



ÇANAKKALE ONSEKİZ MART UNIVERSITY

DEPARTMENT OF PHYSICS

**GENERAL PHYSICS  
LABORATORY MANUAL  
AND  
WORKBOOK**

## General Physics Laboratory

<b>Weeks</b>	<b>Course Content</b>
<b>1-2</b>	Laboratory study methods: Report preparation technique, graphics plotting
<b>3-4</b>	Linear motion with constant velocity experiment
<b>5-6</b>	Motion on a straight line with constant acceleration experiment
<b>7-8</b>	Newton's laws of motion: Experiment with Atwood instrument
<b>9-10</b>	Simple pendulum
<b>11-12</b>	Collisions and the conservation of linear momentum experiment
<b>13-14</b>	Rotational motion
<b>15</b>	Review and make up
<b>16</b>	Final Exam

# LABORATORY INSTRUCTIONS

1. **The most important thing in the laboratory is your safety.** The dangers mostly result from a lack of knowledge of the equipment and procedures.
2. **Personal safety rules must be obeyed with extreme discipline.**
3. When you enter the laboratory never play with the equipment until it has been explained and the instructor has given permission.
4. Keep your experimental equipment and tabletop clean.
5. Report any accident to your instructor immediately.
6. Most of the equipment used in the laboratory is expensive and some of them are delicate. Even after you are familiar with the equipment, always have your experimental setup checked and approved by the instructor before putting it into operation.
7. If any of the equipment is broken or does not function properly, report it to the instructor.
8. Read and study the experiments before you come to the laboratory.

# REPORT WRITING

The experiment report must consist of the following parts:

- **TITLE**
- **PURPOSE OF THE EXPERIMENT**
- **PROCEDURE**
- **TABLES**
- **CALCULATIONS**
- **RESULTS AND DISCUSSION**

**1. TITLE**

The title must be as brief as possible.

**2. PURPOSE OF THE EXPERIMENT**

The purpose of the experiments is outlined in this part.

**3. PROCEDURE**

The procedure of the experiment and the experimental setup are explained in this part.

**4. TABLES**

The measured data and the calculated results are presented in the tables.

**5. CALCULATIONS**

According to the purpose of the experiment, the calculations are done and the graphs are plotted in this part.

First, the formulas must be outlined. If there are multiple formulas of equations each one must be numbered. Second, the units of every parameter and result must be written.

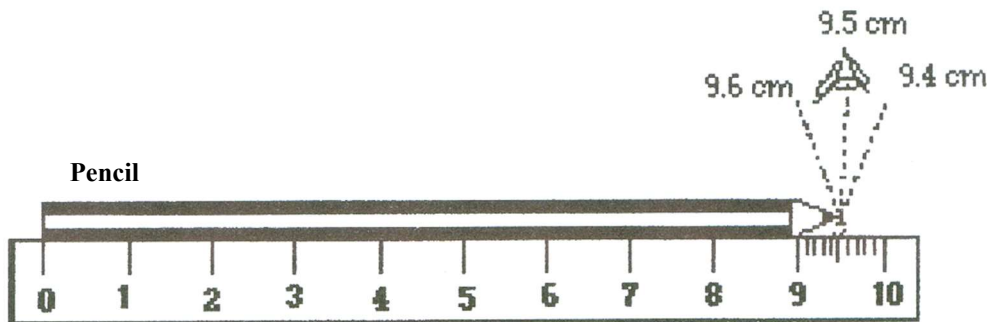
Appropriately scaled graph papers (logarithmic, linear...) must be chosen. The axis must be labeled and scaled.

**6. RESULTS AND DISCUSSIONS**

In this part, the theoretical and experimental results must be compared. The corresponding errors must be outlined and discussed.

# EXPERIMENTAL ERRORS

Physics is based on the measurements of physical quantities such as length, time, mass, speed, velocity, acceleration, force, momentum, temperature.... The measurements must be performed by taking into account the error limits of the measurement setup. As an example, using a ruler results in an error. The zero mark on the ruler is usually a line, which has a certain thickness. Additionally, the looking direction of the researcher to the zero line also may result in an error. For this reason, a certain measurement is not possible.



**Figure 1.** Measurement error of a ruler.

In the physics laboratory, many different measurement instruments are used such as a ruler, voltmeter, thermometer.... The errors due to these instruments are called experimental errors and the quantity of the errors can be estimated. The most accurate result of the measurement can be obtained by considering the error of the measurement.

The experimental error caused by the instrument in measuring can be identified as the smallest unit that can be read from the instrument. For example, for a ruler with a millimeter division, the error caused by the ruler is 1 mm or 0.1 cm. If the measured length is 2.5 cm, the most accurate result will be  $2.5 \pm 0.1$  cm. Additionally, errors should also be taken into account when using measurements in calculations.

