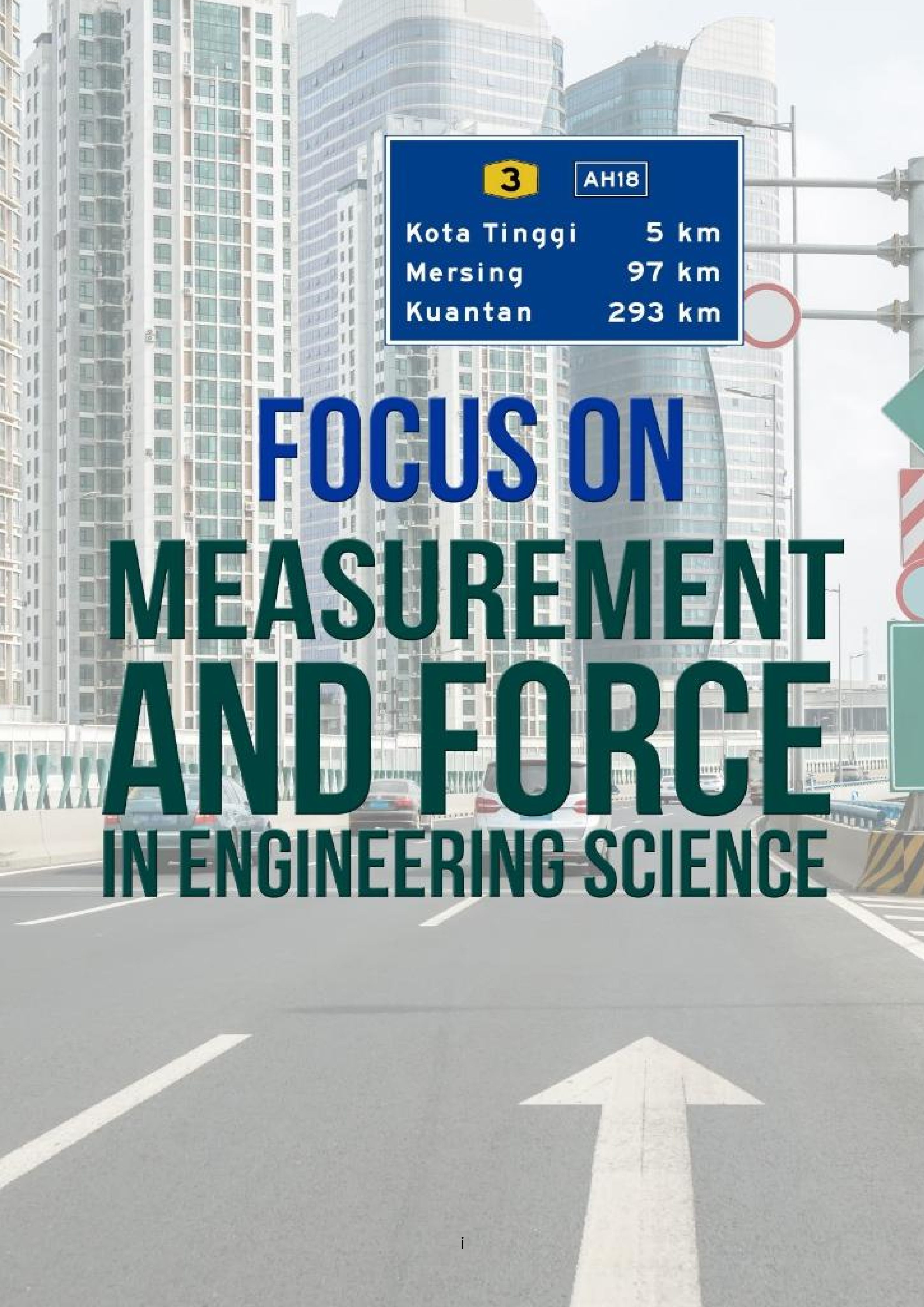
FOCUS ON MEASUREMENT AND FORCE IN ENGINEERING SCIENCE

POLITEKNIK MALAYSIA

KEMENTERIAN PENGAJIAN TINGGI

KOLEJ KOMUNITI MALAYSIA

NORLIDA BINTI SHAARI
ASIAH BINTI IBRAHIM



FOCUS ON MEASUREMENT AND FORCE IN ENGINEERING SCIENCE

Editor
Fazlina binti Yunus

Writers
Norlida binti Shaari
Asiah binti Ibrahim

Ilustrator
Norlida binti Shaari

First Published 2021

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the copyright owner.

Published by
Politeknik Tun Syed Nasir Syed Ismail
Hab Pendidikan Tinggi Pagoh,
KM 1, Jalan Panchor, 84600 Pagoh,
Johor Darul Takzim.
Tel : 06-974 2288 Fax : 06-974 2395

Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

Norlida Shaari, 1982-
FOCUS ON MEASUREMENT AND FORCE IN ENGINEERING SCIENCE / NORLIDA BINTI SHAARI, ASIAH BINTI IBRAHIM.
Mode of access: Internet
eISBN 978-967-25516-3-8
1. Physical measurements.
2. Measurement.
3. Force and energy.
4. Goverment publications--Malaysia.
5. Electronic books.
I. Asiah Ibrahim, 1973-. II. Title.
530.8

ACKNOWLEDGEMENTS

We would like to express our deep and sincere thanks to our head of department, Mr. Hairman bin Omar, who gave us the golden opportunity to do this wonderful eBook writing on the topics of Engineering Science.

We would also like to thank our colleagues and parents who helped us a lot in finalizing this eBook writing within the limited time frame. Our completion of this eBook writing could not have been accomplished without their support, either morally and physically, the contributions are sincerely appreciated and gratefully acknowledged.

And most of all to our great creator, our Almighty God the author of knowledge and wisdom who made this possible.

ABSTRACT

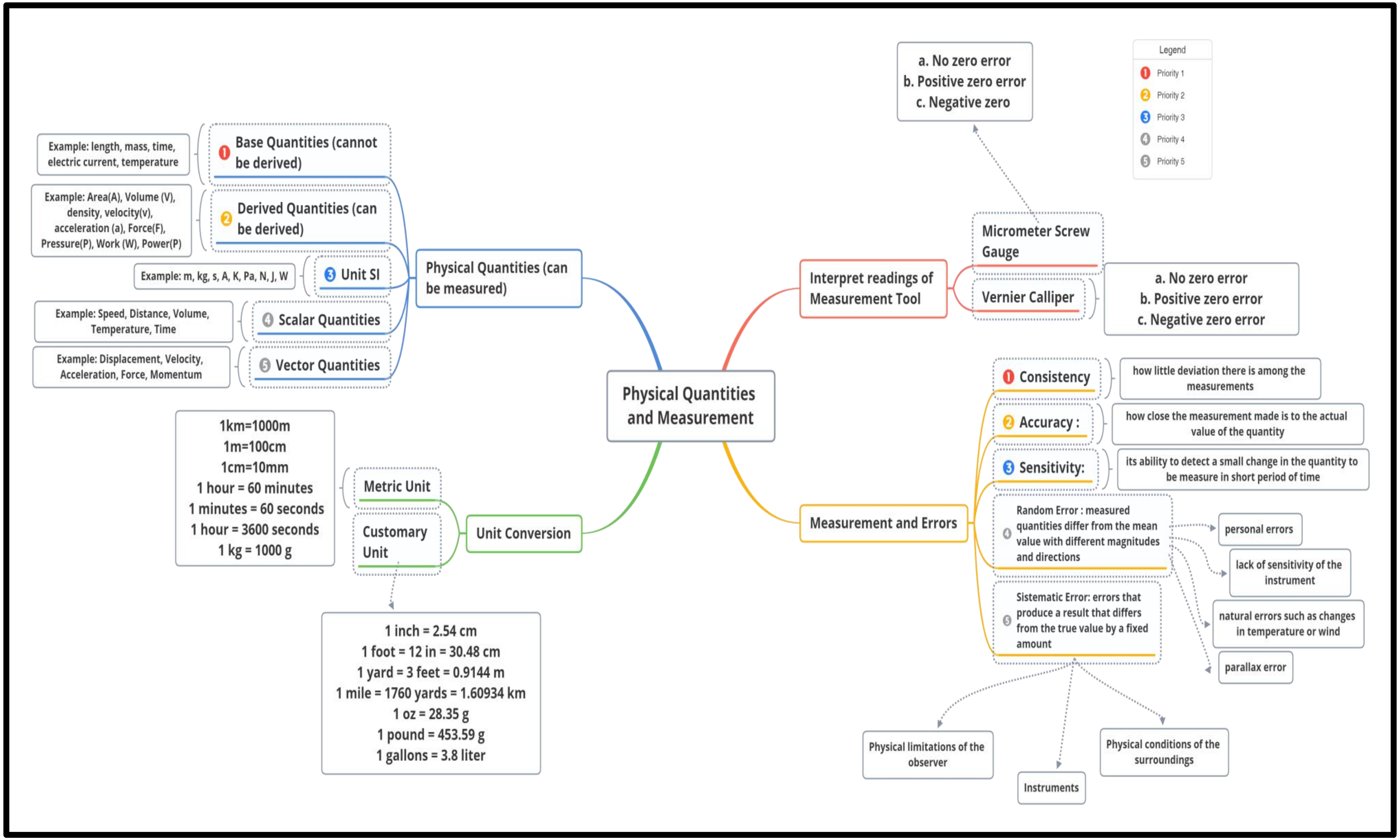
This Electronic book (eBook) aims to introduce the reader to the field of Engineering Science or Physics Education, provides a basic knowledge for all engineering students. This eBook is designed to focus on specific topics, that are, Measurement and Force in Engineering Science. Physical quantities and Measurement topic is the key to explore such the concept of unit conversion from one unit to another and attention is also given to the exposure on how to read and use the measuring tools such as vernier caliper and micrometer screw gauge the right way and accurately. Force and Moment topic covers the theory such as force in equilibrium, why some structures are stronger and many others. Each topic ends with review questions as some exercises to test students' understanding. This eBooks is one way to enhance the digital library with global 24-hours-a-day and 7-days-a-week access to authoritative information, and they enable users to quickly retrieve and access specific reference material easily, quickly and effectively. This eBook is very useful as a digital text book reference for students before they take the theory test. On top of that, it prepares students for the final examinations as well with the exposure to the frequently tested questions that appear in the exam which covers the cognitive level taxonomy blooms and in line with Polytechnic's Malaysia Curriculum.

CONTENTS

TOPIC 1

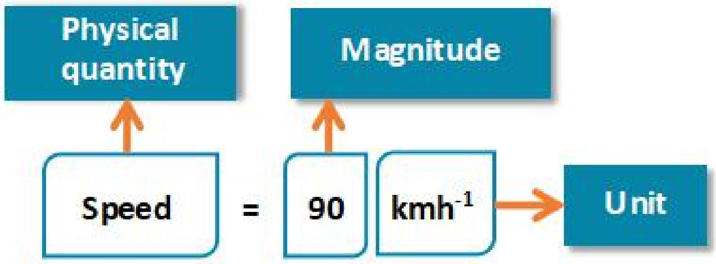
PHYSICAL QUANTITIES & MEASUREMENT

CONCEPT MAP OF PHYSICAL QUANTITIES AND MEASUREMENT



1.1 PHYSICAL QUANTITIES

Physical quantities may be measured using an instrument or can be derived. **A physical quantity must be stated in magnitude** with its **unit**. **Figure 1.1** shows some examples of physical quantities.



a) Temperature = 36.2℃

b) Distance = 5 km

Figure 1.1 Examples of physical quantities

1.1.1 BASE QUANTITIES, DERIVED QUANTITIES AND INTERNATIONAL SYSTEM OF UNITS

- There are two types of physical quantities, that is, base quantities and derived quantities.

Base Quantities

- Fundamental quantities that **cannot be derived** in term of other quantities.
- **Table 1.1** shows five base quantities derived quantities and their respective SI units.

Table 1.1 Five base quantities derived quantities and their respective SI unit

Base Quantity	Base Quantity Symbol	SI Unit	Symbol
Length	l	Meter	m
Mass	m	Kilogram	kg
Time	t	Second	s
Electric Current	I	Ampere	A
Temperature	T	Kelvin	K

Derived Quantities

- Physical quantities that **can be derived from the combination of base quantities** through multiplication or division or both multiplication and division.
- **Table 1.2** shows some examples of derived quantities and their respective derived units.

Table 1.2 Examples of derived quantities and their respective derived units

Derived Quantity	Definition	SI Unit in terms of base units	Alternative name for SI unit
Area, A	length x length	m^2	
Volume, V	length x length x length	m^3	
Density,	mass / volume	$kg\ m^{-3}$	
Velocity, v	length / time	$m\ s^{-1}$	
Acceleration, a	velocity / time	$m\ s^{-2}$	
Force, F	momentum / time	$kg\ m\ s^{-2}$	newton, N
Pressure, P	force / area	$kg\ m^{-1}\ s^{-2}$	pascal, Pa @ $N\ m^{-2}$
Work, W	force x distance	$kg\ m^2\ s^{-2}$	joule, J
Power, P	work / time	$kg\ m^2\ s^{-3}$	watt, W

International System of Units

- The **International System of Units (SI)**, commonly **known as the metric system**, is the international standard for measurement.
- SI units are adopted as standard units to prevent problem causes by the difference in the units of measurement and to allow the accurate exchange of data and scientific knowledge worldwide.
- **Figure 1.2** displays seven SI basic units in the system.

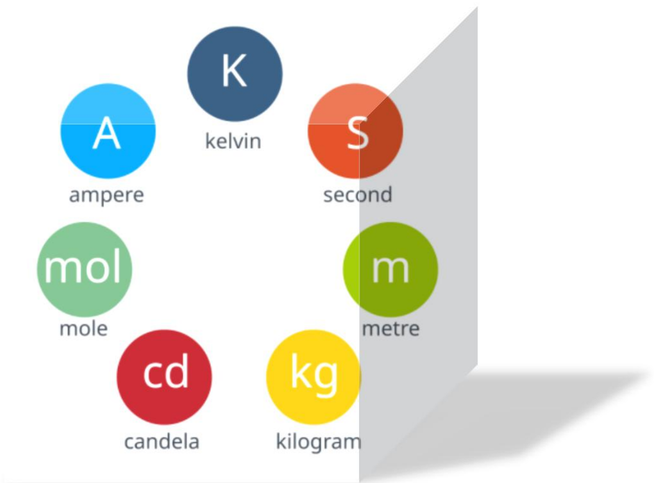


Figure 1.2 SI basic units

1.1.2 SCALAR AND VECTOR QUANTITIES

- Physical quantities can be grouped into scalar quantities and vector quantities.
- **Scalar quantities** are physical quantities that **have only magnitude.**
- **Vector quantities** are physical quantities that **have both magnitude and direction**.
- The difference between scalar quantities and vector quantities can be described by two different situations. **Situation 1** is described when **a truck moves at a speed of 80 km/h**. This situation **involves with a scalar quantity** because **only magnitude** is involved, with the speed of 80 km/h.
- While **Figure 1.3** shows the **situation 2** where, **a truck travels at a distance of 70 km to the eastward direction**. Situation 2 **involves with a vector quantities**.

  We describe the **journey of the truck** by **stating both magnitude and direction** of its travelling:

  (a) The magnitude is 70 km.

  (b) The direction is East.

Figure 1.3 A truck travels at a distance of 70 km to the eastward direction

- Some examples of scalar and vector quantities are listed in **Table 1.3**.

Table 1.3 Examples of scalar and vector quantities

Scan Me

Scalar and vector quantities

Scalar Quantities	Vector Quantities
Speed	Displacement
Distance	Velocity
Volume	Acceleration
Temperature	Weight
Time	Force
Mass	Gravity

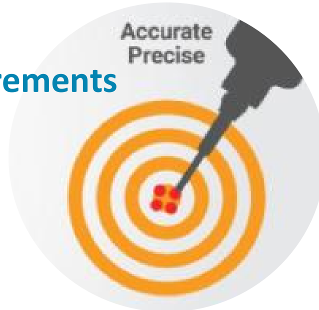
1.2 MEASUREMENT AND ERRORS IN MEASUREMENT

Most experiments require you to make measurements. Measurement is a method to determine the value of a physical quantity. Therefore, in order to have perfect measurements, you need to measure correctly and for that, you must know the measuring procedure and systems.

Measurements are always somewhat different from the "true value." These deviations from the true value are called errors. At some point in the manufacturing process, you will find that differences in measurement results (measured values) will begin to show-up due to one error or another. A variety of issues are able to contribute to a measurement error. If you encounter a measurement error, it is vital that you examine the cause of the error very thoroughly before using a countermeasure. This is important to maintain the quality of your result.

1.2.1 CONSISTENCY, ACCURACY AND SENSITIVITY

Accuracy



- Accuracy measures **how close the value of the measurements** (the results of an experiment) **to the true value**.
- If it is **too far from the target**, it is **not accurate**.

Consistency

- The **consistency** of a measuring instrument is due to its **ability to produce the same reading** when a measurement is repeated.
- **Precision** is referred to the **consistency of** your **results**. In other words, from dartboard analogy, **a sharpshooter may hit the bulls-eye once**, **but** if **he does not hit it with subsequent shots**, his aim **is not able to be considered as a precise target**.

  Figure 1.4 shows the results for four shooters A, B, C and D in a tournament. Each shooter fired four shots.
- If they are **far apart from each other**, they are **not consistent**. We aquire results that are both accurate and consistent.

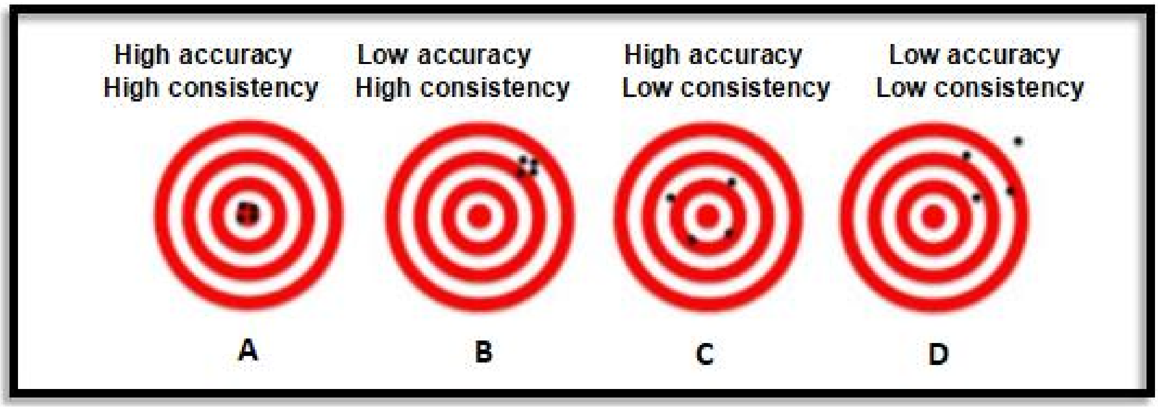


Figure 1.4 Results for four shooters A, B, C and D

Sensitivity

- When an instrument is high in measuring sensitivity, it **may detect or respond to even small changes** in the quantity to be measured.
- **Smaller scale components in measuring are more sensitive**.
- **Figure 1.5** shows several examples of instruments with their respective degree of sensitivity.

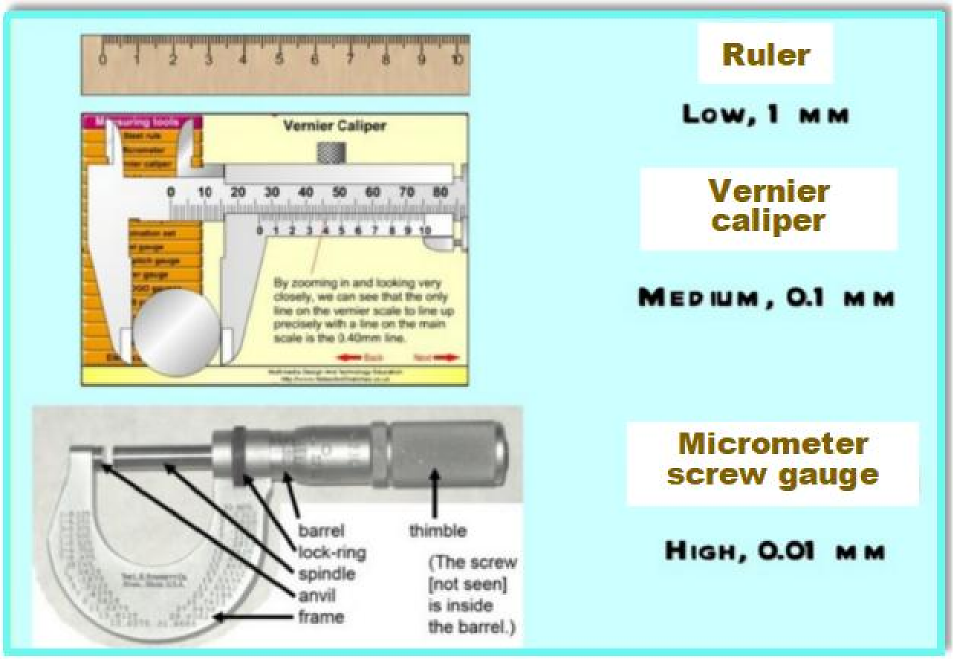


Figure 1.5 Examples of instruments with their respective degree of sensitivity

1.2.2 RANDOM ERROR AND SYSTEMATIC ERROR

Errors in Measurement

- **Error** in measurement is the **difference between the measured value** (value obtained in measurement) of a quantity **and its true value**.
- There are **two main types of errors** in a Measurement System, that are, **random errors** and **systematic errors**.

Random Errors

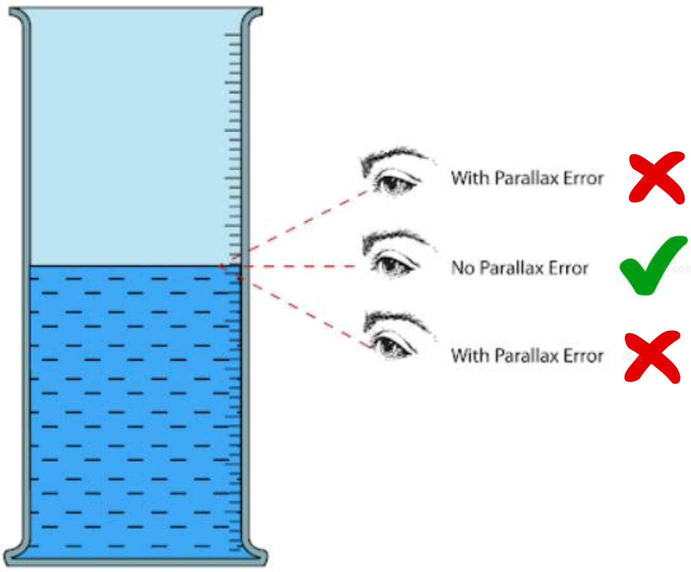
- **Random errors** are errors of measurement in which the **measured quantities differ from the true value** with **different magnitudes** and **directions**.
- **Random errors produce different values in random directions**. For example, you use a scale to weigh yourself and the scale gets 48 kg, 53 kg, and 32 kg.
- Random errors are usually result from the experimenter's inability to take the same measurement in the same manner to obtain the exact same number.

Source of Random Errors

1. Personal errors such as human limitations of sight and touch.
2. Imprecise or unreliable of measurement instrument. The instrument failes to respond at any small changes.
3. Natural errors such as changes volume in temperature or wind, while conducting the experiment.
4. Poorly controlled experimental procedures (e.g., parallax error).

