Physics Notes

BY

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Class:10+1
Unit: I
Topic: Physical World & Measurement

SYLLABUS: UNIT-I

Physics-scope and excitement; Physics, technology and society. Force in nature, conservation laws; Examples of gravitational, electromagnetic and nuclear forces form daily-life experiences (qualitative description only).

Need for measurement; Units of measurement; Systems of units; SI units, Fundamental and derived units.

1-C **Length, mass and time measurements.**

1-D **Dimensions of physical quantities, dimensional analysis and its applications.**

1-E **Accuracy and precision of measuring instruments, Errors in measurement; Significant figures.**

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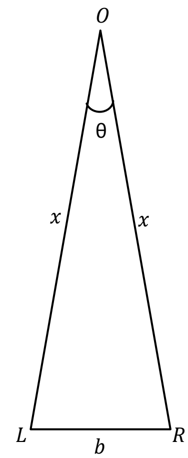
$Unit\ 1 - C$

Q.1. Explain method to measure distance of nearby star using parallax method.

Ans. Large distances, such as the distance of a planet or a star from earth can be measured by the **parallax method**.

Parallax is the name given to change in the position of an object with respect to the background, when the object is seen from two different positions. The distance between the two positions (*i.e.*, points of observation) is called the **basis**.



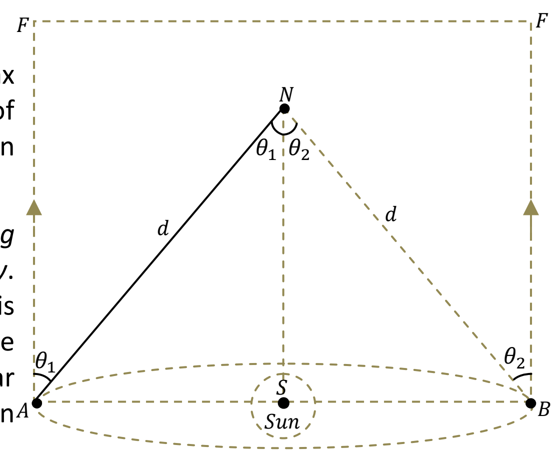
For example, in Fig., when we hold a pen in front of us against the background of a wall and look at the pen first by our left eye *L* (closing the right eye) and then by our right eye *R* (closing the left eye), we find that position of pen changes with respect to the background wall. This is parallax. The distance between the left eye (*L*) and right eye (*R*) in this case is the **basis**. ∠*LOR* is called the *parallax angle* or *parallactic angle*.

Taking *LR* as an arc of length *b* and radius *LO* = *RO* = *x*,
we get $\theta = \frac{b}{x}$

Knowing *b* and measuring θ, we can calculate *x*.

As astronomical distance are too large, parallax angle θ is too small to be measured. Hence, instead of taking distance between two eyes as basis, we may broaden the base suitably.

The parallax method has been used for measuring distances of stars which are less than 100 light years away. The diameter *AB* of earth's orbit around the sun (*S*) is chosen as the base line, Fig., *N* is the nearby star whose distance (*d*) from earth is to be measured. *F* is far off star whose direction is taken practically the same at all position of earth in its orbital motion.



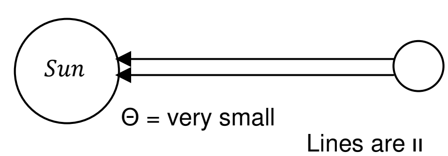
Details to be given:
F→ Faraway star
N→ Nearby Star
A→ One position of Earth
E→ Another position of Earth
(say after 6 months)

Suppose *A* is the position of earth in its orbital motion at any time. Using an astronomical telescope, we measure $\angle FAN = \theta_1$, between the direction of light from distant star *F* and nearby star *N*.

As is clear from Fig.

$\angle FAN = \angle ANS = \theta_1$

After six months, earth is at *B*, a position diametrically opposite to the position *A* on the orbit. $\angle FBN = \theta_2$, between the directions of light from distant star *F* and nearby star *N* is measured again (The distance of nearby star N is so large that any change in the position of N during six months is negligible).



∴ $\angle FBN = \angle BNS = \theta_2$

Clearly, $\angle ANB = \angle ANS + \angle BNS = \theta_1 + \theta_2$

This is the angle which the nearby star N subtends on the orbital diameter of earth.

