The Skills You Should Learn From Doing Experiments

You are doing labs to demonstrate and/or verify the laws of physics. In addition, we hope that you will acquire some skills which will remain with you well after you have finished with the general physics courses and will constantly emphasise on these skills on these skills. In particular, the lab final exam will test if you have learnt some of these skills.

There are four types of skills which we hope you will acquire:

1. **Experimental Skills**.

- Record all measurement taken. Repetitive measurements should be tabulated.
- Know that every measurement and thus be able to identify the major sources of errors.
- Emphasise units and significant figures.
- Be familiar with measuring instruments used in the experiments and to choose the appropriate scale for more precise readings.
- Know how to follow experimental procedures.

2. **Graphical skills**.

- How to linearise the equation so as to plot a straight line graph. How to find the slope/intercepts from the graph and relate them to the linearised equation.
- Use of proper scales in plotting graphs. Label the axes. Show units.

3. **Analytical Skills**.

- To infer relationships, if any, between sets of data.
- Draw conclusions from experimental results and compare with theory

4. **Common Sense Skills**.

- Check your result to see if it makes sense. You should be able to judge whether a measured/calculated value is reasonable or not. Example: a calculated value of g of, say, 1000 m/s^2 is not reasonable; likely you have made a mistake in the calculations and/or units.

Writing Your Lab Report

Your instructor will guide you on how to write a lab report. Here we give an outline of what a typical lab report contain, mention briefly the concept of uncertainly (error) of measurements and finally give a sample report.

1. Lab Report

Students must write a short report about each experiment. The report generally have the following sub-headings: Objective(s), Theory, Data, Analysis and Conclusion.

The Errors in Experimental Physics

1. Sources and Types of Error

Every experimental measurement, no matter how carefully you take it, containssome amount of uncertainty or error. You are measuring against a standard, using an instrument that can never perfectly duplicate the standard, plus you're human, so you might introduce errors based on your technique. The three main categories of errors are systematic errors, random errors, and personal errors. Here's what these types of errors are and common examples.

1.1 Systematic Errors

Systematic error affects all the measurements you take. All of these errors will be in the same direction (greater than or less than the true value) and you can't compensate for them by taking additional data.

1.2 Random Errors

Random errors are due to fluctuations in the experimental or measurement conditions. Usually these errors are small. Taking more data tends to reduce the effect of random errors.

1.3 Personal Errors

When writing a lab report, you shouldn't cite "human error" as a source of error. Rather, you should attempt to identify a specific mistake or problem. One common personal error is lack of experience with a piece of equipment, where your measurements may become more accurate and reliable after you know what you're doing. Another type of personal error is a simple mistake, where you might have used an incorrect reading, or skipped a step in a protocol.

2. Experimental errors (Uncertainty)

An error is an action which is incorrect. The error refers to the difference between the calculated value to the correct (theoretical) value. An error could result in a deviation from the intended performance.

2.1 The Absolute error

$$\text{Absolute error} = \text{Measured value} - \text{Theoretical value}$$

Example:

If you measure gravity and have the following data;
Measured gravity = 9.6 m/s^2.Theoretical gravity = 9.8 m/s^2.
Find the absolute error.

Solution:

$$\text{Absolute error} = \text{Measured value} - \text{Theoretical valueAbsolute}$$
$$\text{error} = 9.6 - 9.8$$
$$\text{Absolute error} = -0.2\ \text{m/s}^2$$

2.2 Relative error

It is based on the absolute error value. It compares how large the error is to themagnitude of the measurement.

$$\text{Relative error} = \frac{\text{Measured value} - \text{Theoretical value}}{\text{Theoretical value}}$$

Example:

If you measure gravity and have the following data;
Measured gravity = 9.6 m/s^2.
Theoretical gravity = 9.8 m/s^2.Find
the relative error.

Solution:

$$\text{Relative error} = \frac{\text{Measured value} - \text{Theoretical value}}{\text{Theoretical value}}$$

$$\text{Relative error} = \frac{(9.6 - 9.8)\ \text{m/s}^2}{9.8\ \text{m/s}^2}$$

$$\text{Relative error} = \frac{-0.2\ \text{m/s}^2}{9.8\ \text{m/s}^2}$$

$$\text{Relative error} = -0.02$$

2.3 The Percent error

The most common error calculation is percent error, which is used when comparing your results against a known, theoretical, or accepted value. As you probably guess from the name, percent error is expressed as a percentage. It is the absolute (no negative sign) difference between the measured value and the theoretical value, divided by the theoretical value, multiplied by 100% to give thepercent:

$$\text{Error\%} = \frac{|\text{Measured value} - \text{Theoretical value}|}{\text{Theoretical value}} \times 100\%$$

Example:

If you measure gravity and have the following data;Measured gravity = 9.6 m/s^2.
Theoretical gravity = 9.8 m/s^2. Find the percent error?

Solution:

$$\text{Error\%} = \frac{|\text{Measured value} - \text{Theoretical value}|}{\text{Theoretical value}} \times 100\%$$

$$\text{Error\%} = \frac{|9.6 - 9.8|\ \text{m/s}^2}{9.8\ \text{m/s}^2} \times 100\%$$

$$\text{Error\%} = \frac{0.2\ m/s^2}{9.8\ m/s^2} \times 100\%$$

$$\text{Error\%} = 2.04\%$$

GRAPHING

1. Objective

How to plot a graph with the experimental observations and how to represent and analyse the laboratory data.

2. Steps in plotting a Graph

2.1 What is to be plotted?

When a student is told to plot, say V_1 **versus** $\mathbf{V_2}$, it is important that he understands that this means: V_1 is the dependent variable, plotted on the ''$\boldsymbol{y}$''or vertical axis, $\mathbf{V_2}$ is the independent variable, plotted on the ''$\boldsymbol{x}$'' or horizontal axis.

2.2 Choice of Scale

The scale for a variable is the number of centimeters of length of the graph paper given to a unit of the variable being plotted. Note that in general, the scales along the x and y axes may be different. Two things need careful consideration before choosing the scales for a graph: the ranges of variables, and convenience in plotting.

a. **Range of variable**: suppose a student has some data for a variable V_1 which ranges from 5 kg to 125 kg. He then should choose a scale which allows him to plot V_1 values from zero to values somewhat greater than 125 kg. Notice in this case that, unless to do so by the instructor, he does not choose to suppress the zero and start the V_1 scale from 5 kg. The reason is that later he may need to use the graph to find values extrapolated (continued to the origin). Also, he allows space on the graph for values somewhat greater than the largest values in the data set (in our example, 125 kg). He does this because later some more data, with larger values, may be acquired or he might need to extrapolate the graph to larger values.

b. **Convenience in plotting**: It turns out that scales of 1, 2, 5 and 10 (and decimal multiple of these, 0.1, 0.2,…10, 20, …..) per centimeter are easiest to use. A scale of 2.5 and 4 per centimeter is somewhat more difficult but can be used. Scales of 3, 6, 7, 9, etc. per centimeter are very difficult to plot and read and to be avoided.
In choosing scales it sometimes helps to turn the paper so that the ''x−axis'' is either the long or short dimension of the paper.

2.3 Label the Axes

The vertical and horizontal axes of the graph paper should carry labels indicating the quantities plotted, with units. In our previous example, the label on the y−axis would be: V_1 (kg). Some instructors also ask students to put a legend on the graph. (Example: Plot of V_1 versus V_2).

2.4 Circle your Data Points

Each data point should have a neat circle drawn around it. If more than one experimental trial is used then circles, triangles, squares, etc. may be used to distinguish these and a legend added: trial1, trial2, etc.

2.5 Drawing a straight line through the data points

When the data fall on a straight line (or are expected theoretically to do so) a ruler may be to draw a straight line through the points.

<u>Observe the following rules:</u>

- the line is drawn to match the data trend, and for data with some ''scatter'' balance some points above and below the line.
- Points which fall far outside the general data trend should be double-checked for correct plotting, then if found correctly plotted, ignored in drawing the line.
- Extrapolations to larger or smaller values, thus outside of the range of the data set, should be indicated by making the line ''dashed'' not solid.

3. Graphical Analysis

For data sets (x ; y) obeying a linear relation: $\boldsymbol{y = mx + b}$, we can use a graph of the data to determine the values of m and b. On the graph, these are found to be:

- $\boldsymbol{b}$: y –Intercept of the graph (value of y when x = 0).
- $\boldsymbol{m}$: slope of the graph:

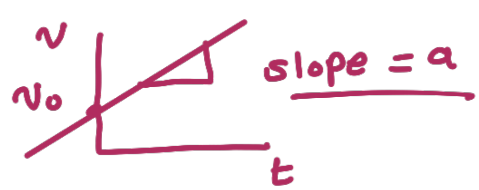
$$\text{Slope} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

Note that in finding the slope, we should choose the points (x_1; y_1), (x_2; y_2) relatively far apart for the sake of accuracy. These values should not be chosen to correspond to experimental data points even if they appear to lie on the straight line.

4. Example

The data set given in table 1 is expected to obey a linear relation: $\boldsymbol{v = v_0 + at}$.

t (s)	4.0	9.0	14.0	20.0	25.0	33.0
v (m/s)	16.8	28.4	40	53.9	65.5	84.2



It's proposed to plot v versus t

1. Calculate the Rough Scale (R.S) and the Best Scale (B.S).

A. For x-axis:

R.S(t) = $\frac{\text{Largest value}}{\text{Number of centimeters in graph paper}}$ = $\frac{33}{11}$ = 3

Note: In general number of centimeters in graph paper for x-axis is taken 18 cm.

