Chapter 1
Physics and Measurement

Physics: fundamental physical science, concerned with the basic principles of the Universe.

☐ Classical mechanics concerned with:
(1) the motion of large objects relative to atoms and
(2) Move at speeds much slower than the speed of light; such as planets, rockets, and baseballs.

Introduction:

☐ Physics study natural phenomena in the Universe.

☐ Physics based on **theory**, expressed in **assumptions, ideas, concepts** which may be expressed in the form of **equations, laws, and formula** to describe natural phenomena.

☐ **Measurements and experimental observations test the validity of the theory** and check formulas used to describe the situation.

1.1 Standards of Length, Mass, and Time

Quantities are of two

(1) Basic quantities such as, **length, mass, time, charge.**

(2) Derived quantities: can be expressed in terms of the basic ones, such as, **velocity, acceleration, force**, etc⋯.

In 1960, an international committee established a set of standards for the fundamental quantities of science. It is called **the SI (Système International)**, and its fundamental units of length, mass, and time are the ***meter, kilogram,*** **and** ***second,*** respectively.
Other standards for SI fundamental units established by the committee are those for temperature (**the *kelvin***), electric current (**the *ampere***), luminous intensity (**the *candela***), and the amount of substance (**the *mole***).

Physical quantities are described:

Qualitatively (وصفا) as ***a unit of standard****; defined as the reference to which the measured quantity are compared.*

Quantitatively (كمية): a number stands before the unit standard, reports **how much the value** of the **unit of standard is**.

Examples: **5 meter, 10 kg, 15 Newton.**

☐ Standardized systems:

☐ **SI- System:** The International System of Units (abbreviated *SI* from the French; Le Système international d'unités) called [**mks** system, **cgs** system]

mks = meter, kilogram, second, m, kg, s

cgs: centimeter, gram, second cm, g, s

Length

☐ Units

- **SI – unit : meter (m) in (mks) , cgs – unit: centimeter (cm)**
- ☐ Defined in terms of meter (m) -- the distance traveled by light in a vacuum during a time of (1/299 792 458 s= 1/c c; being the speed of light)

Mass

☐ Units

- SI – mks - kilogram (kg)
  cgs – gram (g)
- BES – slug (slug)

☐ Defined in terms of kilogram, based on a specific platinum–iridium cylinder kept at the International Bureau of Standards at Sèvres, France

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Time

☐ Units: Second (s) in all three systems , defined before 1900 in terms of mean solar day

☐ Defined by atomic clock in terms of the oscillation of radiation from a cesium-133 atom (9 192 631 700 times period of vibration of light emitted)

<u>U.S. customary system</u>: In this system, the units of **length, mass, and time** are the **foot (ft), slug, and second**, respectively

There are also subunits or multipliers of the basic units = denoted as Prefixes which is a multiplier powers of ten (micro = 10^{-6}, nano = 10^{-9}, Mega = 10^{6}, Giga = 10^{9})

Table 1.4 Prefixes for Powers of Ten

Power	Prefix	Abbreviation	Power	Prefix	Abbreviation
10^{-24}	yocto	y	10^{3}	kilo	k
10^{-21}	zepto	z	10^{6}	mega	M
10^{-18}	atto	a	10^{9}	giga	G
10^{-15}	femto	f	10^{12}	tera	T
10^{-12}	pico	p	10^{15}	peta	P
10^{-9}	nano	n	10^{18}	exa	E
10^{-6}	micro	μ	10^{21}	zetta	Z
10^{-3}	milli	m	10^{24}	yotta	Y
10^{-2}	centi	c			
10^{-1}	deci	d			

1.2 Matter and Model Building

- Matter is ***made up of atoms***, the atom composed of ***electrons*** surrounding a central **nucleus**.
- The ***nucleus*** is filled with ***protons and neutrons***.
- The ***atomic number*** of the element (Z) = the number of protons.
- The ***mass number (A)*** is defined as **the number of protons plus neutrons** in a nucleus (A). ($\mathbf{{}^{A}X_{Z} = {}^{1}H_{1}, {}^{4}He_{2},}$ ${}^{135}U_{92}$)
- Protons and neutrons are composed of quarks. The quark act as a "glue" that holds the nucleus together.
- *Quarks: up, down, strange, charmed, bottom,* and *top.*
- The proton consists of **two up quarks (up, top)** of **charge (2/3e^{+})** and one **down quark: (down) (-1/3e^{+})**.
- The neutron composed of two down quarks **(down, bottom)**, and **one up quark (strange)** giving a net charge of zero.