Reducing Random Errors

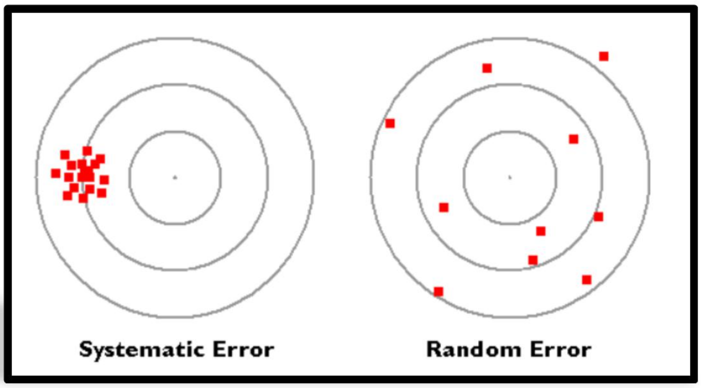
1. Repeating several measurements to obtain an average value.
2. Maintain good experimental technique in mind (e.g., reading from a correct position).



Systematic Errors

- **Systematic errors** are those that **produce a result that differs from** the **true value by** a **fixed amount** and the **measurement** is **always greater or less than the actual value**.
- As for example, when measuring the wrist circumference of participants, you misinterpret the "2" on the measuring tape as a zero-point. All of your measurements have been increased by 2 centimetres.
- **Consistent errors are produced by systematic errors**, for instance, **in a fixed amount** (like 2 cm). If you repeat the experiment, you will get the same error.

- **Figure 1.6** illustrates the contrast between systematic and random error



Scan Me

Systematic and random errors

Figure 1.6 Contrast between systematic and random errors

Source of Systematic Errors

✧ **Instruments**

- Errors in scale (zero error).
- Errors in apparatus (it is damaged and in poor condition).

✧ **Physical conditions of the surroundings**

- Temperature and atmospheric pressure.

✧ **Physical limitations of the observer**

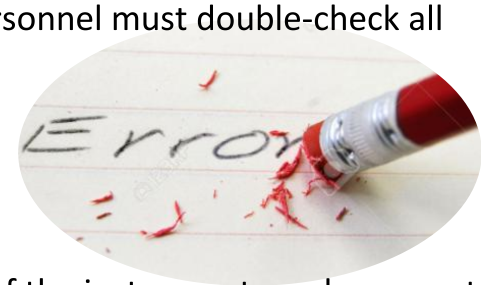
- Reaction duration varies from one person to another.

Reducing Systematic Errors

1. Conduct the experiment with care.
2. Calibrate instruments by checking zero readings and scale calibration.

How to Minimize Measurement ERROR??

1. Using an updated and precise measuring device that does not have any defects while conducting your experiment.
2. Before conducting an experiment, calibrate measurement instruments properly to avoid any inaccurate results.
3. All measurements in an experiment should occur under a controlled condition. External factors such as humidity, pressure, and temperature may all cause data to be skewed.
4. To minimise the effect of human error, personnel must double-check all observations, records, and measurements.



5. Taking several measurements to arrive an average value.
6. Conduct an experiment with care. Use all of the instruments and carry out procedures properly when conducting an experiment.

1.3 SOLVE PROBLEMS OF UNIT CONVERSION

In science, measuring is a fundamental skill, but not all measurement methods are created the same. People measure the same item in different ways and with various units. There must be a way to convert between various units in order for scientists to interact.

1.3.1 UNITS OF MEASUREMENT

There are many units available for a certain amount of physical quantities. This causes us to be confused. If there are multiple units accessible, a conversion factor to convert them to the other unit may exist. **Customary unit** also known as the **U.S. customary unit**, is **based on the English**

system of measurement which is seldom used nowadays. **Table 1.4** shows the distinction between metric unit (**refer subtopic 1.1.1, International System of Units**) and customary unit.

Table 1.4 Distinction between metric unit and customary unit

METRIC UNIT (SI UNIT)	CUSTOMARY UNIT
Used in all parts of the world	Only used in the United States
Easy to convert	Not so simple conversion
Multiple or fraction of 10	No “formula”
Meters, grams, and liters are the units of measurement	Inches, feet, yards, miles, ounces, pounds, tons, fluid ounces, cups, pints quarts, and gallons are the units of measurement
Prefixes like kilo-, centi-, deca are used	

The advantages of metric systems are more dominant, which is why they are so popular and we use them often and. **Table 1.5** and **Table 1.6** respectively show the list of some basic unit conversions and metric units with common conversions.

Table 1.5 Basic unit conversions

Basic Unit Conversion	
Length	1 km → 1000 m 1 m → 100 cm 1 cm → 10 mm
Time	1 hour → 60 minute 1 minute → 60 seconds 1 hour → 3600 seconds
Mass	1 kg → 1000 g

Table 1.6 Metric units with common conversions

Length, Area, Mass and Volume Conversion		
Length		
1 inch (in)		2.54 centimeters (cm)
1 foot (ft)	12 inches (in)	30.48 centimetres (cm)
1 yard (yd)	3 feets (ft)	0.9144 metre (m)
1 mile (mi)	1,760 yards (yd)	1.60934 kilometres (km)
Area		
1 in^2		6.4516 cm^2
1 ft^2		0.09 m^2
1 yd^2	9 ft^2	0.8361 m^2
1 acre	4,840 yd^2	4046.86 m^2 / 0.405 hectare
1 $mile^2$	640 acres	2.590 km^2
Mass (weight)		
1 ounce (oz)		28.35 grams (g)
1 pound (lb)		453.59 grams (g)
Volume		
1 gallons (gal)		3.8 liters (L)
1 ft^3		0.03 m^3
1 yd^3		0.76 m^3

Temperature Conversion	
Temperature	
Convert Fahrenheit (F) to Celcius (C)	(degrees F – 32) x 0.555
Convert Celcius (C) to Fahrenheit (F)	(degrees C x 1.8) + 32

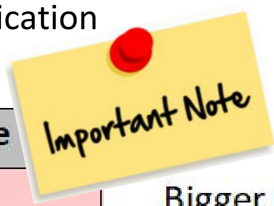
1.3.2 PREFIX

- **Prefixes** are used to **simplify the description of physical quantities** that are either large or tiny **in SI units**.
- Prefixes generate units that are right size for the application, e.g., millimeter for measurement of the dimensions of small screws, or

kilometer for the measurement of distances on maps.

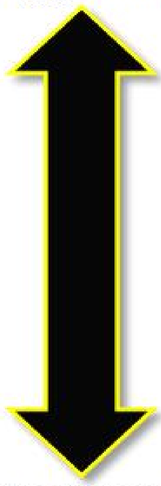
- **Table 1.7** lists some frequently used SI prefixes and their multiplication factors.
- You must to be able to convert between the various prefixes. For instance, you may be requested to do a calculation in kilometres and then provide the answer in metres. **To convert between prefixes**, just **count the steps** and **move the decimal point in that direction**.

Table 1.7 Common SI prefixes and their multiplication



Prefix	Symbol	Value
Tera	T	10^{12}
Giga	G	10^{9}
Mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
mili	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Bigger units



Smaller units

***Note: Need to know all except hecto, deca and deci.**

PREFIXES

EXAMPLE 1.1

Use the appropriate prefixes to represent the following numbers:

(a) 2500000 W

(b) 0.001500 g

(c) 7360 J

(d) 0.000008 m

Solution:

Refer to **Table 1.7,** page 16 to find the appropriate prefixes.

(a) 2500000 W = 2.5×10^6 W = **2.5 MW** where 10^6 = M (Mega)

(b) 0.001500 g = 1.5×10^{-3} g = **1.5 mg** where 10^{-3} = m (mili)

(c) 7360 J = 7.36×10^3 J = **7.36 kJ** where 10^3 = k (kilo)

(d) 0.000008 m = 8.0×10^{-6} m = **8.0 µm** where 10^{-6} = µ (micro)

1.3.3 METRIC AND CUSTOMARY UNITS CONVERSION

Converting Units

In your everyday life, you might need to convert units. For example, suppose you wish to compare dimension of products at a shop. Unless each product size is stated in the same unit. When we convert units, we use conversion factors. Conversion factors are known-to-be-true connections between units. Some examples:

12 inches = 1 foot	**16 ounces = 1 lb**
1 minute = 50 seconds	**24 hours = 1 day**

- Diagram in **Figure 1.7** below illustrates how to convert between metric length units.

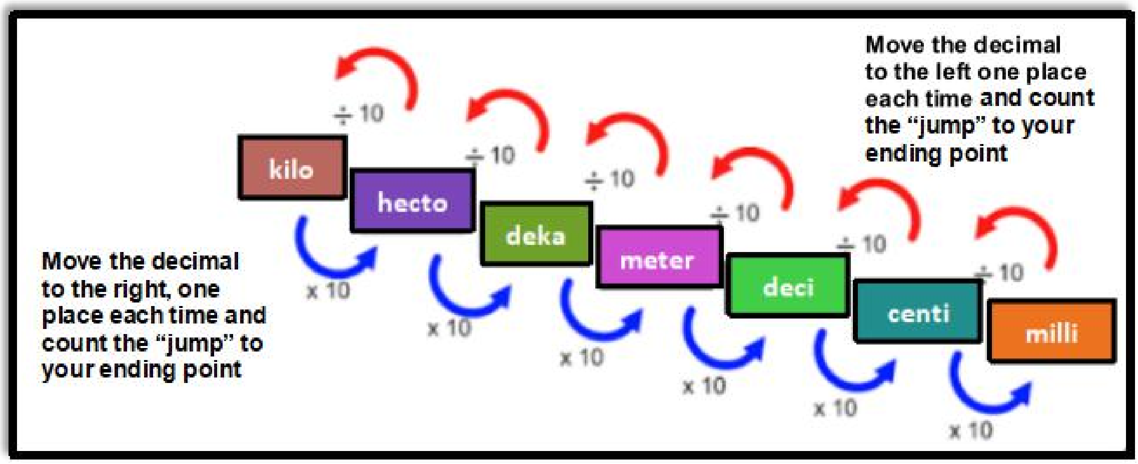


Figure 1.7 Converting between metric units of length

- Steps to converting units:

Step 1: Determine your starting point

Step 2: Count the "jumps" to your ending point.

Step 3: Move the decimal, the same number of jumps in the same direction.

Example:

4 km = ____________ m

Starting point

Ending point

How many jumps does it take?

$$4.\underset{1}{\_}.\underset{2}{\_}.\underset{3}{\_}. = 4000 \text{ m}$$

Note that, **1 km = 1000 m**

Conversion factor
Remember this is not in the question, we **have to know** it.

Write the number (with units) that you want to convert.

$$4 \text{ km} \times \frac{1000 \text{ m}}{1 \text{ km}}$$

Multiply it by a conversion factor, written as a fraction.

Make sure the old units cancel

$$4 \cancel{\text{km}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}} = 4000 \text{ m} \ \checkmark$$

***Note: Multiply all the numbers on the top and divide by the numbers on the bottom.**

When we utilise dimensional analysis, we use a cancellation system in which our objectives is to cancel out "units", and then calculate the remaining numbers. The only units that do not cancel are the units we want to convert to. Let us have a look at some examples of unit conversions.

METRIC UNITS CONVERSION

EXAMPLE 1.2

Convert the following metric units:

(a) $100905\ \mathrm{cm}^2$ to m^2

(b) $80\ \mathrm{kN/m^2}$ to $\mathrm{N/cm^2}$

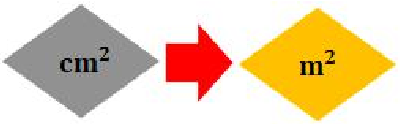
(c) $9969\ \mathrm{kg/m^3}$ to $\mathrm{g/cm^3}$

(d) $\frac{1}{2}$ day to second

Solution:

These problems can be solved by referring to the information provided in **Table 1.5** (page 14) and **Figure 1.7** (page 18).

(a) 100905 cm^2 to m^2



Note that, $\mathbf{100 \text{ cm} = 1 \text{ m}}$

$$= 100905 \text{ cm}^2 \times \frac{1^2 \text{ m}^2}{100^2 \text{ cm}^2}$$

$$= 100905 \cancel{\text{cm}}^2 \times \frac{1 \text{ m}^2}{10000 \cancel{\text{cm}}^2}$$

$$= \mathbf{10.0905 \text{ m}^2}$$

(b) 80 kN/m^2 to N/cm^2

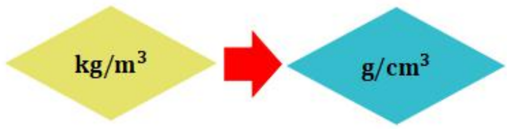
Note that, $\mathbf{1 \text{ m} = 100 \text{ cm}}$

$$= 80000 \frac{\text{N}}{\text{m}^2} \times \frac{1^2 \text{ m}^2}{100^2 \text{ cm}^2}$$

$$= 80000 \frac{\text{N}}{\cancel{\text{m}}^2} \times \frac{1^2 \cancel{\text{m}}^2}{10000 \text{ cm}^2}$$

$$= \mathbf{8 \text{ N/cm}^2}$$

(c) 9969 kg/m^3 to g/cm^3



Note that, $\mathbf{1 \text{ kg} = 1000 \text{ g}}$

$\mathbf{1 \text{ m} = 100 \text{ cm}}$

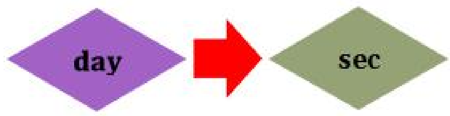
$$= 9969 \frac{\text{kg}}{\text{m}^3} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1^3 \text{ m}^3}{100^3 \text{ cm}^3}$$

$$= 9969 \frac{\cancel{\text{kg}}}{\cancel{\text{m}}^3} \times \frac{1000 \text{ g}}{1 \cancel{\text{kg}}} \times \frac{1^3 \cancel{\text{m}}^3}{100^3 \text{ cm}^3}$$

$$= 9969 \times \frac{1000 \text{ g}}{1000000 \text{ cm}^3}$$

$$= \mathbf{9.969 \text{ g/cm}^3}$$

(d) $\frac{1}{2}$ day to second



Note that, $\boldsymbol{\frac{1}{2}\ day = 12\ hours}$

$\mathbf{1 \text{ hour} = 3600 \text{ s}}$

$$= 12 \cancel{\text{hours}} \times \frac{3600 \text{ s}}{1 \cancel{hour}}$$

$$= \mathbf{43200 \text{ s}}$$

If there are **two units to change** (refer **questions (b) and (c)** for instance), **choose one unit to change first**. Then, multiply by a second fraction to change the other. In other situation, **if one or more of the units is squared or cubed** (as shown in question **(a)**), you are just converting centimeters to meters ($100 \text{ cm} = 1 \text{ m}$). Next, square it ($100^2 \text{ cm}^2 = 1^2 \text{ m}^2$). This will square all numbers and units involved.

CUSTOMARY UNITS CONVERSION

EXAMPLE 1.3

Scan Me

Convert customary units

Convert between the following customary units:

(a) yards (yd) and feet (in), 4 yd = ______feet

(b) ounces (oz) and pounds (lb), 32 oz = ______lb

(c) feet (ft) and inches (in), 5 ft = _______in

Solution:

Refer to the informations provided in **Table 1.6** (page 15).

(a) yards (yd) and feet (in), 4 yd = ______feet

Step 1: Note that, $\mathbf{3 \text{ ft} = 1 \text{ yd}}$

Table 1.6

Length, Area, Mass and Volume Conversion		
Length		
1 inch (in)		2.54 centimeters (cm)
1 foot (ft)	12 inches (in)	30.48 centimetres (cm)
1 yard (yd)	3 feets (ft)	0.9144 metre (m)
1 mile (mi)	1,760 yards (yd)	1.60934 kilometres (km)

Step 2: Therefore, $4 \text{ yd} = 4 \times \mathbf{3 \text{ ft}} = \mathbf{12 \text{ ft}}$

(b) ounces (oz) and pounds (lb), 32 oz = _______feet

Step 1: Note that, $\mathbf{1\ lb = 16\ oz}$

Step 2: Therefore, $32\ \mathrm{oz} = 32 \div \mathbf{16\ oz} = \mathbf{2\ ft}$

(c) feet (ft) and inches (in), 5 ft = ________in

Step 1: Note that, $\mathbf{1\ ft = 12\ in}$

Step 2: Therefore, $5\ \mathrm{ft} = 5 \times \mathbf{12\ in} = \mathbf{60\ in}$

1.4 MEASUREMENT TOOLS READING INTERPRETATION

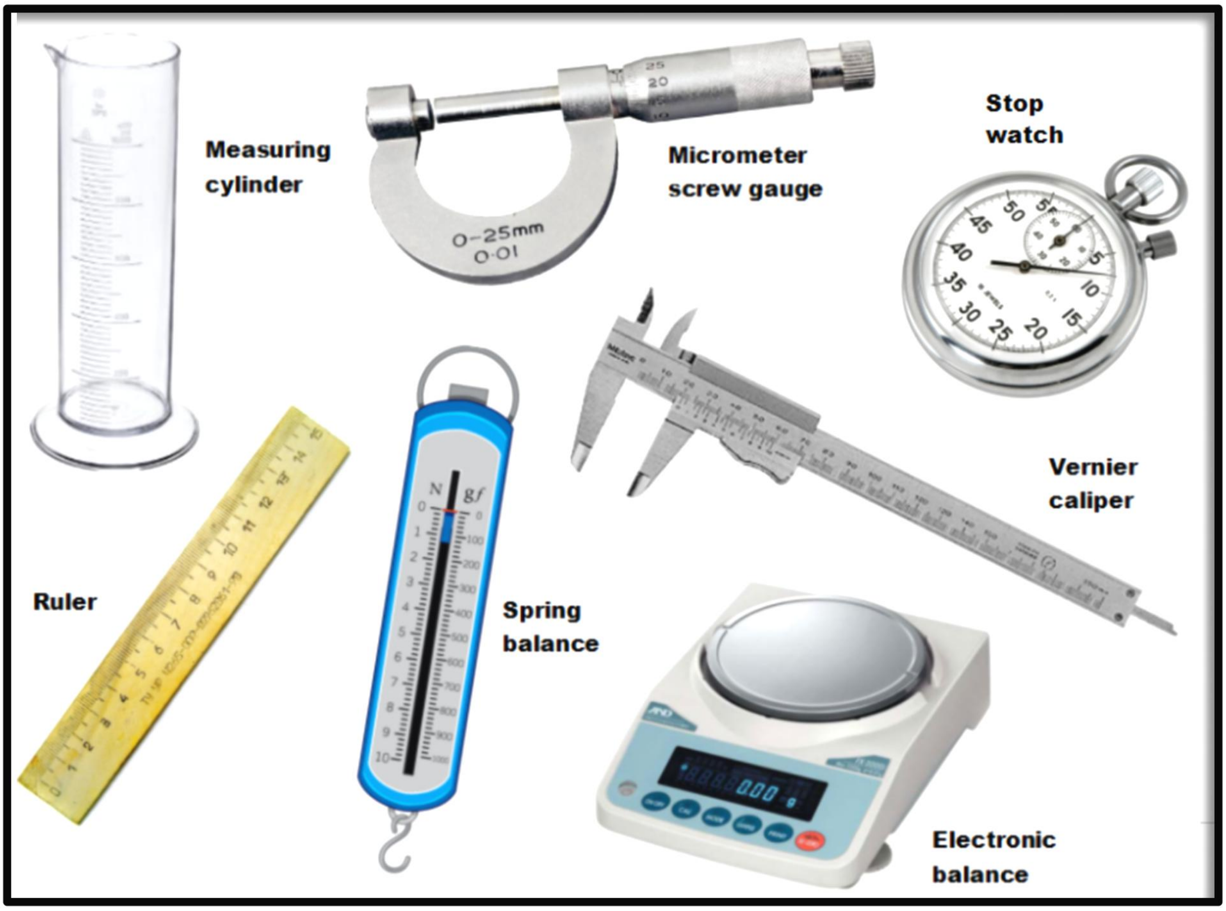


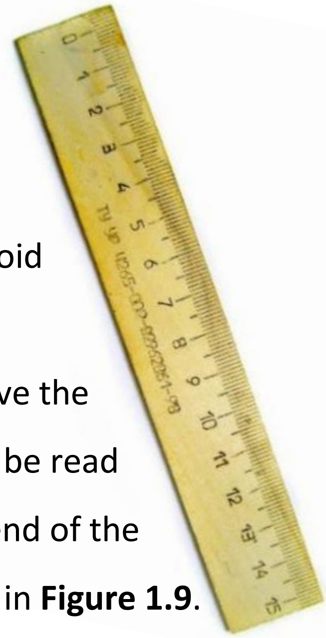
Figure 1.8 Examples of measurement tools

Measurement and Measuring Devices

Experiments are carried out in science and engineering. During experiments, we must take readings. Thus, all these experiments require some kind of measurement. **Figure 1.8** manifests some examples of measurement tools that can be used for measurement purposes. Measurement can be done directly or indirectly. When measurements are taken directly using tools, instruments or other calibrated measuring devices, they are called direct measurement. In this section, we shall study the use of **ruler, vernier caliper** and **micrometer screw gauge** to measure length, diameter and etc.

(a) Ruler

- A ruler is used to **measure lengths from a few cm up to 1 m**.
- A meter ruler **has an accuracy of 0.1 cm** (1 mm).



Precautions While Using a Ruler to Measure Length

1. Ensure that the object is in contact with the ruler to a avoid inaccurate readings.
2. Avoid parallax errors. The eye must be kept vertically above the end of the object so that the corresponding graduatn can be read clearly. If the eye is not kept exactly vertically above the end of the object, it leads into error called “parallax error” as shown in **Figure 1.9**.
3. Avoid zero and end errors. The ends of a ruler, which may be worn out, are a source of errors in measurement. Thus, it is advisable to use the division mark `1' of the scale as the zero point when taking a measurement as illustrated in **Figure 1.10**. The length of the object is obtained by subtracting higher reading from lower reading.

