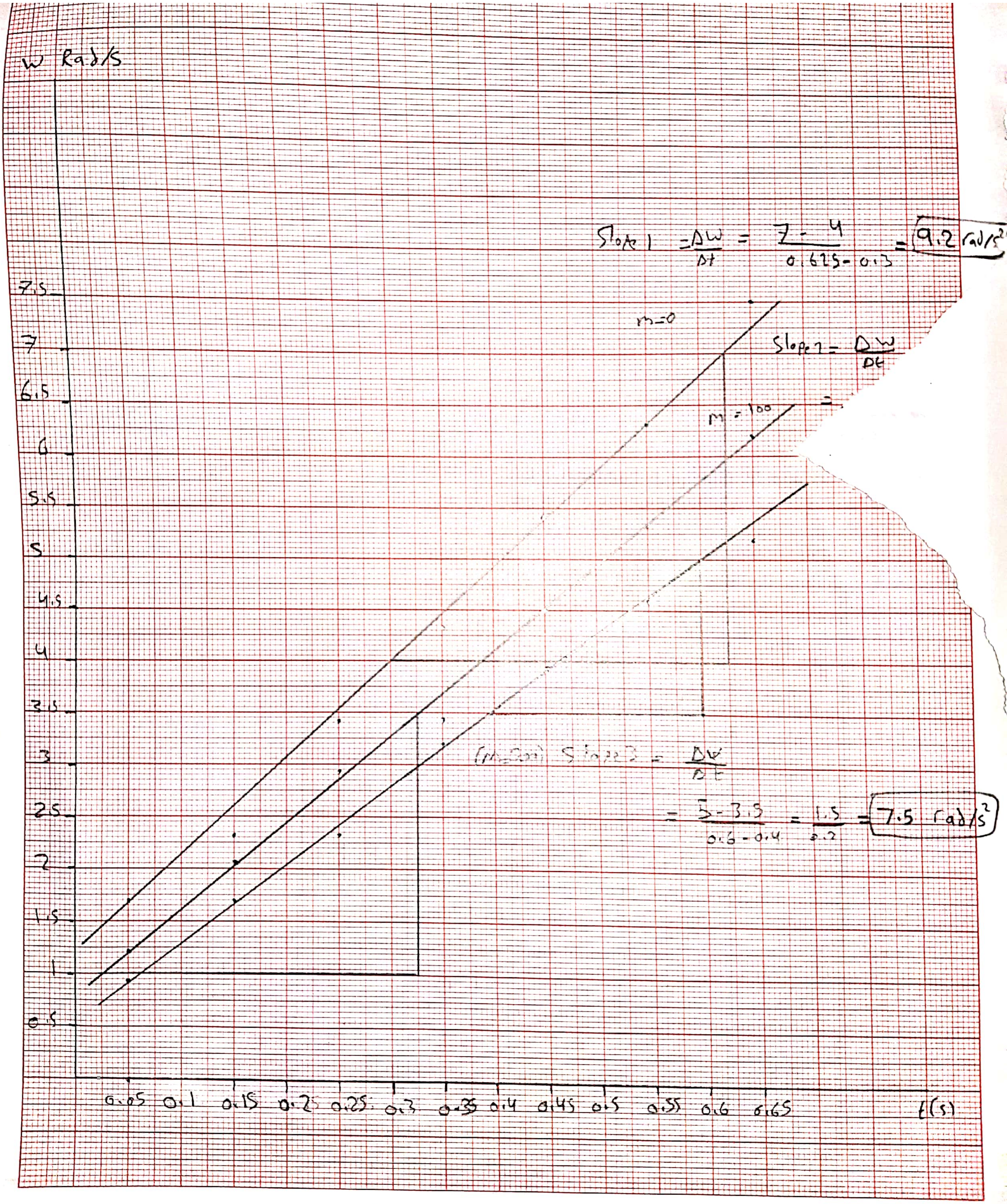

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