POLITEKNIK MALAYSIA
PORT DICKSON

ENGINEERING SCIENCE

VOLUME 1
(CHAPTER 1-3)

NOORAIN ITHNIN
FARA NUR ASMA MOHD BASRI
MOHD SAIFUL PAHRUDIN

POLITEKNIK MALAYSIA
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ENGINEERING SCIENCE

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Noorain binti Ithnin
Fara Nur Asma binti Mohd Basri
Mohd Saiful bin Pahrudin

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PATRON
Mohamad Isa Bin Azhari
Director, Politeknik Port Dickson

ADVISORS
Dr. Nor Haniza Binti Mohamad
Deputy Director (Academic), Politeknik Port Dickson
Salmiah Binti Husain
Head of Mathematics, Science & Computer Department, Politeknik Port Dickson

EDITOR
Noorain Binti Ithnin
Head of Science Unit, Politeknik Port Dickson

FACILITATORS
Nin Hayati Binti Mohd Yusof
Fara Nur Asma Binti Mohd BAsri

WRITERS
Noorain Binti Ithnin
Fara Nur Asma Binti Mohd Basri
Mohd Saiful Bin Pahrudin

GRAPHIC DESIGNER
Noorain Binti Ithnin

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We hereby declare that this module is our original work. To the best of our knowledge it contains no materials previously written or published by another person. However, if there is any, due acknowledgement and credit are mentioned accordingly in the e-book.

PREFACE

Engineering Science provides a comprehensive introduction to Physics. This e-book utilizes a user-friendly approach and is based on the latest syllabus. Fundamental physics concepts and principles are presented in point form, enabling students to quickly identify and understand each idea's essential points.

This e-book consists of three chapters which are physical quantities and measurement, linear motion, and force. It has been designed primarily as a guide for engineering students at the diploma level in Polytechnic. The solving problems in examples and practice questions are similar to past semester examination questions. This e-book hopes that students will gain a solid grasp of fundamental Physics knowledge and apply the knowledge to mastery physics concepts.

An appreciation represents by the author for any helpful criticism and suggestion to improve the quality of this e-book. Further comments and suggestions from an instructor using this e-book are most welcome.

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CHAPTER 1

PHYSICAL QUANTITIES & MEASUREMENT

Learning Outcomes:

At the end of this chapter, you should be able to

- Understand the physical quantities
- Solve Problems of Unit Conversion
- Describe errors in measurement
- Apply the technique of measurement using Vernier Caliper and Micrometer Screw Gauge

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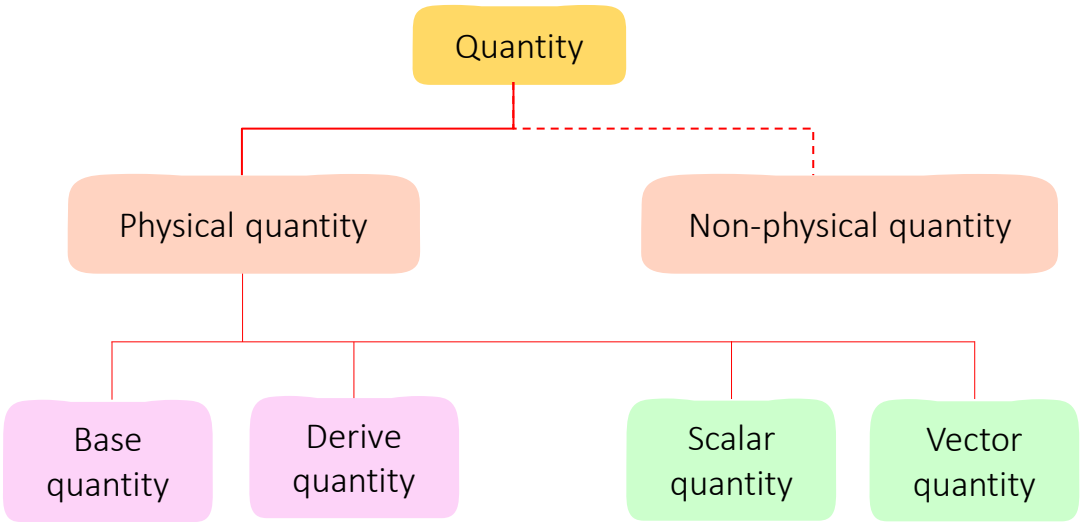
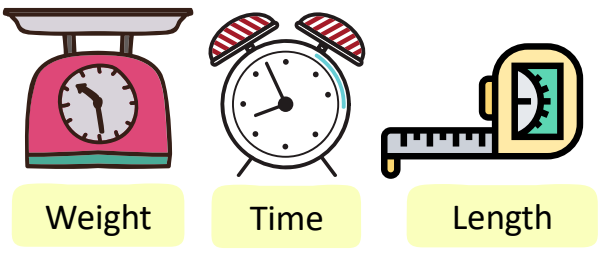
1.1 Physical Quantity

❑ There are two types of quantity:



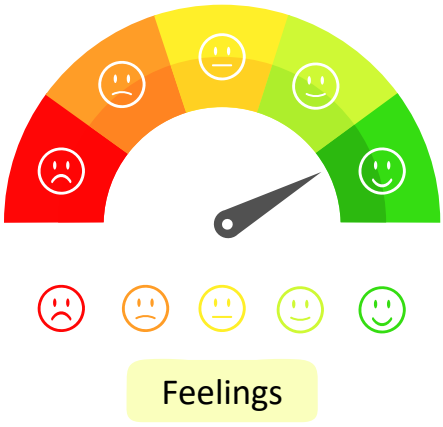
❑ **Physical quantity**

- Physical quantity is a quantity that can be measured.
- Example: speed, length, mass etc.



❑ **Non-physical quantity**

- A quantity that cannot be measured
- Example: Beauty, feelings etc.



Base Quantity

- Base quantity is a physical quantity which cannot be defined in terms of other physical quantity.

Table 1: Base quantity, smbols & SI Unit

Base Quantity	Symbol	SI Unit	Symbol of Unit
Length	ℓ	meter	m
Mass	m	kilogram	kg
Time	t	second	s
Temperature	T	kelvin	K
Current	I	ampere	A
Luminous Intensity	I_v	cendela	cd
Amount of substance	N_A	mole	$mole$

Try this!

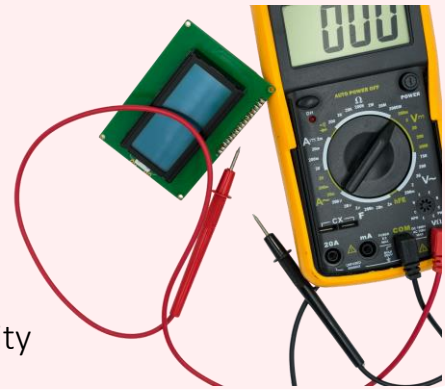
Choose the base quantity measured by multimeter?

A Resistance

B Current

C Voltage

D Luminous Intensity



Derived Quantity

- Derived quantity is a physical quantity that can be derived from a combination of more than two base quantities.

Table 2: Derived quantity & SI unit

Derived Quantity	Symbol	SI Unit	Symbol of Unit
Area	A	square meter	m^2
Volume	V	cubic meter	m^3
Density	ρ	kilogram per cubic meter	$\frac{kg}{m^3}$
Velocity	v	meter per second	$\frac{m}{s}$
Acceleration	a	meter per second squared	$\frac{m}{s^2}$
Force	F	Newton	N
Work	W	Joule	J
Pressure	P	Watt	W

Try this!

Which of the following physical quantities is derived quantity?

A Electric current

B Mass

C Time

D Momentum

International System (SI) of units

- International System (SI) unit is the international standard for measurement.
- A specific SI unit represents each physical quantity.
- The SI unit is made up of special names and symbols.
- Metric prefixes are used to represent very large or very small multiple numbers of physical quantities magnitude.