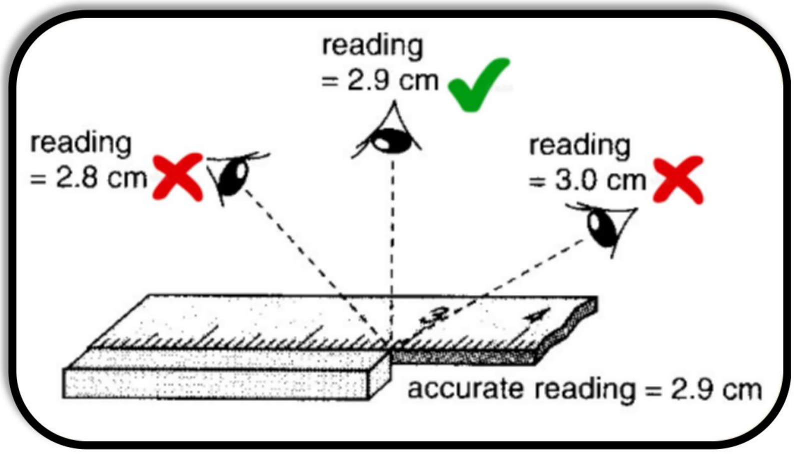


Figure 1.9 Parallax error

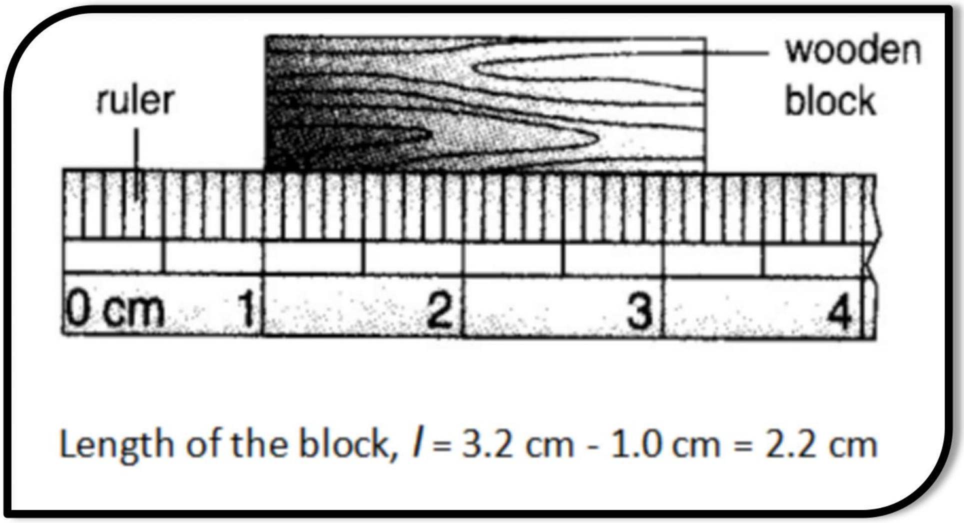


Figure 1.10 Use the division mark `1' of the scale as the zero point when taking a measurement

How to Measure Length Correctly Using a Metric Scale Ruler

Metric rulers may include any **combination of meters (m), centimeters (cm) and milimeters (mm)**. **Figure 1.11** below shows the proper technique to use a metric scale ruler in centimeters.

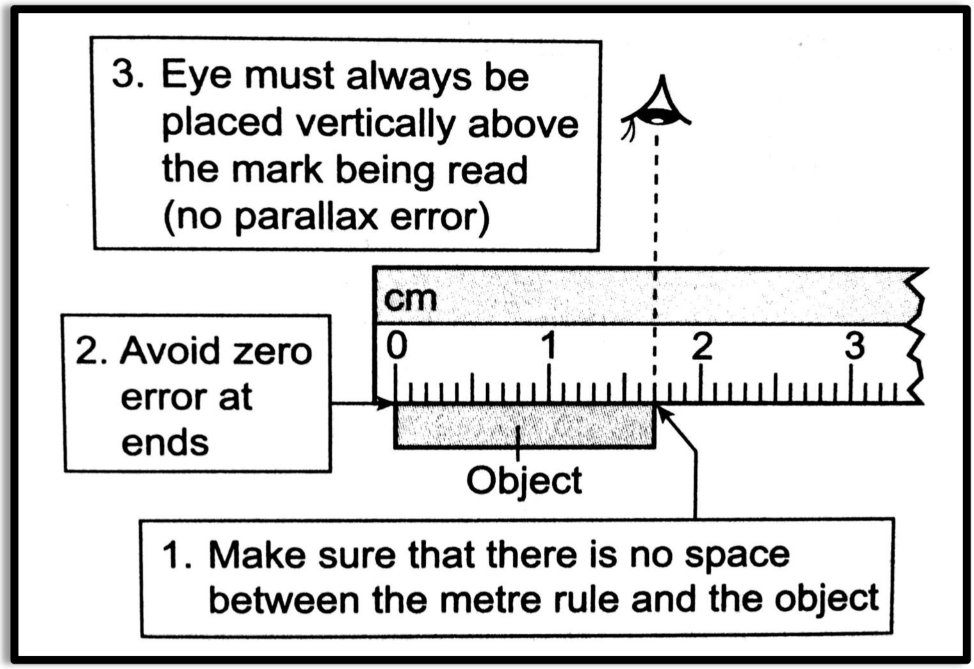


Figure 1.11 Proper technique to use a metric scale ruler in centimeters

(b) Vernier Caliper

- **Vernier caliper** is **more accurate than a ruler**, since it **has the smaller scale of 0.1 mm**.
- It is capable of measuring lengths of less than 10 cm.
- The **accuracy of a vernier caliper** is **up to 0.1 mm** (0.01 cm).
- **Figure 1.12** depicts parts of a vernier caliper and their functions which are as follows:

✧ **Upper jaws (inside jaws) determining inside measurements** such as the diameter of a hole or slot.

✧ **Lower jaws (outside jaws) measuring outside dimensions** such as width, length and diameter.

✧ **Depth rod measuring the depth** of an object or a hole.

Parts of Vernier Caliper

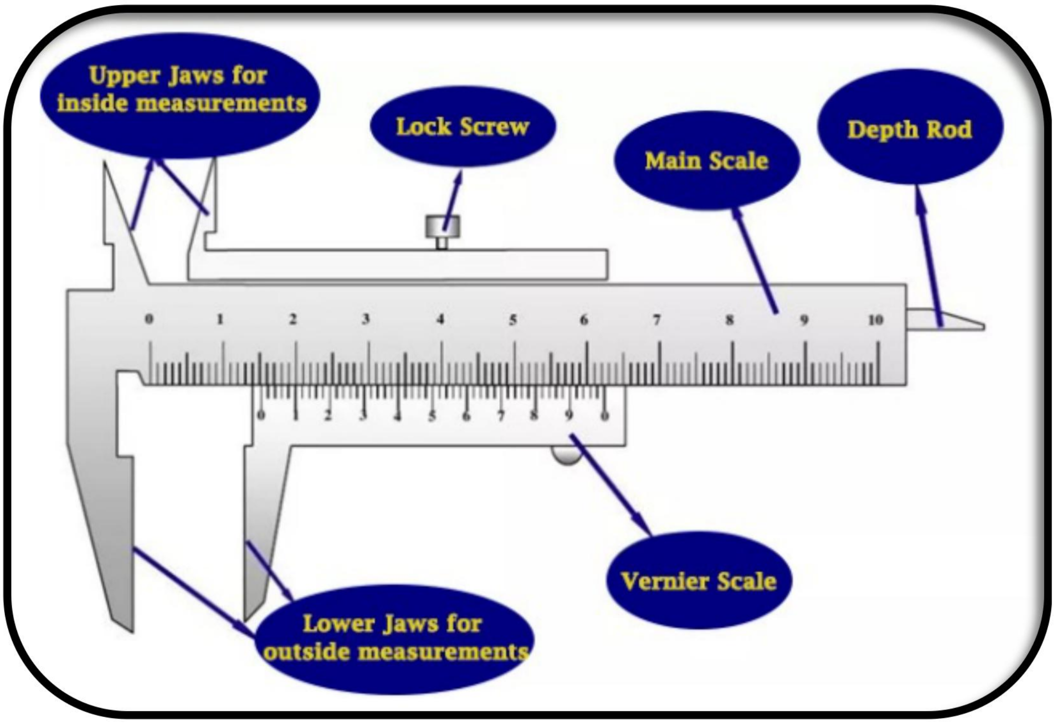


Figure 1.12 Parts of a vernier caliper

1.4.1 STATE THE MEASUREMENT READING FROM THE USE OF VERNIER CALIPERS

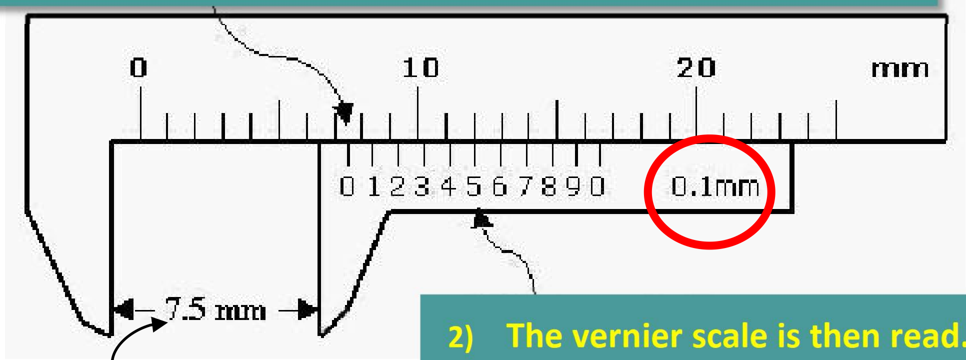
How to Use a Vernier Caliper?

1. To measure outer/inner dimensions of an object, the object is placed between the jaws, which are then moved together until they contact the object.
2. The screw clamp may then be tightened to ensure that the reading does not change while the scale is being read.
3. Take the reading. **Figure 1.13** shows the measurement reading technique for vernier caliper.

Measurement Reading Technique for **Vernier Caliper**

1) The main metric scale is read first.

- This shows that there are 7 whole divisions before the "0"on the vernier scale.
- Therefore, the first number is 7.



2) The vernier scale is then read.

- Count the number of divisions until you get to the division that lines up with the main metric scale.
- You find that, it is 5 divisions on the hundredths scale. This 5 is multiplied by 0.1 mm giving 0.5 as the answer Note: (each division on the hundredths scale is equivalent to 0.1 mm).

3) Final answer.

- The "7" and the "0.5" are added together to give the final measurement of 7.5 mm.

Figure 1.13 Measurement reading technique for vernier caliper

Scan Me

Reading from vernier calipers with 0.01 cm

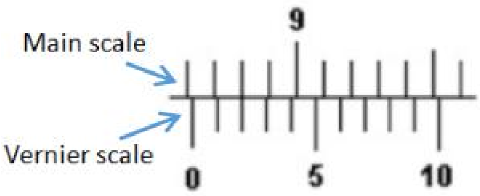
Reading from vernier calipers with 0.02 mm

STATE THE MEASUREMENT READING FROM THE USE OF VERNIER CALIPERS

EXAMPLE 1.4

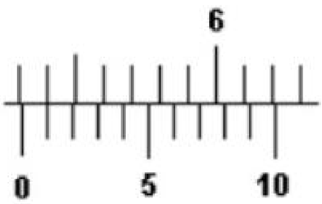
Find the readings of the vernier calipers below.

1.



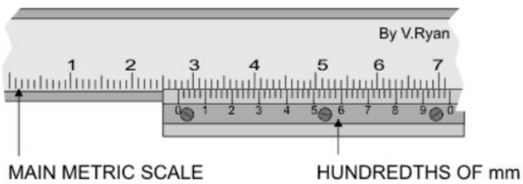
Answer:__________ cm

2.



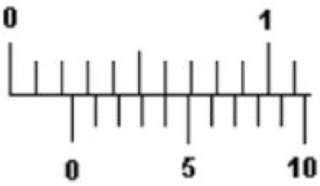
Answer:__________cm

3.



Answer:__________mm

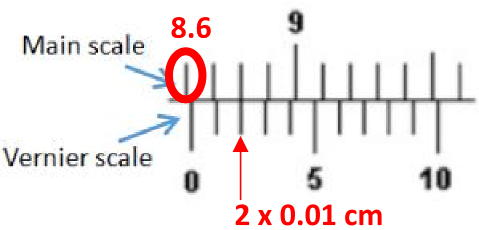
4.



Answer:__________cm

Solution:

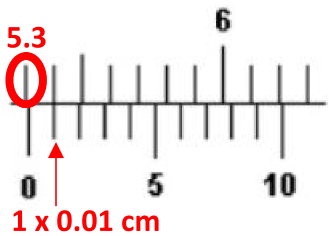
1.



Main scale:		8.6 cm
Vernier scale:	+	<u>0.02 cm</u>
		<u>8.62 cm</u>

Answer: **<u>8.62 cm</u>**

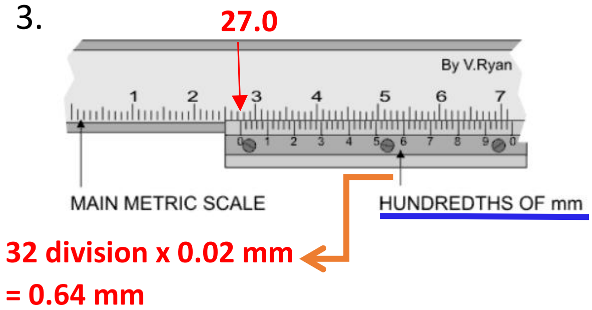
2.



Main scale:		5.3 cm
Vernier scale:	+	<u>0.01 cm</u>
		<u>5.31 cm</u>

Answer: **<u>5.31 cm</u>**

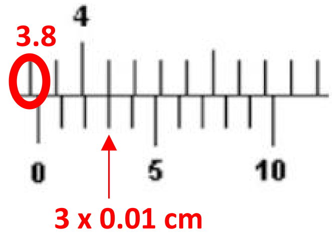
3.



Main scale:		27.0 mm
Vernier scale:	+	0.64 mm
		27.64 mm

Answer: **27.64 mm**

4.



Main scale:		3.8 cm
Vernier scale:	+	0.03 cm
		3.83 cm

Answer: **3.83 cm**

Zero Error of Vernier Caliper

Zero error indicates that a measuring tool gives a false reading when the true value of measured quantity is zero. Zero errors must be subtracted from the observed measurement to get the true value. Zero errors are one of the most commonly occurring errors in measuring instruments such as vernier calipers.

A vernier caliper **zero error occurs when the vernier caliper is set to its closed position**, for example, with the measuring jaws in contact with each other **but** the **zero on the vernier scale does not match with the zero on the main scale**, that is to say **the reading is not zero**. **Zero errors** can occur **due to improper vernier caliper calibration** or as a result of **mechanical shock** which **disturbs the alignment of the jaws**.

There are **3 conditions** of **zero errors of vernier caliper : no zero error, positive zero error and negative zero error.** **Figure1.14** shows cases of zero error in a vernier caliper.

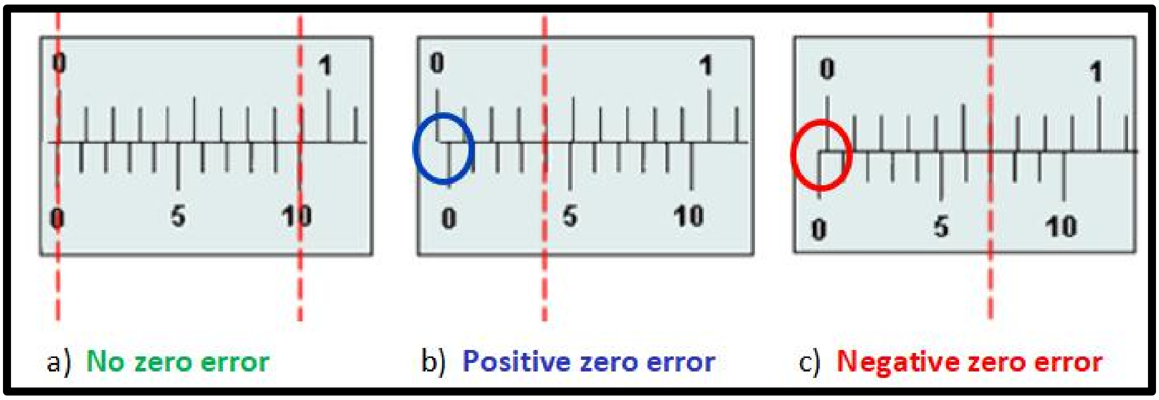
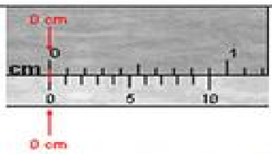
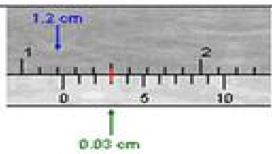
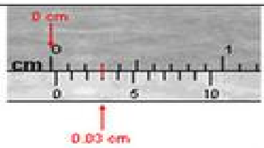
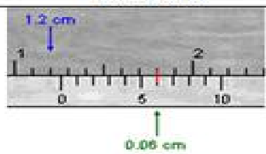
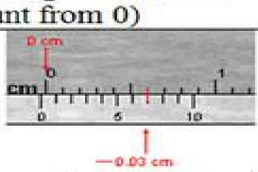
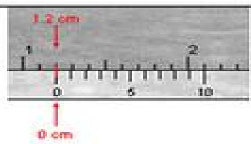


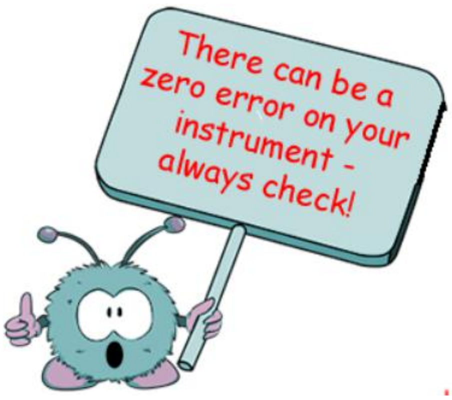
Figure1.14 Cases of zero error in a vernier caliper

- **No Zero Error: The two zero marks coincide.**
- **Positive zero error: The zero of vernier scale is right to the zero mark on the main scale (remember as RIP — Right Is Positive)**
- **Negative zero error : The zero of vernier scale is left to the zero mark on the main scale (remember as, just vice versa of +ve zero error)**

Table 1.8 shows the steps to read the 3 conditions of zero errors of vernier caliper.

Table 1.8 Steps to read the 3 conditions of zero errors of vernier caliper

Checking for zero error	Observed reading	Actual reading = observed reading – zero error
 Two zero marks coincide => No zero error	 Reading = 1.2 + 0.03 = 1.23 cm	1.23 cm as no zero error correction required.
 Zero mark on the vernier scale is slightly to the right of the zero mark on the main scale => positive zero error Reading = + 0.03 cm (count from 0)	 Reading = 1.2 + 0.06 = 1.26 cm	1.26 – (+0.03) = 1.23 cm
 Zero mark on the vernier scale is slightly to the left of the zero mark on the main scale => negative zero error Reading = - 0.03 cm (count from 10).	 Reading = 1.20 cm	1.20 – (- 0.03) = 1.23 cm



STATE THE MEASUREMENT READING FROM THE USE OF VERNIER CALIPERS (WITH ZERO ERROR)

EXAMPLE 1.5

Determine the actual reading for the vernier caliper readings in **Fgure 1.15**.

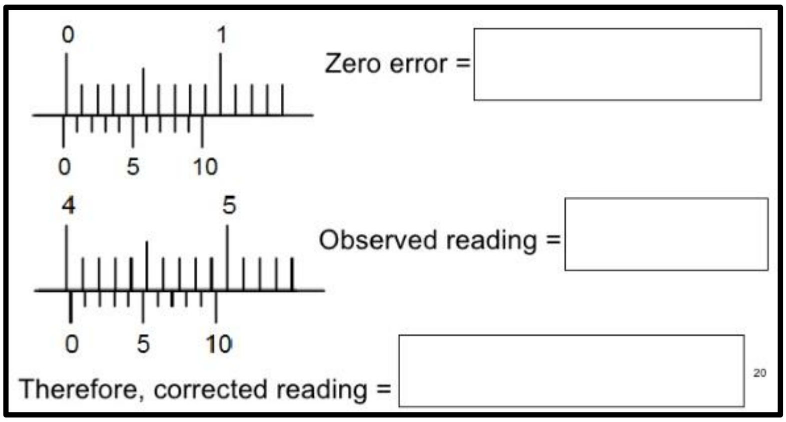
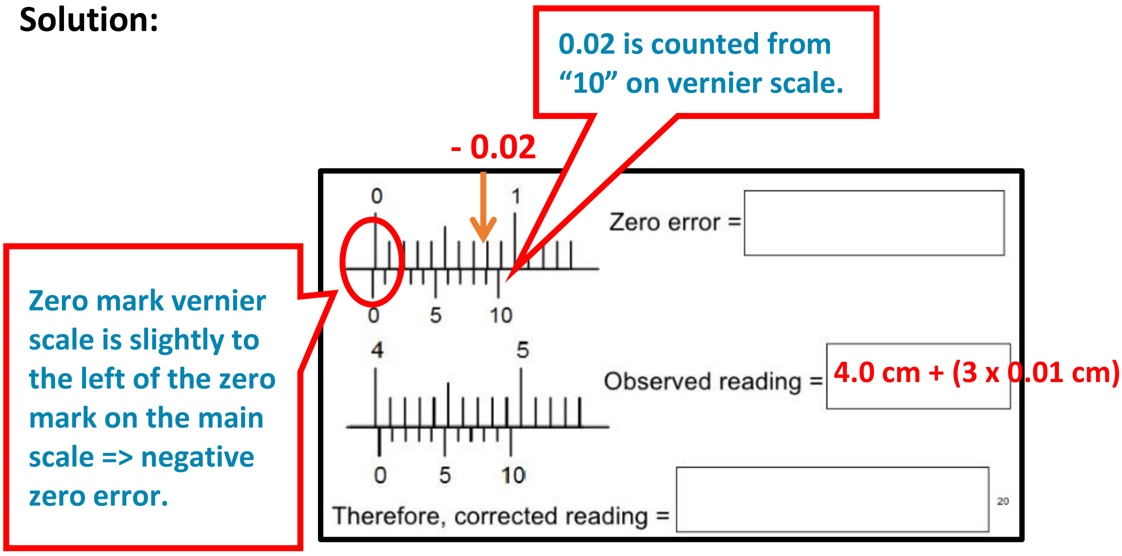


Figure 1.15

Solution:



Zero error $= -\ 0.02 \text{ cm}$

Observed reading $= \ 4.03 \text{ cm}$

Corrected reading $= \ 4.03 \text{ cm} - (-0.02 \text{ cm})$

$$= +\mathbf{4.05\ cm}$$

(c) Micrometer Screw Gauge

- A **micrometer screw gauge** is **more accurate than a ruler and vernier calliper** because it **has** the **smallest scale of 0.01 mm**.
- The range of a micrometer is 0-25 mm.
- The **accuracy of a micrometer is up to 0.01 mm**.

Parts of Micrometer Screw Gauge

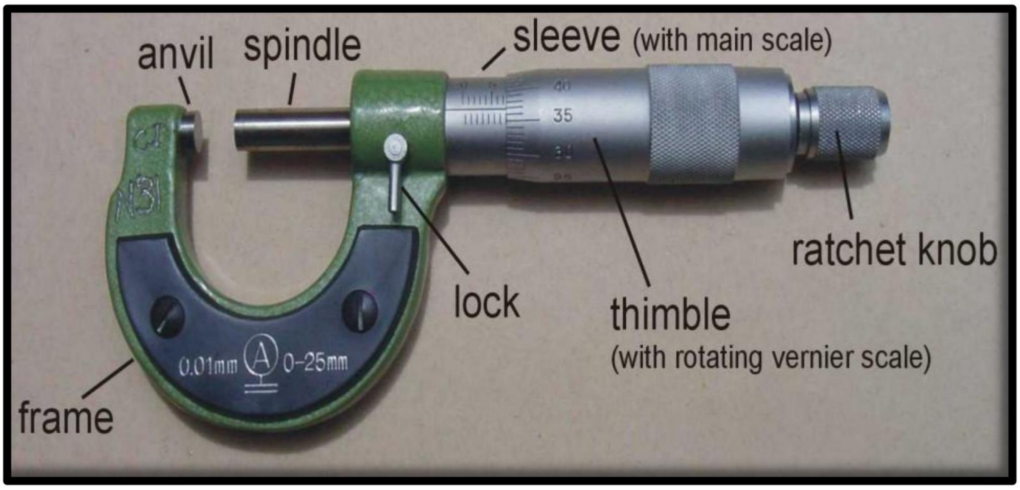


Figure 1.16 Parts of a micrometer screw gauge

The micrometer screw gauge is used for measuring diameters of wires, the thickness and of a workpiece, and much more. **Figure 1.16** shows the parts of a micrometer screw gauge.