Best scale for x-axis: 1 cm (in graph Paper) = 11

B. For y-axis:

R.S(V) = $\frac{\text{Largest value}}{\text{Number of centimeters in graph paper}}$ = $\frac{84.2}{20}$ = 4.21 ≈ 4.2

Note: In general number of centimeters in graph paper for y-axis is taken 26 cm.

Best scale for y-axis: 1 cm (in graph Paper) = 20

2. Plot v versus t

3. Determination of the slope of the straight line.

- The slope point's:

x_1 : 18 x_2 : 27

y_1 : 50.4 y_2 : 71.4

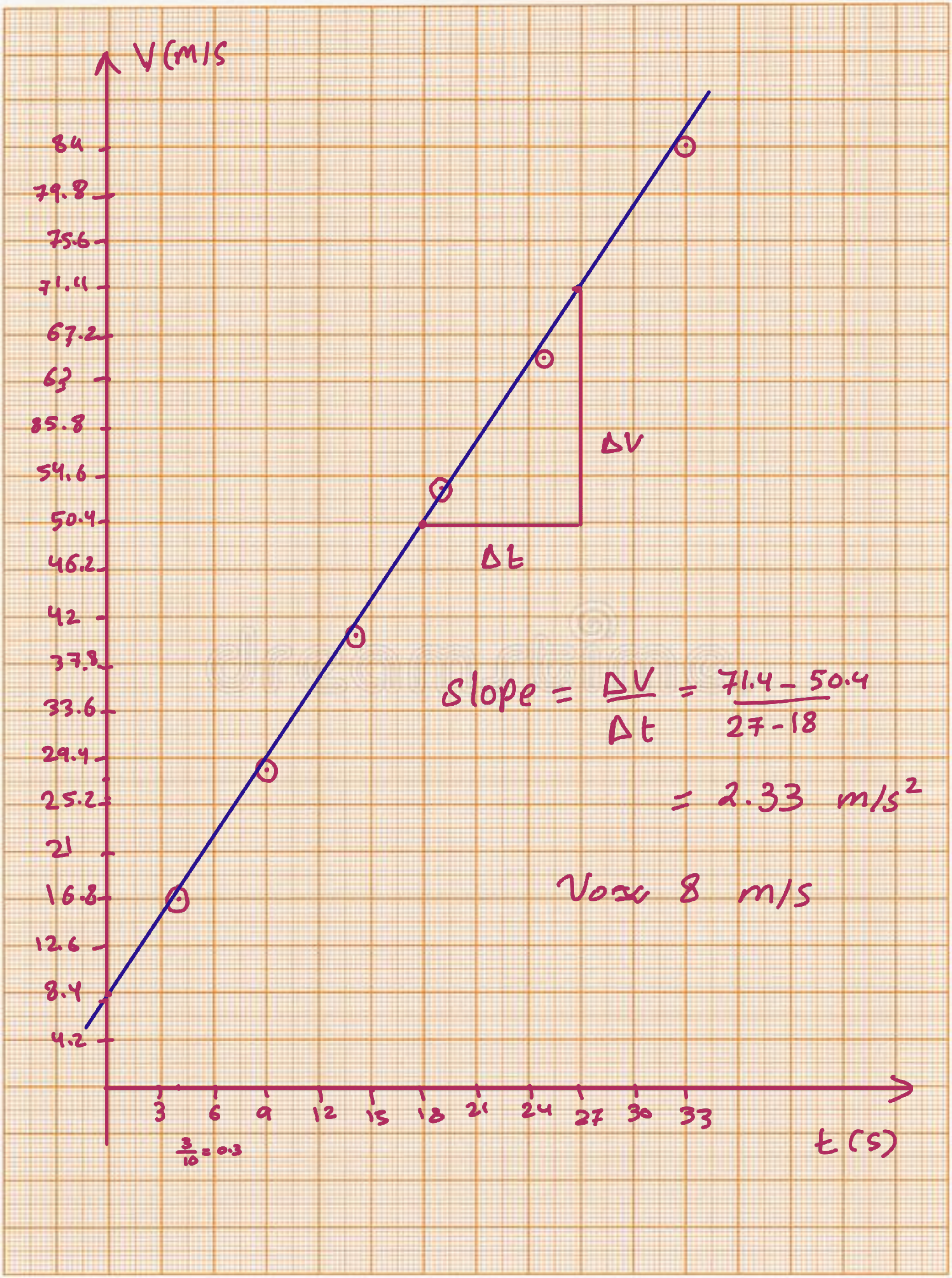
- Calculate the slope and write its unit:

Slope $= \frac{y_2 - y_1}{x_2 - x_1} = \frac{71.4 - 50.4}{27 - 18} = 2.33$

4. Calculate the experimental value of the acceleration a using the equation $v = v_0 + at$.

The acceleration a = Slope = 2.33 m/s²

5. The initial velocity v_0 = 8 m/s


V (m/s
84
79.8
75.6
71.4
67.2
63
85.8
54.6
50.4
46.2
42
37.8
33.6
29.4
25.2
21
16.8
12.6
8.4
4.2
3
6
9
12
15
18
21
24
27
30
33
t (s)
3/10 = 0.3
ΔV
Δt
Slope = ΔV/Δt = (71.4 - 50.4)/(27 - 18)
= 2.33 m/s²
Vo ≈ 8 m/s

Experiment (2):
Accurate Measurements

(Vernier calipers and Micrometer)

1. Objectives

The objective of this experiment is to acquaint the student with basic principles of using measurement instrumentation and to help the student become familiar with several measuring devices used in physics labs. Particular emphasis should be given to the use of the Vernier scale, and micrometer.

2. The Vernier

A typical vernier calipers is shown in figure2. 1. To use this kind of device we need to follow the steps below:

To measure outer dimensions of an object, the object is placed between the jaws, which are then move together until they secure the object.

The first significant figures are read immediately to the left of “zero” of the vernier scale.

The remaining digits are taken from the vernier scale and placed after the decimal point of the main reading. This remaining reading corresponds to the division that lines up with any main scale division. Only one division on the vernier scale coincides with one on the main scale. See figure 2. 2, 2. 3 and 2. 4.

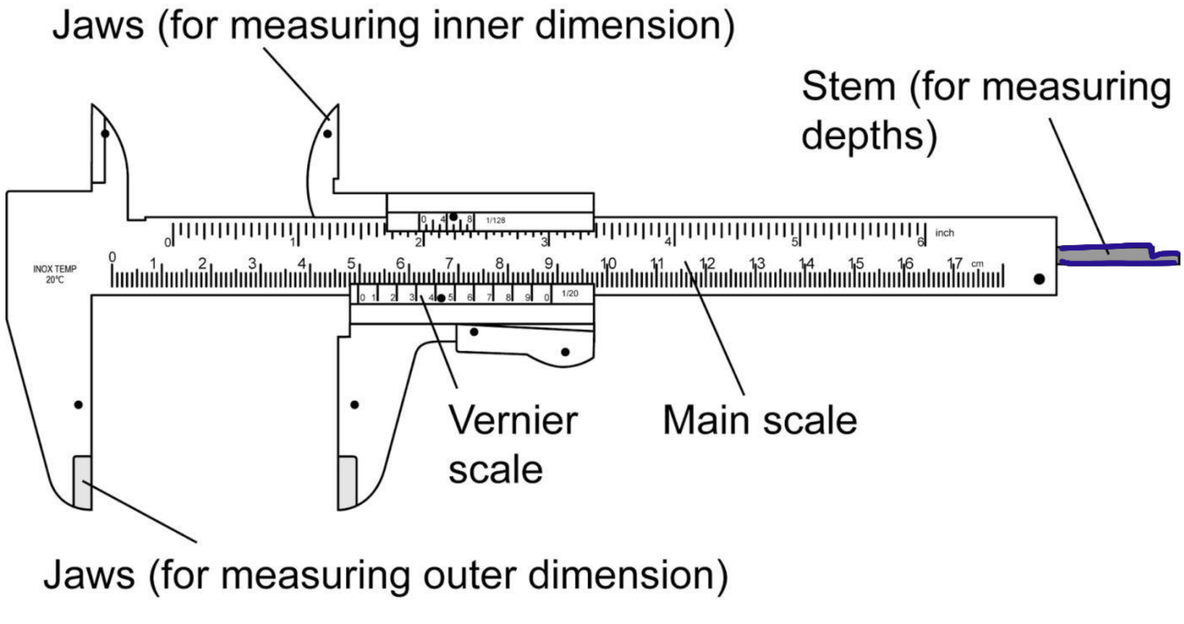
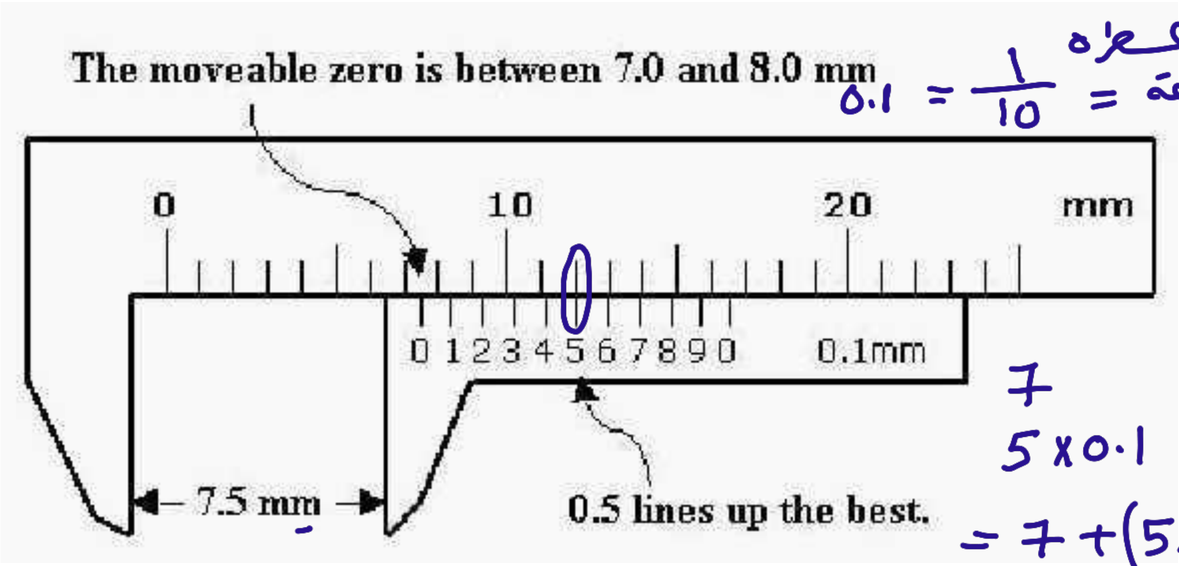