As angle $= \frac{arc}{radius}$ $\therefore$ $\boxed{\theta_1 + \theta_2 = \frac{AB}{AN}}$

or $AN = \frac{AB}{\theta_1 + \theta_2}$

clearly, $AB = 2\,AS$, where AS is distance between sun and earth.

$AB = 2\,AU = 2 \times 1.5 \times 10^{11}\text{m} = 3 \times 10^{11}\text{m}$

IF $(\theta_1 + \theta_2)$ is known (in radian), then AN can be calculated.

The parallax method is also used for determining distance of moon from earth. Two places on the surface of earth, which are far removed from each other from the base line. Parallax angle (*w.r.t.* a far off star) is measured using an astronomical telescope.

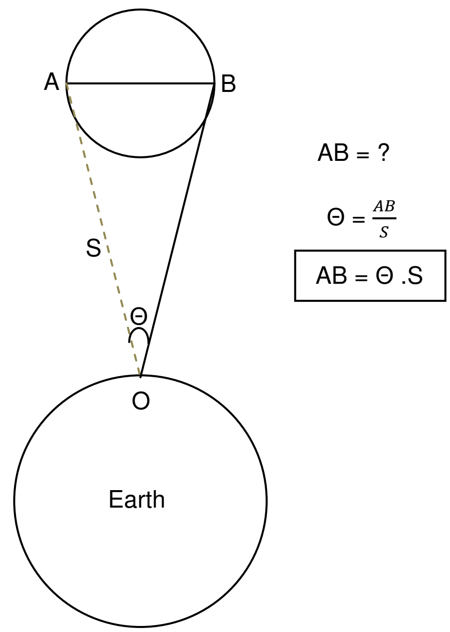
The parallax method is used for measuring distances of nearby stars only.

As the distance of star increases, the parallax angle decreases, and a great degree of accuracy is required for its measurement. Keeping in view the particle limitation in measuring the parallax angle, the maximum distance of a star we can measure by parallax method is limited to 100 light years.

Q.2. **Describe a method to measure diameter of moon (*i.e.* moon as an example).**

Ans. **<u>Size of an Astronomical Object</u>**:-

The size of an astronomical object like moon can be measured using an astronomical telescope. In Fig, *O* is an observation point on earth. An astronomical telescope held at *O* is focused on moon, when we observe an image in the form of a circular disc. We measure $\angle AOB = \theta$, say. It is the angle between the two directions when two diametrically opposite points of the moon are viewed through the telescope.



Let *s* be the average distance of moon from the surface of earth. As *s* is very large compared to the diameter *AB* of moon, therefore

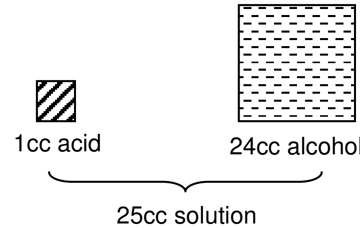
$AB \simeq$ length of circular arc or radius s

$= s\,\theta$

Hence, *AB* can be calculated, when *s* is known and θ is measured.

The angle subtended by the two diametrically opposite ends of the moon at a point on the earth is called the **angular diameter of the moon**. Its value is about 0.5^0.

Q.3. Discuss a method to measure size of a Molecule?



Ans. **Step 1.** acid = $\frac{1}{25}$

Step 2. 1cc of this sol. 19 acc of alcohol

$\underbrace{\frac{1}{25}\text{cc of acid} \quad \frac{24}{25}\text{cc of alcohol}}_{\text{20cc of sol.}}$

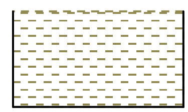
$\frac{1}{25}$cc + [19cc alcohol + $\frac{24}{25}$cc of alcohol]

Solution of oleic acid = $\frac{1}{500}$

with concentration

Step 3. $\frac{1}{500}$ sol.

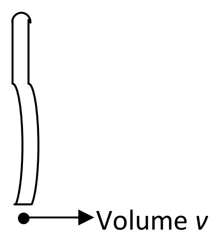
1 unit of acid and 499 unit of alcohol



Step 4. n drops

Total volume = nv

Acid volume = $\left(\frac{nv}{500}\right)$ ----------- (1)

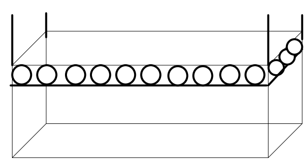


Step 5. Area = A

Thickness = t

Volume = At

From (1) At = $\frac{n.v}{500}$



Step 6. t = $\frac{n.v}{500} \times \frac{1}{A}$

Thickness of layer = size of molecule

Q.1. **Explain**

a) Dimensions

b) Dimensional formula

c) Dimensional equation, with examples.