1.4.2 STATE THE MEASUREMENT READING FROM THE USE OF MICROMETER SCREW GAUGE

How to Use a Micrometer?

1. Turn the thimble until the object is gripped gently between the anvil and spindle
2. Turn the ratchet knob until a "click" sound is heard. This is to prevent exerting too much pressure on the object measured.
3. Take the reading. **Figure 1.17** shows the measurement reading technique for micrometer screw gauge.

Measurement Reading Technique For Metric Micrometer

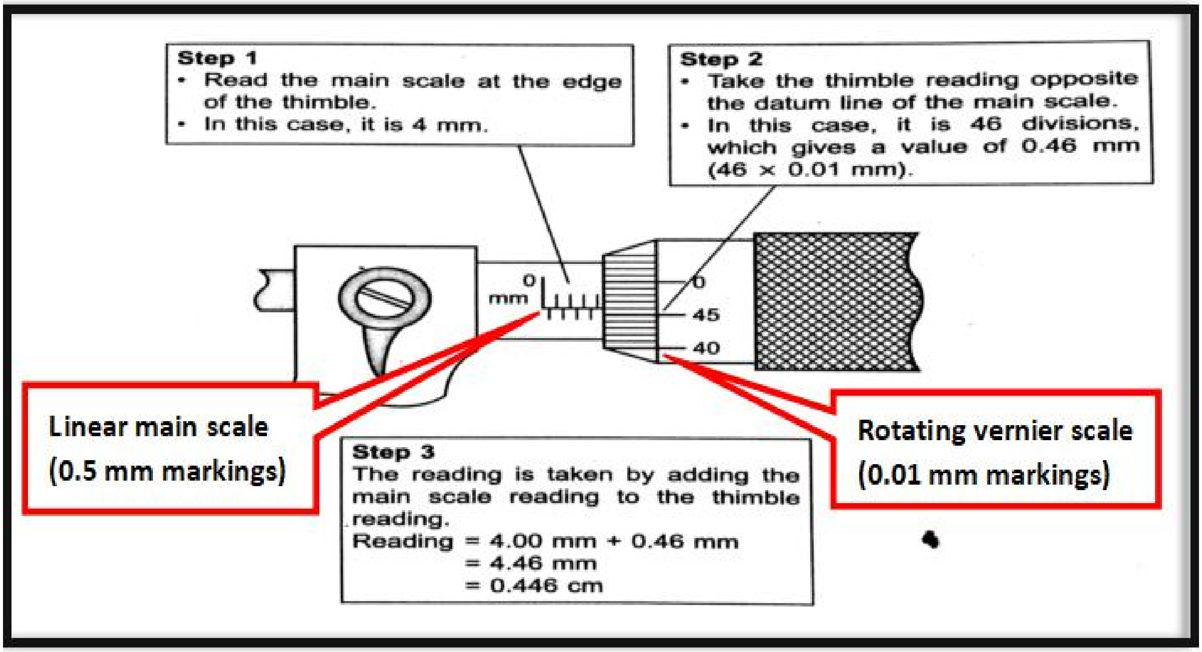


Figure 1.17 Measurement reading technique for micrometer screw gauge

Scan Me

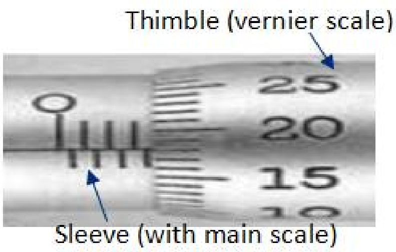
Reading from metric micrometers

STATE THE MEASUREMENT READING FROM THE USE OF MICROMETERS SCREW GAUGE

EXAMPLE 1.6

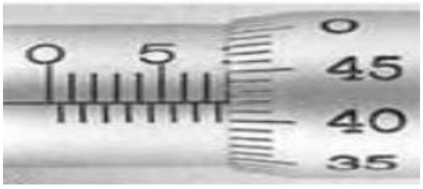
Read the following metric micrometer screw gauge measurements.

1.



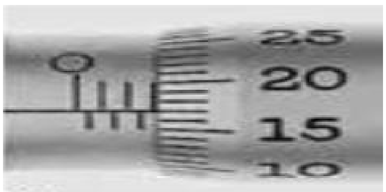
Answer:___________mm

2.



Answer:__________mm

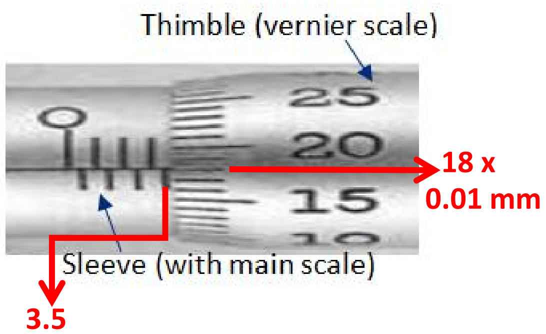
3.



Answer: __________mm

Solution:

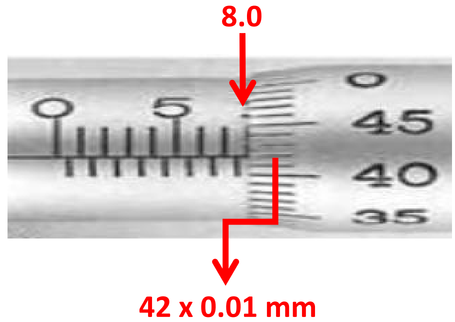
1.



Sleeve:	3.50 mm
Thimble: +	0.64 mm
	3.68 mm

Answer: **3.68 mm**

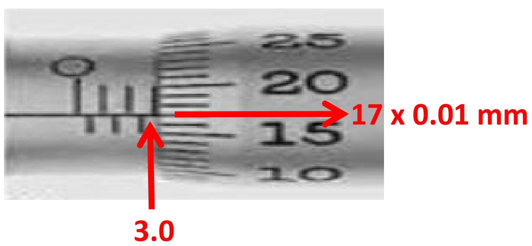
2.



Sleeve:	8.00 mm
Thimble: +	0.42 mm
	8.42 mm

Answer: **8.42 mm**

3.



Sleeve:	3.00 mm
Thimble: +	0.17 mm
	3.17 mm

Answer: **3.17 mm**

Zero Error of Micrometer Screw Gauge

When **using a micrometer screw gauge**, we must **first check** that there is **zero error**. This is to check **whether zero mark on thimble scale coincides to the datum line on the main scale** and **if reading on main scale is 0 when** we are **not measuring anything** (anvil is in contact with spindle). **Figure1.18** shows the cases of zero error in a micrometer screw gauge.

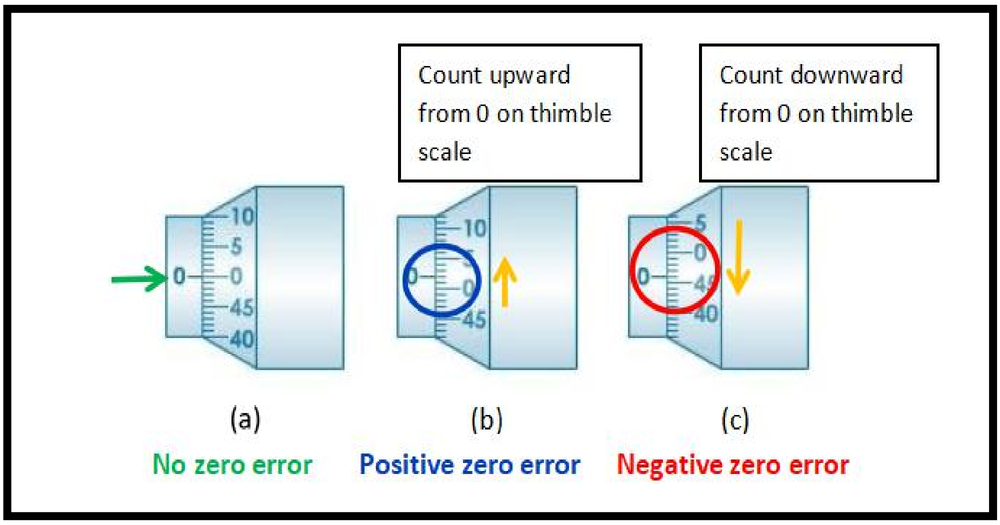
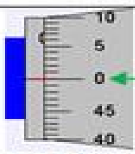
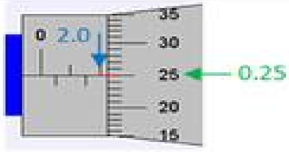
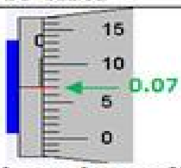
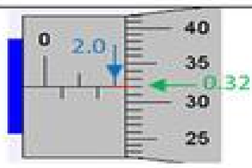
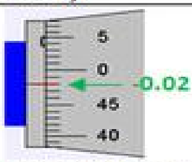
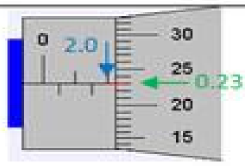


Figure 1.18 Cases of zero error in a micrometer screw gauge

Case (a) **No zero-error** occurs when the **zero mark on thimble scale coincides with datum line on the main scale** and **reading on main scale is "0"**. Case (b) **Positive zero-error** of 2 circular scale division. Positive zero-error **correction** is done **by subtracting** the **positive zero-error** from the actual reading. Case (c) **Negative zero-error** of 4 circular scale division. Negative zero-error **correction** is done **by adding the negative zero-error** from the actual reading. For reading on zero errors, we have to read it from thimble scale. **Table 1.9** shows the steps of checking and correcting zero errors when using the micrometer screw gauge.

Table 1.9 Steps of checking and correcting zero errors of a micrometer screw gauge

Checking for zero error	Observed reading	Actual reading = observed reading – zero error
 zero mark on thimble scale coincides with datum line on the main scale and reading on main scale is 0 => No zero error	 Reading = 2.0 + 0.25 = 2.25 mm	2.25 mm as no zero error correction required.
 Zero mark on datum line can be seen => positive zero error Reading = + 0.07 mm (count from 0)	 Reading = 2.0 + 0.32 = 2.32 mm	2.32 – (+0.07) = 2.25 mm
 Zero mark on datum line cannot be seen => negative zero error Reading = - 0.02 mm (count down from 0)	 Reading = 2.0 + 0.23 = 2.23 mm	2.23 – (- 0.02) = 2.25 mm

STATE THE MEASUREMENT READING FROM MICROMETER SCREW GAUGE USAGE (WITH ZERO ERROR)

EXAMPLE 1.7

Determine the actual reading for the micrometer readings in Fgure 1.18.

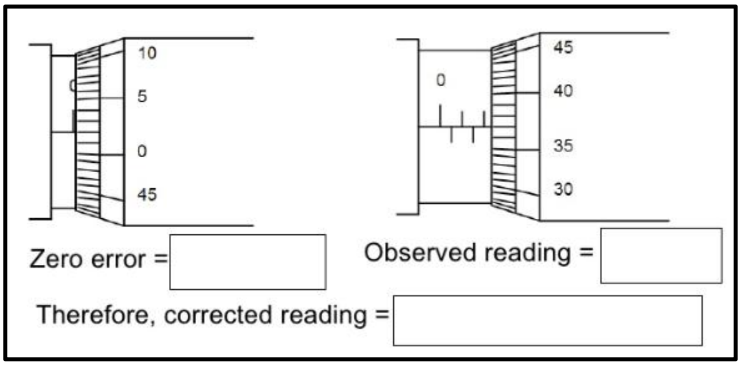
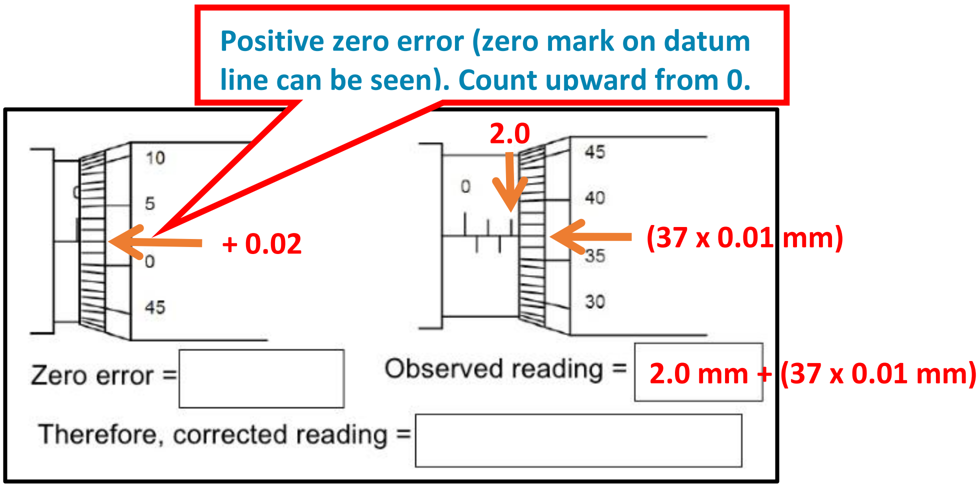


Figure 1.18

Solution:



Zero error $= +\ 0.02\ \mathrm{mm}$

Observed reading $= \ 2.37\ \mathrm{mm}$

Corrected reading $= \ 2.37\ \mathrm{mm} - (+\ 0.02\ \mathrm{mm})$

$$= +\mathbf{2.35\ mm}$$

PHYSICAL QUANTITIES AND MEASUREMENT

EXERCISES

Q1 Describe the differences between base quantity and derived quantity with **TWO (2)** examples.

Q2 List **TWO (2)** base quantities and derived quantities with their respective SI units.

Q3 Classify the given physical quantities below into base and derived quantities.

> 5 packets inside: Total 80.5 g
>
> For each packet, add 150 cm^3 of hot water at 70℃. Stir until thicken.
>
> All done in 3 minutes.
>
> 10 kJ of energy per serving
>
> Expiry date: 23/08/2023

Q4 List the types of errors in measurement.

Q5 Describe **THREE (3)** differences between the errors stated in **Q4**.

Q6 Random errors in an experimental measauarements are caused by unknown and unpredictable changes in an experiment:

a. Give **TWO (2)** examples of cause of random errors.

b. Give **TWO (2)** approaches to minimize random errors.

Q7 The measurement error is defined as the differences between a true value and a measured value. Give **ONE (1)** example of the cause of errors during experiment and state **TWO (2)** best ways of reducing errors.

Q8 Describe the differences between consistency and accuracy by using appropriate diagram.

Q9 Define and give **ONE (1)** example for each following term:

a. Scalar quantity b. Vector quantity

Q10 For each situation below, determine whether each of the quantities involved is a scalar or vector quantity. Explain your answer.

- Fatin buy 4 kg of sugar for her mother to bake cakes.
- Aminah runs 7 km for a Palastine Marathon.
- Danial heats some water from 25°C to 100°C to make hot chocolate.
- An airplane is heading north at an airspeed of 700 km/h.
- A man pushes a heavy crate with a force of 70 N towards a lift.
- A deer running 15 m/s due west.
- Ariel took seven hours to drive his car from Kuala Lumpur to Kota Baharu.

Q11 Use the appropriate prefixes to represent the following numbers:

a. 0.003 g
b. 800000 Hz
c. 2300 N
d. 1700000 m
e. 400000000 W
f. 500 J

Q12 Convert the following metric units:

a. 500000 N/m^2 to kN/mm^2

b. 15 m^3 to cm^3

c. 200 kg/m^3 to g/cm^3

d. 160 km/h to m/s

e. 10 h to s

f. 250 000 μm to km

g. 45 mm/min to m/s

h. 920 mm^2 to m^2

Q13 Convert the following customary units:

a. 35 foot to inches

b. 4 yards to inches

c. 24000 feet to miles

d. 2.6 gallons to litters

e. 50 oz to pound

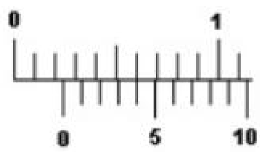
f. $13\frac{3}{4}$ ft^3 to m^3

g. 1 kg to oz

h. 5.18 km^2 to hectare

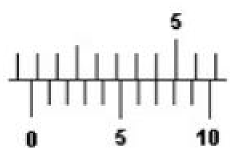
Q14 Read the following vernier caliper measurements.

a.



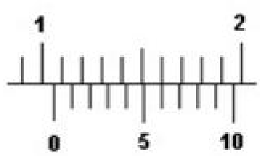
Answer: ___________cm

b.



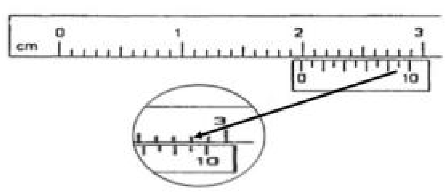
Answer: ___________cm

c.



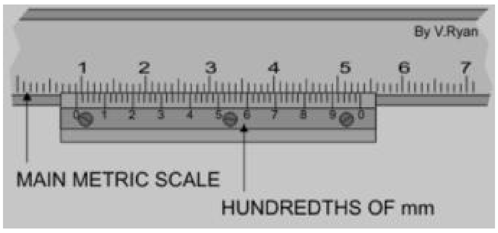
Answer: ___________cm

d.



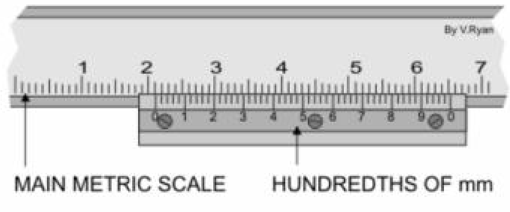
Answer: ___________cm

e.



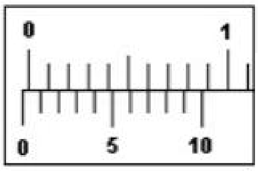
Answer: __________mm

f.

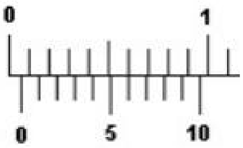


Answer: __________mm

g.



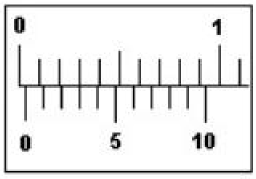
Zerro error =_______



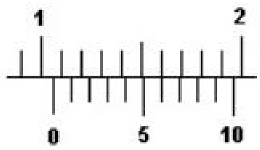
Observed Reading =_______

Corrected reading: ________cm

h.



Zerro error =_______

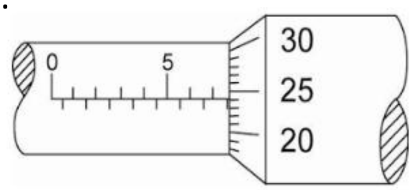


Observed Reading =_______

Corrected reading: ________cm

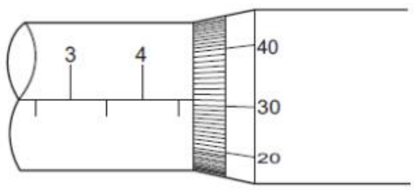
Q15 Read the following metric micrometer screw gauge measurements.

a.



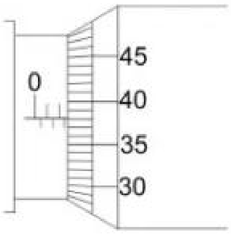
Answer: __________mm

b.



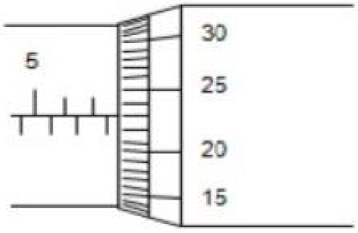
Answer: __________mm

c.



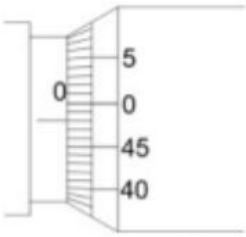
Answer: __________mm

d. If zero error occurred is – 0.05 mm

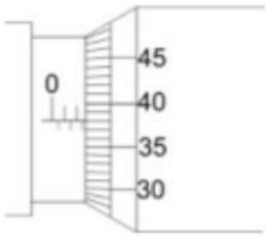


Corrected reading: __________mm

e.



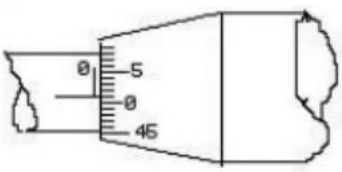
Without an object



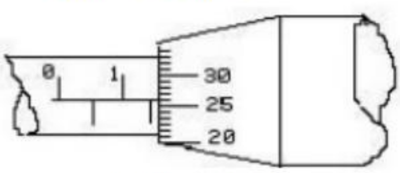
With an object

Answer: __________mm

f.