Table 3: Prefixes

Name	Symbol	Multiplication Factor	Example	Symbol for example
tera	T	10^{12}	terabyte	TB
giga	G	10^{9}	gigahertz	GHz
mega	M	10^{6}	meganewton	MN
kilo	k	10^{3}	kilojoule	kJ
centi	c	10^{-2}	centimeter	cm
milli	m	10^{-3}	milliliter	ml
micro	μ	10^{-6}	microsecond	μs
nano	n	10^{-9}	nanowatt	nW
pico	p	10^{-12}	picogram	pg

Scalar & Vector Quantities

- Scalar quantity

  - Scalar quantity is a quantity that has magnitude only

- Vector quantity

  - Vector quantity is a quantity that has magnitude and direction

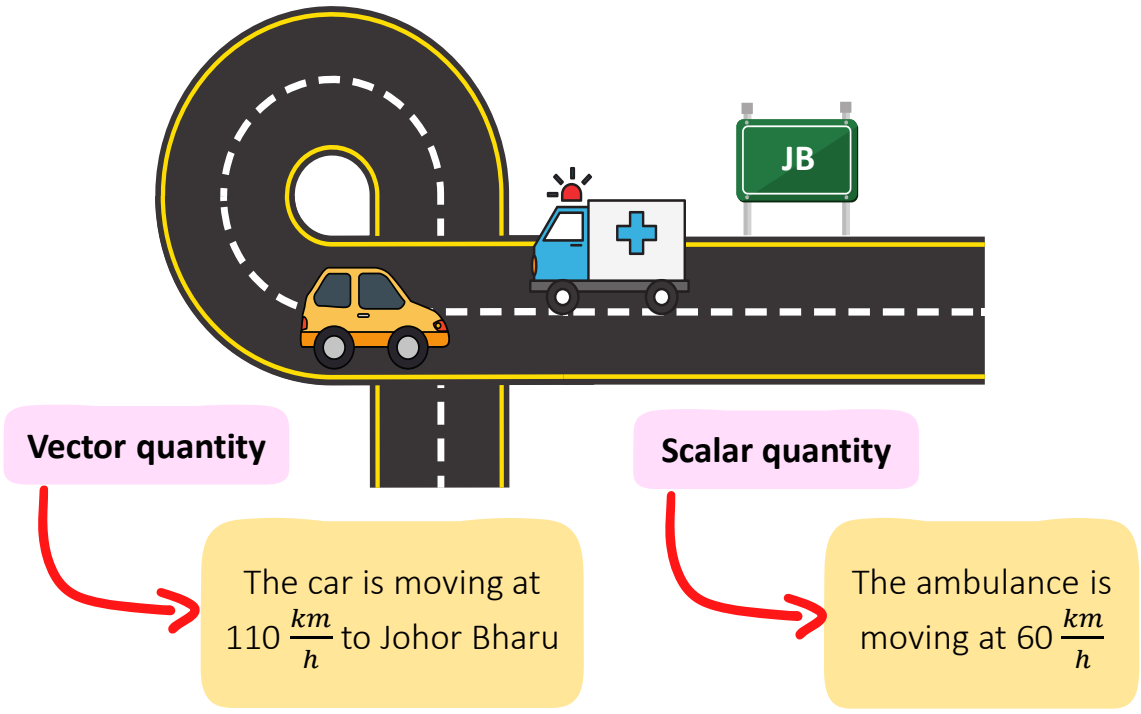
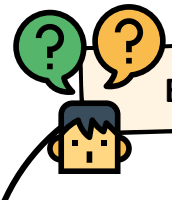


Table 4: Scalar and vector quantity

Scalar Quantity	Unit	Vector Quantity	Unit
Speed	$\frac{m}{s}$	Velocity	$\frac{m}{s}$
Distance	m	Displacement	m
Mass	kg	Weight	N

1.2 Unit Conversion

- In certain situations, the values of physical quantities need to be changed from one unit to another. The easiest way to do a conversion is by unit cancellation.



Example 1

Convert $175\ \frac{km}{h^2}$ to $\frac{m}{s^2}$

Step 1

Write each conversion factor as a fraction with comparable units (example: km,m,cm for length)

$$175\ \frac{km}{h^2} \times \frac{m}{km} \times \frac{h^2}{s^2}$$

Step 2

Place the 1 by the larger unit/unit with prefixes
Place the multiplication factor on the opposite side

$$175\ \frac{km}{h^2} \times \frac{10^3\ m}{1\ km} \times \frac{1\quad h^2}{(3600)^2\ s^2}$$

Step 3

Cancel out units that appear on top and bottom

$$175\ \frac{\cancel{km}}{\cancel{h^2}} \times \frac{10^3\ m}{1\ \cancel{km}} \times \frac{1\quad \cancel{h^2}}{(3600)^2\ s^2}$$

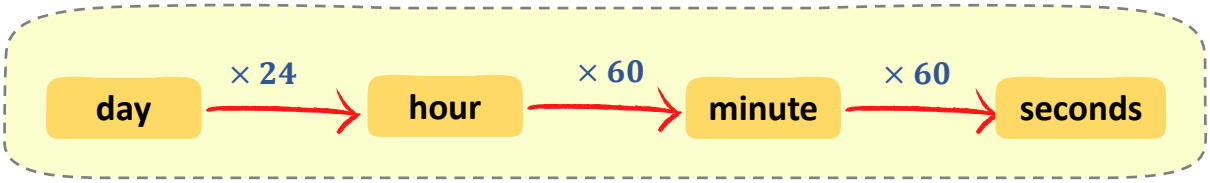
Step 4

Solve the multiplication problem

$$= \frac{175 \times 10^3}{3600^2} = 0.0135\ \frac{m}{s^2}$$

For videos on conversion of unit, click this link!
https://bit.ly/2VPej0N

Conversion of Metric Unit



Example 2

Convert 26.5 cm^2 to m^2

Solution:

$$26.5\ cm^2 \times \frac{(10^{-2})^2\ m^2}{1 cm^2}$$

$$= 26.5 \times (10^{-2})^2$$

$$= 2.65 \times 10^{-4}\ m^2$$

Example 3

Convert 85.5 $\frac{km}{h}$ to $\frac{m}{s}$

Solution:

$$85.5\ \frac{km}{h} \times \frac{10^3\ m}{1\ km} \times \frac{1\ h}{3600\ s}$$

$$= \frac{85.5 \times 10^3}{3600}$$

$$= 23.75 \frac{m}{s}$$

Example 4

Convert 78 kN to μN

Solution:

$$78\ kN \times \frac{10^3 N}{1\ kN} \times \frac{1\ \mu N}{(10^{-6})\ N}$$

$$= \frac{78 \times 10^3}{10^{-6}}$$

$$= 7.8 \times 10^{10}\ \mu N$$

Example 5

Convert 7 $\frac{g}{cm^3}$ to $\frac{kg}{m^3}$

Solution:

$$7\ \frac{g}{cm^3} \times \frac{1\ kg}{10^3 g} \times \frac{1\ cm^3}{(10^{-2})^3\ m^3}$$

$$= \frac{7}{10^3 \times (10^{-2})^3}$$

$$= 7000 \frac{kg}{m^3}$$

Practice Question 1

Convert the following metric unit

a) $13\ GW\ to\ MW$

Answer: $1.3 \times 10^4\ MW$

b) $471\ \frac{kg}{m^3}\ to \frac{g}{cm^3}$

Answer: $0.471 \frac{g}{cm^3}$

c) $165\ \frac{km}{h^2}\ to \frac{m}{s^2}$

Answer: $0.0127\ \frac{m}{s^2}$

d) $9786\ \frac{\mu m}{min}\ to \frac{m}{s}$

Answer: $1.631 \times 10^{-4}\ \frac{m}{s}$

e) $7.8\ \frac{g}{mm^3}\ to \frac{kg}{m^3}$

Answer: $7.8 \times 10^6\ \frac{kg}{m^3}$

f) $19.62\ \frac{kN}{cm^2}\ to \frac{N}{m^2}$

Answer: $1.962 \times 10^8\ \frac{N}{m^2}$

g) $0.8\ kHz\ \ to\ \mu Hz$

Answer: $8.0 \times 10^8\ \mu Hz$

h) $17.98\ cm^2\ \ to\ \ m^2$

Answer: $1.798 \times 10^{-3}\ m^2$

i) $2\ TB\ \ to\ MB$

Answer: $2 \times 10^6\ MB$

j) $40.5\ days\ \ to\ \ min$

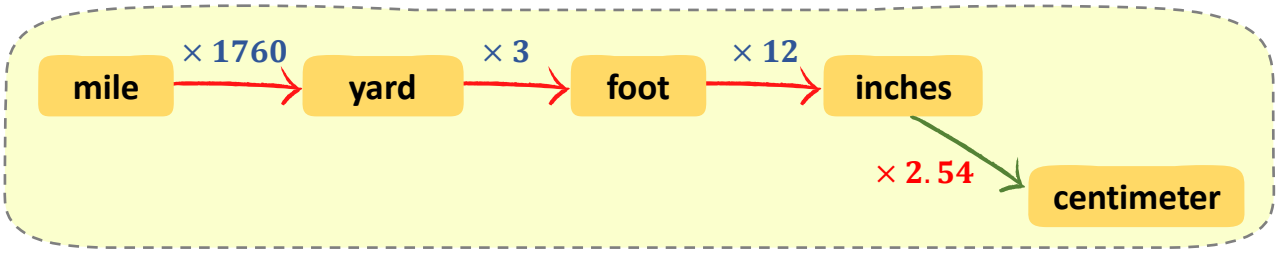
Answer: 5.832×10^4 min

k) $178\ \frac{km}{h}$ to $\frac{m}{s}$

Answer: $49.44\ \frac{m}{s}$

For more exercise on conversion of metric unit , scan this QR code!