Figure 2. 1: vernier components

There are three kind of precision in the vernier calliper 0.1 mm, 0.05 mm and 0.02 mm.

1.1 Vernier at 0.1 mm precision

The main (stationary) scale is divided into millimeters. The Vernier (moveable) scale is 9 mm long and consists of 10 divisions. Each division on the Vernier scale, then, is 0.9 mm long or 0.1 mm shorter than a main scale division. Note that the first division on the Vernier scale is 0.1 mm from the first division on the main scale; the second Vernier division is 0.2 mm from the second main division scale division, etc. If the Vernier is adjusted so that the first divisions of the two scales are aligned, the distance between the jaws of the caliper is 0.1 mm. If the jaws are opened further, until the second divisions on the scales are aligned, the distance between the jaws will be 0.2 mm (figure 2. 2).



$0.1 = \frac{1}{10} =$ دقة، عشرة اعشارية

7

5×0.1

$= 7 + (5 \times 0.1)$

$= 7.5$ mm

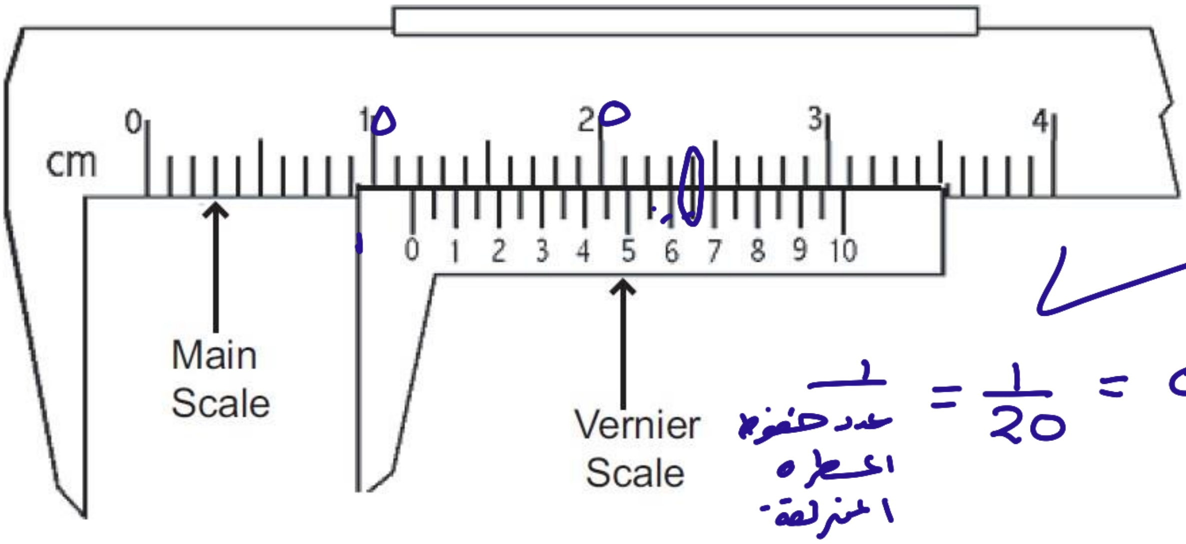
Figure 2. 2: Vernier at 0.01 precision

In general, the number of the Vernier line which is aligned with a line on the main scale is equal to the number of tenths of a millimeter between the caliper jaws. If the separation between the jaws is more than one millimeter, the reading of the Vernier is added to the reading of the main scale up to the zero point of the Vernier scale. The uncertainty of the Vernier is the same as the least count, which is 0.1mm. Figure 2, therefore, shows a reading of 7.5 mm ± 0.1 mm, or 0.0075 m ± .0001 m.

1.2 Vernier at 0.05 mm precision

In figure 3 the zero of the vernier (index) passed of the division 11 mm in the main scale. In the vernier the reading is 0.65 mm (the 13th mark is aligned, then 13x0.05 = 0.65 mm

The total reading is 11 mm + 0.65 mm = 11.65 mm. $(11 + 13 \times 0.05) = 11 + 0.65 = 11.65$



11

13x0.05

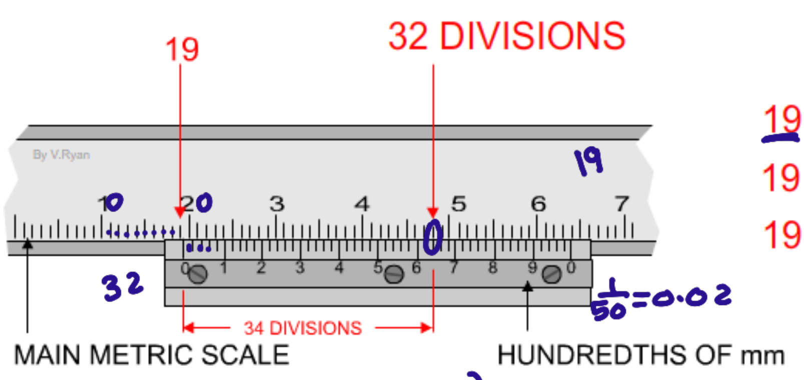
$\dfrac{1}{\text{عدد حزوز الاداة المنزلقة}} = \dfrac{1}{20} = 0.05$

Figure 2. 3: vernier at 0.05 mm precision

1.3 Vernier at 0.02 mm precision

In figure 2. 4 the zero of the vernier (index) passed of the division 19 mm in the main scale. In the vernier the reading is 0.64 mm (the 19th mark is aligned, then 19x0.02 = 0.64 mm

The total reading is 19 mm + 0.64 mm = 19.64 mm.



19 + 32 X 0.02

19 + 0.64

19.64mm (final answer)

$19 + (32 \times 0.02)$

Figure 2. 4: vernier at 0.02 mm precision

$19 + 0.64$

19.64

3. The Micrometer screw gauge

3. 1. Description

Another instrument used for measuring length is the micrometer. See Figure 2. 5. The micrometer works with a screw that produces the advancement of half a millimeter (0.5mm) of the spindle in each turn .The thimble has a scale graduated into 50 divisions, each one equaling 0.01mm. The uncertainty of the reading of the micrometer is + 0.005 mm. It is ten times smaller than that of the caliper. The sleeve where the thimble turns is graduated in divis ions of 0.5 mm. We notice that the sleeve's scale has divisions in the upper and lower parts of the horizontal line of reference. The divisions of the upper part show the millimeters while those of the lower part show halves of millimeters.

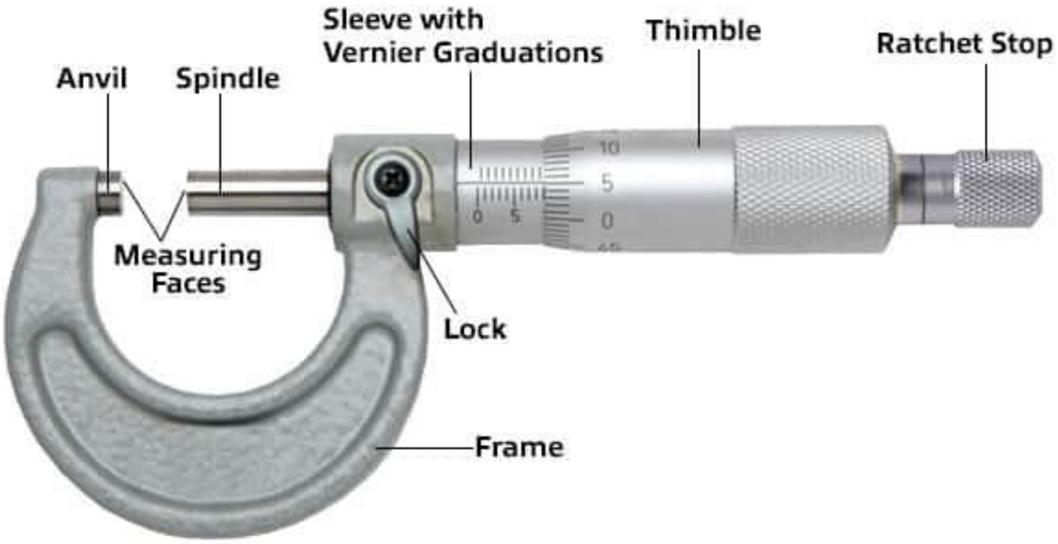


Figure 2. 5: micrometer components

To make a measurement, you first read the horizontal scale indicated by the left edge of the thimble, and then you add the number that is found aligned to the horizontal line of the sleeve, which we have called the reference line. In the extreme right of the micrometer shown in figure 5 there is a ratchet that limits the magnitude of the pressure that can be applied to the measured object.