Without an object



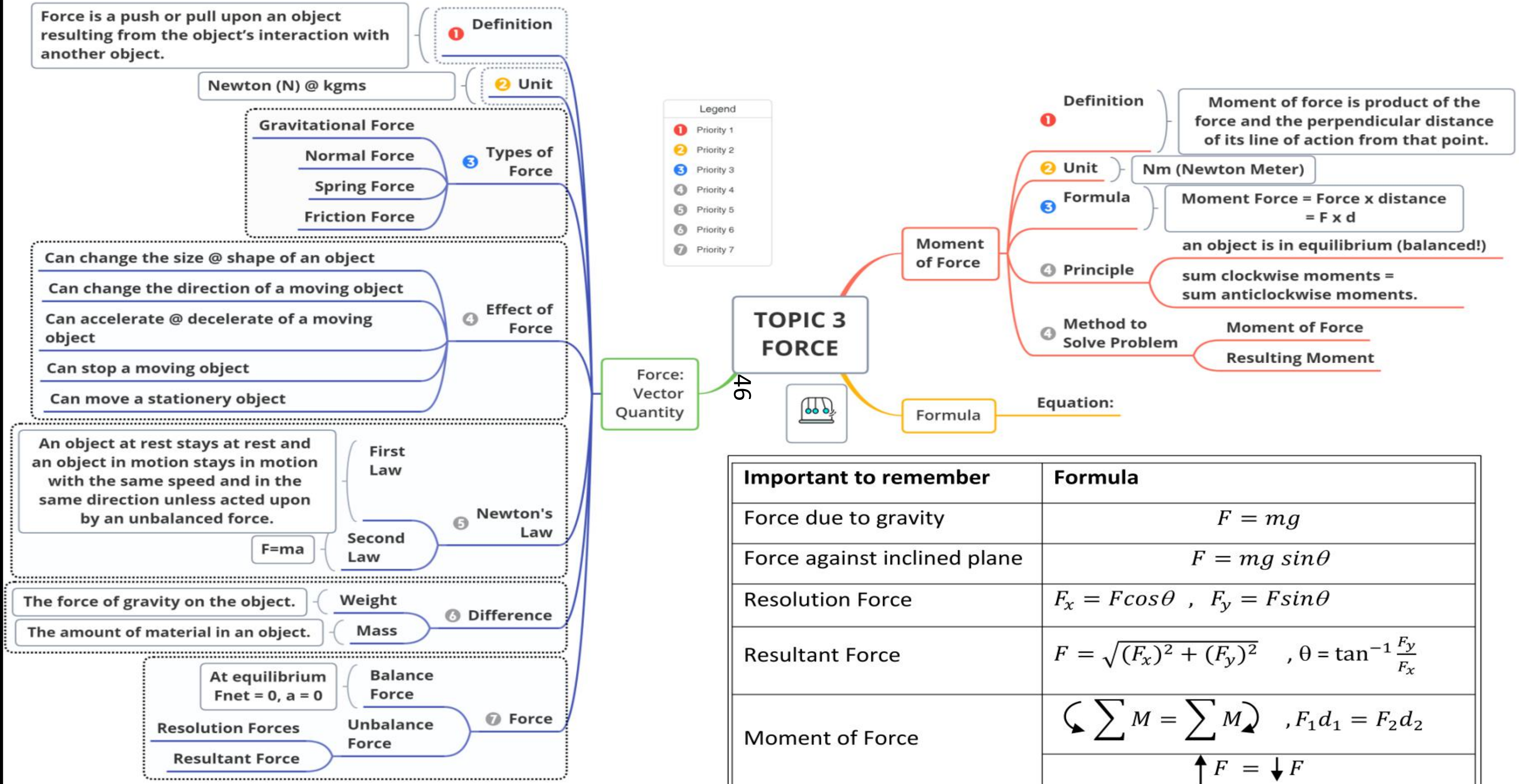
With an object

Answer: __________mm

TOPIC 2

FORCE

CONCEPT MAP OF FORCE



Important to remember	Formula
Force due to gravity	$F = mg$
Force against inclined plane	$F = mg\ sin\theta$
Resolution Force	$F_x = Fcos\theta$, $F_y = Fsin\theta$
Resultant Force	$F = \sqrt{(F_x)^2 + (F_y)^2}$, $\theta = \tan^{-1}\frac{F_y}{F_x}$
Moment of Force	$\circlearrowright \sum M = \sum M \circlearrowleft$, $F_1 d_1 = F_2 d_2$
	$\uparrow F = \downarrow F$
Resultant Force	$x = \dfrac{F_1(0) + F_2(x_2) + F_3(x_3)}{F_1 + F_2 + F_3}$

2.1 CONCEPT OF FORCE

- Force is defined as any influence that changes the state of motion of an object.
- Force also known as a push or a pull action is a **vector quantity** which has both magnitude and direction as shown in **Figure 2.1.**

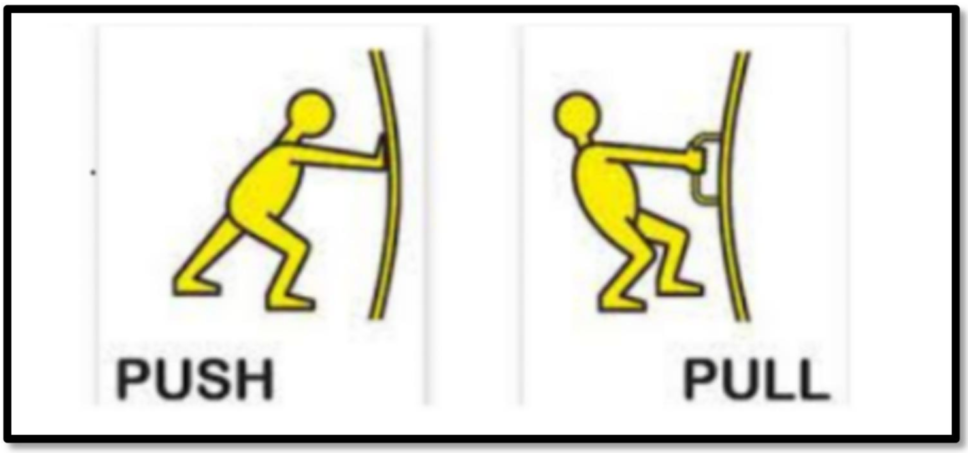


Figure 2.1 Pushes and pulls of forces is a vector quantity

2.1.1 DEFINITION OF FORCE AND ITS UNIT

- Force is a quantitative measure of the **interaction between any physical**, concerning its motion, geometrical shape, direction and its environment.
- In the theory of physics, a force also known as any influence that will change the motion of an object, for **example its velocity proportional to acceleration**.
- Force is a derived quantity that can be measured in **Newton (N)** or that causes an object with a **mass of 1 kg to accelerates at 1 m/s^2 (1 $kgms^{-2}$)**.

2.1.2 TYPES OF FORCE

- There are many types of forces. Several main types of force are :

i. Gravitational force or Weight

- Can be defined as the **gravitational force acting on the object.** If the mass of an object is m kg, then its weight can be calculated as ;

$$F = W = mg$$

gravitational acceleration on the earth, $g = 9.81\ ms^{-2}$

- The force of gravity on the earth is always directed 'downwards' due to the centre of the earth and equal to the weight of the object as shown in **Figure 2.2.**

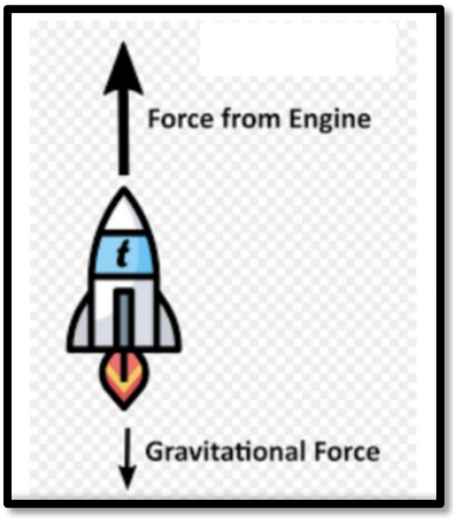


Figure 2.2 Gravitational force acting on the rocket

ii. Frictional force

- Can be defined as the **force that opposes the relative motion of two surfaces.** Frictional force can be illustrated such as in **Figure 2.3.**

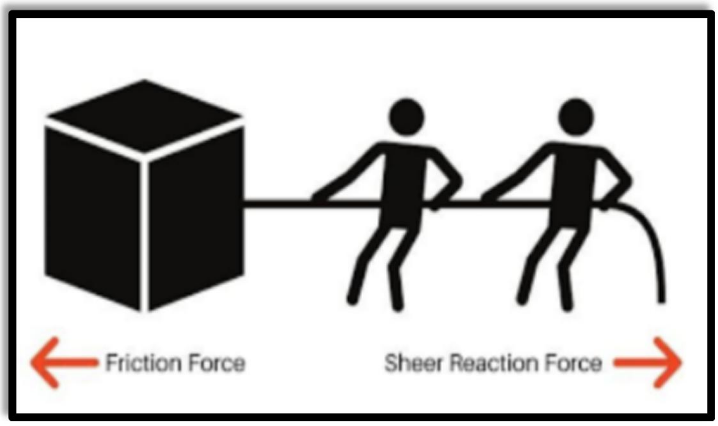


Figure 2.3 Frictional force acting against the pulling force and motion

- Types of frictional force are :
  - **static friction** : friction that acts on stationary object
  - **kinetic friction** : friction that acts while the object is moving

iii. Reaction force

- The force also known as normal reaction, that **opposes the force exerted on a surface** which is perpendicular to the surface, **in 90°** as shown in **Figure 2.4.**

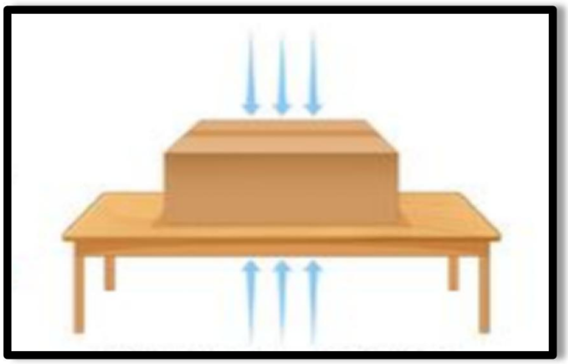


Figure 2.4 Reaction force acting perpendicular to the surface

iv. Magnetic force

- Force exerted on a magnetic object, **acting between the magnetic poles of two magnets**, as shown in **Figure 2.5.**

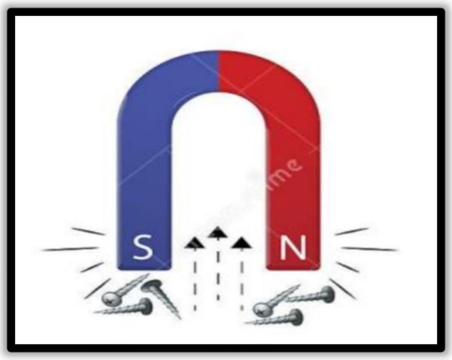


Figure 2.5 Magnetic force acting on the conductor nail

v. Electrical force

- The **electric force between stationary charged body** is conventionally known as the electrostatic force. Electrostatic force is an attractive and repulsive force between particles are caused due to their electric charges.
- **Figure 2.6** shows electric charge and electric force :

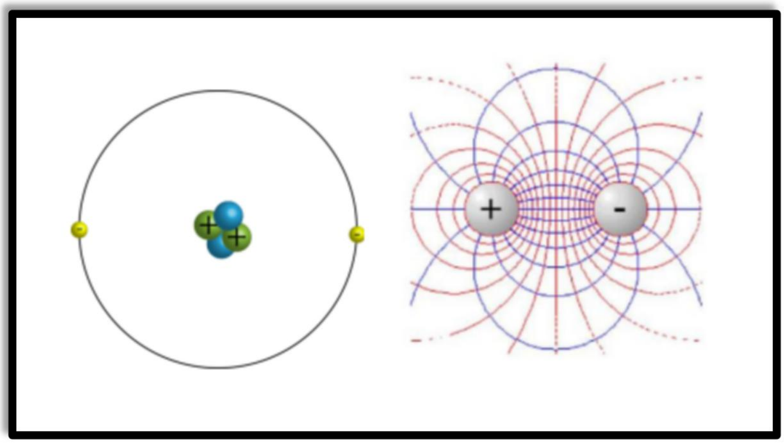


Figure 2.6 Particles of electric charge and electric force

- There are several example acting of forces :
  - **Push :** a force to move something away
  - **Pull :** a force to move something toward us
  - **Gravity :** a force that attracts two object sitting next to each other
  - **Magnetism :** a force that pulls metal toward a magnet
  - **Friction :** a force that slows or stops when objects rub together

2.1.3 EFFECTS OF NET FORCE

- When the forces acting on an object are balanced, they cancel each other out, known as the **net force** because the force **is equal to zero.**

- **Figure 2.7** shows general effects of net force.

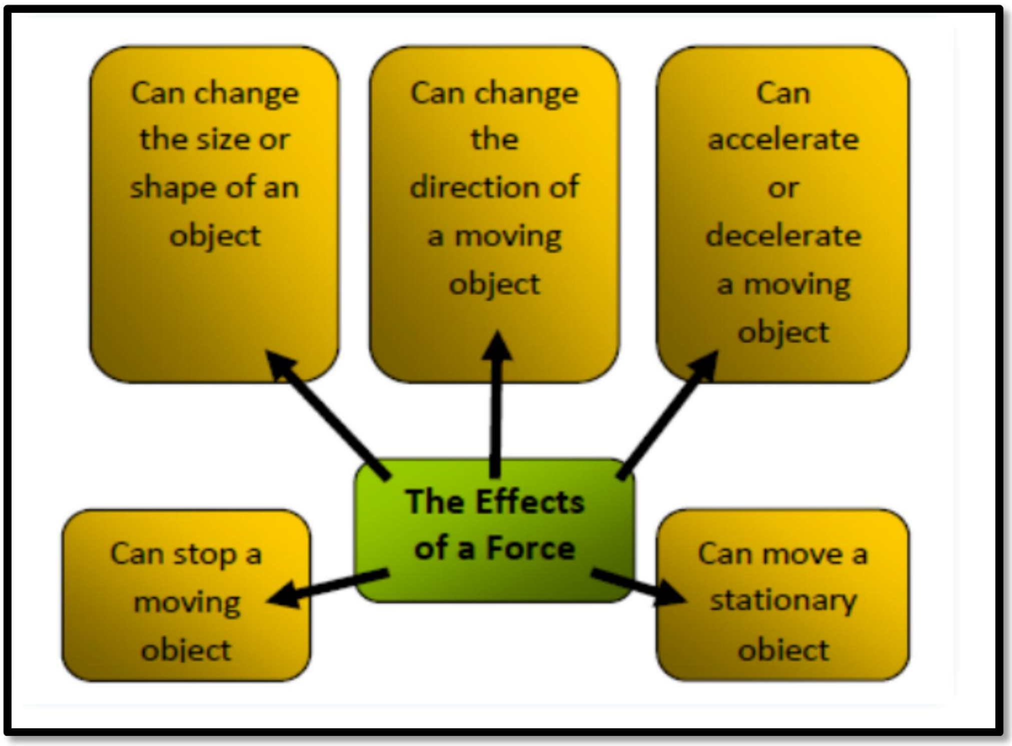


Figure 2.7 The effects net force

- An examples effects of net force as shown in **Figure 2.8 (a), (b) and (c) :**

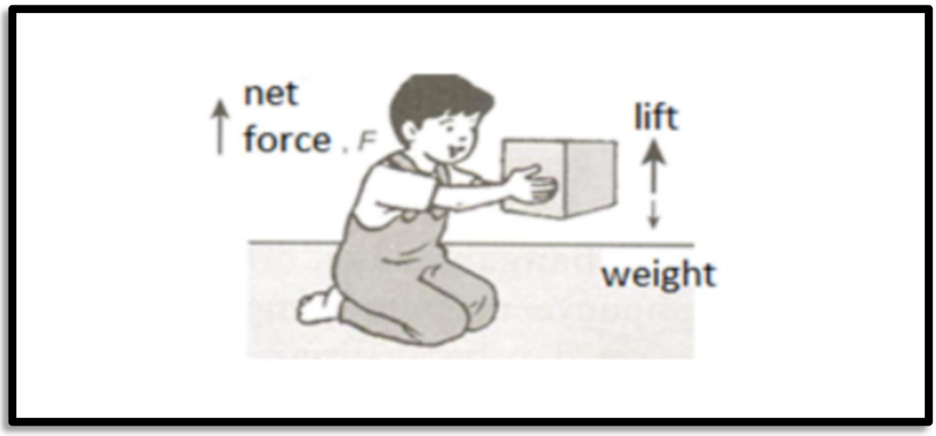


Figure 2.8 (a) Upward net force

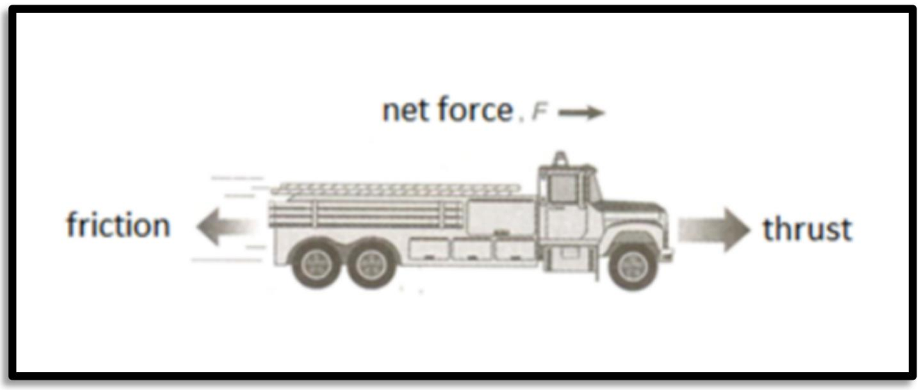


Figure 2.8 (b) Forward net force

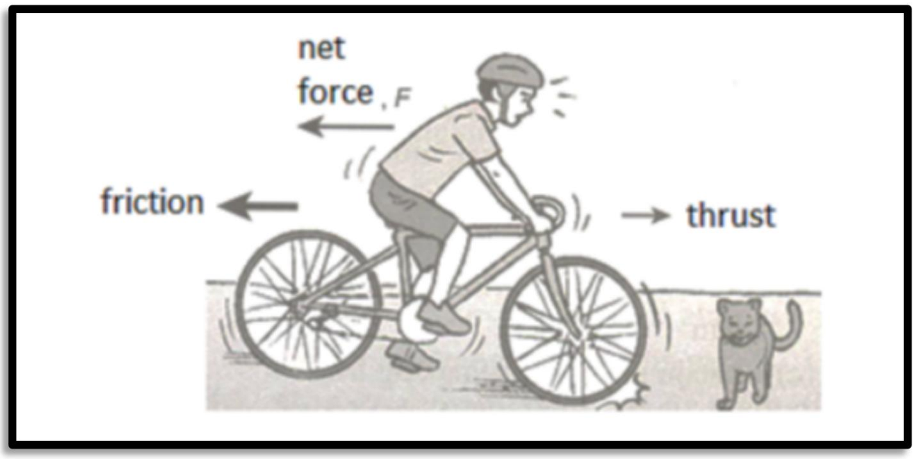


Figure 2.8 (c) Backward net force

2.1.4 NEWTON'S FIRST LAW AND SECOND LAW

Newton's First Law ($\sum F = 0$)

- Newton's First Law of motion states that **an object at rest will remains at rest** and **an object in motion will remains in motion** with the same speed and direction, until unbalanced force occurs on the objects.
- **Figure 2.9** shows an example of Newton's First Law.

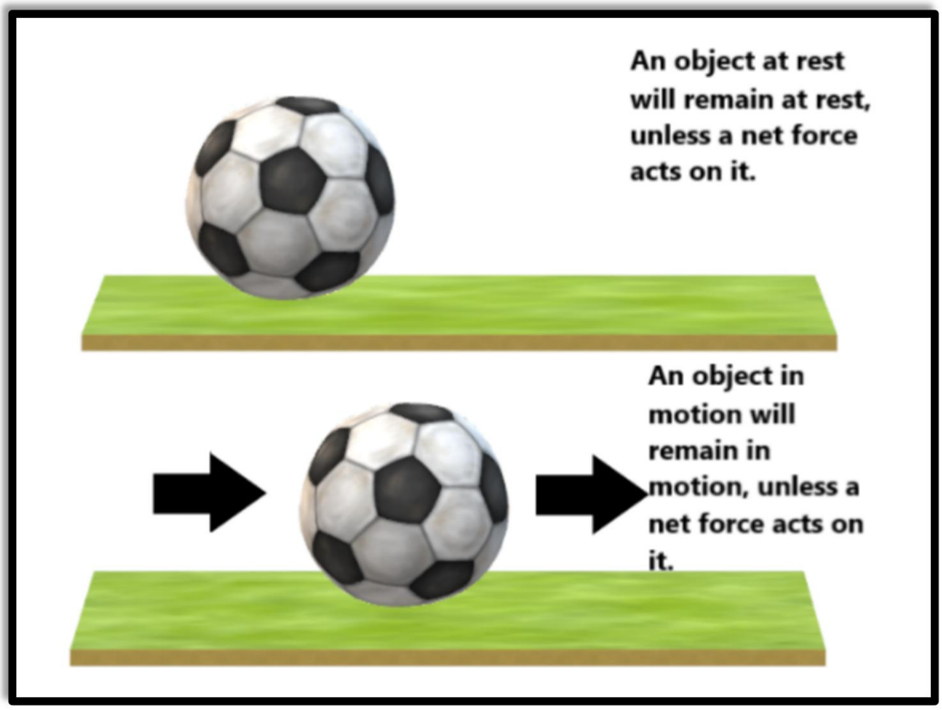
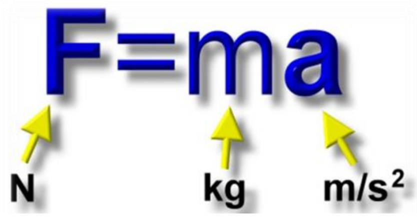


Figure 2.9 An example of Newton's First Law

- **Inertia** is the tendency of an object to stay at rest or preserve its state of motion. This concept is quantified in **Newton's First Law of Motion.**
- **The greater the mass, the stronger the inertia** and it will make an object reluctant to move up or to stop. This external physical quantity which is required to change the state of motion of an object is called force.

Newton's Second Law (∑ F = ma)

- Newton's second law is about the **relationship between force, mass and acceleration** and can be described as below:



F = net force **m = mass** **a = acceleration**

- For example, to launch a rocket, the magnitude of thrust is increased, which in turn increases the acceleration. According to the second law of motion given by Sir Issac Newton, the **force is proportional to the acceleration**, therefore the speed achieved by the rocket finally helps it to escape the earth's gravitational field and enter space.

2.1.5 WEIGHT AND MASS

What is the difference between weight and mass? Many people use these terms interchangeably, on Earth it might works. However, on the Moon or on other planets, we will have to get more precise when we talk about how much stuff is in our stuff. The difference between weight and mass as shown in **Table 2.1**.

Table 2.1 Comparison of mass and weight

NO	MASS	WEIGHT
1	Mass is a property of matter. An object's mass is the same everywhere.	Weight depends on the effect of gravity. The influence of gravity determines weight. The weight varies according to where you are.
2	Mass can never be zero.	Weight can be zero if no gravity acts upon an object, as in space.
3	Mass does not change according to location.	Weight increases or decreases with higher or lower gravity.
4	Mass is scalar quantity. It has magnitude only.	Weight is a vector quantity. It has magnitude and is directed toward the centre of the earth.
5	Mass may be measured using an ordinary balance.	Weight is measured using a spring balance.
6	Mass is usually measured in grams and kilograms.	Weight is often measured in Newton, a unit of force.

- Relationship between weight, force, mass and acceleration of gravity.

<u>W = mg</u> applies at all times, even when the object is not accelerating

$$W = F = mg$$

<u>W = F</u> if an object is in free fall, only gravity force

W = weight F = net force

m = mass

g = acceleration of

2.1.6 DEFINITION FORCES IN EQUILIBRIUM

- If the size and direction of a force acting on an object are exactly balanced, then **there is no net force acting on the object** and the object is said to be in equilibrium.
- **Figure 2.10 (a) and (b)** show two objects are at equilibrium. However, the forces are not equal.

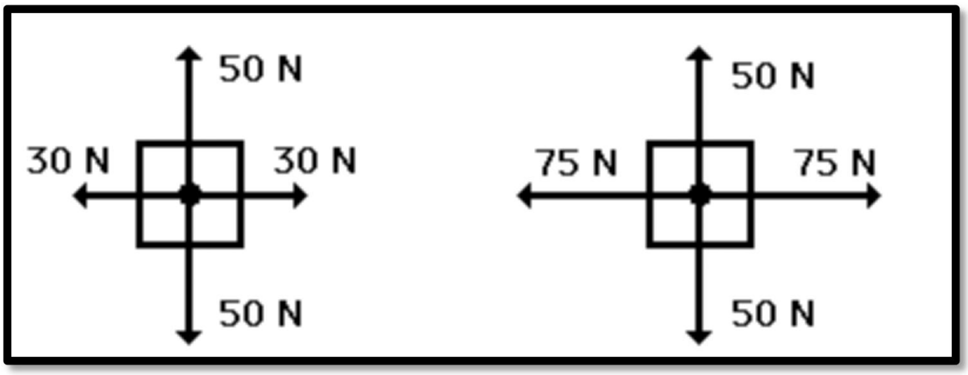


Figure 2.10 (a) Two objects are at equilibrium since the forces are balanced

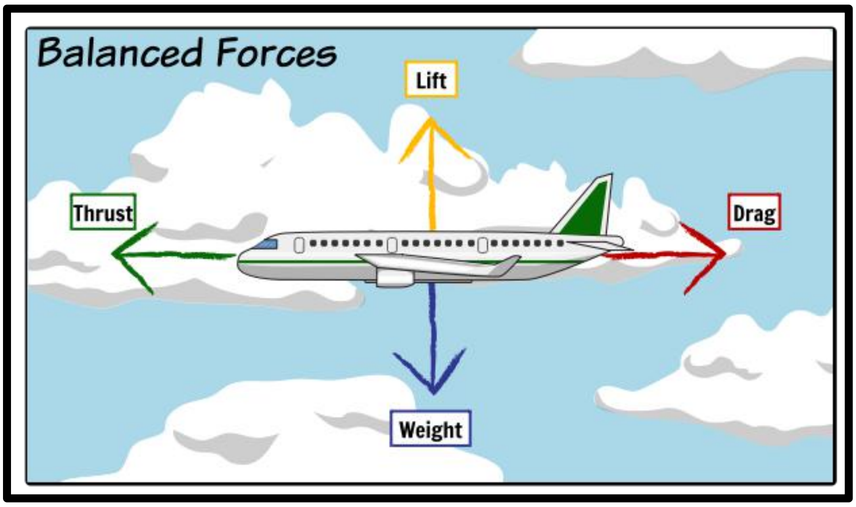


Figure 2.10 (b) Size and direction of the forces acting on an object are exactly balanced

- Types of equilibrium (in balance) :
    - **Static equilibrium –** if the combined effects of all the forces acting on a body is zero (rest), then its static equilibrium.
    - **Dynamic equilibrium -** when a body is in state of uniform motion and the resultant of all the force acting upon it is zero, it is a dynamic equilibrium.
- **Figure 2.11** shows a relationship between equilibrium and a non-equilibrium.