<u>Density and Atomic Mass</u>

The density ρ **(rho) =** ***mass per unit volume*** $\rho = \dfrac{m}{V}$

The atomic mass units (u) where **1 u = 1.660 538 7 × 10^{-27} kg**, used to measure masses of atoms

Example: How Many Atoms in the Cube?

A solid cube of aluminum (density **2.70** g/cm^3) has a volume of **0.200** cm^3.
It is known that **27.0 g** of aluminum contains **6.02 × 10^{23}** atoms.
How many aluminum atoms are contained in the cube?

Solution:

(1) Find the mass of the cube of volume 0.200 cm^3

$$\rho = \frac{m}{V} \Rightarrow m = \rho V = 2.7 \times 0.2 = 0.54 \text{ g}$$

(2) The number of atoms in 0.54 g is then;

$$N_{cube} = N_A \cdot (\text{no. of moles}) = N_A \times \frac{0.54}{27} = 6.02 \times 10^{23} \times \frac{0.54}{27.0} = 1.20 \times 10^{22} \text{ Atoms}$$

1.3 Dimensional Analysis

☐ In physics, **Dimension** denotes the **physical nature of a quantity**

Example: Distance has dimension of Length measured in **cm, m, or feet.**

Symbols which specify the dimensions:
Dim. **length**= L
Dim. **Mass=M** , and,
Dim. **time = T**, respectively.

Brackets [ ] used to denote **the dimensions** of a physical quantity.

☐ **Example:** Dimensions of the speed **[υ] = L/T.**

[1] Dimensional analysis checks if an equation is correct using Dimension

[2] Dimensional analysis is also used to set up an expression

Dimensions treated as mathematical operation

Take the form: $x \propto a^n t^m$ Where **x** represents travel distance, **a** acceleration, and **t** an instant of time.

Dimension of left is length: $[x] = L = L^1 \cdot T^0$

Dimension of right: $[a^n t^m] = (L/T^2)^n (T^m)$

$$[x] = [a^n\, t^m],$$

$$L^1 \cdot T^0 = L^n \cdot T^{m-2n} \qquad \Rightarrow n = 1$$

$$\Rightarrow m-2n = 0 \;,\; m=2\times1=2$$

$$x \;\; \alpha \;\; a\, t^2$$

☐ Example of dimensional analysis

d = v t

Distance = velocity× time

L = (L/T) T = L [الابعاد يمينا=الابعاد يسارا]

☐ Example 1.1 Analysis of an Equation

Show that the expression $v = a \cdot t$ is dimensionally correct, where v represents speed, **a** acceleration, and **t** an instant of time.

Solution : For the speed term,

Left side $[v] = \frac{L}{T} : \frac{m}{s}$

Right side $[at] = [a][t] = \frac{L}{T^2} \cdot T = \frac{L}{T}$ the expression is dimensionally correct.

☐ Example 1.2 Analysis of a Power Law

Suppose we are told that the acceleration **a** of a particle moving with uniform speed **v** in a circle of radius **r** is proportional to some power of **r**, say r^n, and some power of **v**, say v^m. Determine the values of n and m and write the simplest form of an equation for the acceleration.

Solution take a to be

$$a = k\, r^n v^m$$

where k is a dimensionless constant of proportionality.

$$[a] = [k\, r^n v^m] = [r^n][v^m] \;\; ; \;\; [k] = 1$$

$$\frac{L}{T^2} = L^n \cdot \frac{L^m}{T^m} = \frac{L^{n+m}}{T^m} \quad \Rightarrow n+m=1, \quad m=2 \quad \text{and} \quad n=-1$$

or $\quad a = kv^2 r^{-1}, \quad a = k\frac{v^2}{r}.$

1.4 Conversion of Units

converts units from one system of measurement (SI, US-customary) to another or within the same system.

☐ Examples:

1 mile = 1 609 m = 1.609 km
1 ft = 0.3048 m = 30.48 cm

1 m = 39.37 in. = 3.281 ft

1 in. = 0.0254 m = 2.54 cm (exactly)

The ratio between each pair of the above examples is 1.