Conversion of Customary Unit



Example 1

Convert 4.8 *feet to inches*

Solution:

$$4.5\ feet \times \frac{12\ inches}{1\ feet}$$

$$= 4.5 \times 12$$

$$= 54\ inches$$

Example 2

Convert 1.8 *feet to yards*

Solution:

$$1.8\ feet \times \frac{1\ yard}{3\ feet}$$

$$= \frac{1.8}{3}$$

$$= 0.6\ yards$$

Example 3

3.8 miles to feet

Solution:

$$3.8\ miles \times \frac{1760\ yards}{1\ mile} \times \frac{3\ feet}{1\ yards}$$

$$= 3.8 \times 1760 \times 3$$

$$= 20064\ feet$$

Example 4

Convert 1.7 *yards to inches*

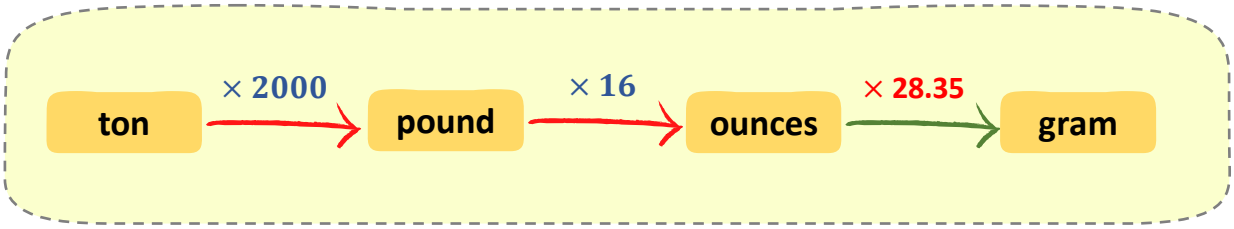
Solution:

$$1.7\ yards \times \frac{3\ feet}{1\ yard} \times \frac{12\ inches}{1\ feet}$$

$$= 1.7 \times 3 \times 12$$

$$= 61.2\ inches$$

Conversion of Customary Unit



Example 1

Convert 78 *pounds to ounces*

Solution:

$$78\ pounds \times \frac{16\ ounces}{1\ pounds}$$

$$= 478 \times 16$$

$$= 1248\ ounces$$

Example 2

Convert 270 *ounces to pounds*

Solution:

$$270\ ounces \times \frac{1\ pounds}{16\ ounces}$$

$$= \frac{270}{16}$$

$$= 16.875\ pounds$$

Example 3

Convert 6.5 *ounces to grams*

Solution:

$$6.5\ oz \times \frac{28.35\ g}{1\ oz}$$

$$= 6.5 \times 28.35$$

$$= 184.275\ g$$

Example 4

Convert 46.3 *pounds to grams*

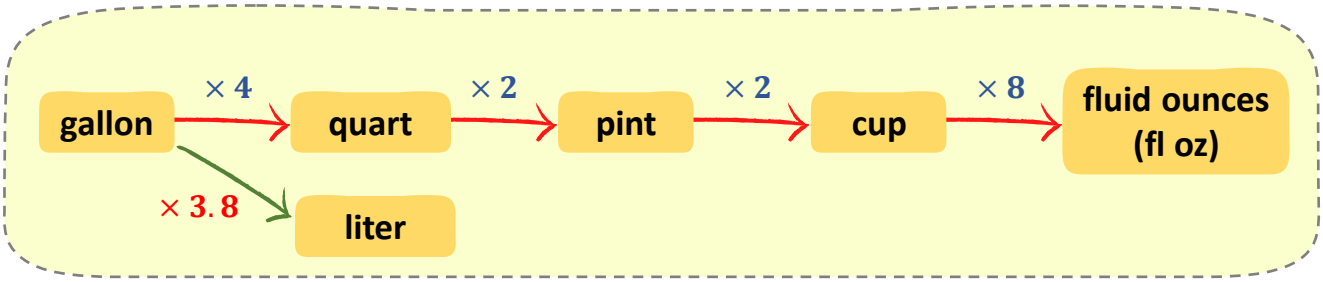
Solution:

$$46.3\ lb \times \frac{16\ oz}{1\ lb} \times \frac{28.35\ g}{1\ oz}$$

$$= 46.3 \times 16 \times 28.35$$

$$= 21001.68\ g$$

Conversion of Customary Unit



Example 1

Convert 6.9 *cups to fl oz*

Solution:

$$6.9\ cups \times \frac{8\ fl\ oz}{1\ cup}$$

$$= 6.9 \times 8$$

$$= 55.2\ fl\ oz$$

Example 2

Convert 67 *fl oz to pints*

Solution:

$$67\ fl\ oz \times \frac{1\ cup}{8\ fl\ oz} \times \frac{1\ pints}{2\ cups}$$

$$= \frac{67}{8 \times 2}$$

$$= 4.188\ pints$$

Example 3

Convert 1.8 *quarts to cup*

Solution:

$$1.8\ quarts \times \frac{2\ pints}{1\ quart} \times \frac{2\ cup}{1\ pints}$$

$$= 1.8 \times 2 \times 2$$

$$= 7.2\ cups$$

Example 4

Convert 40.8 *pints to gallons*

Solution:

$$40.8\ pints \times \frac{1\ quarts}{2\ pints} \times \frac{1\ gallons}{4\ quarts}$$

$$= \frac{40.8}{2 \times 4}$$

$$= 5.1\ gallons$$

Practice Question 2

Convert the following customary unit

a) 480 $inches\ to\ yard$

Answer: 13.33 $yards$

b) 745 $inches^2\ to\ feet^2$

Answer: 5.174 $feet^2$

c) 91.6 $pounds\ to\ ounces$

Answer: 1465.6 $ounces$

d) 3.4 $gallons\ to\ cups$

Answer:54.4 $cups$

e) 65.1 $\frac{miles}{h}\ to\ \frac{km}{h}$

Answer:104.768 $\frac{km}{h}$

f) 80.5 $feet^2\ to\ m^2$

Answer:602.035 m^2

g) 0.8 $pounds\ \ to\ kilogram$

Answer: 0.363 kg

h) 21.6 $gallons\ to\ liters$

Answer: 81.765 ℓ

i) 29025 $feet\ to\ km$

Answer: 8.847 km

j) 4.54 $yards\ to\ meter$

Answer: 4.151 m

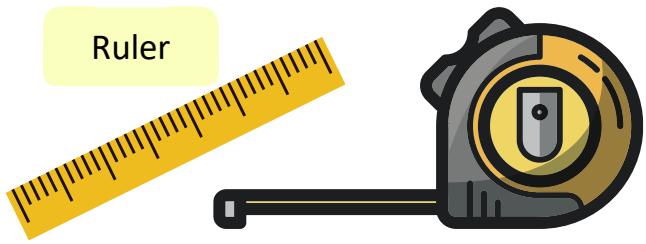
k) 85.6 $ft^3\ to\ m^3$

Answer: 17.76 $\times 10^3 m^3$

1.3 Measurement

- Measurement is the process of determining the **size** or **magnitude** of a physical quantity of an object.
- Before a measuring instrument exists, people use the palm, forearm and feet to measure the length. However, these methods gave inaccurate results.
- Nowadays, people use a ruler and measuring tape to measure a length.

Ruler

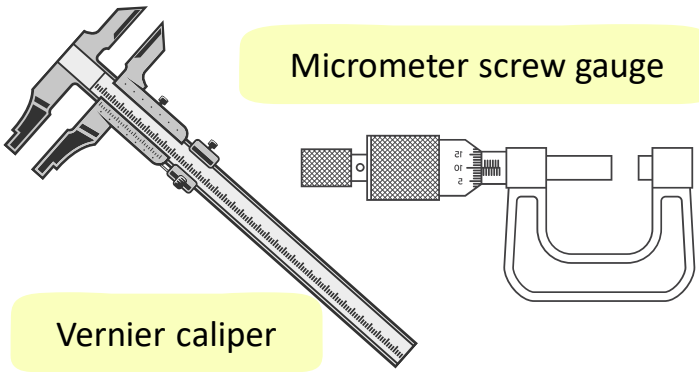


Measuring tape

The accuracy of a ruler and measuring tape is 0.1 cm

- In engineering, we perform practical lab work and experiments where readings are taken using suitable measuring instruments.
- For example, in locksmithing or metalworking, the vernier caliper and micrometer screw gauge are more suitable for making accurate and precise cuts over metallic surfaces. Both measuring instruments help to measure the thickness and diameter with high accuracy and precision.

Micrometer screw gauge



Vernier caliper

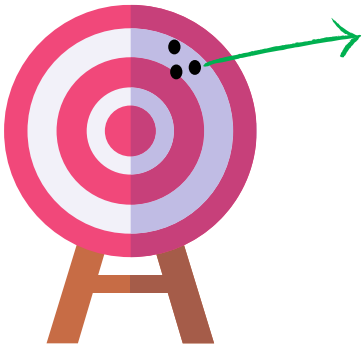
Some vernier caliper can measure up to 0.002 cm
In comparison, some micrometer screw gauge can measure up to 0.001 mm

Consistency, Accuracy & Sensitivity

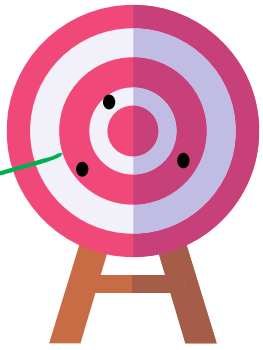
- When making a measurement, we must be aware of the consistency and accuracy of the measurement.
- In order to ensure consistency and accuracy, the measuring instrument used must have appropriate sensitivity.