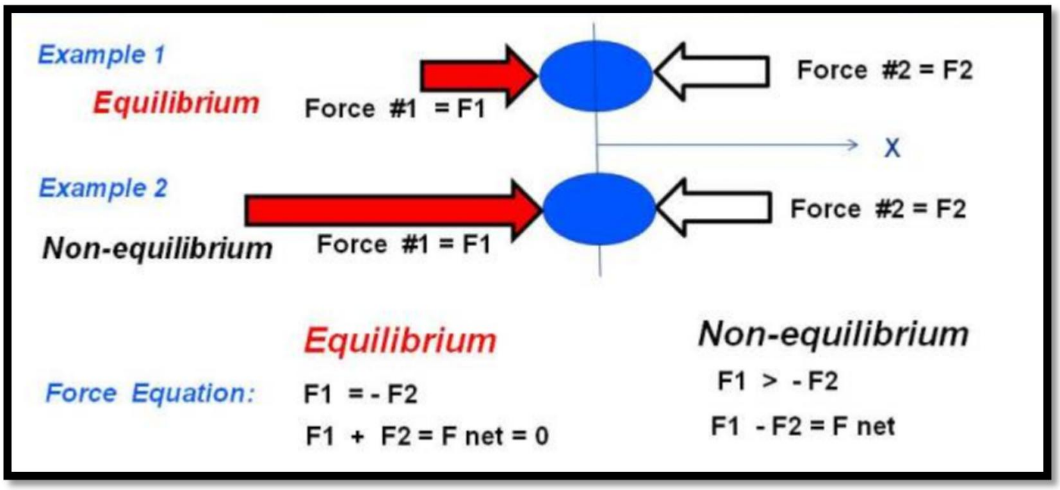


Figure 2.11 Equilibrium and non-equilibrium factor

2.1.7 CALCULATE RESULTANT FORCE

- Resultant force can be defined as a system of forces is acting on an object, the difference between the forces is called the Resultant force. For example, **2 N force to the left and 7 N force to the right gives a resultant force of 5 N to the right.**
- **Figure 2.12 (a), (b), (c)** shows an example of the size and direction of resultant force, determines how a body moves.

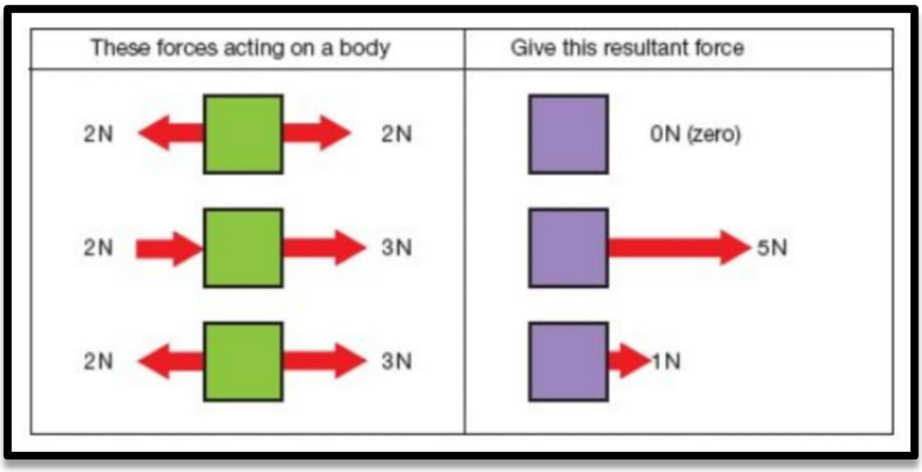


Figure 2.12 (a) Resultant force

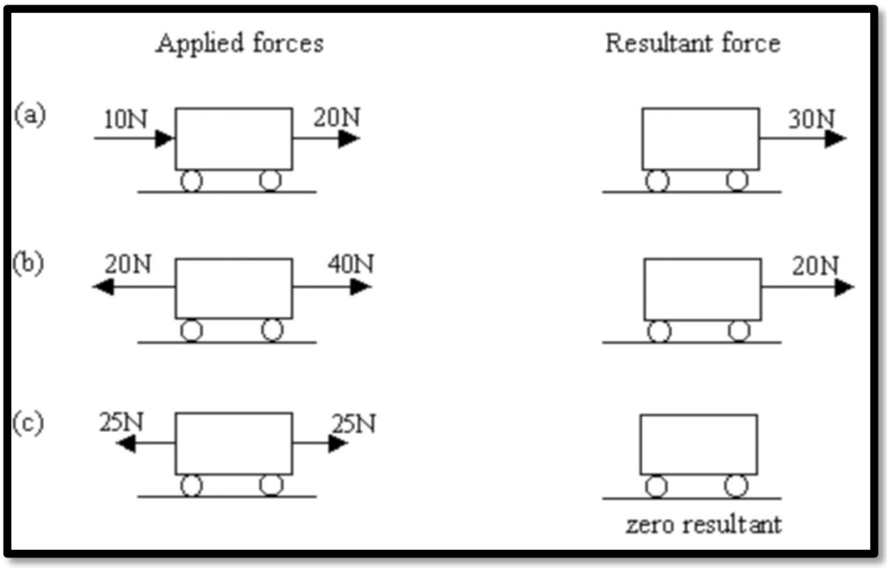


Figure 2.12 (b) Multi direction of force action

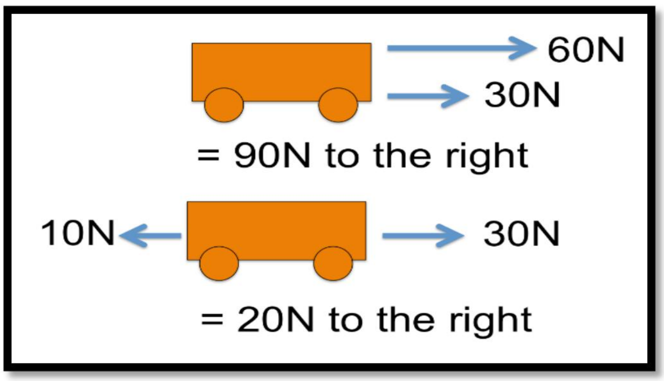
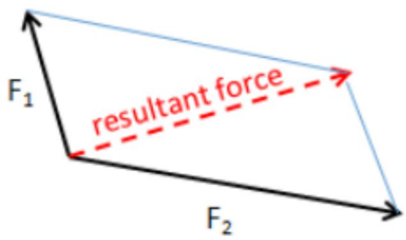
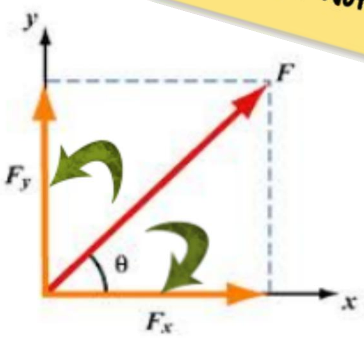


Figure 2.12 (c) Different direction of resultant force action

2.1.8 APPLICATION OF THE CONCEPT OF FORCE THROUGH RESOLUTION METHODS

- Resolution of a force can be defined as **the process of splitting up the given force into several components**, without changing its effect on the body.
- The resultant of two or more vectors of forces can be found by adding the forces components and related formula as shown below.





Formula for **resolving a force:**

$$F_x = F\cos\theta \quad and \quad F_y = F\sin\theta$$

Formula for **resulting forces:**

$$\text{resultant force}, F = \sqrt{(F_x)^2 + (F_y)^2}$$

$$\text{direction @ angle}, \theta = tan^{-1}\frac{F_y}{F_x}$$

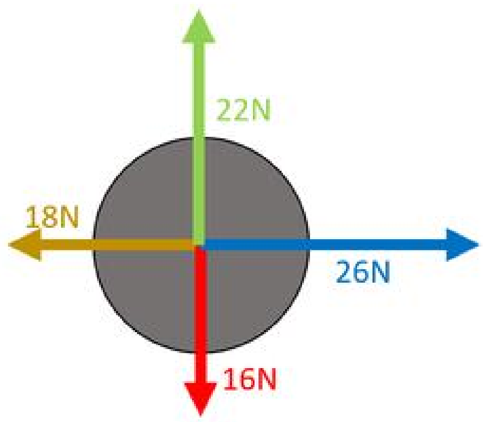
$$\boxed{F_x = F\cos\theta}$$

$$\boxed{F_y = F\sin\theta}$$

APPLICATION OF THE CONCEPT OF FORCE THROUGH RESOLUTION METHODS

EXAMPLE 1

Determine the angle of each force ;



Solution steps :

- *First, determine how many force do you have in the diagram?*
- *Then, find the angle for each of the force.*

*** built the solution table, so that you can clearly see the angle.*

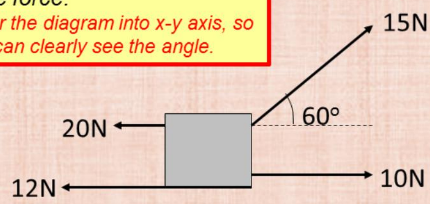
F	α	Fx = F Cos α	Fy = F Sin α
F1=26N	0^0	26 Cos 0^0 = 26 N	26 Sin 0^0 = 0 N
F2=22N	90^0	22 Cos 90^0 = 0 N	22 Sin 90^0 = 22 N
F3=18N	180^0	18 Cos 180^0 = -18N	18 Sin 180^0 = 0 N
F4=16N	270^0	16 Cos 270^0 = 0 N	16 Sin 270^0 = -16 N
Σ		**8 N**	**6 N**

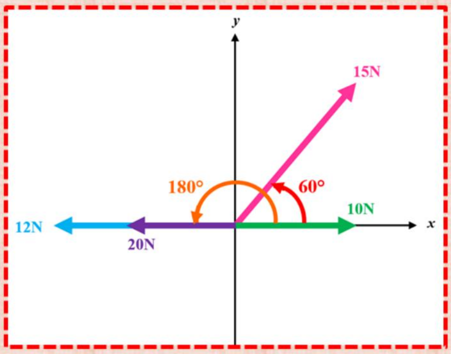
EXAMPLE 2

Diagram shows forces acting on an object. Calculate the resulting force acting on the object and draw resulting force diagram ;

- First, determine how many force do you have in the diagram?
- Then, find the angle for each of the force.

*** transfer the diagram into x-y axis, so that you can clearly see the angle.*





F	θ	Fx = F cos θ	Fy = F sin θ
10 N	0°	10 cos 0°= 10 N	10 sin 0°= 0 N
15 N	60°	15 cos 60°= 7.5 N	15 sin 60°= 12.99 N
20 N	180°	20 cos 180°= -20 N	20 sin 180°= 0 N
12 N	180°	12 cos 180°= -12 N	12 sin 180°= 0 N
		∑Fx = -14.5 N	∑Fy = 12.99 N

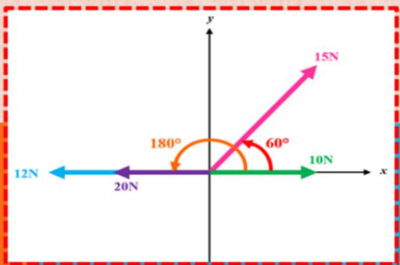
Calculate the resultant force

$$S = \sqrt{[(F_x)^2 + (F_y)^2]}$$
$$= \sqrt{[(-14.5)^2 + (12.99)^2]}$$
$$= \sqrt{(210.25 + 168.74)}$$
$$= \sqrt{(378.99)}$$
$$= \underline{19.468\ N}$$

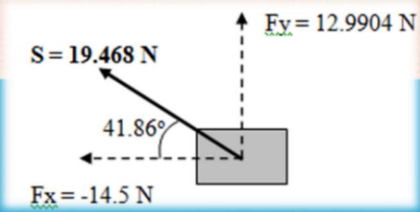
Calculate the degree acting on the force

$$\tan\theta = \frac{Fy}{Fx} = \frac{12.99}{-14.5} = -0.8959$$

$$\theta = \tan^{-1} -0.8959 = \underline{-41.86^\circ}$$

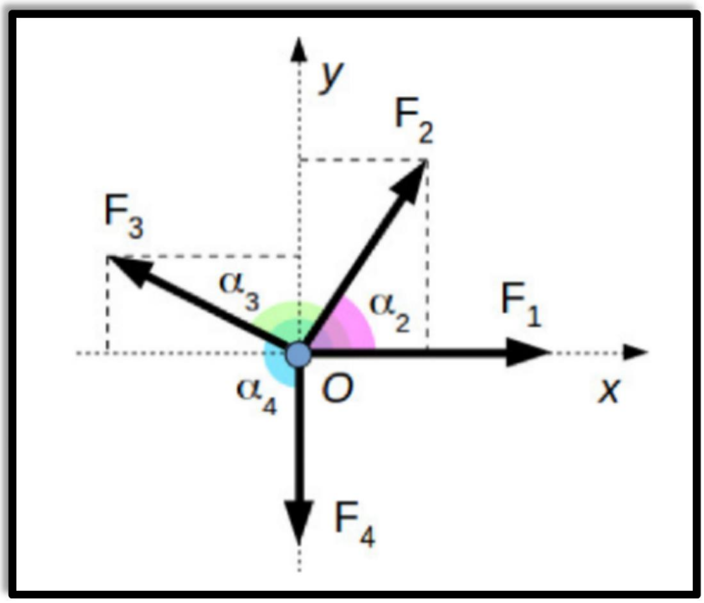


Draw the resulting force diagram



EXAMPLE 3

Calculate the resulting force acting on the object ;



F	α	Fx =F Cos α	Fy =F Sin α
F1=10N	0^0	10 Cos 0^0 = 10 N	10 Sin 0^0 = 0 N
F2=5N	37^0	5 Cos 37^0 = 3.99 N	5 Sin 37^0 = 3 N
F3=5N	150^0	5 Cos 150^0 = -4.33 N	5 Sin 150^0 = 2.5 N
F4=4N	270^0	4 Cos 270^0 = 0 N	4 Sin 270^0 = -4 N
Σ		**9.66 N**	**1.5 N**

Resultant Force , R = $\sqrt[2]{\sum(f_x)^2 + \sum(f_y)^2}$

$= \sqrt{(9.66)^2 + (1.5)^2}$

$= \sqrt{93.316 + 2.25}$

$= \sqrt{95.566}$

$= \mathbf{9.776\ N}$

$$\text{Direction, } \theta = tan^{-1}\frac{f_y}{f_x}$$

$$= tan^{-1}\frac{1.5}{9.66}$$

$$= \mathbf{2.71^0}$$

2.2 MOMENT OF FORCE CONCEPT

- Forces can cause **an object to rotate and the turning effect of the force** is called a moment.
- If a resultant force acts on an object about a fixed turning point (the pivot) it will cause the object to rotate. **For example turning a nut with a spanner, applying a screwdriver, opening a door fixed on hinges.**
- Let us imagine pushing a door open. You push on the door handle and the door rotates around its hinges (the hinges are a pivot). You exerted a force that caused the door to rotate, the rotation was the result of the moment of your pushing force.

2.2.1 DEFINITION OF MOMENT FORCE AND ITS UNIT

- In physics, moment of force is a measure of its tendency to cause a body to rotate about a specific point or axis.
- The rotational or turning effect, the moment, has a magnitude easily calculated from the formula:

$$\boxed{\mathbf{M = F \times d}}$$

- Where **M** = the moment of a force **(Nm)**, **F** = force applied **(N)** and **d** is the pependicular distance **(m)** from the pivot point to the line of action of the force.
- **Figure 2.13 (a), (b)** shows the moment of a force. The maximum moment produces by pushing/pulling the spanner at a right angle (at 90°) to the line **(d)** between the pivot point and the line of action where the force is applied.

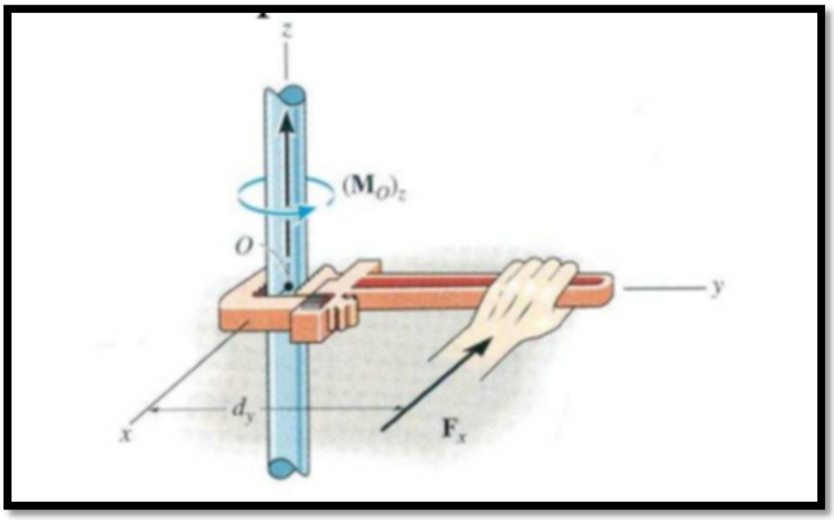


Figure 2.13 (a) Basic moment of a force by turning the spanner

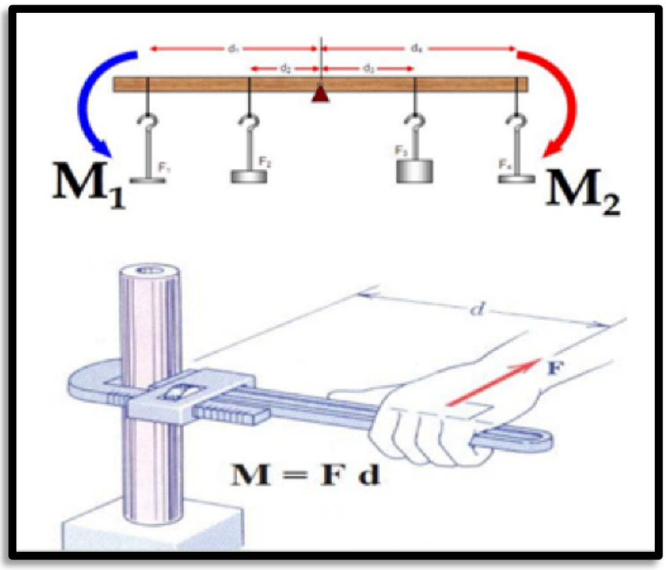


Figure 2.13 (b) Law and application of moment

- The characteristics of moment as shown in **Table 2.2**.

Table 2.2 Characteristics of moment

No	Characteristics of moment
1.	It is the measurement of the perpendicular distance from the point of rotation to the force's line of action
2.	The symbol of the moment is M and SI unit is Nm
3.	Moment is a static force
4.	Moment is produced by any lateral force and used in non-rotational events
5.	Moment is referred to the nature of the force to move the object.