Ans.a) **<u>Dimesions</u>**:-

Dimensions are powers of L, M ,T, etc. to represent a physical quantity.

<u>Example</u>:-

1. Velocity = $\frac{Distance}{Time}$

$= \frac{L}{T}$

$= L^1.T^{-1}$

$[V] = [M^0.L^1.T^{-1}]$

Dimensions of velocity are 0 in Mass, 1 in length and -1 in time.

2. Acceleration $= \frac{L}{T^2}$

$= L^1.T^{-2}$

[Acc.] = $[M^0.L^1.T^{-2}]$

Dimensions of Acc. Are 0 in Mass, 1 in length and -2 in time.

b) **<u>Dimensional Formula</u>**:-

It is an expression which tells us how a physical quantity depends on M, L, T etc.

<u>Example</u>:-

1. $[M^0.L^1.T^{-1}]$ is dimensional formula of velocity.
2. $[M^0.L^1.T^{-2}]$ is dimensional formula of acceleration.

c) **<u>Dimensional Equations</u>**:-

When a physical quantity is equated to its dimensional formula, it is called dimensional equation.

<u>Example</u>:-

1. [V] = $[M^0.L^1.T^{-1}]$
2. [acc] = $[M^0.L^1.T^{-2}]$

Q.2. Use dimension concept to convert one unit of a system to another system of units.

Ans. Dimensional analysis can be used to convert one unit of a system to another.

<u>Example</u>:-

1. Convert $\frac{1\ km}{1\ hr}$ to $\frac{m}{sec}$

<u>Step 1</u>. Identify the physical quantity
e.g:- here it is speed.

<u>Step 2</u>. $n_1 u_1 = n_2 u_2$

<u>Step 3</u>. $n_1[M_1^0 L_1^1 T_1^{-1}] = n_2[M_2^0 L_2^1 T_2^{-1}]$

<u>Step 4</u>. (1) $\left(\frac{km}{hr}\right)$ = (?)$\left(\frac{m}{sec}\right)$

$$[n_1][M_1^0 L_1^1 T_1^{-1}] = [n_2][M_2^0 L_2^1 T_2^{-1}]$$

$$(1)\ [M_1^0 \underset{\text{Km}}{\underset{\downarrow}{L_1^1}} \underset{\text{hr}}{\underset{\downarrow}{T_1^{-1}}}] = (n_2)[M_2^0 \underset{\text{m}}{\underset{\downarrow}{L_2^1}} \underset{\text{sec}}{\underset{\downarrow}{T_2^{-1}}}]$$

$$(1)\ \left[\left(\frac{M_1}{M_2}\right)^0 \left(\frac{L_1}{L_2}\right)^1 \left(\frac{T_1}{T_2}\right)^{-1}\right] = n_2$$

$$(1)\ \left[(1)\left(\frac{1km}{1m}\right)^1 \left(\frac{1hr}{1sec}\right)^{-1}\right] = n_2$$

$$(1)\ \left[(1)\left(\frac{1000m}{1m}\right)^1 \left(\frac{3600sec}{1sec}\right)^{-1}\right] = n_2$$

$$(1)\ (1)\ (1000)\ (3600)^{-1} = n_2$$

$$\frac{1000}{3600} = n_2$$

$$\boxed{\frac{5}{18} = n_2}$$

<u>Conclusion</u>:- $\boxed{1\ \frac{\text{km}}{\text{hr}} = \left(\frac{5}{18}\right).\ m/sec}$

2. Convert 1 newton to dyne

Step 1. Identify the physical quantity
e.g:- here it is force.

<u>Step 2</u>. $n_1 u_1 = n_2 u_2$

<u>Step 3</u>. $n_1[M_1^1 L_1^1 T_1^{-2}] = n_2[M_2^1 L_2^1 T_2^{-2}]$

Step 4. $n_1[\underset{\substack{\downarrow \\ 1\text{kg}}}{M_1^1}\ \underset{\substack{\downarrow \\ 1\text{m} \\ (\text{SI})}}{L_1^1}\ \underset{\substack{\downarrow \\ 1\text{sec}}}{T_1^{-2}}] = n_2[\underset{\substack{\downarrow \\ 1\text{g}}}{M_2^1}\ \underset{\substack{\downarrow \\ 1\text{cm} \\ (\text{cgs})}}{L_2^1}\ \underset{\substack{\downarrow \\ 1\text{sec}}}{T_2^{-2}}]$