☐ Examples:

15 inch = 15 inch × 2.54 cm/1 inch = 38.1 cm

10 liter water = 10 liter ×1000cm^3/ 1 liter = 10,000 cm^3

10 gram = 10 cm^3 × 1 gram/cm^3

The ratios: 1 inch/2.54 cm, 1000 cm^3/ 1 liter, 1 gram/cm^3 are conversion factors.

☐ Example 1.3 Is He Speeding?

On an interstate highway in a rural region of Wyoming, a car is traveling at a speed of **38.0 m/s**. Is this car exceeding the speed limit of **75.0 mi/h**?

(1mi = 1 mile , h = hour)

1 mi = 1609 m , $1h = 60 \ min \times \frac{60s}{m} = 3600s$

$$38m/s = 38 \times \left(\frac{1}{1609}mi\right)\left(\frac{1}{1/3600h}\right) =$$

$$38\times\left(\frac{1}{1609}\text{mi}\right)\left(\frac{3600}{1}\frac{1}{\text{h}}\right)=85\,\text{mi/h}$$ Car exceeding the speed limit.

What is the speed of the car in km/h?

$$85.0\,\text{mi/h}=85.0\times(1.609\text{km})/\text{h}=137\,\text{km/h}$$

1.5 Estimates and Order-of-Magnitude Calculations

Estimated physical quantities can be approximated by a value,

The estimate may be made even more approximate by expressing it as an *order of magnitude,* which is a power of ten determined as follows:

1. *Express the number in **scientific notation**, with the multiplier of the power of ten between 1 and 10 and a unit.*

2. *If the multiplier is less than 3.162 (the square root of 10), the order of magnitude of the number is the power of 10 in the scientific notation. If the multiplier is greater than 3.162, the order of magnitude is one larger than the power of 10 in the scientific notation.*

The symbol ~ is used for "is on the order of."

☐ Examples

1- The value of a quantity **increases** by **three orders of magnitude**, means that its value increases by a factor of about $\mathbf{10^3 = 1\,000}$.

2- The order of magnitude of:

$0.0086 \approx 0.009 = 9\times10^{-3} \sim 10^{-2}$ **($9>\sqrt{10} = 3.162$ increment power by 1)**

$0.0021 \approx 0.002 = 2\times10^{-3} \sim 10^{-3}$ **(don't increment)**

$720 \approx 700 = 7\times10^{2} \sim 10^{3}$ **(increment 1)**

(Increase power whenever the number > square root of 10 = 3.162

☐ Example 1.4 Breaths in a Lifetime

Estimate the number of breaths taken during an average life span.

Solution:

As an estimated calculation consider the life span is about **70 years** = (Age)

and the average **number of breaths that a person takes in 1 min. is 10.**

Chose the year yr = 400 day, and the day = 25 h.

No. of min. in one year = 1 yr× 400 days ×25 h ×60 min = 6×10^5 min

In 70 years there will be

$$(70\ \text{yr})(6\times 10^5\ \text{min/yr}) = 42\times10^6 \approx 40\times10^6 = 4\times10^7\ \text{min}$$

$$\text{No. of breaths} = 10\times(4\times10^7)$$

$$= 4\times10^8 \sim 10^9\ \text{breaths.}$$

1.6 Significant Figures

☐ **measured quantities** are always **uncertain**.

This **experimental uncertainty** can depend on factors, such that the quality of the apparatus, the skill of the experimenter, and the number of measurements performed. **Accuracy (or uncertainty)** in measurement we write the result in terms of **significant figures**.

When the value obtained, **the last digit** is **uncertain (doubtful)**, the **other digits are certain.** Therefore the number of significant figures in a result is simply the number of figures that are known with **some degree of reliability**.

☐ Rules for deciding the number of significant figures in a measured quantity:

- **All non-zero digits are significant digits** (**zero is insignificant if there is no decimal point**)

  4 , 40, 400 has **one significant digit**

  1.3 , 130 , 1300 has **two significant digits**

  4 325.334 has **seven significant digits**

- **Zeros are significant only:**

1- **If they lie between two significant digits**.

109 has **three significant digits**

3005 has **four significant digits**

40.001 has **five significant digits**

2- **If they lie after a significant figure if there is a decimal point**.