- **Figure 2.14 (a), (b)** shows an example of an application moment

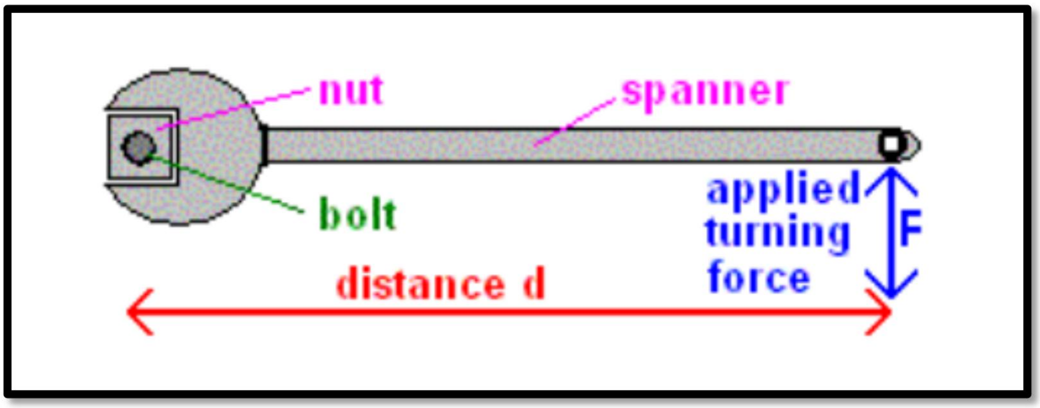


Figure 2.14 (a) Moment application

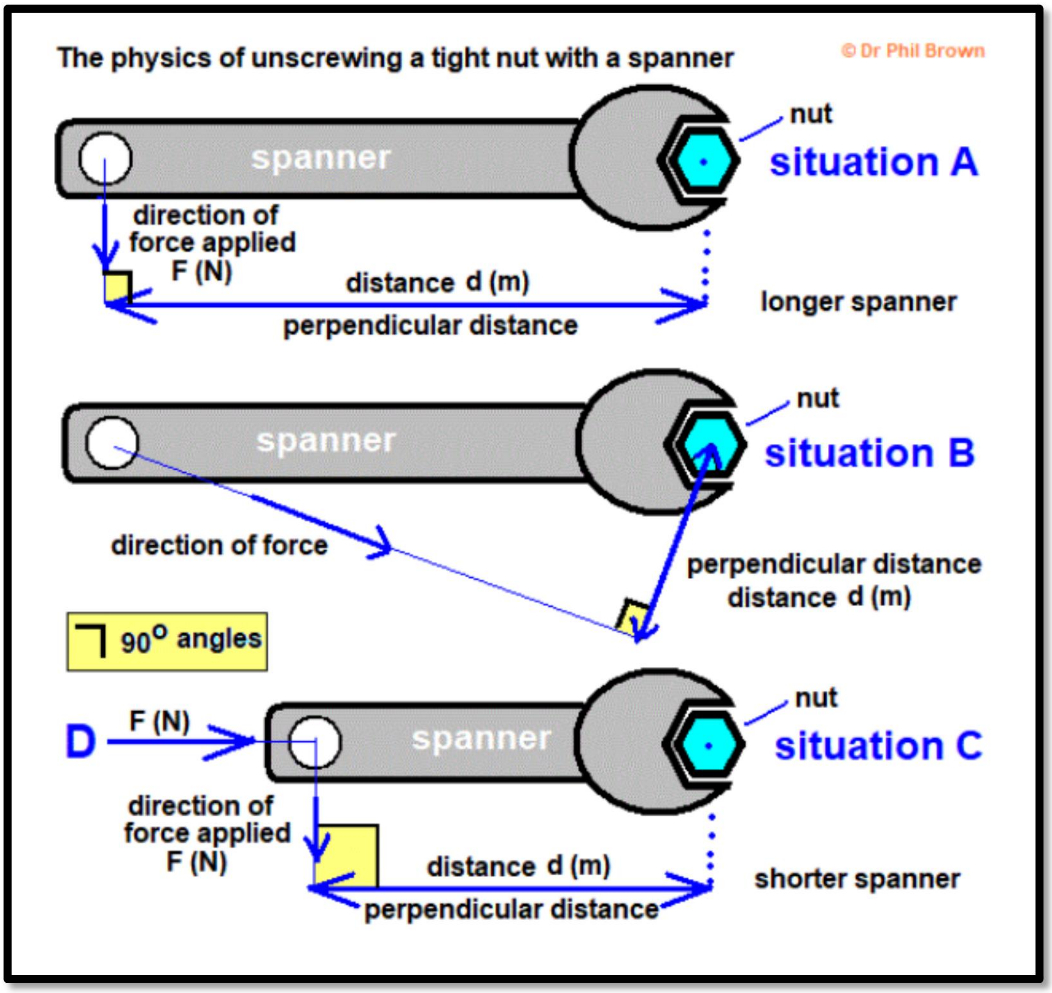
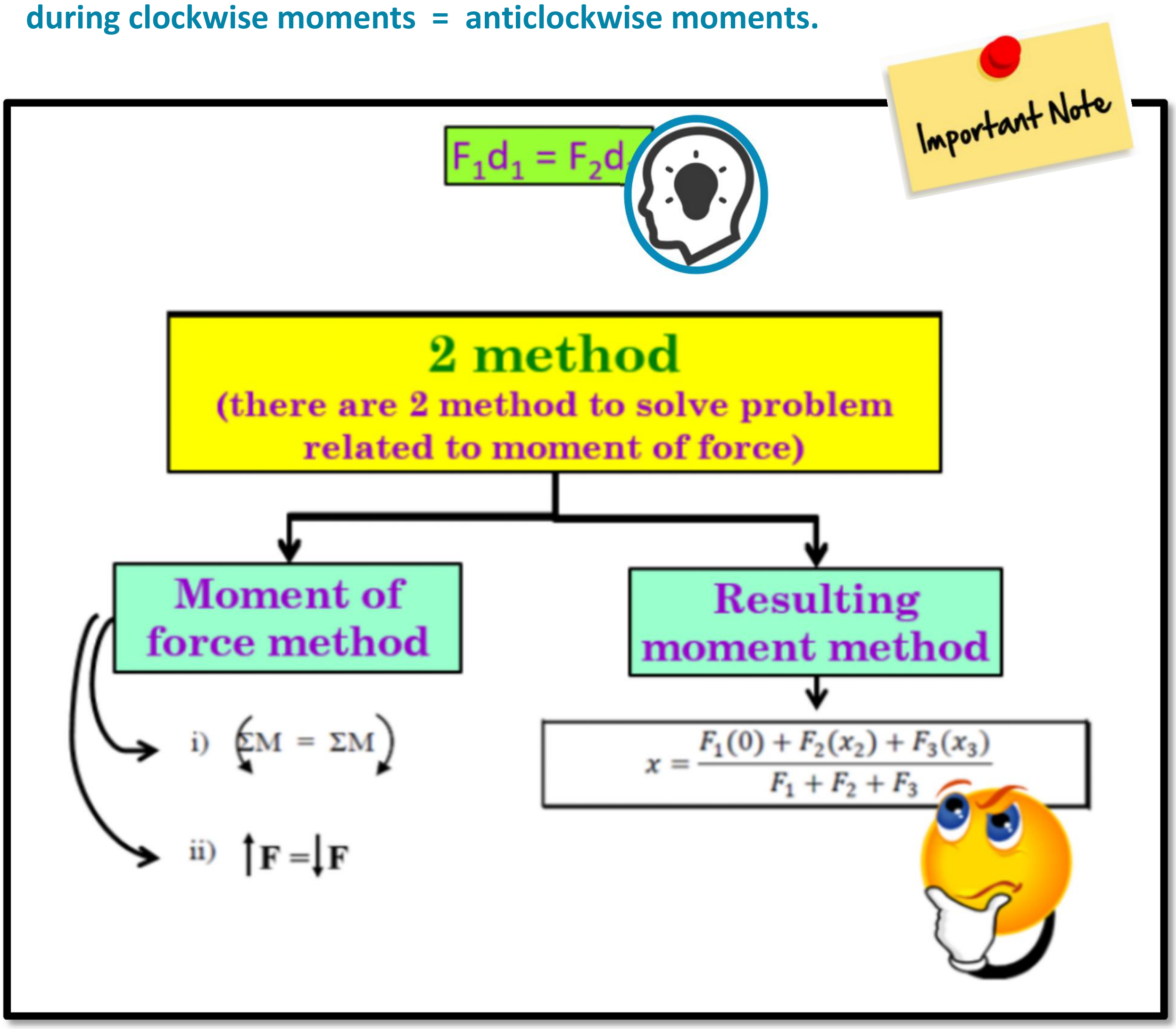


Figure 2.14 (b) Mechanical forces of rotation

- If a **resultant force** acts on an object about a fixed turning point (the **pivot**) it **will cause the object to rotate**, has a magnitude easily calculated from the formula M = F x d.
- The maximum moment by pushing/pulling the spanner at a right angle (at 90°) to the line (d) between the pivot point and the line of action where the force is applied.

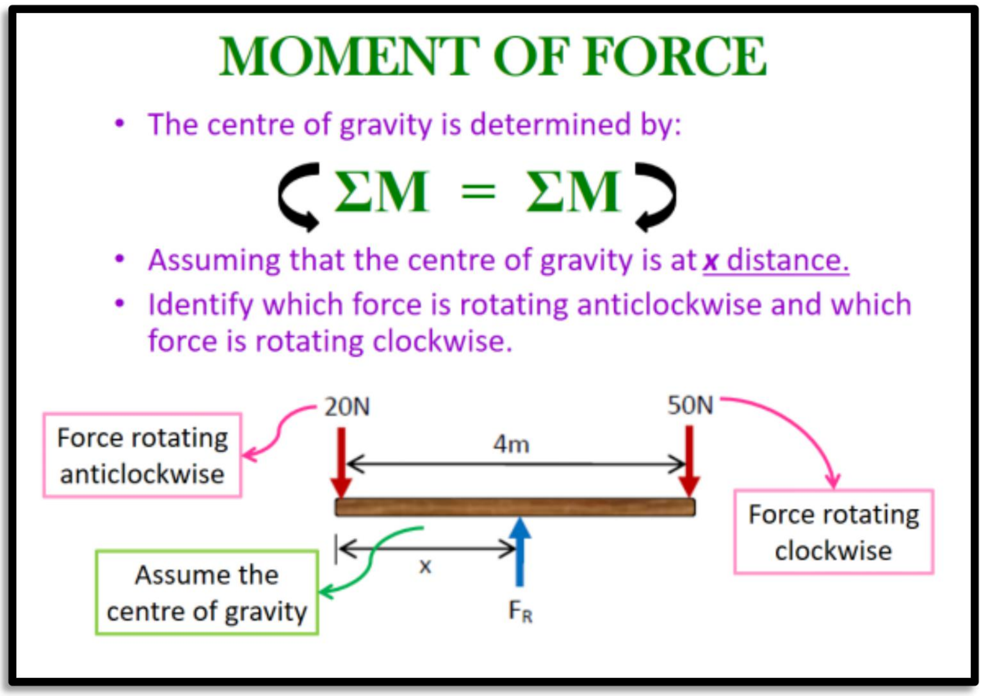
2.2.2 MOMENT OF FORCE PRINCIPLE

- **The Principle of Moments:**
  - An object is in equilibrium (balanced!).
  - The sum of the clockwise moments is equal to the sum of the anticlockwise moments.
- There are **two methods** to solve problem related to the moment of force **during clockwise moments = anticlockwise moments.**

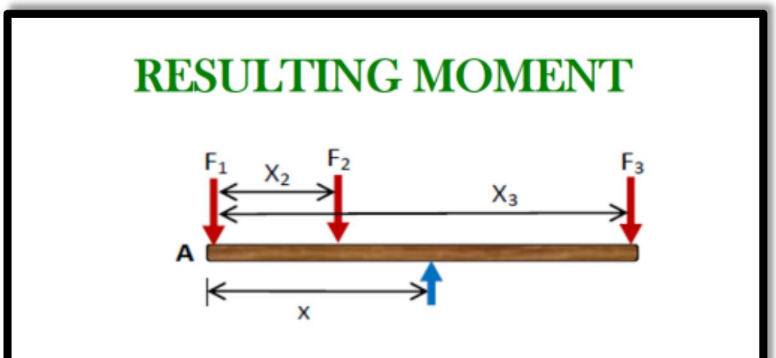


2.2.3 APPLICATION OF THE MOMENT OF FORCE CONCEPT AND FORMULA IN SOLVING THE RELATED PROBLEMS

- The concept of moment of force as it is referring to the centre of gravity as below :



- The concept of resulting moment of force referring to the centre of gravity is determined by dividing sum of moment with sum of forces as below **(assume centre of gravity at x and take A as reference).**

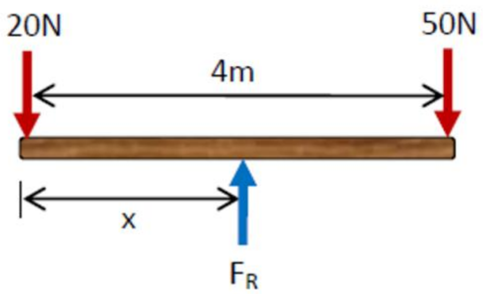


$$x = \frac{F_1(0) + F_2(x_2) + F_3(x_3)}{F_1 + F_2 + F_3}$$

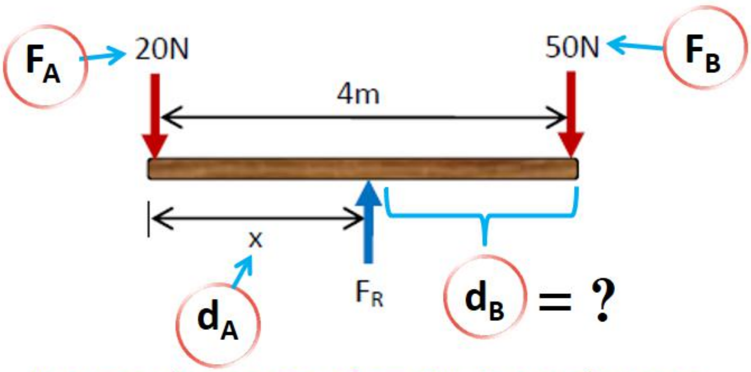
MOMENT OF FORCE METHOD

EXAMPLE 1A

Determine the center of gravity for the system shown below by assuming the object is in equilibrium.



solution:



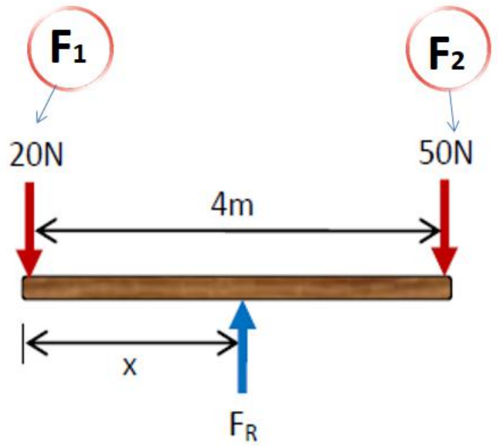
Assume the center of gravity is at ***x*** distance

$\circlearrowleft \sum M$	=	$\sum M \circlearrowright$
$F_A\, d_A$	=	$F_B\, d_B$
20 (x)	=	50 **(4 – x)**
20 x	=	200 – 50 x
70 x	=	200
x	=	200/70
	=	**<u>2.86 m</u>**

RESULTING MOMENT METHOD

EXAMPLE 1B

By using the same diagram, determine the center of gravity for the system.



solution:

$$x = \frac{F_1(0) + F_2\,(x_1)}{F_1 + F_2}$$

$$= \frac{20(0) + 50(4)}{20 + 50}$$

$$= \frac{0 + 200}{70}$$

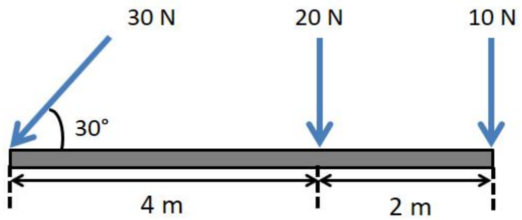
$$= \mathbf{2.86\ m}$$

MOMENT OF FORCE METHOD

EXAMPLE 2A

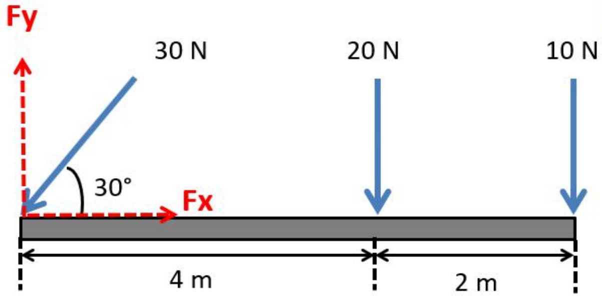
Find the centre of gravity to keep it in equilibrium by using moment of force method.

Solution ;



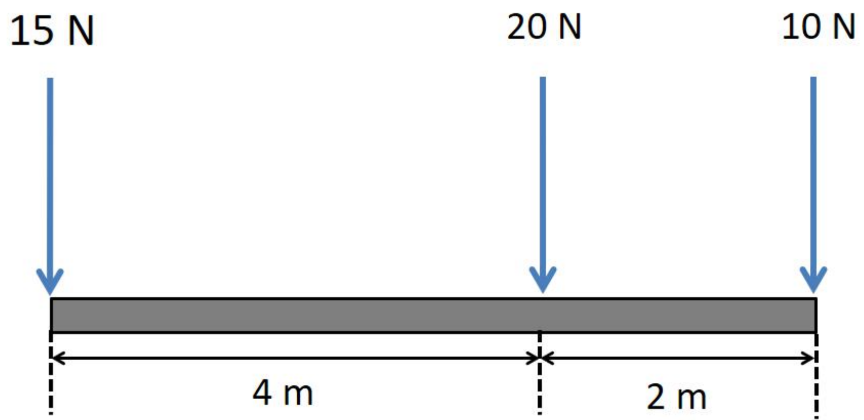
1. Do resolution for 30 N.

2. Find Fy so that all the force are in vertical.



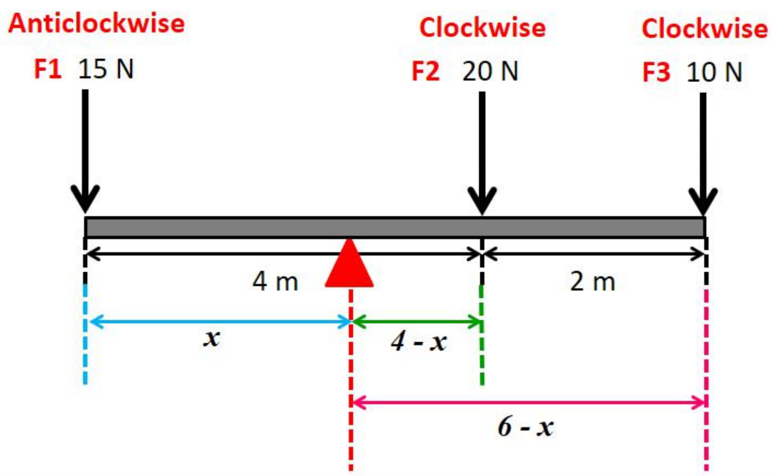
$$
\begin{aligned}
F_y &= F \sin \theta \\
&= 30 \sin 30^\circ \\
&= 15 \text{ N}
\end{aligned}
$$

3. Draw the new diagram by replacing 30 N with the Fy value.



- Let us the pivot between F1 and F2;

4. Assume the location of the pivot.



5. Identify whether the force is clockwise or anticlockwise.

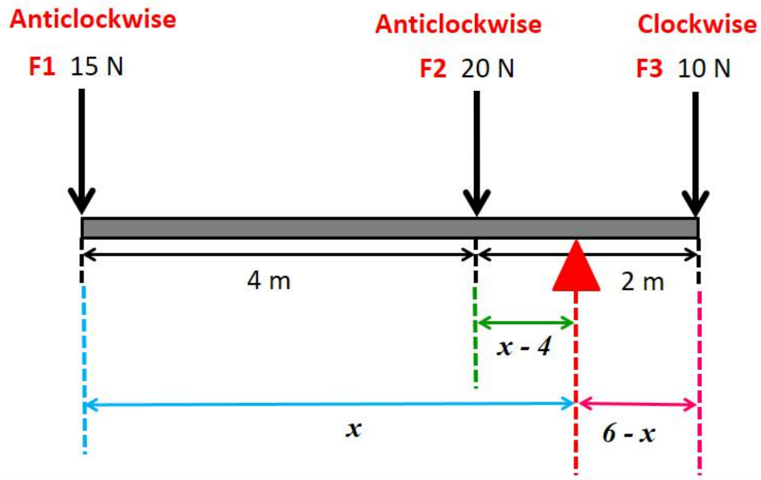
6. Find the distance for each force. (The distance is between force and pivot)

7. Write the formula for moment of force method and substitute all the force with their distance in the formula. Find the value of x.

$$
\begin{aligned}
\sum M &= \sum M \\
F_1 d_1 &= F_2 d_2 + F_3 d_3 \\
15\,(x) &= 20\,(4 - x) + 10\,(6 - x) \\
15x &= 80 - 20x + 60 - 10x \\
15x &= 140 - 30x \\
15x + 30x &= 140 \\
45x &= 140 \\
x &= \frac{140}{45} \\
x &= 3.11 \text{ meter}
\end{aligned}
$$

- Let us change the pivot between F2 and F3;

*** You may assume that the pivot is in between F2 and F3.*



*** Then, follow the same steps as previous. Determine whether the force is clockwise or anticlockwise and find the distance for each force.*

*** Hence, substitute all the force with their distance in the formula.*

$$
\begin{aligned}
\sum M &= \sum M \\
F_1d_1 + F_2d_2 &= F_3d_3 \\
15\,(x) + 20\,(x-4) &= 10\,(6-x) \\
15x + 20x - 80 &= 60 - 10x \\
35x - 80 &= 60 - 10x \\
35x + 10x &= 60 + 80 \\
45x &= 140 \\
x &= \frac{140}{45} \\
x &= 3.11 \text{ meter}
\end{aligned}
$$

*** supposedly you will get the same answer as before.*

- Use the same diagram by using **resulting moment method** (the answer should be as the same as before).

FORCE

SET 1

1. List **FOUR (4)** examples of forces.
2. State **THREE (3)** differences between weight and mass.
3. The solar panels are fitted to a frame supported by a beam, as shown in the **Figure 1 (a)** and the forces are acted on the beam as shown in the **Figure 1 (b)** below. Calculate the size of reaction force, R_2 by considering the moments at R_1.

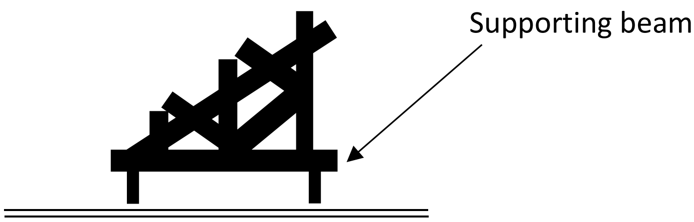


Figure 1

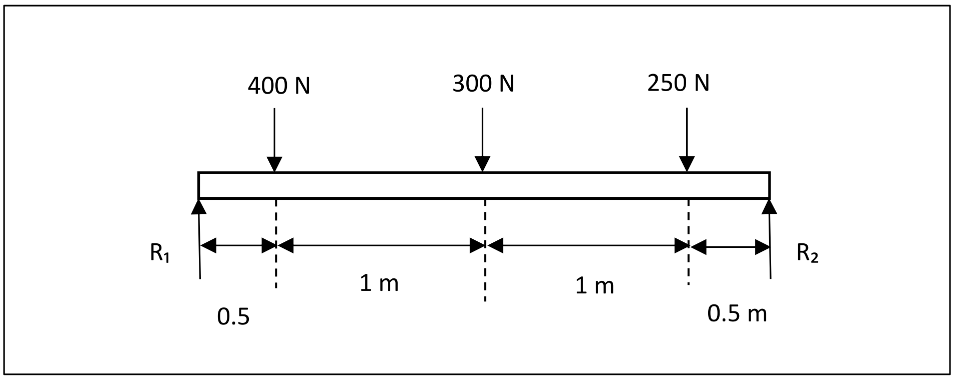


Figure 1 (b)

SET 2

1. i. Define force and state its unit.

   ii. Define force in equilibrium.

2. Find the moment of each force shown below at the point O. (g = 9.81 m/s²)

i.

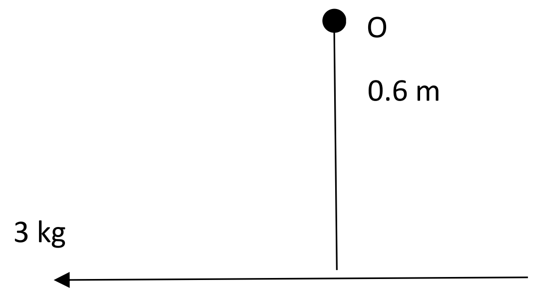


Figure 2 (a)

ii.

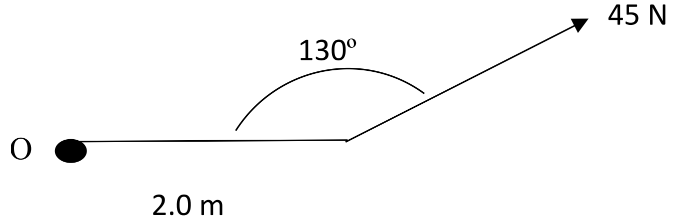


Figure 2 (b)

3. Calculate the magnitude and the direction of the resultant force from **Figure 2 (c)**. (Use g = 10 m/s²)

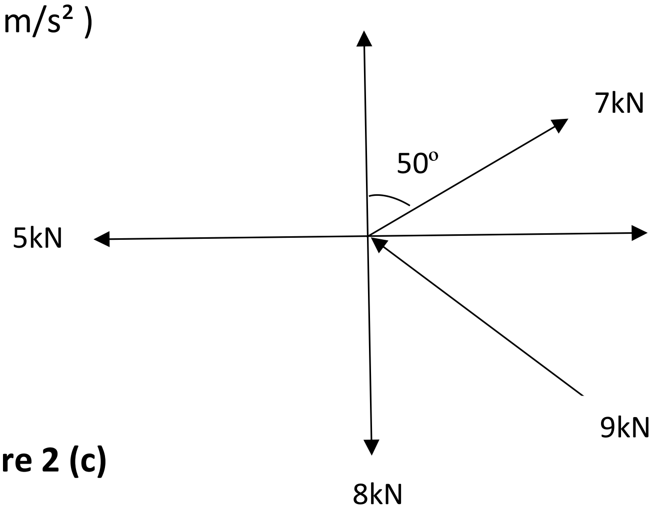


Figure 2 (c)

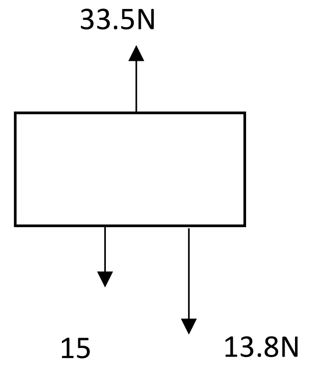
SET 3

1. State :
   i. the definition of moment and its unit.

   ii. **TWO (2)** types of moment.

