

## Unit 1

# M

## Measurement and Practical Work

Physics is the study of the basic laws of nature. Its beauty lies in the discovery and application of these laws of nature to make life simple and create a better world. For example, from rockets sent to space to integrated chips in computers, to lasers used to perform eye surgery. From atoms and subatomic particles to solar system and galaxies all obey the laws of physics.

Rocketry and space travel have their roots firmly planted in the physical laws. The transportation industry relies heavily on physics in the development of engines and the design of aerodynamic vehicles. Entire electronics and computer industries owe their existence to the invention of transistors, that come from the electrical nature of solids. The telecommunication industry depends on electromagnetic waves from theory of electricity and magnetism. x – ray, ultrasonic and magnetic resonance concepts of physics are also used for observing images of the interior of the human body. The laser used in space exploration and in Medicine is a direct application of the principles of atomic physics ... etc.

### 1.1 Science of Measurement

Physics is all about observing natural phenomena and then experimenting. Hence, it is a science of measurement.

#### The Scientific Method

Science is an organized body of knowledge that is based on a method of looking at the world. The same problem may be analyzed differently by different scientists. However, there are common guidelines for the practice of science that most scientists pass through. These general approaches to problems are called *scientific methods*.

**Scientific Method:** Is a systematic procedure scientists use to acquire knowledge in science.

Scientific method ensures a *rigorous, evidence based structure* where only ideas that have been carefully tested are accepted as scientific theory.

☛ The common steps or processes in scientific method are:

- **Ask a Question**  
This may be based on an observation. Such as why is the sky blue? Why does the sun shine?
  - **Do Background Research or Use Existing Knowledge**  
Your question might be already answered by other. If so, search what has been said about it.
  - **Form a Hypothesis**  
Make a temporary explanation or guess possible answer for your observation or question
  - **Make predictions from your Hypothesis**
  - **Do Experiment**  
Make practical work under known conditions to test the truth of your hypothesis.
  - **Analyze your Experimental Data**  
Examine in detail using mathematical relations or qualitatively the meaning of your set of data
  - **Draw Conclusion**  
Generate the outcome of the overall result. See if your hypothesis was correct. If not, construct a new hypothesis and repeat.
- ☛ If your hypothesis is correct, it will be cross checked and tested by others before it becomes an accepted scientific theory. This process of peer review is important to get evidence based and not made up scientific theory.

## 1.2 Significant Figures

Significant figures are those digits that correctly indicate the precision of a measurement. They show the limits of accuracy and the beginning of uncertainty.

**Significant Figures:** Are reliably known or meaningful digits in a measured or calculated quantity.

### Rules For Determining The Number of Significant Figures

1. All non- zero digits are significant  
For example, 132.73 contains 5 significant figures
2. All zeros between two non zero digits are significant  
For example, 207.009 contains 6 significant figures
3. A) All zeros to the left of understood decimal point but to the right of a non- zero digit are not significant  
For example, 307000 contains 3 significant figures

B) All zeros to the left of understood decimal point but to the right of a non-zero digit are significant if they come from a measurement.

For example, 400m has 3 significant figures

4. All zeros to the left of an expressed decimal point and to the right of a non-zero digit are significant

For example, 307000. Contains 6 significant figures

5. All zeros to the right of a decimal point but to the left of non-zero digit are not significant provided there is only a zero to the left of the decimal point.

For example, 0.000345m contains 3 significant figures

6. All zeros to the right of a decimal point and to the right of a non-zero digit are significant

For example, 0003040 and 40.00m each has 4 significant figures

### Illustrative Example

1. State the number of significant figures for the following

i. 600900

ix. 426.071

ii. 25300

xi. 6.032

iii. 648700.

xii. 0.0631

iv. 400m

xiii. 0.007

v. 7785

xiv. 0.0050

vi. 5212.0

xv. 6.320

vii. 978.850

xvi.  $9.1 \times 10^{-31}$

viii. 984.06

xvii.  $2.64 \times 10^{24}$

xviii. 0.2370

xix. 0.045

xx. 0.0006032

### **Solution**

i. 4

viii. 5

xv. 4

ii. 3

ix. 6

xvi. 2

iii. 6

xi. 4

xvii. 3

iv. 3

xii. 3

xviii. 4

v. 4

xiii. 1

xix. 2

vi. 5

xx. 4

vii. 6

## Arithmetic operations with significant figure

### 1. Addition and Subtraction

In addition or subtraction, the number of decimal places which are significant in the result is the same as the smallest number of significant decimal places in any number used in the sum or difference.

- Use the least number of decimal places

### 2. Multiplication and Division

In multiplication or division, the number of significant figures in the product or the quotient is the same as the smallest number of significant figures in any of the factors.