Let's consider X and Y measurements, that have errors  $\Delta X$  and  $\Delta Y$ , respectively. To find  $R = X + Y$  with the closest accuracy,  $\Delta R$  must be calculated and  $R \pm \Delta R$  must be used, such as:

$$R + \Delta R = (X + \Delta X) + (Y + \Delta Y)$$

$$R + \Delta R = (X + Y) + (\Delta X + \Delta Y) \quad (1)$$

$$R - \Delta R = (X - \Delta X) + (Y - \Delta Y)$$

$$R - \Delta R = (X + Y) - (\Delta X + \Delta Y) \quad (2)$$

$$R \pm \Delta R = (X + Y) \pm (\Delta X + \Delta Y) \quad (3)$$

$$\Delta R = \Delta X + \Delta Y \quad (4)$$

For,  $R = X - Y$

$$R \pm \Delta R = (X - Y) \pm (\Delta X + \Delta Y)$$

$$\Delta R = \Delta X + \Delta Y \quad (5)$$

**When measured values are added or subtracted, the maximum error is the sum of the errors of both magnitudes.**

Let's consider X and Y measurements, that have errors  $\Delta X$  and  $\Delta Y$ , respectively. To calculate  $P=X.Y$ ,  $\Delta P$  must be calculated to find the result with the closest accuracy. It can be obtained by:

$$P + \Delta P = (X + \Delta X). (Y + \Delta Y)$$

$$P + \Delta P = X\left(1 + \frac{\Delta X}{X}\right)Y\left(1 + \frac{\Delta Y}{Y}\right)$$

$$P + \Delta P = X.Y\left(1 + \frac{\Delta X}{X} + \frac{\Delta Y}{Y} + \frac{\Delta X.\Delta Y}{X.Y}\right) \quad (6)$$

In Equation 6. the last term  $\frac{\Delta X.\Delta Y}{X.Y}$  can be neglected since it is respectively smaller than the other terms.

$$P + \Delta P = X.Y\left(1 + \frac{\Delta X}{X} + \frac{\Delta Y}{Y}\right) \quad (7)$$

$$P - \Delta P = X.Y\left(1 - \frac{\Delta X}{X} - \frac{\Delta Y}{Y}\right) \quad (8)$$

As a result, Equation 9. is obtained.

$$P \pm \Delta P = X.Y \pm X.Y\left(\frac{\Delta X}{X} + \frac{\Delta Y}{Y}\right)$$

$$\Delta P = P\left(\frac{\Delta X}{X} + \frac{\Delta Y}{Y}\right) \quad (9)$$

The percentage error can be written as:

$$\frac{\Delta P}{P}. 100 = \left(\frac{\Delta X}{X}. 100 + \frac{\Delta Y}{Y}. 100\right) \quad (10)$$

For the division,  $D = \frac{X}{Y}$ , similar to the previous calculations the error ' $\Delta D$ ' and the percentage error can be written as,

$$\Delta D = D.\left(\frac{\Delta X}{X} + \frac{\Delta Y}{Y}\right) \quad (11)$$

$$\frac{\Delta D}{D} \cdot 100 = \left( \frac{\Delta X}{X} \cdot 100 + \frac{\Delta Y}{Y} \cdot 100 \right) \quad (12)$$

respectively.

For X, Y and Z measurements the percentage error of  $R = \frac{X^n Y^m}{Z^k}$  the following equation can be used:

$$\frac{\Delta R}{R} \cdot 100 = n \left( \frac{\Delta X}{X} \cdot 100 \right) + m \left( \frac{\Delta Y}{Y} \cdot 100 \right) + k \left( \frac{\Delta Z}{Z} \cdot 100 \right) \quad (13)$$

For the trigonometric calculations such as,

$$R = \sin\theta$$

the following equation can be used:

$$\Delta R = |\sin(\theta + \Delta\theta) - \sin\theta| \quad (14)$$

where  $\Delta\theta$  is the error in the angle  $\theta$ .

# SIGNIFICANT FIGURES

One of the ways of indicating the error in a measurement is by the number of figures recorded. For example, for the distance measured with a ruler marked in millimeters we record  $2.55 \pm 0.05$  cm, so this distance would be written with three significant figures, 2.55.

In recording measurements, the correct number of significant figures must be used and when possible, the more definite indication  $\pm$  must be added. To record the results of the measurement correctly, the digits including the last one estimated are called **significant figures**.

The number of significant figures has nothing to do with the location of the decimal point. The number of significant figures in a measurement is determined as follows.