Step 5. $n_1 \left[\left(\frac{M_1}{M_2}\right)^1 \left(\frac{L_1}{L_2}\right)^1 \left(\frac{T_1}{T_2}\right)^{-2}\right] = n_2$

Step 6. $(1) \left[\left(\frac{1kg}{1g}\right)^1 \left(\frac{1m}{1cm}\right)^1 \left(\frac{1sec}{1sec}\right)^{-2}\right] = n_2$

Step 7. $(1) \left[\left(\frac{1000g}{1g}\right)^1 \left(\frac{100m}{1cm}\right)^1 (1)^{-2}\right] = n_2$

Step 8. (1) (1000) (100) = n_2

$10^5 = n_2$

$\boxed{1 \text{ newton} = 10^5 \text{ dyne}}$

Q.3. Use dimensional analysis to check accuracy of dimensional formula

i) Vel = $\sqrt{\frac{2GM}{R}}$

ii) E = mc^2

Ans.

i) Velocity = $\sqrt{\frac{2GM}{R}}$

LHS = Velocity i.e. $\left(\frac{Distance}{Time}\right)$

Vel = $[M^0.L^1.T^{-1}]$

RHS = $\sqrt{\frac{2GM}{R}}$

= $\left(\frac{2GM}{R}\right)^{½}$

= $\left[\frac{(\cancel{M}^{-1}.L^3.T^{-2})\,\cancel{M}^1}{L^1}\right]^{½}$

= $[M^0.L^2.T^{-2}]^{½}$

= $(M)^{\frac{0}{2}}.(L)^{\frac{2}{2}}.(T)^{\frac{-2}{2}}$

= $M^0.L'.T^{-1}$

= LHS

The formula is dimensionally correct.

ii) E = mc^2

LHS = Energy

= Force x distance

= $M^1.L^1.T^{-2}$ x L

= $M^1.L^2.T^{-2}$

RHS = mass x $(speed\ of\ light)^2$

= M x $\left(\frac{L}{T}\right)^2$

= $M^1.L^2.T^{-2}$

= LHS

The equation is dimensionally correct.

Q.4. Use dimensional analysis to derive formula for time period of pendulum

Example: T depends on

- **Mass**
- **Length**
- **Acc. Due to gravity.**

Ans. T α m^a l^b g^c

a, b, c → ?

Step 1.

$$[M^0.L^0.T^1] = (mass)^a\ (length)^b (acc. due\ to\ gravity)^c$$

$$= [M^1.L^0.T^0]^a\ [M^0.L^1.T^0]^b\ [M^0.L^1.T^{-2}]^c$$

Step 2.

$$= M^{a+o+o},\quad L^{o+b+c},\quad T^{o+o-2c}$$

Step 3.

As two sides are dimensionally same

$M^0.L^0.T^1 = M^a,\quad L^{b+c},\quad T^{-2c}$

Compare powers

a = 0, b + c = 0, -2c = 1

$\boxed{a = 0}$ $\boxed{b = \frac{1}{2}}$ $\boxed{c = \frac{1}{-2}}$

Step 4.

T α M^0 $l^{½}$ $g^{-½}$

T α $l^{½}$ $g^{-½}$

T α $\frac{l^{½}}{g^{½}}$

T α $\left(\frac{l}{g}\right)^{½}$

T α $\sqrt{\frac{l}{g}}$

$$\boxed{T = 2\pi\sqrt{\frac{l}{g}}}$$

$\underline{Unit\ 1 - E}$

Q1. What do you understand by errors of measurement? Discuss briefly the various types of errors.

Ans. **ERRORS OF MEASUREMENT**:-

This difference in the true value and the measured value of a quantity is called error of measurement.

Types of Errors

(a) **Systematic Errors**:- These are the errors whose causes are known. Such errors can, therefore be minimized. For example:

(1) *Instrumental errors* may be due to imperfection of design and erroneous manufacture of the instruments. Often, there may be zero error in the instrument.

(2) *Personal errors* may be due to inexperience of the observer. For example, lack of proper setting of the apparatus:

(3) *Error due to imperfection arise* on account of ignoring certain facts. For example, error in weighing arising out of buoyancy is usually ignored.

(4) *Errors due to external causes arise* due to changes in temperature, pressure, humidity etc. during the experiment.