- Use the least number of significant figures

### Illustrative Example

2.
  - a. Add 17.35g to 25.6g
  - b. Add  $6.75 \times 10^3$  cm and  $4.52 \times 10^2$  cm
  - c. Subtract 36.8 km from 97 km

**Solution:** a.  $17.35 \text{ g} + 25.6 \text{ g} = 42.95 \text{ g}$

- The answer is 43.0g

- b. First convert to the same power of ten

$$4.52 \times 10^2 \text{ cm} = 0.452 \times 10^3 \text{ cm} = 0.45 \times 10^3 \text{ cm}$$

$$6.75 \times 10^3 \text{ cm} + 0.45 \times 10^3 \text{ cm} = 7.20 \times 10^3 \text{ cm}$$

$$\text{c. } 97 \text{ km} - 36.8 \text{ km} = 60.2 \text{ km}$$

- The answer is 60 km

3.
  - a. Multiply 3.8 and 0.125 with due regard to significant figure
  - b. Divide 8.2 by 3.885

**Solution:** a.  $3.8 \times 0.125 = 0.475$

- The answer is 0.48

$$\text{b. } \frac{8.2}{3.885} = 2.11068$$

- The answer is 2.1

### 1.3 Uncertainty in Measurements

Numbers obtained by measurement are always inexact. There are many causes of uncertainty, but the most common are:

- The person taking the measurement
- The measuring device

- The environment where the measurement is being made.
- The nature of the object being measured.

**Uncertainty:** Is the amount of doubt in a measurement

For example, if the width of this book is reported as:

$$10 \text{ cm} \pm 0.25 \text{ cm}$$

It means that, the true value is unlikely to be less than 9.75 cm or greater than 10.25 cm. hence, we can observe that, 0.25cm is the uncertainty

### Percentage Uncertainty

It is a way of expressing the uncertainty in terms of percentage.

$$\text{Percentage uncertainty} = \frac{\text{Uncertainty}}{\text{measured value}} \times 100$$

For example, the percentage uncertainty of  $10 \pm 0.25$  is,

$$\% \text{ uncertainty} = \frac{0.25}{10} = 2.5\%$$

So we can write as,  $10\text{cm} \pm 2.5\%$

### Keep in Mind That:

- Percentage uncertainty tells us the amount in a measurement we are not sure of in percent.  
For instance " $47\Omega \pm 10\%$ " means, the true value differs from  $47\Omega$  by 10%. So it is between 42 and  $52\Omega$ .
- As a rule, percentage uncertainty should be expressed in two significant figures.
- In multiplication and division, the percentage uncertainty of the given values should be added.

### Illustrative Example

4. If  $I = 2.0 \text{ A} \pm 0.05\text{A}$ . Find the percentage uncertainty

**Solution:** Percentage uncertainty  $= \frac{0.05}{2.0} \times 100 = 2.5\%$

So we can write  $I = 2.0\text{A} \pm 2.5\%$

5. If  $v = 6.25 \text{ v} \pm 0.8\%$  and  $R = 4.5\Omega \pm 2\%$ , find  $I$

**Solution:**  $I = \frac{V}{R} = \left( \frac{6.25}{4.5} \right) \pm (0.8 + 2)\%$

$$\Rightarrow I = 1.4\text{A} \pm 2.8\% = 1.4\text{A} \pm 0.04\text{A}$$

6. If  $\overline{V}_{av} = 3.86 \text{ m/s} \pm 3.5\%$  and  $t = 2.4 \text{ sec} \pm 4.7\%$

Find  $\vec{S}$

**Solution:**  $\vec{S} = (\vec{V}_{av})(t) = (3.86)(2.4) \pm (3.5 + 4.7)\%$

$$\Rightarrow \vec{S} = 9.3\text{m} \pm 8.2\%$$

7. If  $r = 2.6\text{ cm} \pm 2.34\%$ , Find area of the circle

**Solution:**  $A = \pi r^2 = \pi(2.6)(2.6) \pm (2.34 + 2.34)\%$   
 $6.8\pi\text{ cm}^2 \pm 4.7\%$

8. Given  $I = 6.2\text{A} \pm 1.6\%$ ,  $V = 24.7\text{v} \pm 0.2\text{v}$ .

Find  $R$

**Solution:**  $R = \frac{V}{I} = \left(\frac{24.7}{6.2}\right) \pm (0.8 + 1.6)\%$

$$R = 4.0\ \Omega \pm 2.4\%$$

**Note that,** the percentage uncertainty of  $24.7\text{v} \pm 0.2\text{v}$  is

$$\left(\frac{0.2}{24.7}\right) \times 100 = 0.8\%$$

#### 1.4 Errors in Measurement

The deviation of a measured value from the standard or accepted value is called *error*.

**Error:** Is a value which is not actual or true.

- ☛ Accepted or true value is the actual value of the measured object without any experimental error.