Consistency

The ability of the instrument to give consistent readings when the same physical quantity is measured more than once



Consistent

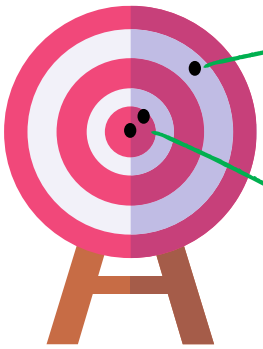


Inconsistent

The consistency of measurement can be improved by:
- ✓ Taking a reading with caution
- ✓ Avoid parallax error
- ✓ Make sure the measuring instrument used is not defective

Accuracy

The ability of an instrument to give measurement of a physical quantity which are close to the actual value



Inaccurate

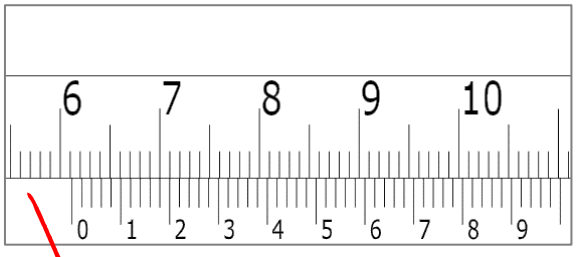
Accurate

The accuracy of measurement can be improved by:

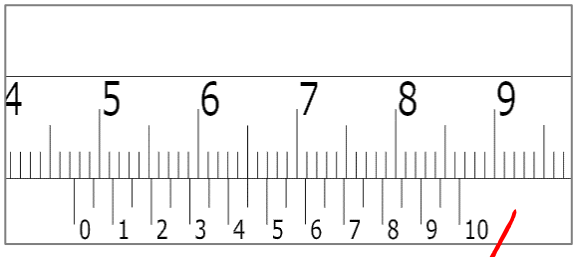
- ✓ Using a measuring instrument that is more sensitive
- ✓ Avoid parallax error
- ✓ Avoid zero error
- ✓ Repeating measurement

Sensitivity ------ The ability of the instrument to detect small changes in a quantity measured

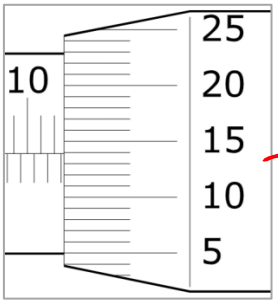
- ❑ The smaller the minimum scale division, the more sensitive the measuring instrument is.



The least count of this vernier caliper is 0.002 cm



The least count of this vernier caliper is 0.005 cm

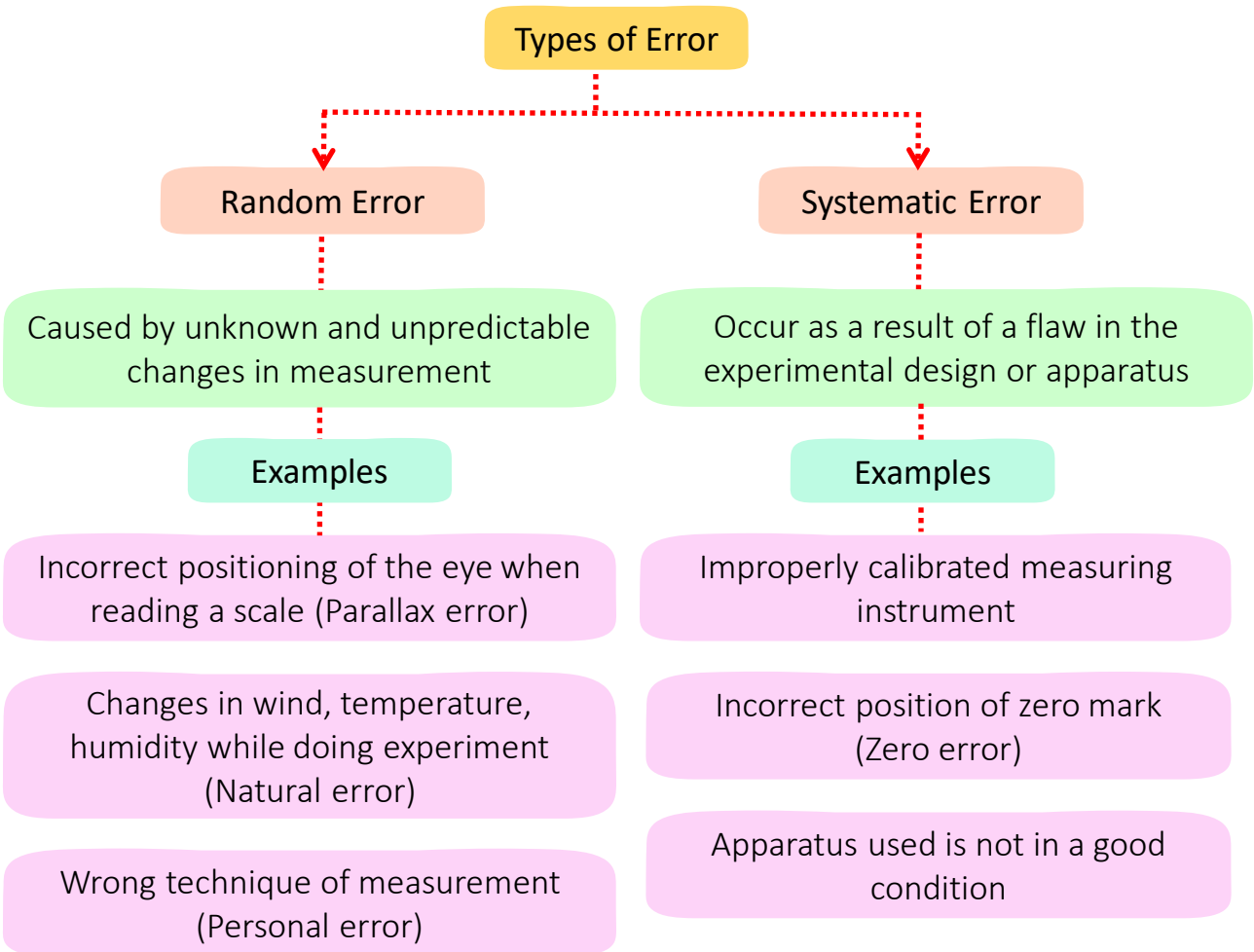


The least count of this micrometer screw gauge is 0.01 mm

Least count is the smallest value that can be measured by the measuring instrument

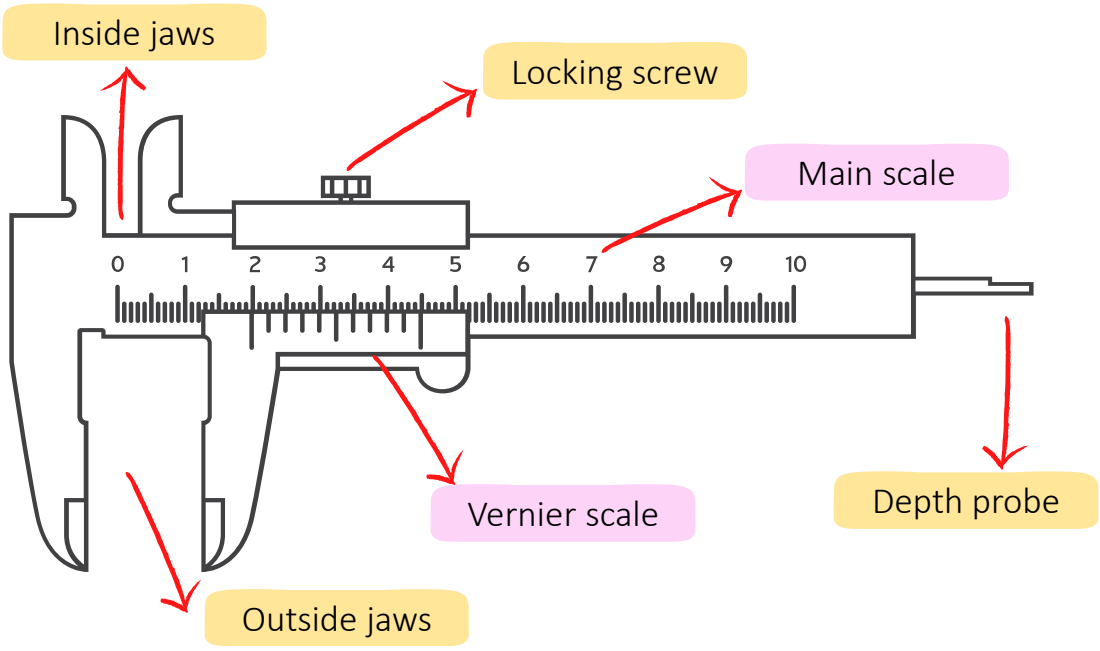
Errors in Measurement

- Measurement is done by bringing the target object into contact with the measuring instrument to read its physical quantity.
- However, errors may occur in the process of measuring the object. An error is a difference between the actual value and the value obtained from the measurement.
- There are two types of error: random error and systematic error
- A random error will affect the precision of measurement. While systematic error can influence a measurement's accuracy.