(b) **Random Errors:-** These errors may arise due to a large variety of factors. The causes of such errors are, therefore, not known precisely. Hence it is not possible to eliminate the random errors.

The random errors can be minimized by repeating the observation a large number of times and taking the arithmetic mean of all the observations.

(c) **Gross Errors:-** These errors arise on account of shear carelessness of the observer. For example:

(1) Reading an instrument without setting it properly.

(2) Taking the observations wrongly without caring for the sources of errors and the precautions.

(3) Recording the observations wrongly.

(4) Using wrong values of the observations in calculations

Q2. Discuss how errors propagate in sum, difference, product and division of quantities.

Ans. **<u>PROPAGATION OR COMBINATION OF ERRORS</u>:-**

(a) Error in sum of the quantities

Suppose $x = a + b$

$$\Delta x = \pm (\Delta a + \Delta b)$$

Hence maximum absolute error in sum of the two quantities is equal to sum of the absolute errors in the individual quantities.

(b) Error in difference of the quantities

Let $x = a - b$

$$\Delta x = \pm (\Delta a + \Delta b)$$

Maximum absolute error in difference of two quantities is equal to sum of the absolute error in the individual quantities.

(c) Error in product of quantities

Let $x = a \times b$

$$\frac{\Delta x}{x} = \pm \left[\frac{\Delta a}{a} + \frac{\Delta b}{b}\right]$$

(d) Error in division of quantities

Let $x = a/b$

$$\frac{\Delta x}{x} = \pm \left[\frac{\Delta a}{a} + \frac{\Delta b}{b}\right]$$

(e) Error in quantity raised to some power

Let $x = a^n/b^m$

$$\frac{\Delta x}{x} = \pm \left[n\frac{\Delta a}{a} + m\frac{\Delta b}{b}\right]$$

Q3. What is meant by '*accuracy*' and '*precision*' of measuring instruments?

Ans. **<u>ACCURACY AND PRECISION</u>:-**

(a) **Accuracy** is *the extent to which a reported measurement approaches the true value of the quantity measured.*

(b) **Precision** *is the degree of exactness or refinement of a measurement.*

Q4. What is meant by significant figures? Give any four rules for counting significant figures.

Ans. **SIGNIFICANT FIGURES**:-

Significant figures in the measured value of a physical quantity tell the number of digits in which we have confidence. Larger the number of significant figures obtained in a measurement, greater is the accuracy of the measurement. The reverse is also true.
Significant figures often represent the accuracy with which a physical quantity is measured. Therefore, number of significant figures in a physical quantity depends upon the least count of the instrument used for its measurement.

COMMON RULES FOR COUNTING SIGNIFICANT FIGURES:-

Following are some of the common rules for counting significant figures in a given expression:

Rule1. *All non zero digits are significant.*

For example: x=1234 has four significant figures. Again x=189 has only three significant digits.

Rule2. *All zeros occurring between two non zero digits are significant*.

For example: x= 1007 has four significant figures. Again x= 1.0809 has five significant figures.

Rule3. *In a number less than one, all zeros to the right of decimal point and to the left of a zero digit are NOT significant.*

For example: x = 0.0084 has only two significant digits. Again, x = 1.0084 has five significant figures. This is on account of Rule2.

Rule4. *All zeros on the right of the last non zero digit in the decimal part are significant.*

For example: x=0 .00800 has three significant figures 8, 0, 0. The zeros before 8 are not significant Again 1.00 has three significant figures.

Rule5. *All zeros on the right of non zero digit are NOT significant.*

For example: x= 1000 has only one significant figure. Again x= 378000 has three significant figures.

Rule6. *All zeros on the right of the last non zero digit become significant, when they come from a measurement.*

For example: suppose distance between two stations is measured to be 3050 m. It has four significant figures. The same distance can be expressed as 3.050 km or 3.050×10^5 cm. In all these expressions, number of significant figures continues to be four.

Thus we conclude that change in the units of measurement of a quantity does not change the number of significant figures.

Q5. a) Explain "*Rounding Off*" rules with examples.
b) Explain "*Arithmetical Operations*" with significant figures.

Ans.a) **Rounding Off Rules**:-

While rounding off measurements, we use the following rules by convention:

Rule 1. If the digit to be dropped is less than 5, then the preceding digit is left unchanged.
For example:
x= 7.82 is rounded off to 7.8 Again x = 3.94 is rounded off to 3.9.

Rule 2. If the digit to be dropped is more than 5, then the preceding digit is raised by one.
For example:
x= 6.87 is rounded off to 6.9 Again x= 12.78 is rounded off to 12.8.