0.10 has two significant digits (the **leading** zero is not significant, but the **trailing** zero is significant);

0.0010 has two significant digits (the last two) ;

3.20 has three significant digits, (note: 320 has two significant figures);

320.0 has 4 significant figures

Example: measurement of the area

Of a computer disk label using a meter stick as a measuring instrument. **The accuracy to which we can measure lengths is ± 0.1** cm (**the smallest division**). **Length (L)** is measured to be **6.4 cm**, but the correct length lies somewhere

between **6.4 cm** and **6.6 cm**. **Width (W)** is measured to be **5.5 cm**, the actual value lies between **5.3cm and 5.4 cm.**

The measured values are written as: (best value ± uncertainty) unit

L = 6.4 ± 0.1 cm (2 sig. fig.)
W = 5.5 ± 0.1 cm (2 sig. fig.)

The last digit is uncertain, and determines the **absolute uncertainty or experimental errors**.

A mass of 15.20 g indicates an absolute **uncertainty of 0.01 g**. So we write:

m = 15.2 ± 0.01 (wrong)
m = 15.20 ± 0.01 (right)

To find the area A = W×L

A = W×L = (**5.5 ± 0.1**) × (**6.4 ± 0.1**) [Treat them as polynomials]

= [5.5×6.4] ± [5.5×0.1 + 6.4×0.1 + 0.1×0.1]

$= 35.2 \pm [0.55 + 0.64 + 0.01] = 35.2 \pm 1.2$

Another way to find ΔA is to use $\frac{\Delta A}{A} = \frac{\Delta L}{L} + \frac{\Delta W}{W}$

$$\Delta A = A[\frac{\Delta L}{L} + \frac{\Delta W}{W}] = 35.2 \times 0.0338 = 1.20 \approx 1.2$$

Rule: In multiplication and division, the answer must *have the same number of significant figures as that in the component with the least number of significant figures.* Then,

A + ΔA = 35 ± 1 (A = 35 has 2 sig. fig as the measured values.

error = 1 = small unit of last digit)

For example,

3.0 (2 significant figures) × 12.60 (4 significant figures) = 37.8000, which should be rounded off to 38 (2 significant figures)

3.0 × 12.60 = 37.8000≈ 38

Zeros come after nonzero significant figure lead to misinterpretation. For example, **suppose the mass of an object is given as 1 500 g. This value is ambiguous** because we do not know whether the last two zeros are being used to locate the decimal point or whether they represent significant figures in the measurement.

To remove this ambiguity, it is common to use scientific notation

We express the mass as: 1.5×10^3 g (with two significant figures)

1.50×10^3 g (with three significant figures)

1.500×10^3 g (if there are four significant figures)

The same rule holds for numbers less than 1, so

$0.000\,23 = 2.3 \times 10^{-4}$ (both with 2 sig. fig.)

$0.000\,230 = 2.30 \times 10^{-4}$ (both with 3 sig. fig.)

For addition and subtraction:

When numbers are added or subtracted, the number of decimal places in the result should equal the smallest number of decimal places of any term in the sum.

As an example of this rule, consider the sum

23.2 + 5.174 = 28.374 =28.4

$$\underset{one}{23.\,2} + \underset{three}{5.174} = 28.374 = \underset{one\ d.d.}{28.\quad 4}$$

Our answer must have only **one decimal place**, because the lowest number of decimal places is one, for **23.2**. Write the answer as **28.4** not as **28.374**

For example: 123 + 5.35 = 128 and not 128.35.

1.000 1 + 0.000 3 = 1.000 4 **(4 decimal digits)**

1.002 - 0.998 = 0.004, **(3 decimal digits but only one significant)**

101 - 1.0 = **100** **[no decimal place]**

100 +0.1 = **99.9 =100** **[1 decimal place]**

If the number of significant figures in the result must be reduced, there is a general rule for rounding off numbers: **[التقريب]**

(1) The last digit retained is increased by 1 if the last digit dropped > 5.

For example, 12.6 is rounded to 13

(2) If the last digit dropped < 5, the last digit retained is kept unchanged.

For example, 12.4 is rounded to 12

(3) If the last digit to be dropped is 5, the last remaining digit should be rounded to the nearest even number. (i.e. is increased by one if it is odd, but left as it is if even.

For example, 11.5 is rounded to 12 .0 and

12.5 is rounded to 12.0

Example 1.8 Installing a Carpet

A carpet is to be installed in a room whose length is measured to be **12.71 m** and whose width is measured to be 3.64 m. **Find the area of the room**.