1.4 Vernier Caliper

- Vernier caliper is a measuring tool used for measuring linear dimensions. It is used to measure the thickness, diameter and depth of an object.
- It is mainly used in mechanical engineering, education, aerospace, automobile, metalworking, woodworking and medical.
- The structure of the vernier caliper is shown below:



Structure	Function
Inside jaws	For measuring inner dimension of object
Outside jaws	For measuring outer dimension of object
Depth Probe	For measuring depth inside of object
Locking screw	To lock the vernier arm from moving
Main scale	For main scale reading
Vernier scale	For secondary scale reading

How to read the vernier caliper?

- Figure below shows the reading of the vernier caliper. The main scale is marked in divisions of 0.1 cm, while the vernier scale is obtained using the formula of least count depending on the number of divisions on the vernier scale.

Question

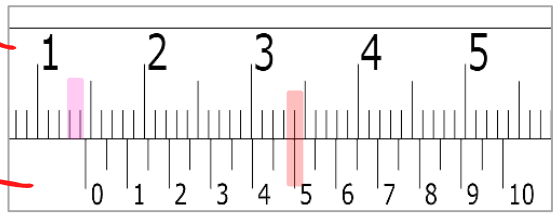
The following vernier caliper has no zero error. Determine the reading on the caliper.

Main scale

Smallest division is 0.1 cm

Vernier scale

Total division is 20



Step 1 Find the least count

Least count is the smallest value that can be measured by the measuring instrument

$$\textbf{Least count} = \frac{\text{smallest division on main scale}}{\text{number of division on vernier scale}}$$

$$= \frac{0.1}{20}$$

$$= 0.005\ cm$$

Step 2 Read the main scale marking just before the zero marking on the vernier scale

$$\textbf{Main scale} = 1.4\ cm$$

How to read the vernier caliper?

Step 3

Find the vernier scale marking which joins the main scale marking

Vernier scale $= 10 \times 0.005\ cm = 0.05\ cm$

Step 4

Find the obtained reading

Obtained reading $=$ Main scale $+$ Vernier scale

$= 1.4 + 0.05$

$= 1.45\ cm$

Additional Question

If the vernier caliper has $+0.002\ cm$ of zero error. Determine the reading on the caliper.

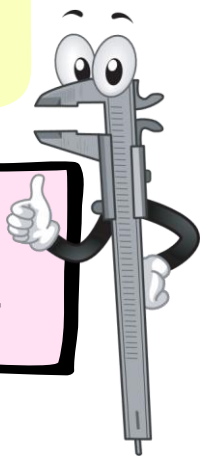
Step 5

Find the actual reading

Actual reading $=$ Obtained reading $-$ zero error

$= 1.45 - (+0.002)$

$= 1.448\ cm$

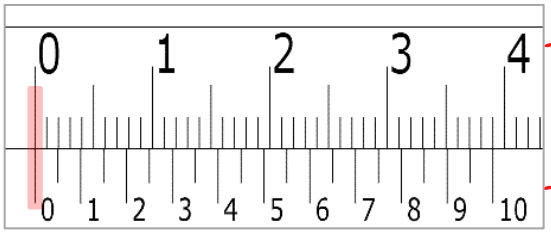


Obtained reading = Main scale + Vernier scale

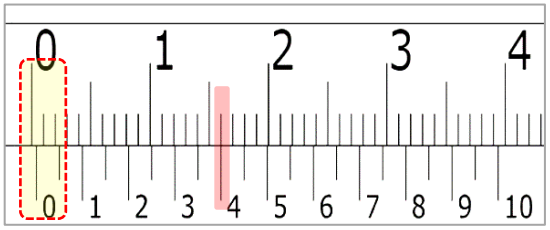
Actual reading = Obtained reading − zero error

Zero Error of Vernier Caliper

- Before finding the actual reading of the measurement, we need to check for zero error. **Zero error** is an error that occurred due to wear and tear or manufacturing defects of the instrument.
- Zero error is obtained when the jaws are closed firmly. If the main scale zero and vernier scale zero marks form a straight line, then there is no zero error.



- **Positive zero error** occurs if the vernier scale zero position is to the right of main scale zero markings.

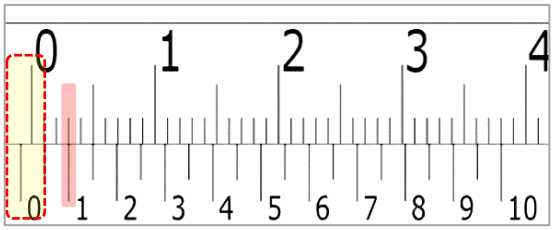


+ zero error

Find the vernier scale marking which joins the main scale marking

$$\textbf{Zero error} = 8 \times 0.005\ cm$$
$$= +0.04\ cm$$

- **Negative zero error** occurs if the vernier scale zero position is to the left of main scale zero markings.



− zero error

Find the vernier scale marking which joins the main scale marking

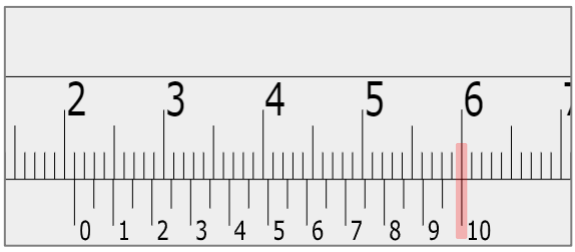
$$\textbf{Zero error} = -[0.1 - (2 \times 0.005)\ ]\ cm$$
$$= -0.09\ cm$$

Vernier Caliper

Example 1

The following vernier caliper has no zero error.

Determine the obtained reading on the caliper.



Solution:

$$Least\ count = \frac{0.1}{20} = 0.005\ cm$$

$$Main\ scale = 2.0\ cm$$

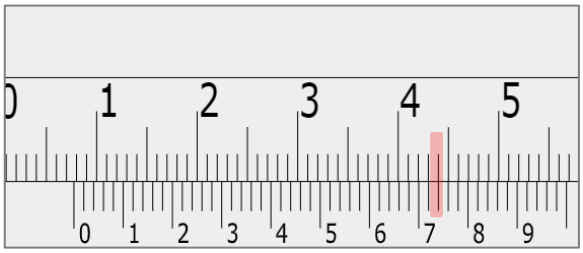
$$Vernier\ scale = 20 \times 0.005 = 0.1\ cm$$

$$Obtained\ reading = 2.0 + 0.1 = 2.1\ cm$$

Example 2

The following vernier caliper has no zero error.

Determine the obtained reading on the caliper.



Solution:

$$Least\ count = \frac{0.1}{50} = 0.002\ cm$$

$$Main\ scale = 0.7\ cm$$

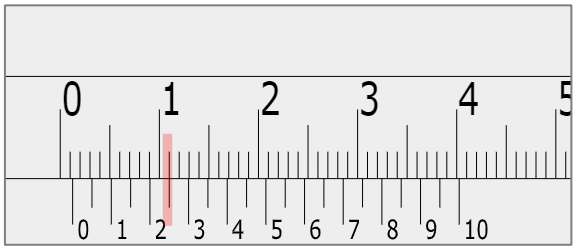
$$Vernier\ scale = 37 \times 0.002 = 0.074\ cm$$

$$Obtained\ reading = 0.7 + 0.074 = 0.774\ cm$$

Vernier Caliper

Example 3

The following vernier caliper has $+0.003\ cm$ of zero error. Determine the reading on the caliper.



Solution:

$$Least\ count = \frac{0.1}{20} = 0.005\ cm$$

$$Main\ scale = 0.1\ cm$$

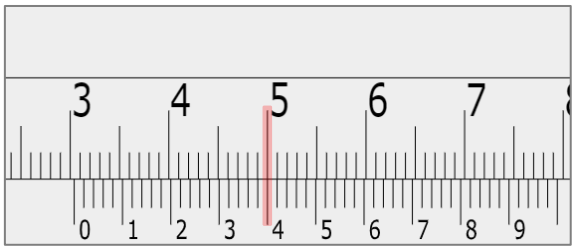
$$Vernier\ scale = 5 \times 0.005 = 0.025\ cm$$

$$Obtained\ reading = 0.1 + 0.025 = 0.125\ cm$$

$$True\ reading = 0.125 - (+0.003) = 0.122\ cm$$

Example 4

The following vernier caliper has $-0.009\ cm$ of zero error. Determine the reading on the caliper.