2. Determine the direction of the force for the diagram below.

i.



ii.

3. Calculate the magnitude and angle of the resultant force for **Figure 3 (a)**.

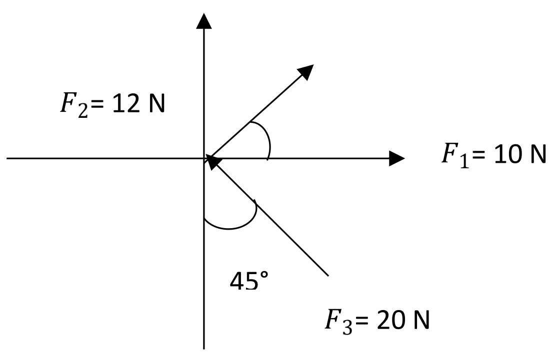


Figure 3 (a)

SET 4

1. State **FOUR (4)** effects of force on an object.
2. Describe **THREE (3)** differences between mass and weight
3. Determine the magnitude and direction of resultant force produced from the system of forces below, using the resolution method in **Figure 4 (a)**.

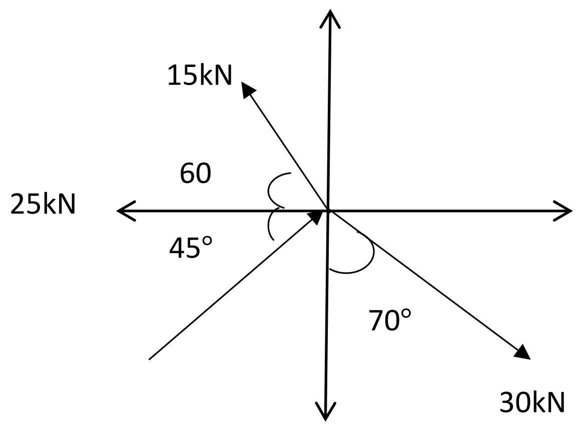


Figure 4 (a)

4. Calculate the centre of gravity of the beam in **Figure 4 (b),** so that it is in equilibrium.

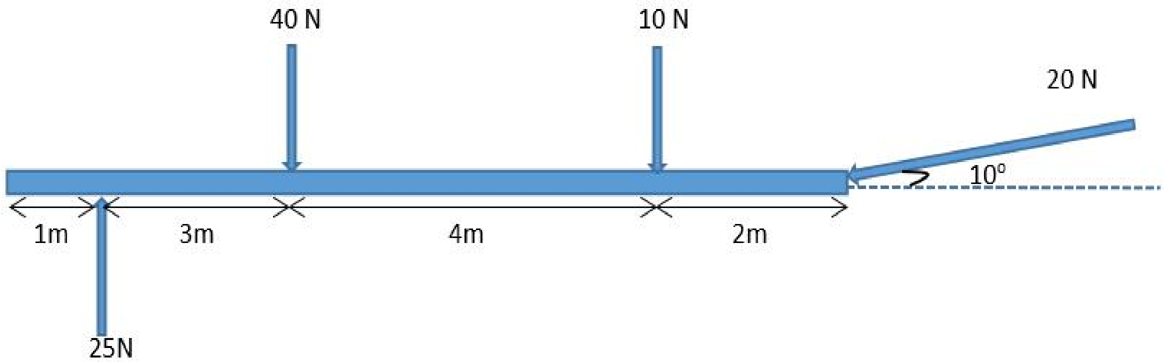


Figure 4 (b)

SET 5

1. State **TWO (2)** differences between weight and mass.
2. i. Describe Newton's Second Law

   ii. Based on **Figure 5 (a)**, determine the value of F_1 so that the object is in equilibrium.

Figure 5 (a)

3. **Figure 5 (b)** shows forces acting on a block.Calculate the magnitude of resultant force acting on the block.

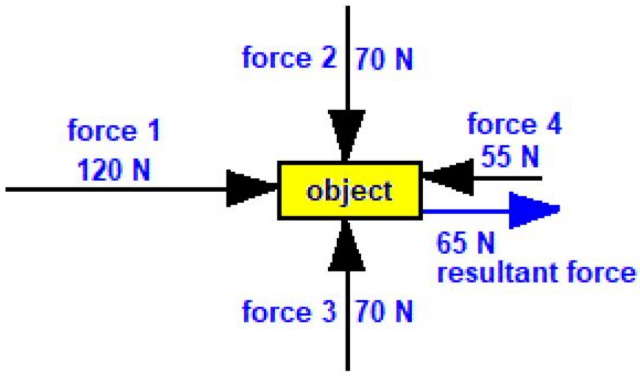


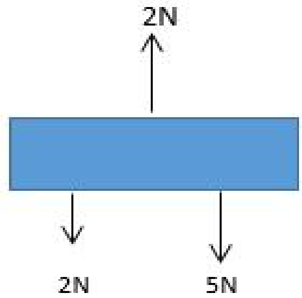
Figure 5 (b)

SET 6

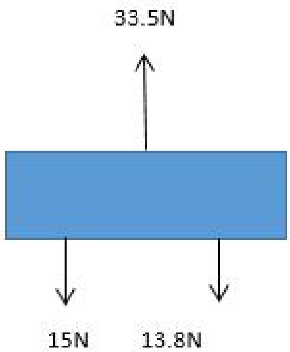
1. Find the magnitude of the resultant force and determine its direction for each of situation's below :

i.

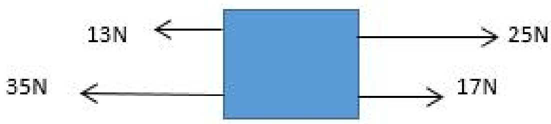
ii.



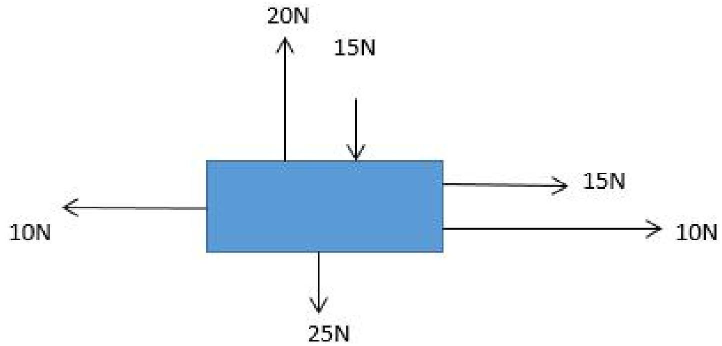
iii



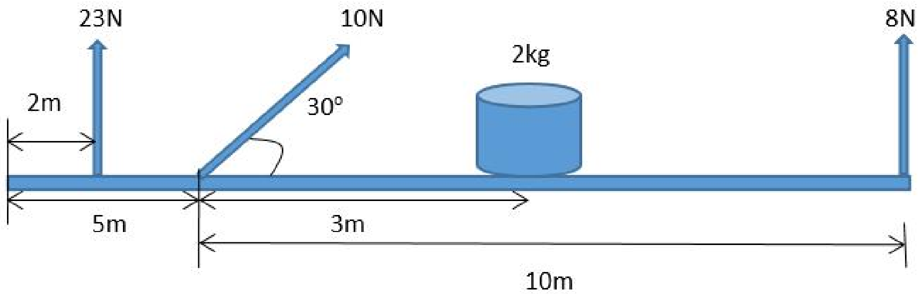
iv.



2. Calculate the net force acting on the x-axis and y-axis of an object below:

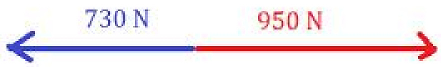


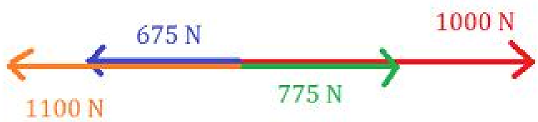
3. Calculate the centre of gravity of the following beam so that it is in equilibrium.



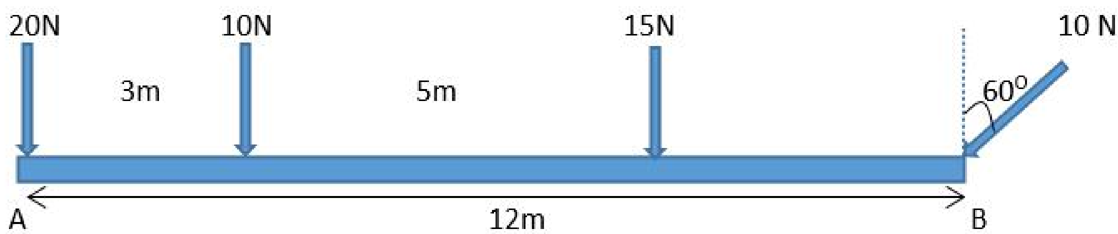
SET 7

1. Find the magnitude of the resultant force and determine its direction for each of situation's below :





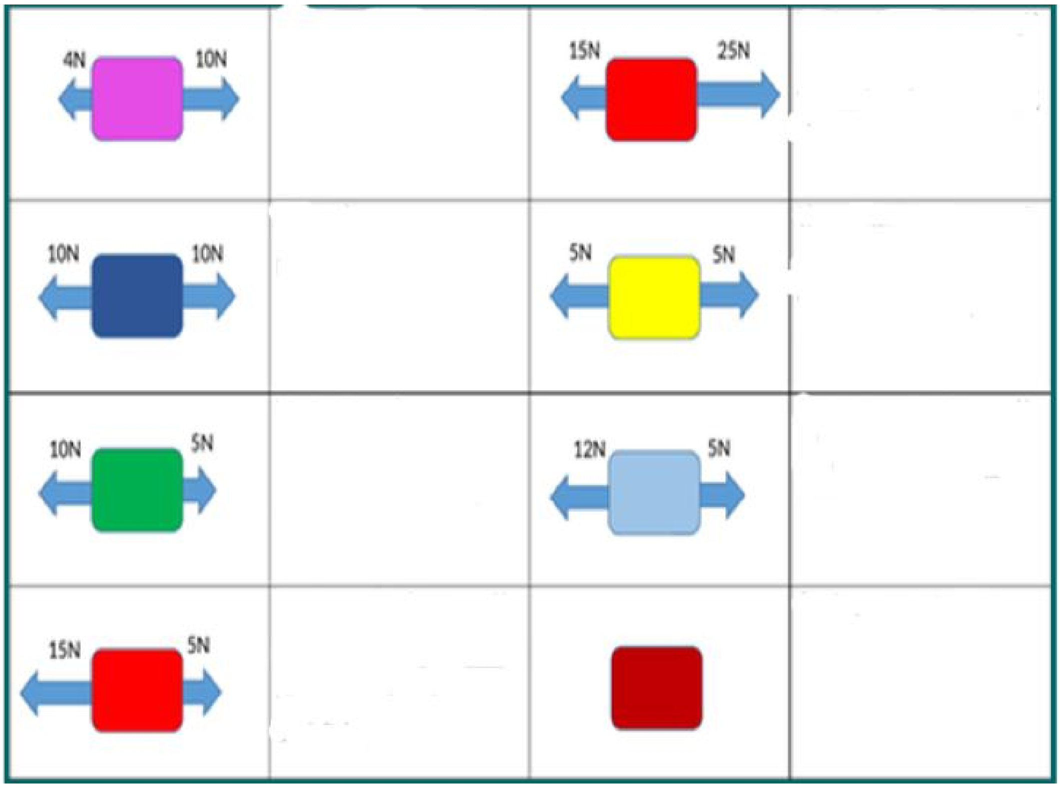
2. Calculate the centre of garvity of the following beam so that it is in equilibrium.



From point A

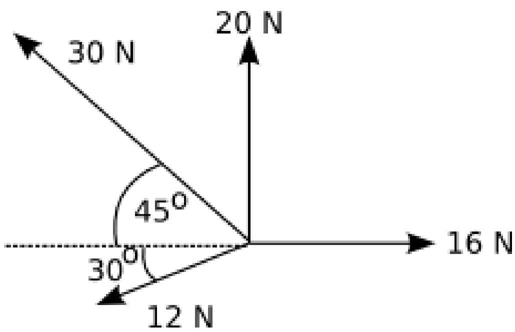
SET 8

1. Find the magnitude of the resultant force and determine its direction for each of situation below :



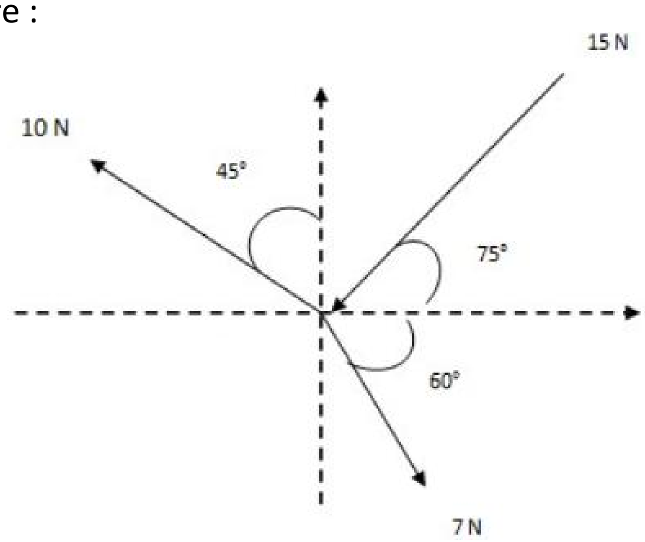
2. Determine the magnitude and direction of the resultant of these forces when they are pulling away from the point. The following forces act at a point:

- 16 newtons due east
- 20 newtons due north
- 30 newtons north west
- 12 newtons 30° south of west



SET 9

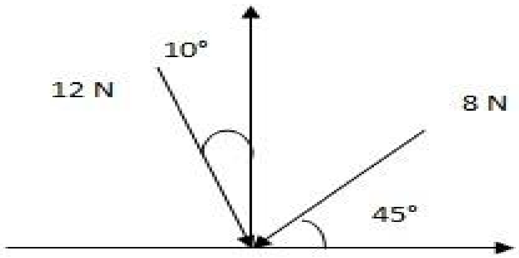
1. Define force and its S.I unit
2. Express force definition below :
   i. Push
   ii. Pull
   iii. Gravity
   iv. Magnetism
   v. Friction
3. State **TWO (2)** examples of activities that involve force in everyday life.
4. State **FOUR (4)** effects of force on an object.
5. Describe Newton's Second Law.
6. State **TWO (2)** differences between weight and mass.
7. State the definition of moment and its unit.
8. Find the moment of 20 N force with an axis of rotation at a distance 0.5 m from the force.
9. A spanner of length 10 cm is used to open a nut by applying a minimum force of 5 N. Calculate the moment to force required.
10. Calculate the magnitude of resultant force and the direction of the following figure :



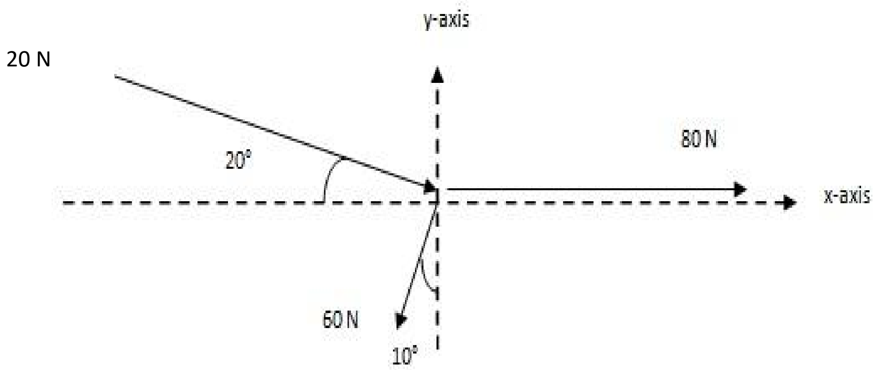
SET 10

Calculate the magnitude of resultant force and the direction of the following figures :

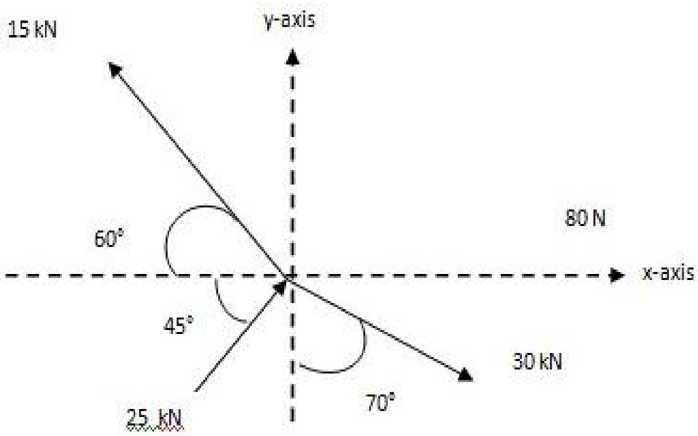
1.



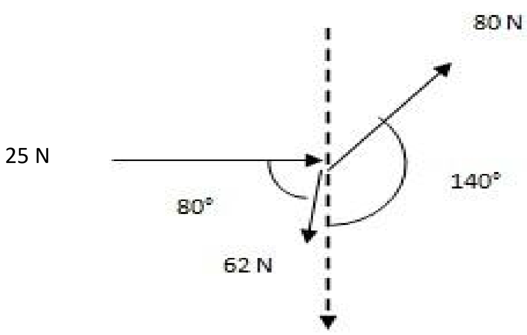
2.



3.



4.



GLOSSARY

A. PHYSICAL QUANTITIES AND MEASUREMENT

Physical quantities:

Physical that can be measured.

Based quantity:

Physical quantity that can not be derived from other physical quantities.

Derived quantities:

Quantities that are derived from the combination of several base quantities by multiplication or division.

Scalar quantities:

Physical quantities with magnitude only.

Vector quantities:

Physical quantities with direction and magnitude.

Error:

The difference between the actual value of a quantity and the value obtained in measurement.

Systematic errors:

Errors that produce a result that differs from the true value by a fixed amount and the measurement is always greater or less than the actual value.

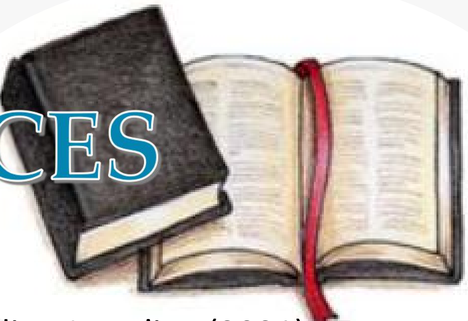
Random errors:

Errors of measurements in which the measured quantities differ from the mean value with different magnitudes and directions. However this readings are closed to the real value.

B. FORCE

Force: Push or pull upon an object resulting from the object's interaction with another object.
Weight: The force of gravity on the object.
Mass : The amount of material in an object.
Balance Force: When all the forces that act upon an object are balanced.
Force in equiblirium: An object at rest is equilibrium because the force acting on it are balance and resultant force is zero.
Resolution of Forces: Breaking down a single vector into 2 or more components.
Moment of force: Product of the force and the perpendicular distance of its line of action from that point.

REFERENCES



Yew Kok Leh, Chang See Leong, & Abdul Halim Jama'in. (2021). *Focus Physics*. Bangi: Pelangi Sdn. Bhd.

Chia Song Choy, Koay Kheng Chuan, Dr. Ooi Hean Beng, Mohd Khairul Anuar Md Mustafa & Rema Ragavan. (2019). *Dual Language Programme Physics Form 4*. Petaling Jaya: Sasbadi Sdn. Bhd.

Asiah Ibrahim, Normazita Mat Ali, & Norlida Shaari. (2018). *Drill and Practice of Engineering Science*. Kuala Lumpur: Perpustakaan Negara Malaysia.

Fazlina Yunus, Norlida Shaari, & Asiah Ibrahim. (2019). *Progressive Exercises for Engineering Science*. Kuala Lumpur: Perpustakaan Negara Malaysia.

Azhari Zakaria, Azia Idayu Awang, Hardyta Bujang Pata, Khairani Yaakub, & Noor Affande Abdul. (2015). *Engineering Science*. Shah Alam: Oxford Fajar. Sdn. Bhd

Khairani, Linawati, Zeyana, & Azah. (2017). *Engineering Science-Active Learning Guidance*. Kuala Lumpur: Perpustakaan Negara Malaysia.

Excel@Physic. (2014). *Micrometer Screw Gauge: Zero Error.* Retrieved August 19, 2021, from http://www.excelatphysics.com/micrometer-screw-gauge.html

Dont' Memorise. (2017, May 15). *Scalar Quantity and Vector Quantity Physics* [Video]. YouTube. https://www.youtube.com/watch?v=Pj8Zh0A-uLU

Fizzics Organization. (2021, February 15). *Random and systematic error explained* [Video]. YouTube. https://www.youtube.com/watch?v=huDRfgbc1HA

Eng. Waleed Alzaghal. (2020, December 6). *Reading Metric Vernier Caliper with 0.02 mm Resolution* [Video]. YouTube. https://www.youtube.com/watch?v=J3IEx1HxpwU

Azlina Awang. (2021, Feb 6). *Use of Measuring Instruments, Accuracy, Consistency, Sensitivity and Errors* [Video]. YouTube. https://www.youtube.com/watch?v=iccOqHn1pL4

myhometuition. (2014, July 14). *Micrometer Screw Gauge - Taking Reading* [Video]. YouTube. https://www.youtube.com/watch?v=QH5UoTDwqVM

Mathispower4u. (2011, June 17). *Examples: Convert Lengths Between the Standard and Metric System* [Video]. YouTube. https://www.youtube.com/watch?v=3HumkXBKP0k

Debbie, B. (2015, February 5). Understanding the Effects of a Force. *Physic.* http://missdebbiephysics.blogspot.com/2015/02/form-4-25-understanding-effects-of-force.html

x-engineer.org. (2021). *How to calculate the resultant force acting on an object.* Retrieved August 17, 2021, from https://x-engineer.org/undergraduate-engineering/physics/solid-mechanics/calculate-resultant-force-object/

the Physics Classroom. (2014). *Balance and Unbalance Forces.* Retrieved August 15, 2021, from https://www.physicsclassroom.com/class/newtlaws/Lesson-1/Balanced-and-Unbalanced-Forces

National Aeronautics and Space Administration. (2021, May 13). *Equilibrium 2 Forces*. Retrieved August 17, 2021, from https://www.grc.nasa.gov/www/k-12/airplane/equilib.html

BYJU'S. (2021). *Difference Between Torque And Moment*. Retrieved August 21, 2021, from https://byjus.com/physics/difference-between-torque-and-moment/

e ISBN 978-967-25516-3-8

9 7 8 9 6 7 2 5 5 1 6 3 8