Solution

$A = 12.71 \times 3.46 = 43.976\ 6\ m^2$ (Answer must be rounded off so as to have only 3 sig. fig. as the measured quantity with the lowest number of significant figure)

$\rightarrow A = 44.0$ (3 sig. fig)

Chapter one

Physics and Measurements

تتحدد أي كمية طبيعية بعاملين اثنين هما العدد والوحدة . أي أنه لا يمكن ذكر أعداد أو أرقام مجردة دون تحديد الوحدة التي تقاس بها تلك الكمية الفيزيائية.

فمثلاً لتحديد كتلة جسم نقول أن كتلته تساوي 20كيلوجرام و لكي نقول أن الكتلة تساوي 20000 جرام يجب أن يكون هناك علاقة بين الكيلوجرام و الجرام و هي 1كجم = 1000جرام.

1-1 الكميات الفيزيائية Physical quantities

نكتب المعادلات و القوانين الفيزيائية بدلالة كميات فيزيائية تفسر الظواهر وتصفها ، من هذه الكميات : القوة – الزمن – السرعة – الكثافة – درجة الحرارة – الشحنة و غير ذلك.

و تنقسم الكميات الفيزيائية إلى:

- **كميات أساسية:** هي الكتلة M و الطول L و الزمن T
- **كميات مشتقه:** هي كميات مشتقة من الكميات الأساسية مثل الحجم V و السرعة v و العجلة a و غير ذلك من الكميات.

2-1 وحدات الكميات الفيزيائية Units of physical quantities

أي كمية فيزيائية يجب أن يكون لها وحدة قياس إلى جانب قيمتها العددية إذ أنه لا معنى لقولنا أن المسافة بين مدينة غزة ومدينة القدس هي 80 (دون ذكر وحدة القياس) لأن 80 كيلو متر تختلف عن 80 متر تختلف عن 80 ميل حيث أن الكيلو متر والمتر والميل هي وحدات قياس الطول.

أنظمة القياس

- النظام الدولي ISU: متر – كيلوجرام – ثانيه (mks) (M K S system) و أحياناً يسمى بالنظام الفرنسي المطلق أو سنتيمتر – جرام – ثانيه (cgs) (C G S system).
- النظام البريطاني: قدم – باوند – ثانيه (F B S).

الجدول (1-1) يبين وحدات القياس الأساسية والجدول (1-2) يبين بعض وحدات القياس المشتقة.

جدول (1-1) وحدات القياس الأساسية:

الكمية	الوحدة بالنظام الدولي (ISU)	الوحدة بالنظام البريطاني (FBS)
الكتلة (Mass)	كيلوجرام (*kg*)	باوند
الطول أو المسافة (Length)	متر (*m*)	قدم
الزمن (Time)	ثانية (*s*)	ثانية

جدول (1-2) وحدات القياس المشتقة

الكمية	الوحدة بالنظام الدولي (ISU)	الوحدة بالنظام البريطاني (FBS)
المساحه	متر ^{2} (m^2)	قدم ^{2}
الحجم	متر ^{3} (m^3)	قدم^3

الكثافة = الكتلة / الحجم	kg/m^3	باوند / قدم^3
قوة	نيوتن (N)	ثقل باوند (LB)
الضغط = قوة / مساحة	N/m^3 (باسكال)	ثقل باوند / قدم^2

3-1 أبعاد الكميات الفيزيائية Dimensions of physical quantities

بُعد أي كمية فيزيائية يحدِد طبيعة هذه الكمية فيما إذا كانت كتلة Mass أو طول Length أو زمن Time وتكتب أبعاد أي كمية طبيعيه بدلالة الكتلة (M) والطول (L) والزمن (T) والجدول (3-1) يوضح أبعاد بعض الكميات الفيزيائية.