Solution:

$$Least\ count = \frac{0.1}{50} = 0.002\ cm$$

$$Main\ scale = 3.0\ cm$$

$$Vernier\ scale = 20 \times 0.002 = 0.04\ cm$$

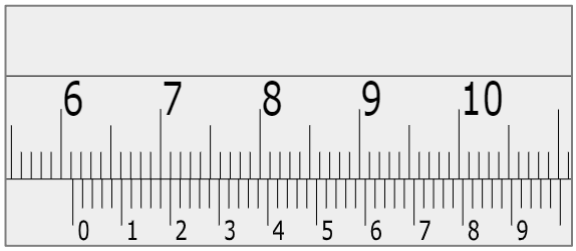
$$Obtained\ reading = 3.0 + 0.04 = 3.04\ cm$$

$$True\ reading = 3.04 - (-0.009) = 3.049\ cm$$

Practice Question 3

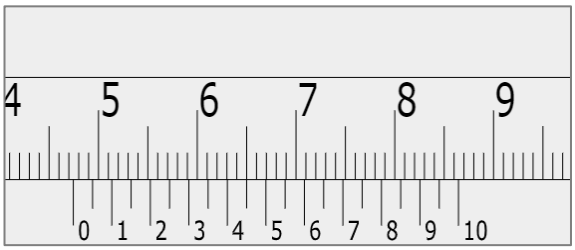
Determine the reading on the caliper:

a)



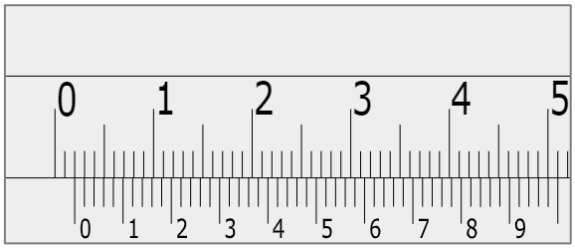
Answer: 6.118 cm

b)



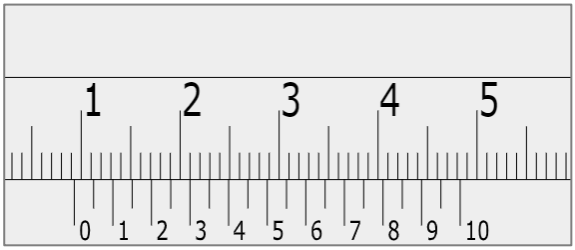
Answer: 4.745 cm

c)



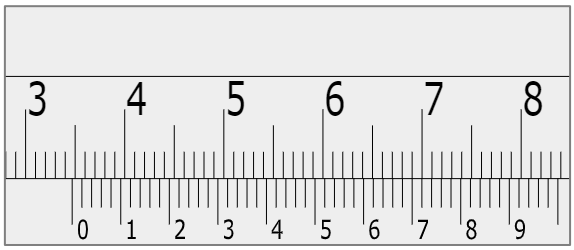
Answer: 0.20 cm

d)



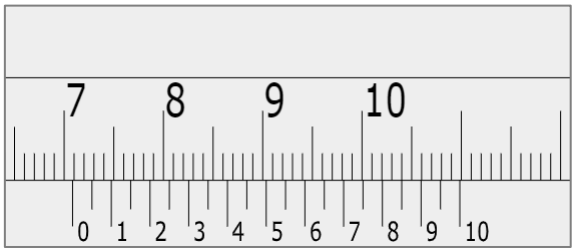
Answer: 0.93 cm

e)



Answer: 3.47 cm

f)

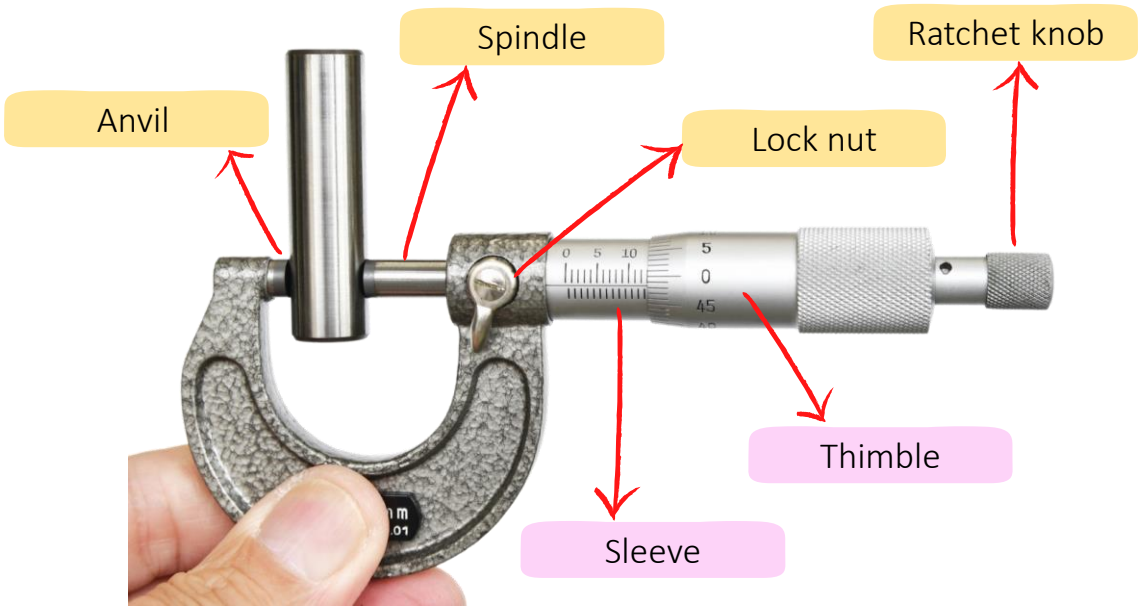


Answer: 7.085 cm

For more exercise on vernier caliper, scan this QR code!

1.5 Micrometer Screw Gauge

- A micrometer screw gauge is a measuring instrument that features a calibrated screw that is primarily used to measure small dimensions of thickness smaller than those measured by a vernier caliper.
- The gauge application is widely used in almost all fields of science, such as in engineering, manufacturing, and different scientific experiments.
- The structure of the micrometer screw gauge is shown below:



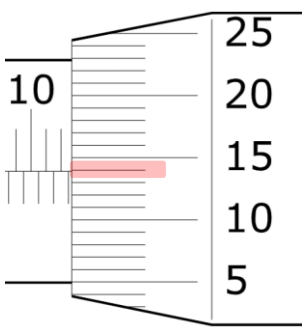
Structure	Function
Anvil & Spindle	Held the object in between
Lock nut	To lock and hold the scales at a particular position
Ratchet knob	Limit the gauge by preventing spindle from moving further
Sleeve	For main scale reading
Thimble	For secondary scale reading

How to read the Micrometer Screw Gauge?

- Figure below shows the reading of the micrometer screw gauge. The main scale is marked in divisions of 0.5 mm, while the circular scale is obtained using the formula of least count depending on the number of divisions on the circular scale.

Question

The following micrometer screw gauge has no zero error. Determine the reading on the gauge.



Main scale

Smallest division is 0.01 mm

Circular scale

Total division is 50

Step 1 Find the least count

$$\textbf{Least count} = \frac{\text{smallest division on main scale}}{\text{number of division on circular scale}}$$

$$= \frac{0.5}{50}$$

$$= 0.01\ mm$$

Step 2 Read the main scale marking just before the zero marking on the circular scale

$$\textbf{Main scale} = 10.5\ mm$$

How to read the Micrometer Screw Gauge?

Step 3

Find the circular scale marking which joins the main scale marking

Circular scale $= 14 \times 0.01\ mm = 0.14\ mm$

Step 4

Find the obtained reading

Obtained reading = Main scale + Circular scale

$= 10.5 + 0.14$

$= 10.64\ mm$

Additional Question

If the micrometer screw gauge has $-0.06\ mm$ of zero error. Determine the reading on the gauge.

Step 5

Find the actual reading

Actual reading = Obtained reading − zero error

$= 10.64 - (-0.06)$

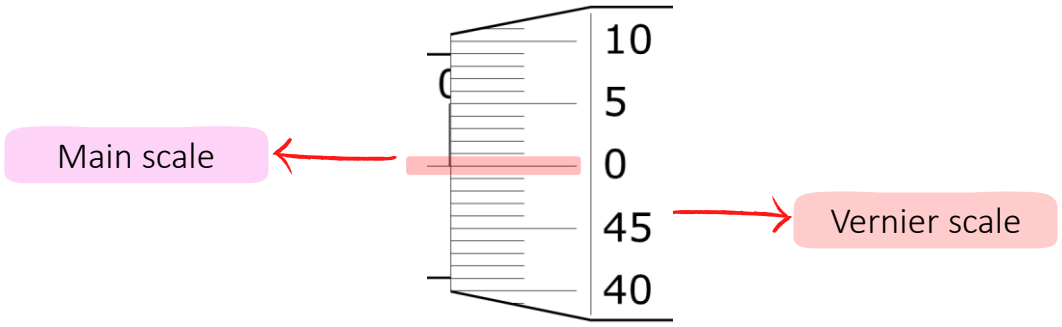
$= 10.70\ mm$

Obtained reading = Main scale + Circular scale

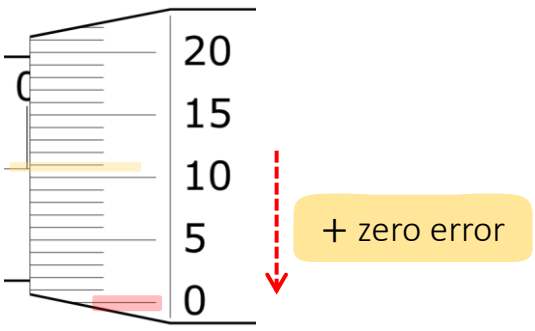
Actual reading = Obtained reading − zero error

Zero Error of Micrometer Screw Gauge

- **Zero error** is obtained when the gauge is fully closed. If the main scale zero markings and circular scale zero marking form a straight line, there is no zero error as shown in figure below.