3.2 . Some examples

In figure 2. 6 the last graduation visible to the left of the thimble is 13 mm and the 0.5 mm division is visible below the main scale; therefore the reading is 13.5 mm than the thimble lines up with the main scale at 26 hundredths of millimeter (0.26 mm); the total reading is 13.5 mm + 0.26 mm equal 13.76 mm.

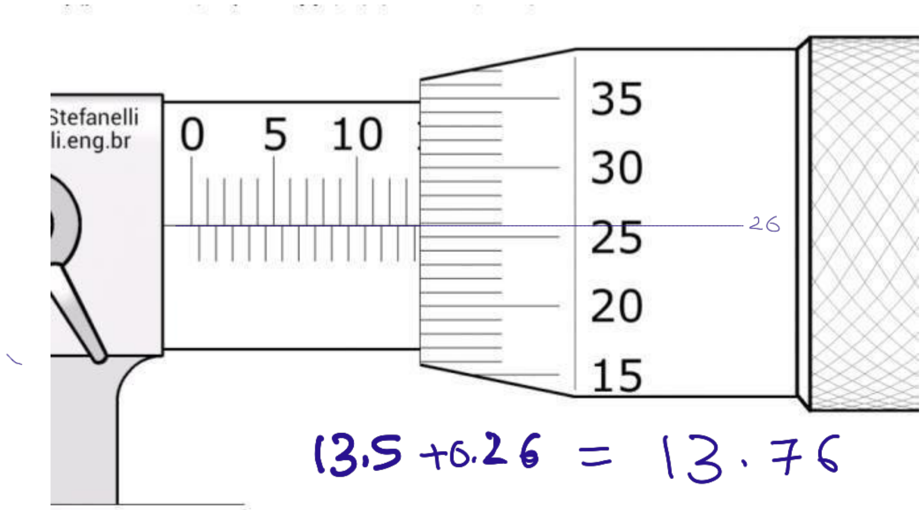


Figure 2. 6: A reading of 13.76 mm

In figure 2. 7 the 0.5 mm division is visible below the main scale; therefore the reading is 2.78 mm.

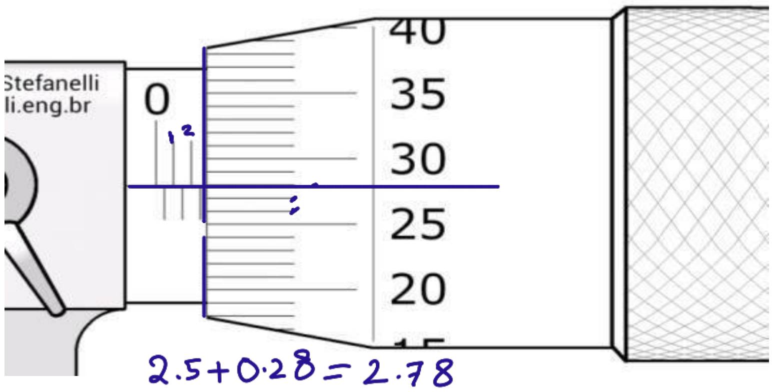


Figure 2. 7: A reading of 2.78 mm

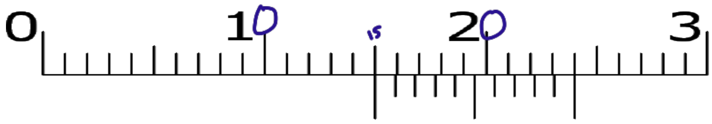
Exercises

In the following situation write the correct reading and precision below each figure.

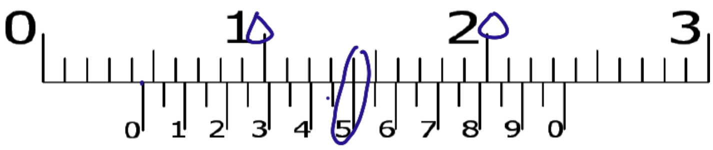
1. **The vernier**

الدقة

Reading = $15 + 0 \times 0.1$ $\boxed{15 \text{ mm}}$ mm　　　Precision = $\frac{1}{10} = 0.1$ mm

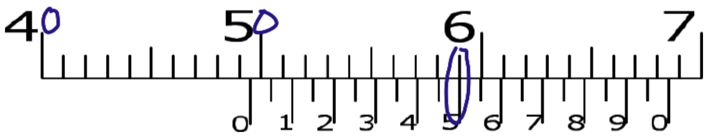


Reading = $4 + (10 \times 0.5)$ $\boxed{4.5}$ mm mm　　　Precision = $\frac{1}{20} = 0.05$ mm

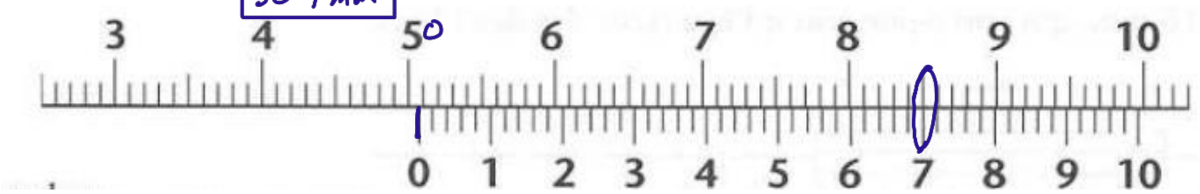


Reading = $49 + 10 \times 0.05$ mm　　　Precision = $\frac{1}{20} = 0.05$ mm

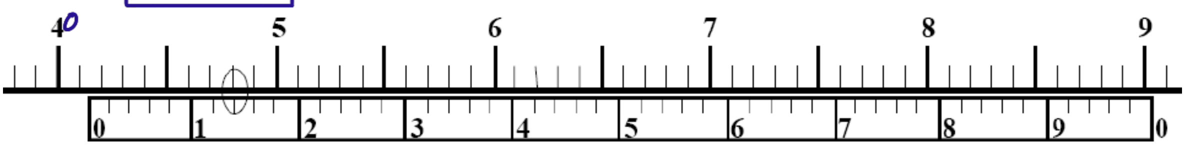
$49 + 0.5 = \boxed{49.5 \text{ mm}}$



Reading = $50 + 35 \times 0.02$ $\boxed{50.7 \text{ mm}}$ mm　　　Precision = $\frac{1}{50} = 0.02$ mm

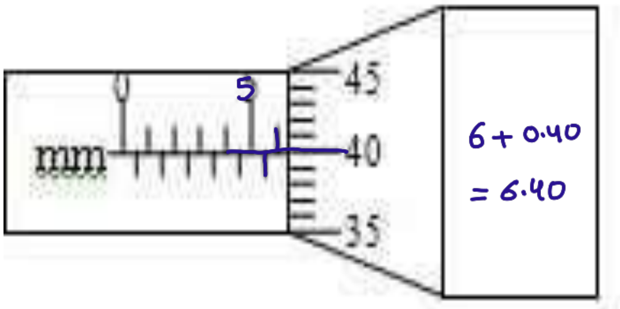


Reading = $41 + (7 \times 0.02)$ $\boxed{41.14 \text{ mm}}$ mm　　　Precision = $\frac{1}{50} = 0.02$ mm



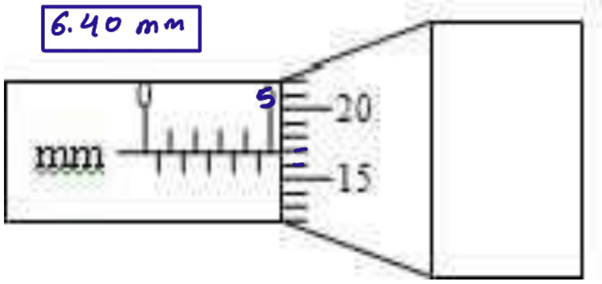
Reading = 　　　mm　　　Precision = 　　　mm

2. The Micrometer



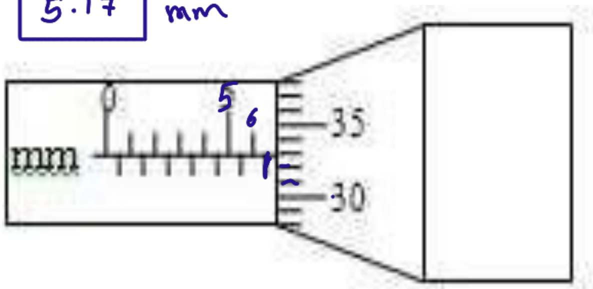
Reading = 6+0.40 mm Precision = 0.01 mm

$\boxed{6.40 \text{ mm}}$



Reading = 5 + 0.17 mm Precision = 0.01 mm

$\boxed{5.17}$ mm



Reading = 6.5 + 0.33 mm Precision = 0.01 mm

$\boxed{6.83}$ mm

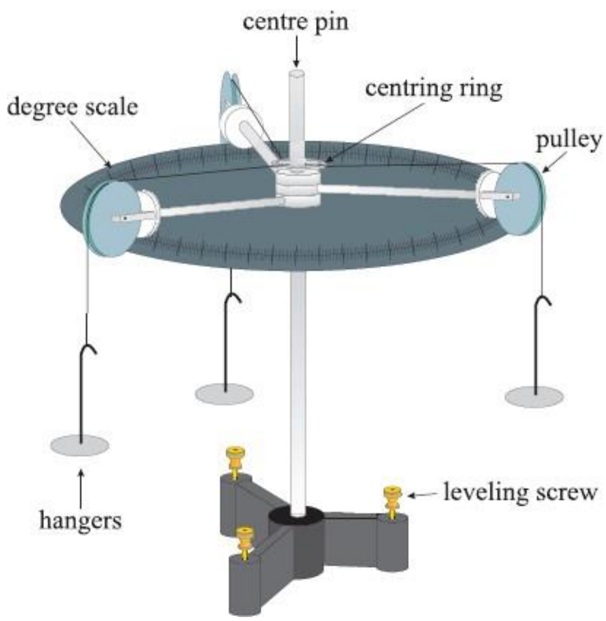
Experiment (3):
Force Table (Addition of Vectors)