جدول (3-1) حساب أبعاد بعض الكميات الفيزيائية

الكمية الفيزيائية	بُعد الكمية الفيزيائية
الكثافة $\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{V}$	$[\rho] = \frac{M}{L^3} = ML^{-3}$
السرعة الخطية= $v = \frac{\text{distance}}{\text{time}} = \frac{x}{t}$	$[v] = \frac{L}{T} = LT^{-1}$
العجلة = $v = \frac{v}{\text{time}} = \frac{v}{t}$	$[a] = \frac{LT^{-1}}{T} = LT^{-2}$
القوة = الكتلة × التسارع	$[F] = M \times LT^{-2} = MLT^{-2}$
الشغل = القوة ×المسافة	$[W] = MLT^{-2} \times L = ML^2T^{-2}$

نظرية الأبعاد و تطبيقاتها:

تحتم نظرية الأبعاد على أن يكون طرفا المعادلات الرياضية متجانسين من حيث الأبعاد. لذلك نجد أن من فوائد الأبعاد ما يلي:

أ- التحقق من صحة القوانين الفيزيائية.

ب- اشتقاق وحدات الثوابت التي تعتمد عليها العلاقات الرياضية المختلفة.

ج- التحويل من وحدات النظام الدولي (النظام الفرنسي) إلى النظام البريطاني (النظام الإنجليزي).

اختبار صحة القوانين

لإثبات صحة أي معادلة يجب أن تكون أبعاد الطرف الأيسر تساوي أبعاد الطرف الأيمن ، فمثلاً قانون البندول البسيط هو:

$$T = 2\pi\sqrt{\frac{L}{g}} \qquad (1\text{-}1)$$

فإذا كتبنا معادلة الأبعاد لهذا القانون فإننا نعتبر 2π عدد لا يعتمد على أي من الوحدات الأساسية و على ذلك فليس له وجود في معادلة الأبعاد.

أبعاد الطرف الأيمن هي:

$$\sqrt{\frac{L}{LT^{-2}}} = \sqrt{T^2} = T \qquad (1\text{-}2)$$

أي أن أبعاد الطرف الأيمن تساوي أبعاد الطرف الأيسر وعلى ذلك يكون القانون صحيحاً.

ما هي وحدات α ؟

$$x = \alpha t^2$$

$$[\alpha] = \frac{[x]}{[t^2]} = \frac{m}{s^2} : \frac{L}{T^2}$$

$$\text{compare:} \qquad m \; : \; \frac{m}{\cancel{s^2}} \cdot \cancel{s^2}$$

Significant Figures: الارقام المعنوية

كل رقم ما عدا الصفر معنوي ، الصفر معنوي بين معنويين او اذا وقع يمين معنوي في حالة وجود خانة عشرية.

4 , 40, 400 has one significant fig.

13 , 130 , 1300 has two significant fig.

4 325.334 has seven significant fig.

109 has three significant digits

3005 has four significant digits

40.001 has five significant digits

0.10 has two significant digits

(the leading zero is not significant, but the trailing zero is significant);

0.0010 has two significant fig. (the last two) ;

3.20 has three significant digits,

(note: 320 has two significant figures);

320.0 has 4 significant figures

في حالة الضرب والقسمة الجواب نفس عدد ارقم المعنوية للاقل

area A = W×L

A = W×L = (5.5) × (6.4) = 35.2

الجواب يجب ان يأخذ رقمين معنويين كما هو حال الكمية الاقل وكلاهما لها رقمين.

في حالة الجمع والطرح فإن الحاصل يحتوي على نفس العدد من الخانات العشرية المساوية للعدد الاقل:

123 + 5.35 = 128 not 128.35. **ليس هناك خانة عشرية**

1.0001 + 0.0003 = 1.0004 **(4 decimal digits)**

1.002 - 0.998 = 0.004, **(3 decimal digits but only one significant)**

101 - 1.0 = **100** **[no decimal place]**

100 +0.1 = **99.9** **[1 decimal place]**

عندما يحذف رقم يقرب فنزيد لما قبله 1 اذا كان اكبر من 5 او اذا كان 5 وقبله رقم فردي

For example, 12.6 is rounded to 13

For example, 12.4 is rounded to 12

11.5 is rounded to 12 .0

12.5 is rounded to 12.0

الخطأ في قياس الكمية هو اصغر تدريج في اداة القياس ، للمسطرة :

$\Delta L = \pm 1\ mm = \pm\ 0.1\ cm$

$\Delta x = 9.5\ \pm 0.1\ \ cm$ صحيحة

$\Delta x = 9.50\ \pm 0.1\ \ cm$ غير صحيحة

[$\Delta x = 9.50\ \pm 0.01\ cm$ 0.01 هي الصحيحة لان الجهاز يقرأ لغاية]