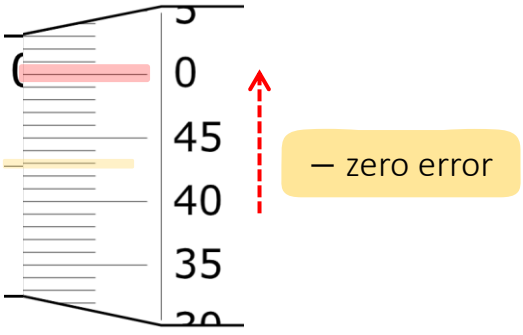
- **Positive zero error** occurs if the circular scale zero position is below the main scale zero markings.



Find the circular scale marking which joins the main scale marking

$$\textbf{Zero error} = 10 \times 0.01\ mm$$
$$= +0.10\ mm$$

- **Negative zero error** occurs if the circular scale zero position is above the main scale zero marking.



Find the circular scale marking which joins the main scale marking

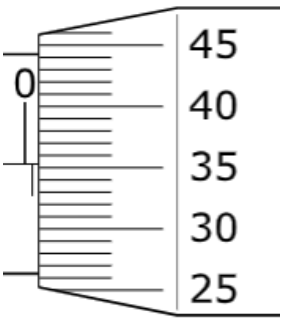
$$\textbf{Zero error} = 7 \times 0.01\ mm$$
$$= -0.07\ mm$$

Micrometer Screw Gauge

Example 1

The following micrometer screw gauge has no zero error. Determine the obtained reading on the gauge.

Solution:



$$Least\ count = \frac{0.5}{50} = 0.01\ mm$$

$Main\ scale = 0.5\ mm$

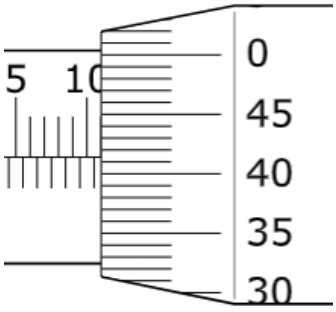
$Circular\ scale = 35 \times 0.01 = 0.35\ mm$

$Obtained\ reading = 0.5 + 0.35 = 0.85\ mm$

Example 2

The following micrometer screw gauge has no zero error. Determine the obtained reading on the gauge.

Solution:



$$Least\ count = \frac{0.5}{50} = 0.01\ mm$$

$Main\ scale = 10.5\ mm$

$Circular\ scale = 41 \times 0.01 = 0.41\ mm$

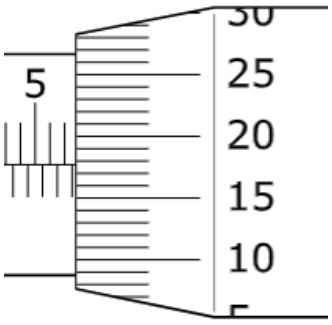
$Obtained\ reading = 10.5 + 0.41 = 10.91\ mm$

Micrometer Screw Gauge

Example 3

The following micrometer screw gauge has $+0.01\ mm$ of zero error. Determine the reading on the gauge.

Solution:



$$Least\ count = \frac{0.5}{50} = 0.01\ mm$$

$Main\ scale = 7.5\ mm$

$Circular\ scale = 17 \times 0.01 = 0.17\ mm$

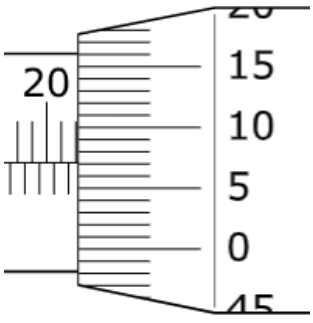
$Obtained\ reading = 7.5 + 0.17 = 7.67\ mm$

$True\ reading = 7.67 - (+0.01) = 7.66\ mm$

Example 4

The following micrometer screw gauge has $+0.06\ mm$ of zero error. Determine the reading on the gauge.

Solution:



$$Least\ count = \frac{0.5}{50} = 0.01\ mm$$

$Main\ scale = 22.0\ mm$

$Circular\ scale = 7 \times 0.01 = 0.07\ mm$

$Obtained\ reading = 22.0 + 0.07 = 22.07\ mm$

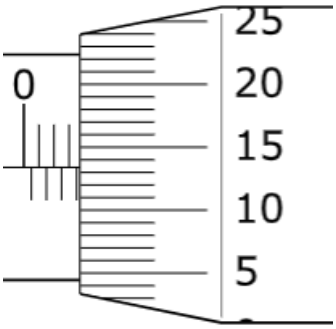
$True\ reading = 22.07 - (+0.06) = 22.01\ mm$

Micrometer Screw Gauge

Example 5

The following micrometer screw gauge has $-0.03\ mm$ of zero error. Determine the reading on the gauge.

Solution:



$$Least\ count = \frac{0.5}{50} = 0.01\ mm$$

$Main\ scale = 3.5\ mm$

$Circular\ scale = 13 \times 0.01 = 0.13\ mm$

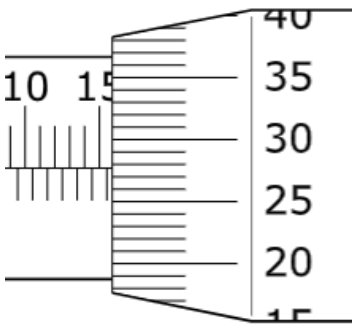
$Obtained\ reading = 3.5 + 0.13 = 3.63\ mm$

$True\ reading = 3.63 - (-0.03) = 3.66\ mm$

Example 6

The following micrometer screw gauge has $-0.09\ mm$ of zero error. Determine the reading on the gauge.

Solution:



$$Least\ count = \frac{0.5}{50} = 0.01\ mm$$

$Main\ scale = 15.5\ mm$

$Circular\ scale = 27 \times 0.01 = 0.27\ mm$

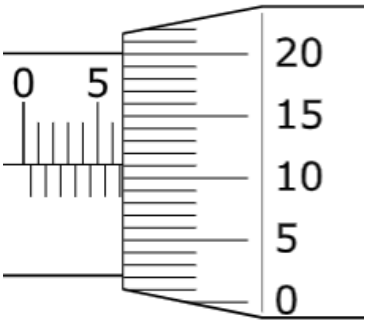
$Obtained\ reading = 15.5 + 0.27 = 15.77\ mm$

$True\ reading = 15.77 - (-0.09) = 15.86\ mm$

Practice Question 4

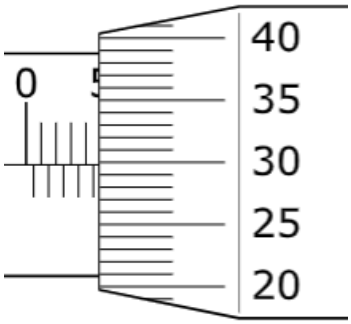
Determine the reading on the gauge:

a)



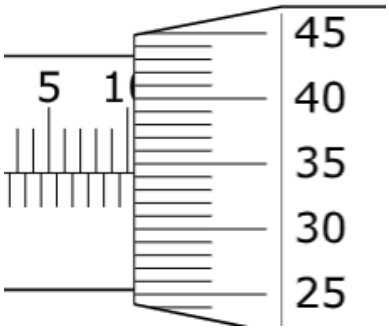
Answer: 6.51 mm

b)



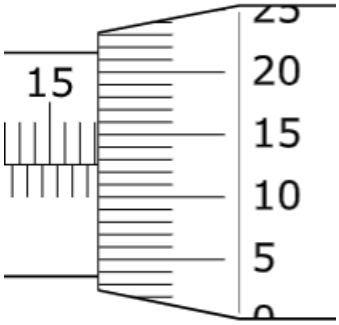
Answer: 4.79 mm

c)



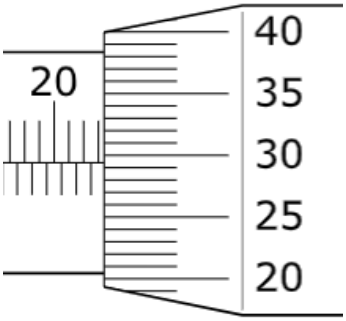
Answer: 10.34 mm

d)



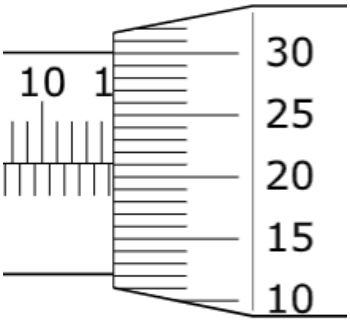
Answer: 18.12 mm

e)



Answer: 23.29 mm

f)



Answer: 14.71 mm

For more exercise on micrometer screw gauge, scan this QR code!