1. Aim of the experiment: الهدف

The purpose of this experiment is to study how to add two vectors to find the resultant vector, using three methods namely, (a) graphically, (b) analytically and (c) experimentally.

2. Apparatus Used: الأدوات Force , hang , ruler, protactor

The apparatus used in this experiment is called ''force table'' which is consisted of a level horizontal disc to which movable pulleys are attached. The outer ring of a force table is calibrated in degrees from 0° to 360° (see the figure).



Strings are attached at one end to a ring at the center of the table. On the other end, the string passes over a pulley and hangs vertically. A mass hanger may be hung from each of the vertical strings. Forces are applied to the central ring by placing a mass on each mass holder.
A removable pin within the ring prevents it from moving until all the forces are nearly balance. The direction of the force vector is represented by clamping a pulley at the appropriate position on the circular scale.
The magnitude of each individual force applied to the ring is equal to the magnitude of the weight $\vec{W}$of the mass attached to the end of the string (including the weight of the mass holder). Thus, we can write the following equation:

$$F= \vec{W}= mg$$

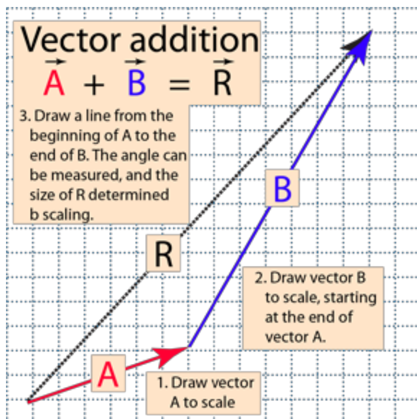
Where m is the total mass suspended from the string, including the mass of the mass holder, and g is the acceleration due to the gravity ($g = 9.8\ m/s^2$) in SI system of units.

3. Theory:

The resultant of two or more vectors can be found using the three methods as stated below.

3.1 Graphical Method

Vectors are added graphically according to following rule:
Draw all vectors in a way that the tail of the second vector is placed at the head of the first vector (head to tail). Similarly, the tail of the third vector is placed at the head of the second vector, and so on. The Figure below illustrates this rule.



Sometimes, it may be necessary to move the arrows (vectors) to fulfil the condition of having head- to-tail shape. This is fine if you do not change the lengths or directions of vectors.
Suppose you have two vectors A and $\vec{B}$.Each vector must have a magnitude and a direction. To find the resultant $\vec{R}$ of adding these vectors, follow these steps:

- Choose a graphing scale to convert the magnitude of each vector into length. For our experiment, choosing $\mathbf{1\ N{=}5\ \boldsymbol{cm}}$ should be good.
- Draw x and y axes and try to locate the origin point at the middle of the graphing sheet.
- Use a protractor to measure the angle of each vector. This angle represents the direction of the vector.
- Now, move one of the two vectors so that they become head to tail.
- Draw an arrow from the tail of the first vector to the end of the last vector.
- This arrow represents the resultant $\vec{R}$ The length and the angle of this arrow are the magnitude and the direction of the resultant $\vec{R}$ respectively.

3.2 Component or Analytical Method

In this method, the resultant of several vectors is obtained by using vector ''resolution''. This means that each vector must be resolved in two components, one on the x—axis and the other on the y—axis.
Suppose you have the vectors shown in the first Figure is based on the vector resolution rules, vector Awill have the following components:

- $A_x = A \cos \theta_A$
- $A_y = A \sin \theta_A$

Where A is the magnitude of the vector $\vec{A}$.
Similarly, vector $\vec{B}$will have:

- $B_x = B \cos \theta_B$
- $B_y = B \sin \theta_B$

The components of the resultant vector $\vec{R}$are simply:

- ✓ $R_X = A_X + B_X = A \cos \theta_A + B \cos \theta_B$
- ✓ $R_Y = A_Y + B_Y = A \sin \theta_A + B \sin \theta_B$

Now, we can find the magnitude and the direction of $\vec{R}$from the following equations:

$$R = \sqrt{R_X^2 + R_Y^2}$$

$$\theta = tan^{-1} \left(\frac{R_Y}{R_X}\right)$$

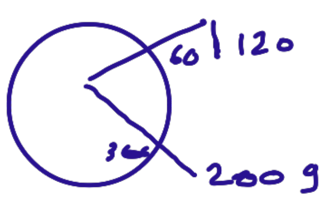
4. Procedure

Now, we will find the magnitude and direction of the resultant $\vec{R}$ experimentally by using the force table:

m1 60

1. Hang a mass of $120\ g$ at an angle of $60°$. Next, calculate the weight (force) of the total mass (the hung mass + mass of hanger). Call this force A.

2. Hang a mass of $200\ g$ at an angle of $300°$. Next, calculate the weight (force) of the total mass (the hung mass + mass of hanger). Call this force $\vec{B}$.



hanger 110

hung 10

120

3. Now, try to change both the mass and the angle of the third pulley so that the ring at the middle of the force table stays still at the center. Magnitude of this force is represented by $\vec{R}$. However, the angle of this force is equal to $\theta_{exp}= \beta+180°$; $\beta<180$ Or $\theta_{exp}= \beta-180°$; $\beta>180$. Here β represents the angle obtained from force table. The values that you obtain from this step are the experimental values of resultant direction.

4. Use the values of both vectors A and $\vec{B}$ to find the magnitude and the direction of the resultant $\vec{R}$ by using the component method as stated earlier. These values are theoretical values (the standard values).

5. Calculate the percentage errors in both R and θ that you obtain from step 3 (by comparing them to the values obtained from step 4).

6. Use the values of both vectors A and $\vec{B}$ to find the magnitude of the resultant and direction of $\vec{R}$ by using the graphical method.

7. Calculate the percentage errors in both R and θ that you obtain from step 6 (by comparing them to the values obtained from step 4).

Force Table

1. Objective: الهدف

2. Experimental Method

تجريبية

$\div 1000$ $\times 9.8$

Vector	Hung mass (g)	Hunger mass (g)	Total mass (g)	Total mass (kg)	Weight (N)	Angle (^{0})
$\vec{A}$	110	10	$\boxed{120}$	0.120	1.176	60
$\vec{B}$	✓	✓	200	0.2	1.96	300
$\vec{R}$			175	0.175	R_{exp} = 1.71	θ_{exp} = 160

الموازنة

≈

160 − 180
−23

3. Component Method

Hint: Magnitude of the vector $\vec{A}$ = Value of the weight vector $\vec{A}$ in table

Magnitude of the vector $\vec{B}$ = Value of the weight vector $\vec{B}$ in table

1.176 $\theta = 60$

a) Vector $\vec{A}$

A_X = A cos θ = 1.176 cos 60 = 0.588

A_Y = A sin θ = 1.176 sin 60 = 1.018

b) Vector $\vec{B}$

B_X = B cos θ = 1.96 cos 300 = 0.98

B_Y = B sin θ = 1.96 sin 300 = −1.697

c) Vector $\vec{R}$

R_X = Ax + Bx = 0.588 + 0.98 = 1.568

R_Y = Ay + By = 1.018 + −1.697 = −.679

R_{th} = $\sqrt{1.568^2 + (-0.679)^2}$ = 1.708 ✓

θ_{th} = $\tan^{-1}\left(\frac{-0.679}{1.568}\right)$ = −23.4

+ 180

$\boxed{= 156}$

d) Percentage Error:

Error in R = $|R_{exp} - R_{th}|\ /R_{th} \times 100\%$

= $\left|\frac{1.71 - 1.708}{1.708}\right| \times 100\%$

Error in θ = $|\theta_{exp} - \theta_{th}|\ /\theta_{th} \times 100\%$

= $\left|\frac{160 - 156}{156}\right| \times 100\%$

4. Graphical Method:

The scale used in the graph paper is **1 N = 5 cm**

60 ضرب 5

- The magnitude of $\vec{A}$ = 1.176 N = 5.88 cm
- The magnitude of $\vec{B}$ = 1.96 N = 9.8 cm 300
- The length of R_{Gr} from the graph = 8.54 cm = 1.7 N 5 ÷
- The angle θ_{Gr} measured from the graph = 23.3