The most common types of errors in measurement are:

1. **Random error:** Is unpredictable error that has no pattern or bias and it makes the reading above or below the true value.  
 → Can be reduced by taking several readings and average them
  2. **Parallax error:** Is caused by improper position of the eye while taking record of a measured value  
 → Can be reduced by taking reading of the measured value perpendicularly
  3. **Systematic error:** It shows bias or trend and makes your reading too high or too low  
 → Can be reduced by redesigning the measuring instrument or by taking measurement properly
  4. **Zero error:** Is caused by an instrument that does not start from the zero mark  
 → Can be reduced by making the appropriate instrument adjustment.
- ☛ In a more general sense, errors are of three types

- Personal error: Example, parallax error, systematic error
- Instrumental error: Example, systematic error, zero error
- Environmental error: Example, random error.

### 1.5 Precision and Accuracy

Precision and accuracy are terms which are used to express uncertainty in measurement.

**Precision:** Is the closeness or exactness of measured values to each other

The precision is good or high if each of the measurements is close to the average value

- The more precise a reading is, the smaller the uncertainty.  $1.0\text{m} \pm 0.1\text{m}$ ,  $1.00\text{m} \pm 0.01\text{m}$ ,  $1.000\text{m} \pm 0.001\text{m}$  are in order of increasing precision.

**Accuracy:** Is the closeness of a measured value to its true or correct value.

For example, if the true or accepted value of  $g = 9.8066 \text{ m/s}^2$ , and if you make three measurements of  $g_1 = 9.76 \text{ m/s}^2$ ,  $g_2 = 9.86 \text{ m/s}^2$ , and  $g_3 = 9.82 \text{ m/s}^2$  the most accurate value is  $g_3 = 9.82 \text{ m/s}^2$  since it is closest to  $g = 9.8066 \text{ m/s}^2$ .

- Measurements of high precision are more likely to be accurate than are those of poor precision, but even highly precise measurements are sometimes inaccurate.

### 1.6 Writing a Laboratory Report

A Laboratory report is a written composition of the result of an experiment, written precisely and clearly using good grammar and punctuation and includes;

**Title:** Tells name of the experiment

**Objective:** States the purpose of experiment, i.e what to achieve

**Theory:** Describes the equations, concepts and principles to be used

**Material:** Describes substances, equipments or instruments to be used

**Procedure:** Tells steps used in doing the experiment

**Data:** Represents the measured values and observed information

**Data Analysis:** Describes the data in meaningful manner using graphs, tables, software results.

**Result and Discussion:** Interpretation of the data analyzed with the possible sources of error.

**Conclusion:** Summary of the implication of experiment result

**Evaluation:** Assessment of the reliability and validity of the experiment result and designing a way of improving the experiment to make it realistic.

### Illustrative Example

9. Which one of the following experimental errors can be reduced by taking repeated measurements (UEE: 2007)
- |                      |                  |
|----------------------|------------------|
| A. parallel errors   | C. Random errors |
| B. Systematic errors | D. Zeros errors  |
- Answer: C**

### Unit 1: Additional Examples

10. The number of significant figures in 0.00040 m is
- |      |      |      |      |
|------|------|------|------|
| A. 1 | B. 2 | C. 3 | D. 4 |
|------|------|------|------|

**Explanation:** All zeros to the right of a decimal point and a non-zero digit are significant.

**Answer: B**

11. The number of significant figures in 600m is
- |      |      |      |      |
|------|------|------|------|
| A. 1 | B. 2 | C. 3 | D. 4 |
|------|------|------|------|

**Explanation:** Zeros to the right of non-zero digit are significant when they come from a measurement.

**Answer: C**

12. The number of significant figures in 3.80 m is
- |      |      |      |      |
|------|------|------|------|
| A. 1 | B. 2 | C. 3 | D. 4 |
|------|------|------|------|

**Answer: C**

13. Which of the following is false regarding significant figures

- |    |                                                                                                                                        |
|----|----------------------------------------------------------------------------------------------------------------------------------------|
| A. | All non – zero digits are significant                                                                                                  |
| B. | The zeros appearing in the middle of a number are significant while those at the end of a number without a decimal point are ambiguous |
| C. | The power of 10 are counted while counting the number of significant figures.                                                          |
| D. | Greater the number of significant figure in a measurement, smaller is the percentage error.                                            |

**Answer: C**

14. The number of significant figures in 0.01020

- |      |      |      |      |
|------|------|------|------|
| A. 3 | B. 4 | C. 5 | D. 6 |
|------|------|------|------|

**Answer: B**

15. The number of significant figures in 0.900 is

- |      |      |      |      |
|------|------|------|------|
| A. 1 | B. 2 | C. 3 | D. 4 |
|------|------|------|------|

**Answer: C**

16. The number of significant figures in 0.007 is

- |      |      |      |      |
|------|------|------|------|
| A. 1 | B. 2 | C. 3 | D. 4 |
|------|------|------|------|

**Answer: A**

17. The number of significant figures in  $0.0060 \times 10^{-18}$  m is

- |      |      |      |      |
|------|------|------|------|
| A. 2 | B. 3 | C. 4 | D. 5 |
|------|------|------|------|

**Answer: A**