1. The leftmost nonzero digit is the most significant.
2. If there is no decimal point, the rightmost nonzero digit is the least significant.
3. If there is a decimal point, the rightmost digit is the least significant, even if it is zero.
4. All digits between the least and most significant digits are considered to be significant.

## Example:

Some measurements are recorded as; 255 mm; 15.2 cm; 7.09 V; 245000 mA; 0.0523 km, 4.70 g. How many significant figures do we have in these measurements?

Answer: We have three significant figures in each of these measurements.

**Significant notation:** Write the results of a measurement as two factors; the first factor contains all the significant figures, having one nonzero digit in front of the decimal point, and the second factor, is a power of 10.

## Example:

$$255 \text{ mm} = 2.55 \times 10^2 \text{ mm}$$

$$2.04 \text{ V} = 2.04 \times 10^0 \text{ mm}$$

$$170000 \text{ mA} = 1.75 \times 10^5 \text{ mA}$$

**Multiplication and division:** In the multiplication or division of numerical measurements, retain in the result only as many figures as the number of significant figures in the least accurate number used in the calculation.

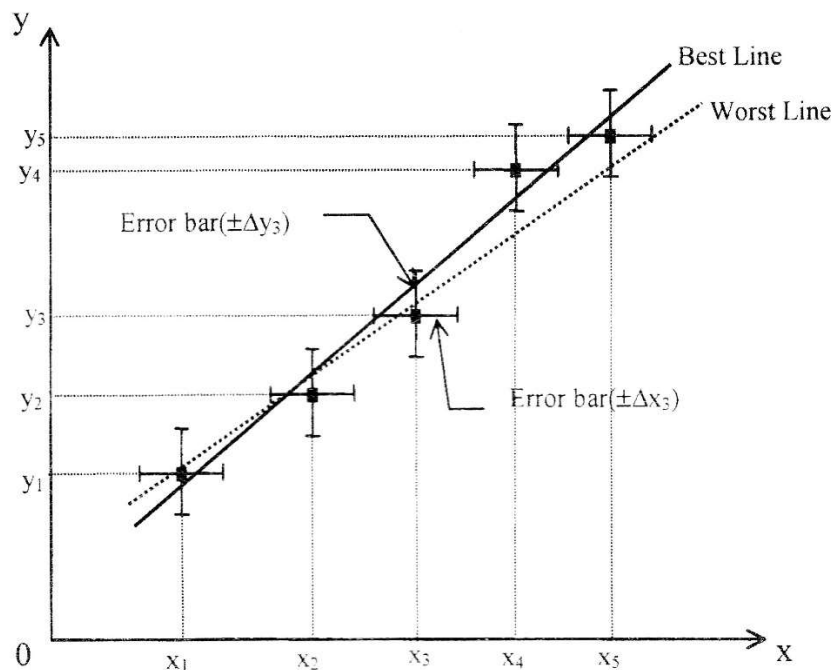


**Addition and subtraction:** When carrying out addition and subtraction with numerical measurements, do not carry out the result beyond the first column (from the left) that contains a doubtful digit.

# GRAPHS

The quantitative relationship between the physical quantities involved in an experiment, these quantities are presented in tables and/or graphs. A graph must include the following properties:

1. The title of the graph must be written on the graph paper.
2. The axis must be labeled with the quantity plotted and its proper units must be written.
3. The graph must be scaled in a presentation way that all of the data must be distributed as wide as possible over the area of the graph paper.
4. The error bars representing the uncertainty of the measurements should be plotted in each data point.



**Figure 2.** Example of a straight-line graph with error bars.

For  $y = mx + b$  equation, where  $x$  and  $y$  are the variables and  $m$  and  $b$  are the constants. When the graph of these two quantities is plotted, the graph is a straight line. To plot this graph first, the data must be pointed on the coordinate system, starting from  $(x_1, y_1), (x_2, y_2)$ ... etc. Second, the error bars must be drawn, such as  $\Delta x_1$  in  $x$ -axis and  $\Delta y_1$  in  $y$ -axis. In practice, the measured points could be scattered because of the error they contain. In such a case, The best straight line passing through the data points must be drawn. The best straight line can be drawn by using a transparent ruler. The best straight line should pass from as many data points as possible and equal number of data points should be distributed on either side of the best line. Additionally, the best straight line must pass inside as many error bars as possible. Third, the worst straight line must be drawn by considering the error bars as shown in Figure 1. The slope of the best straight line gives 'm' and the intersection of the line with the  $x$ -axis gives 'b'.

$$m = \frac{y_2 - y_1}{x_2 - x_1} \quad (15)$$

The error ' $\Delta m$ ' is calculated from the absolute difference between the slopes of the best and the worst straight lines.

$$\Delta m = |m - m^l| \quad (16)$$