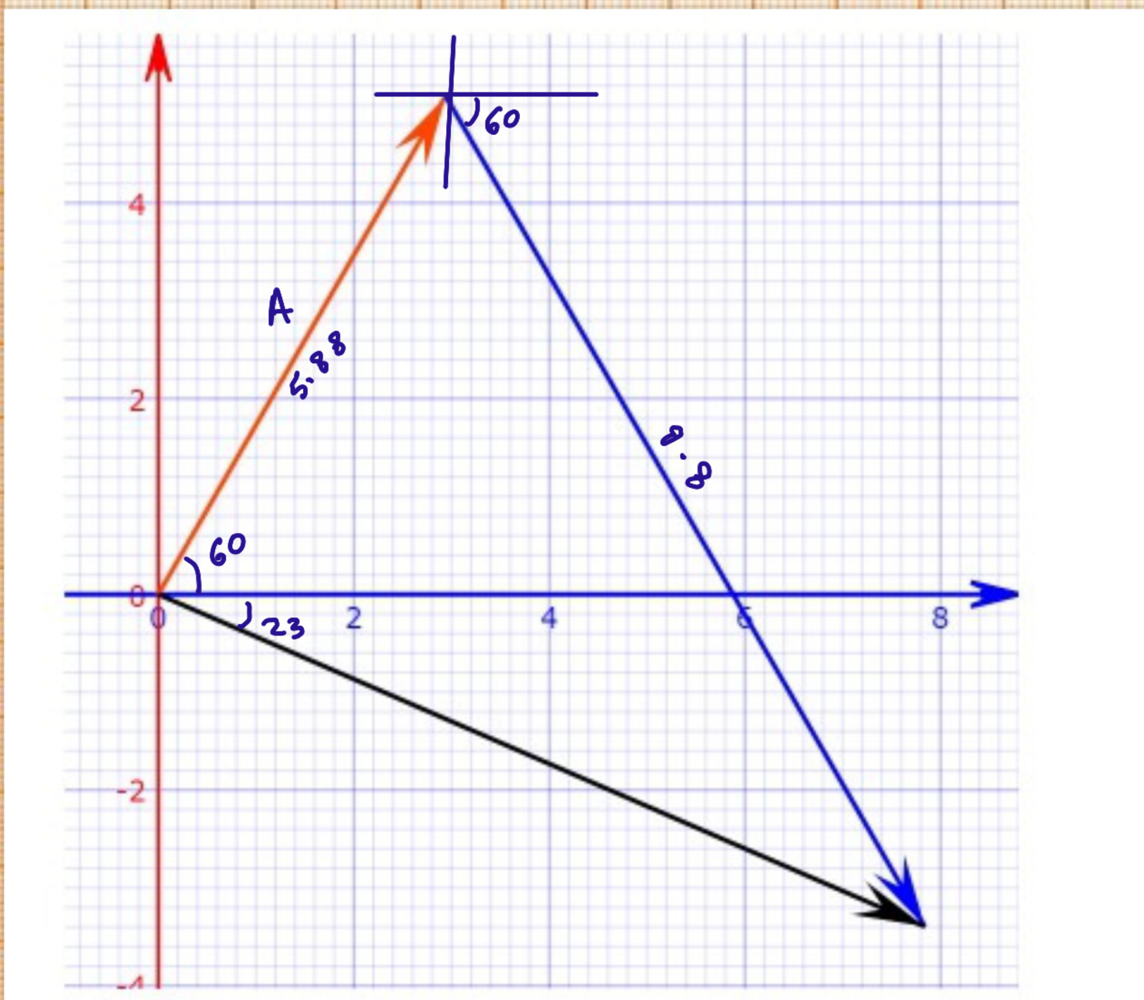
Percentage Error:

Error in R = $|R_{exp} - R_{Gr}|\ /R_{Gr} \times 100\%$

= $\left|\frac{1.71 - 1.7}{1.7}\right| \times 100\%$

Error in θ = $|\theta_{exp} - \theta_{Gr}|\ /\theta_{Gr} \times 100\%$

= $\left|\frac{23 - 23.3}{23.3}\right| \times 100\%$


60
A
5.88
8.8
60
23
4
2
0
-2
0
2
4
6
8

Experiment (4):
Freely Falling Body

1. Aim of the experiment:

The purpose of the lab is to investigate the relationship between position and time for an object in free fall. Then determine the acceleration due to gravity g.

2. Theory:

If a body falls to the ground in the Earth's gravitational field from a height *h*, it undergoes a constant acceleration *g* (Air resistance is ignored). Such a falling motion is called free fall.

In this experiment a steel ball is suspended from an electromagnet as shown in the Figure below. As soonas it is released into free fall, an electronic timer is started. After it has fallen a distance *h* the ballhits a target plate at the bottom which stops the time measurement at a time *t*. Since the ball isnot moving before it starts to fall at time $t_0 = 0$ its initial velocity is zero, i.e., $v_0 = 0$. Therefore, thedistance covered in time *t* is given as follows:

$$h = \frac{1}{2} g t^2 \qquad (1)$$

where *t* is the time of fall and *g* is the acceleration due to gravity.

One can experimentally check the validity of Eq. 1 by repeatedly dropping a steel ball and accurately measuring the time it takes to cover a fixed distance *h*. The distance *h* through which the ball falls is a nonlinear function of the time *t*, as can be shown by comparing a straight-line fit with a parabolic fit for the measured data. To obtain a linear graph it is necessary to plot the fall distance against the square of the fall time (Plot of *h* versus t^2). Hence, from the slope of this line, the gravitational acceleration *g* can then be calculated using Eq. 1.

3. Experimental Procedure:

- Observe the apparatus as set up in the lab; a sketch of it is also shown in the Figure. Initially as teel ball is suspended from an electromagnet. When you tap the key it starts the timer, at the same time power to the electromagnet is interrupted so that the ball falls. After falling a distance *h*, the ball strikes a contact plate which stops the counter, which then displays the time of fall, *t*.
- We will do the experiment by leaving the contact plate fixed in place and moving the holding magnet to give various distances of fall.
- Adjust the position of the electromagnet so that the height of fall is approximately 0.7m. Now measure the distance setting accurately and record this as your first value of *h* in the given table. Check that timer is set to "ms" (1ms = 10^{-3} s) and properly reset to zero. Tap the key, observe the timer begin running and then stops as the ball strikes

the contact plate. The value displayed on the counter is the time t taken for the ball to fall the distance h. Repeat the measurement one more time. Entering your results in the given table 1 and average the resulting times.

Figure: Experiment set-up for measuring the fall time of a steel ball as a function of the distance h between the trigger mechanism and a contact plate

- Reduce the height h by 0.1 m by lowering the holding magnet, for a new reading each time repeating the procedure in step 3.

- Calculate the percentage error of g. The percentage error is given by:

$$\text{P.E.} = |g_{exp} - g_{th}|/g_{th} \times 100\%$$

FREELY FALLING BODY

1. Objective:

The purpose of the lab is to investigate the relationship between position and time for an object in free fall. Then determine the acceleration due to gravity *g*.

2. Formula used:

$h = \frac{1}{2} g t^2$

3. Observations:

Complete the following table.

متوسط تربيع

÷100

	$h(m)$	$t_1\,(s)$	$t_2\,(s)$	$t_{avg}\,(s)$ $\frac{t_1+t_2}{2}$	$t^2\,(s^2)$
70	*0.7*	0.376	0.378	0.377	0.142
60	*0.6*			0.349	0.122
50	*0.5*			0.319	0.102
40	*0.4*			0.285	0.081
30	*0.3*				
	0.2				

$h(m)$ $\times 10^{-2}$	t^2 $\times 10^{-3}$
70	142
60	122
50	102
⋮	

4. Data Analysis:

It's proposed to plot h **versus** t^2

1. Calculate the Rough Scale (R.S) and the Best Scale (B.S).

   A. For x-axis: t^2

   $$\text{R.S}(x) = \frac{\text{Largest value}}{\text{Number of centimeters in graph paper}} = \frac{142}{14} \approx 10$$

   Best scale for x-axis: 1 cm (in graph Paper) = $\frac{10}{10} = 1$

B. For y-axis:

$$R.S(y) = \frac{\text{Largest value}}{\text{Number of centimeters in graph paper}} = \frac{70}{14} = 5$$

Best scale for y-axis: 1 cm (in graph Paper) = $\frac{5}{10} = 0.5$

2. Plot h versus t^2

3. Determination of the slope of the straight line.

- The slope point's:

x_1 : 66×10^{-3}

y_1 : 30×10^{-2}

x_2 : 80×10^{-3}

y_2 : 40×10^{-2}

- Calculate the slope and write its unit:

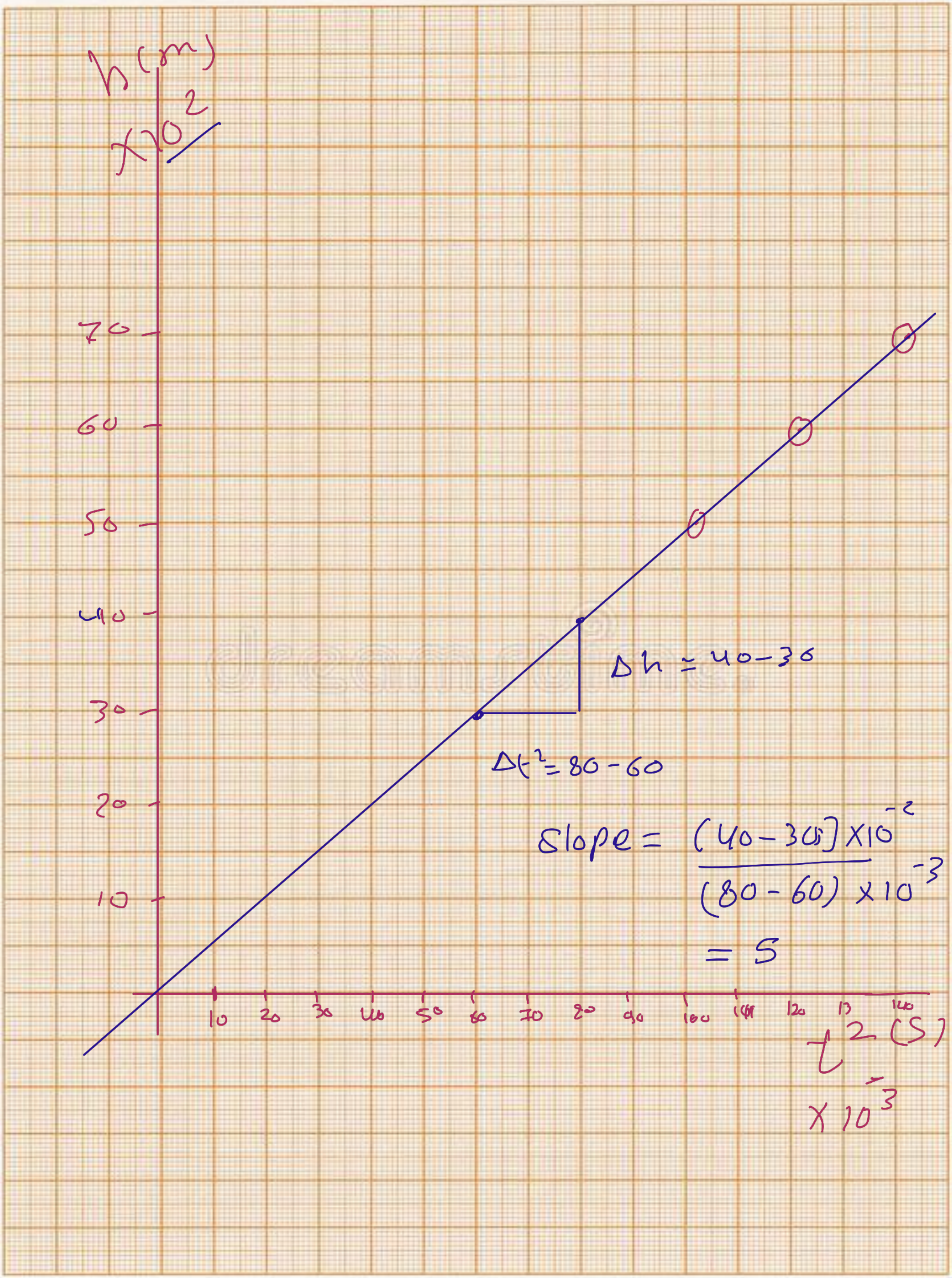
$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{(40-30) \times 10^{3}}{(80-60) \times 10^{-2}} = 5 \ m/s^2$$

4. Calculate the experimental value of the acceleration due to gravity g_{exp}.

$g_{exp} = 2 \times slop = 10 \ m/s^2$

5. Calculate the percentage error in the experimental result. (The standard value of acceleration due to gravity is given $g_{th} = 9.80 \ m/s^2$)

The percentage error (%)= $\left| \frac{10 - 9.8}{9.8} \right| \times 100\%$


h (m)
x10^2
70
60
50
40
30
20
10
Δh = 40-30
Δt^2 = 80-60
Slope = (40-30) x10^-2 / (80-60) x10^-3
= 5
10 20 30 40 50 60 70 80 90 100 110 120 130 140
t^2 (S)
x 10^-3

Experiment (5):
Newton's Second Law of Motion

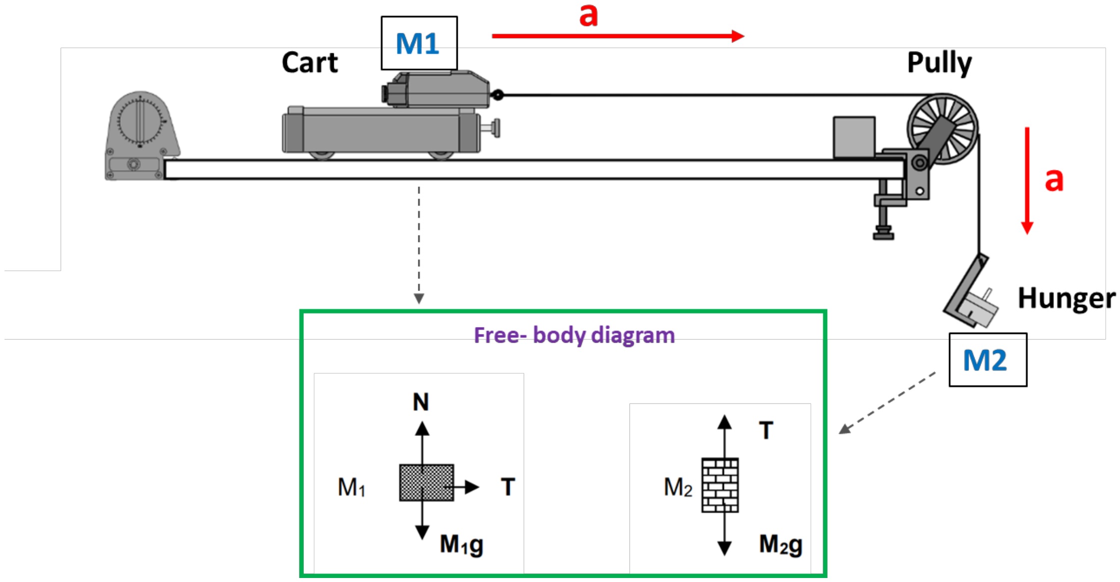
1. Aim of the experiment

The purpose of this experiment is to verify the Newton's second law of motion and to determine the gravity acceleration (g) .

2. Theory:

Newton's Second Law states that the net force (F) applied on object, is proportional to its acceleration (a):

$$F = ma \qquad (1)$$



The Figure shows a mass $\mathbf{m_1}$ on a flat surface. There is tension T in the rope connecting the masses, whichis linked to a second mass m_2 by a pulley. If we assume that m_1 is moving on a frictionless surface, we cansee that three forces are acting on it, but only one of them—the force along the x-axis—is responsible for the movement of the body. This is because m_1's weight and the normal force from the table N are equal in magnitude and directed in the opposite direction, and their sum is zero. So, Eq. (1) may be expressed as:

$$T = ma \qquad (2)$$

However, the two forces acting on mass m_2 are its weight m_2g and the tension **T**, by assuming that the pully is frictionless. Because m_1 and m_2 are connected, the acceleration of m_2 has the same magnitude as the acceleration of m_1. In equation form:

$$m_2g - T = m_2a \qquad (3)$$

In order to determine the acceleration of the system, we will solve Eq. (2) and Eq. (3) together, to obtain:

$$\boxed{a = \frac{m_2}{(m_1 + m_2)} g} \qquad (4)$$

3. Experimental Procedure:

1. Install the track and the photogate to be perfectly horizontal
2. Add masses of 500 g to the cart (Knowing that the mass of the cart is 500 g). now, the total mass of m_1=1000g (1kg). This value will be kept constant during the experiment.
3. Add a mass 50g to the hunger (Knowing that the hunger mass is 5g) the total mass now of m_2=55g
4. Release the cart and read the acceleration (a) value on the screen of the accelerometer.
5. Repeat **step 4** three times and each time record the value of **a** in your table (a_1,a_2 and a_3)
6. Calculate the a_{avg} and record the result in the table.
7. Repeat the above steps for different masses of m_2 and each time record the acceleration.

Newton's Second Law of Motion

1. Objective: the purpose of the experiment to verify Newtons 2nd low and to determine the acceleration of gravity

2. Formula used:

$$a = \left(\frac{m_2}{m_1+m_2}\right) g$$

3. Observations:

Complete the following table.