Rule 3. If the digit to be dropped is 5 followed by digits other than zero, then the preceding digits is raised by one.
For example:
x= 16.351 is rounded off to 16.4 Again x= 6. 758 is rounded off to 6.8.

Rule 4. If the digit to be dropped is 5 or 5 followed by zeros, then the preceding digit is left unchanged, If it is even.
For example:
x= 3.250 becomes 3.2 on rounding off
Again x = 12.650 becomes 12.6 on rounding off.

Rule 5. If the digit to be dropped is 5 or 5 followed by zeros, then the preceding digit is raised by one, if it is odd.
For example:
x = 3.750 is rounded off to 3.8 Again x = 16. 150 is rounded off to 16.2.

b) **ARITHMETICAL OPERATIONS WITH SIGNIFICANT FIGURES:-**

(a) **Addition and subtraction**
In addition or subtraction, the number of decimal places in the result should equal the smallest number of decimal places of terms in the operation.

For example:
the sum of three measurements of length; 2.1 m, 1.78 m and 2.046 m is 5.926m, which is rounded off to 5.9 m (up to smallest number of decimal places).

(b) **Multiplication and Division**
In multiplication and division, the number of significant figures in the product or in the quotient is the same as the smallest number of significant figures in any of the factors.

For example:
suppose x= 3.8 and y = 0.125, Therefore, x y = (3.8) (0.125) = 0.475. As least number of significant figures is 2 (in x=3.8). Therefore, x y = 0.475 = 0.48 is rounded off to two significant figures.

Q6. What is *Absolute Error*, *Relate Error* and *%age Error*? Explain with examples.

Ans. ABSOLUTE ERROR, RELATIVE ERROR AND PERCENTAGE ERROR:-

a) **Absolute error** in the measurement of a physical quantity is the magnitude of the difference between the true value and the measured value of the quantity.

$a_m = \frac{a_1 + a_2 + \cdots \ldots a_n}{n}$

$\Delta a_1 = a_m - a_1$

$\Delta a_2 = a_m - a_2$

……………

$\Delta a_n = a_m - a_n$

b) **Mean absolute error**: It is the arithmetic mean of the magnitudes of absolute errors in all the measurement of the quantity*. It is represented by Δa Thus

$$\Delta a = \frac{\Delta a_1 + \Delta a_2 + \cdots \ldots \Delta a_n}{n}$$

c) **Relative error or Fractional error**: The relative error or fractional error of measurement is defined as the ratio of mean absolute error to the mean value of the quantity measured thus.
Relative error or Fractional error

$$= \frac{\text{Mean absolute error}}{\text{Mean value}} = \frac{\Delta a}{a_m}$$

Percentage error $= \frac{\Delta a}{a_m} \times 100\%$

Sample problem: The refractive index of water is found to have the values 1.29, 1.33, 1.34, 1.35, 1.32, 1.36, 1.30 and 1.33 calculate the mean value, absolute error, the relative error and the percentage error.

Sol. Here, mean value of refractive index

$$\mu = \frac{1.29 + 1.33 + 1.34 + 1.35 + 1.32 + 1.36 + 1.30 + 1.33}{8}$$

μ = 1.3275 = 1.33 (rounded off to two places of decimal).

Absolute errors in measurement are:

$\Delta \mu_1 = 1.33 - 1.29 = 0.04$
$\Delta \mu_2 = 1.33 - 1.33 = 0.00$
$\Delta \mu_3 = 1.33 - 1.34 = -0.01$
$\Delta \mu_4 = 1.33 - 1.35 = -0.02$
$\Delta \mu_5 = 1.33 - 1.32 = +0.01$
$\Delta \mu_6 = 1.33 - 1.36 = -\ 0.03$
$\Delta \mu_7 = 1.33 - 1.36 = +0.03$
$\Delta \mu_8 = 1.33 - 1.33 = 0.00$

Mean absolute error, Δμ = $\frac{\sum |\Delta \mu_i|}{n}$

$$= \frac{0.04 + 0.00 + 0.01 + 0.02 + 0.01 + 0.03 + 0.03 + 0.00}{8}$$

$= \frac{0.14}{8}$ = 0.0175 = 0.02

Relative error $= \pm \frac{\Delta\mu}{\mu} = \pm \frac{0.02}{1.33}$

= ± 0.015

= ± 0.02

Percentage error

= ± 0.015 × 100 = ± 1.5 %