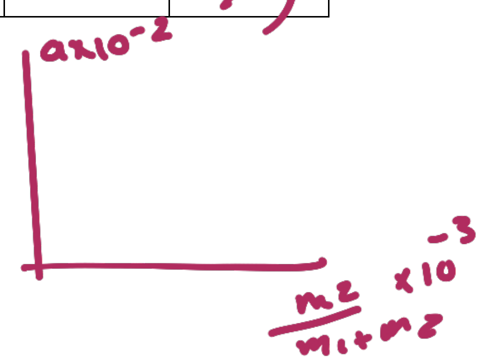
1kg

48×10^{-2}

m_2 (g) ÷1000	m_2 (kg)	$\frac{m_2}{m_1+m_2}$ (kg)	a_1 (cm/s^2)	a_2 (cm/s^2)	a_3 (cm/s^2)	a_{avg} (cm/s^2)	m_2 (kg)
55	0.055	0.052	47.7	47.5	47.9	$\frac{a_1+a_2+a_3}{3}$	
65	0.065	0.061					
75							
85							
95							

4. Data Analysis:

It's proposed to plot $\mathbf{a_{avg}}$ versus $\frac{m_2}{m_1+m_2}$



1. Calculate the Rough Scale (R.S) and the Best Scale (B.S).

   A. For x-axis:

   R.S(x) = $\frac{\text{Largest value}}{\text{Number of centimeters in graph paper}}$ = $\frac{87}{9} = 9.6 \approx 10$

   Best scale for x-axis: 1 cm (in graph Paper) = $\frac{10}{10} = 1$

B. **For y-axis:**

R.S(y) = $\frac{\text{Largest value}}{\text{Number of centimeters in graph paper}}$ = $\frac{87}{9}$ = 9.6 x 10

Best scale for y-axis: 1 cm (in graph Paper) = $\frac{10}{10}$ = 1

2. Plot $\mathbf{a_{avg}}$ versus $\frac{m_2}{m_1 + m_2}$

3. Determination of the slope of the straight line.

- The slope point's:

x_1 : 48 x_2 : 87

y_1 : 52 y_2 : 97

- Calculate the slope and write its unit:

Slope $= \frac{y_2 - y_1}{x_2 - x_1} = \left(\frac{87-52}{87-48}\right)\frac{\times 10^{-2}}{\times 10^{-3}} = 8.9 \; m/s^2$

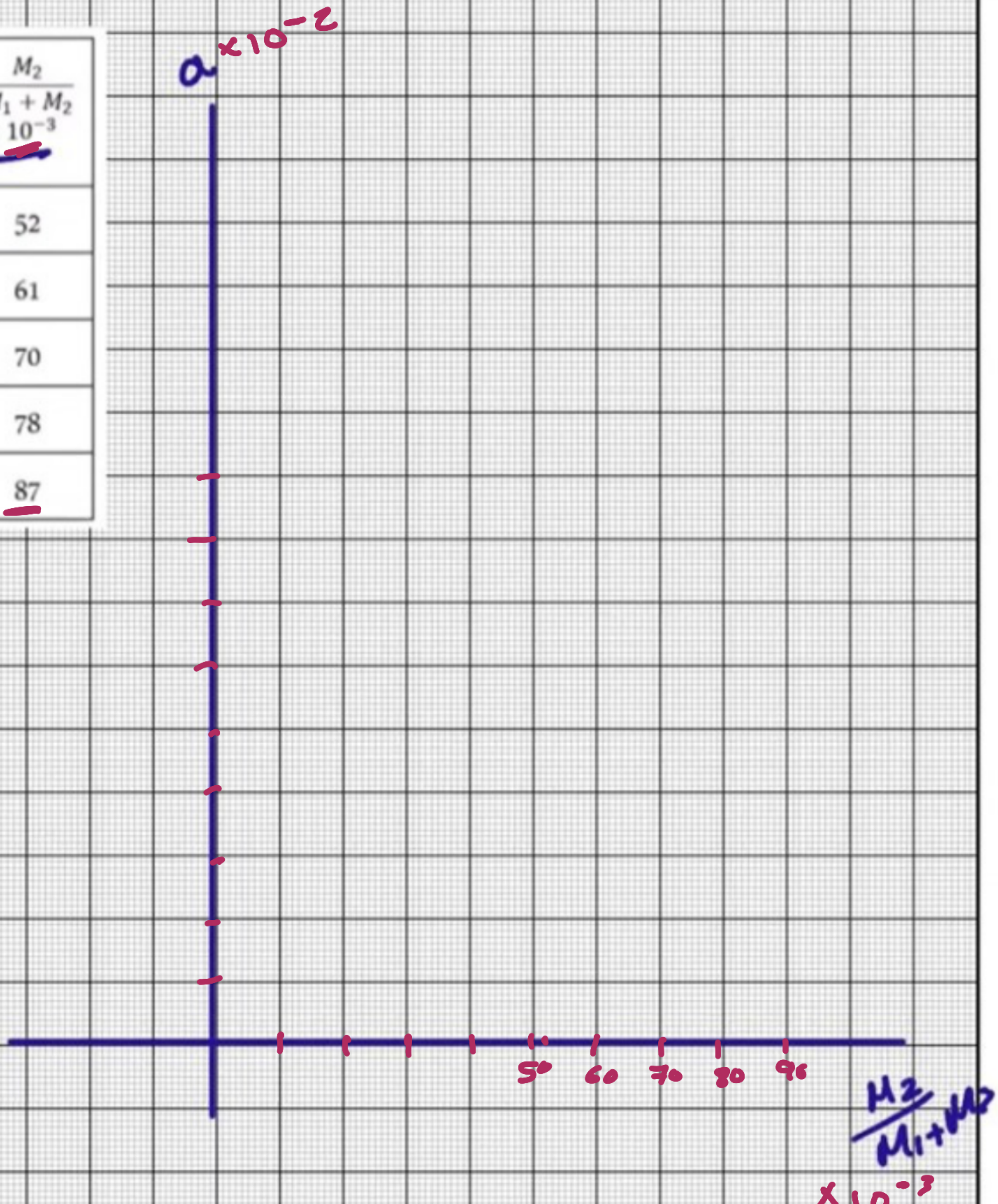
4. Calculate the experimental value of the acceleration due to gravity g_{exp}.

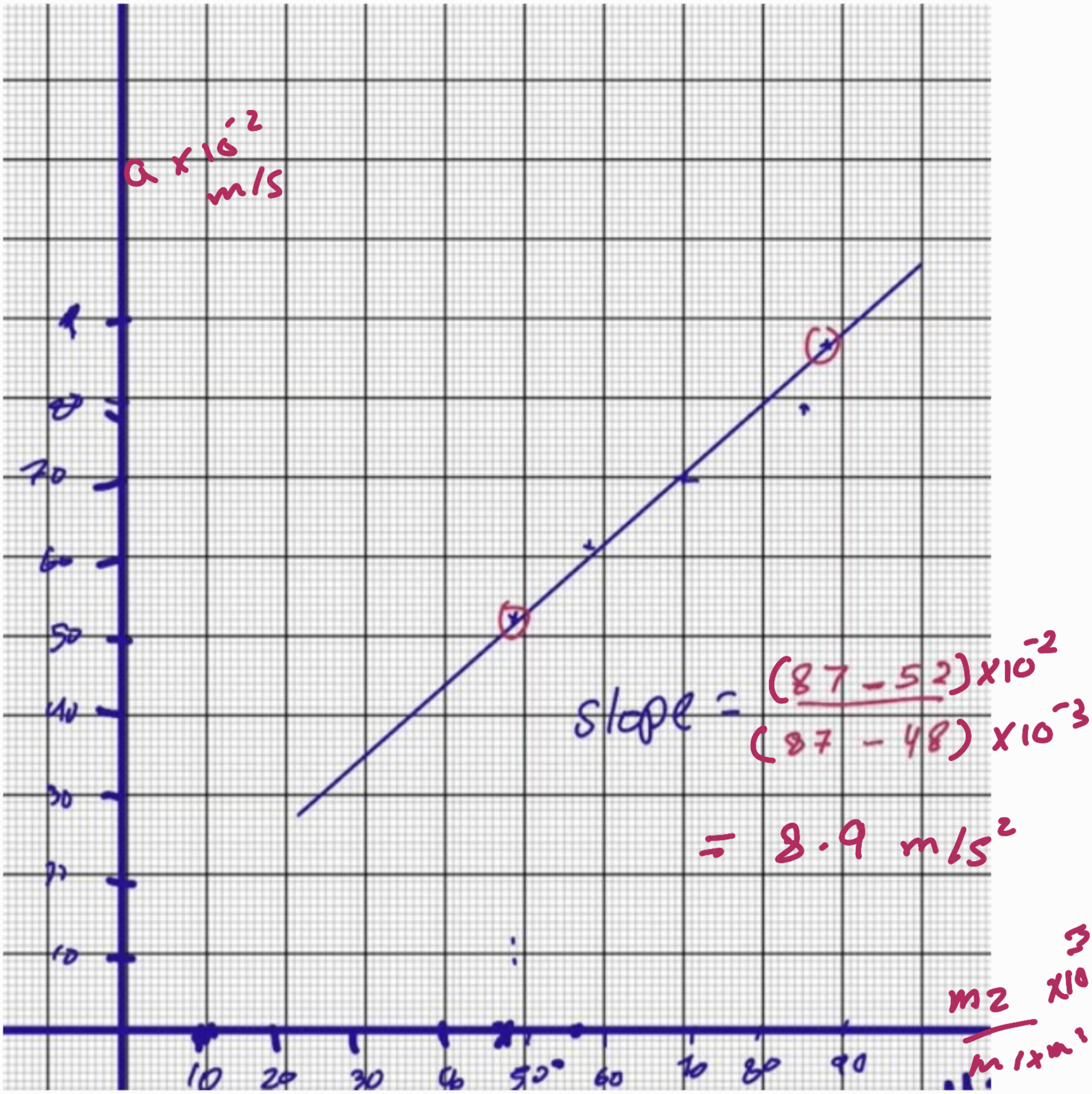
Slope = g = 9.9 m/s²

5. Calculate the percentage error in the experimental result. (The standard value of acceleration due to gravity is given $g_{th} = 9.80 \; m/s^2$)

The percentage error (%)= $\left|\frac{8.9 - 9.8}{9.8}\right| \times 100$

$a_{Ave} \times 10^{-2}$ (m/s^2)	$\frac{M_2}{M_1 + M_2} \times 10^{-3}$
48	52
57	61
70	70
85	78
87	87




a ×10^-2 m/s
m2 ×10^3
m1×m1
slope = (87 − 52)×10^-2 / (87 − 48)×10^-3
= 8.9 m/s^2