CHAPTER 2
LINEAR MOTION

Learning Outcomes

At the end of this chapter, students should be able to:

- ✓ Define linear motion.
- ✓ Define uniform and non-uniform motion.
- ✓ Describe distance, displacement, speed, velocity, average velocity, acceleration and deceleration.
- ✓ Apply the concept of linear motion in solving the related problems by using formula
- ✓ Illustrate velocity-time graph.
- ✓ Determine the velocity, acceleration and displacement from the graphs.

WRITTEN BY:
FARA NUR ASMA BINTI MOHD BASRI

2.1 APPLY THE CONCEPT OF LINEAR MOTION

2.1.1 LINEAR MOTION

- Linear motion is a motion along a **straight line**.
- Linear motion is the most basic of all motion.
- Differentiate these:

Linear Motion

- Fruits falling from the trees.
- A car moving at the same speed in a straight line.
- A man moving on an escalator.

Non Linear Motion

- A spinning top.
- The rotation and motions of the Earth.
- School of fish swim in the ocean.

2.1.2 UNIFORM AND NON-UNIFORM MOTION

- The linear motion can be of two types which is:
  a) **A uniform linear motion** with constant velocity or zero acceleration, and
  b) **A non-uniform linear motion** with variable velocity or non-zero acceleration.
- According to Newton's first law of motion, objects that do not experience any net force will continue to move in a straight line with a constant velocity until they are subjected to a net force.
- The main physical quantities involved in linear motion are distance, displacement, speed, velocity, acceleration and deceleration.

2.1.3 DISTANCE, DISPLACEMENT, SPEED, VELOCITY AND ACCELERATION

❑ **Distance** and **displacement** are two quantities that may seem to mean the same thing, yet have distinctly different definitions and meanings.

Distance

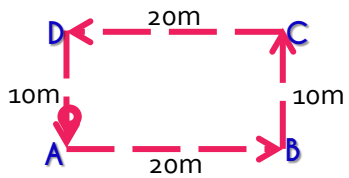
- Refers to the total length travelled during its motion from one location to another.
- Scalar quantity (which has only a magnitude).
- SI Unit meter (m)
- Example: A student walks a total of 100 meters.

Displacement

- Refers to the distance travelled in a specified direction and the object's overall change in position.
- Vector quantity (which has magnitude and direction).
- SI Unit meter (m)
- Example: A man drives 10 meters to the south and then continues another 20 meters to the west.

Example 1

Calculate the distance and displacement of the movement from point A to B, C, D and ended at the same point A.



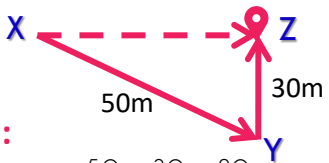
Solution:

Distance = 20 +10 + 20 +10 = 60m

Displacement = +20 + 10 – 20 – 10 = 0m

Example 2

Calculate the distance and displacement covered by Alexa if she travels from point X to Z through point Y.



Solution:

Distance = 50 + 30 = 80m

Displacement = distance from P to R in a straight line. We can use the Pythagorean Theorem:

$XY^2 = XZ^2 + ZY^2$

$50^2 = XZ^2 + 30^2$

$XZ = \sqrt{50^2 - 30^2} = 40m.$

Example 3

What is the distance and the displacement of a marathon participants if they begin at the entrance of KL Tower, run 10 kilometers and finish back at the same spot ?

Solution:

The distance is 10km while the displacement of the participants are 0 kilometers. While they have covered a distance of 10 kilometers, they are actually not displaced. They finish where they started. A round-trip motion always has a displacement of 0.

Example 4

Calculate the distance and the displacement of a bus driver who drove around a roundabout with 7m of radius in town.

Solution:

The distance moved by the bus is the circumference of a circle with a radius of 7 meters.

Circumference = $2\pi r$

= $2 \times \pi \times 7$

= 43.98m

The displacement of the bus is zero.

This is because the bus starts from one point and ended up at the same point.

Practice Question 1

An athlete trains at a 400m track. If he runs a complete 5 rounds for training, calculate his distance and displacement.

Ans: Distance = 2000m
Displacement = 0m

Practice Question 2

Lisa walks 200 m to the north and turns back 25m to the south. Calculate the distance and displacement.

Ans: Distance = 225m
Displacement = 175m

Practice Question 3

Brian drove 3km to the east and then another 4km to the south. Calculate his total journey and the possible displacement if he drove direct to his desired destination.

Ans: Distance = 7km
Displacement = 5km

Practice Question 4

Angela started her morning walk from her house towards a nearby playground which is 500m in distance. She then made a return journey and continued walking pass her house for another 800m distance. Calculate Angela's total distance and displacement.

Ans: Distance = 7km
Displacement = 5km

- **Speed** and **velocity** - Just as distance and displacement, despite their similarities, speed and velocity also have distinctly different meanings.

Speed

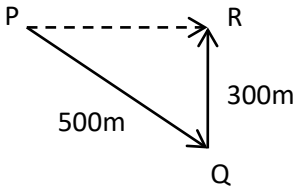
- It refers to the distance travelled in a certain amount of time.
- Speed can also be described as how fast an object is moving.
- Scalar quantity (which has only a magnitude).
- $\textbf{Speed} = \dfrac{distance\ (m)}{time\ (s)}$
- SI Unit meter (m/s) @ $\mathbf{ms^{-1}}$ @ $\frac{m}{s}$ @ meter per second.

Velocity

- It refers to the speed of an object in a specified direction.
- Velocity can also be described as the rate at which an object changes its position.
- Vector quantity (which has magnitude and direction).
- $\textbf{Velocity} = \dfrac{displacement\ (m)}{time\ (s)}$
- SI Unit meter (m/s) @ $\mathbf{ms^{-1}}$ @ $\frac{m}{s}$ @ meter per second.

Example 1

Figure shows the travel path taken by Lily from point P to point R. She took 300 seconds to reach her destination. Calculate the speed and the velocity experienced by Lily.



Speed $= \dfrac{distance\ (m)}{time\ (s)}$

$= \dfrac{(500+300)m}{300\ s}$

$= 2.67\ ms^{-1}$

Velocity $= \dfrac{distance\ (m)}{time\ (s)}$

$= \dfrac{400m}{300\ s}$

$= 1.33\ ms^{-1}$

Example 2

Roy rides his motorcycle in a straight line for 0.2km in 0.1 minutes. Calculate his speed in SI unit.

Solution:

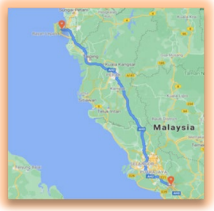
$$\text{Speed} = \frac{distance\ (m)}{time\ (s)}$$

$$= \frac{0.2\ \text{km}}{0.1\ \text{min}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{min}}{60\ \text{sec}}$$

$$= 33.33\ ms^{-1}$$

Example 3

A car travels 425km from Seremban to Georgetown, Penang in 5 hours. Calculate the velocity base on this information and give the answer in SI unit.



Solution:

$$\text{Speed} = \frac{distance\ (m)}{time\ (s)}$$

$$= \frac{425\ \text{km}}{5\ \text{hrs}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{hrs}}{3600\ \text{sec}}$$

$$= 23.61\ \boldsymbol{ms^{-1}}$$

Average Velocity

- If an object travels with different velocities all along the movement, then the velocity of the whole journey can be calculated as the *average velocity*. The average velocity can be calculated as:

$$\textbf{\textit{Average velocity}} = \frac{total\ displacement\ (m)}{time\ (s)}$$

Example 1

Figure shows a path travelled by a cyclist from point X to point Z. Calculate:

a) The velocity from X to Y
b) The velocity from Y to Z
c) The average velocity from start to the end point.

a) Velocity from **x to y**

$$= \frac{displacement\ (m)}{time\ (s)}$$

$$= \frac{300\ m}{10\ s}$$

$$= 30\ ms^{-1}$$

b) Velocity from **y to z**

$$= \frac{displacement\ (m)}{time\ (s)}$$

$$= \frac{100\ m}{5\ s}$$

$$= 20\ ms^{-1}$$

c) average velocity from **x to z**

$$= \frac{total\ displacement\ (m)}{time\ (s)}$$

$$= \frac{400\ m}{15\ s}$$

$$= 26.67\ ms^{-1}$$

Practice Question 1

Alif rides a motorcycle for 8500 meters that takes 250 seconds. Calculate his speed.

Ans: $34 ms^{-1}$

Practice Question 2

It took 4 hours for a bus to travel the distance between two cities at a speed of 90 km/hr. What is the distance between the two cities?

Ans: 360 km

Practice Question 3

How long will it take for a car to travel 280 kilometers if it is travelling at a speed of 110 $kmhr^{-1}$

Ans: 2.55 hr

Practice Question 4

Sarah rides her bicycle for 30 minutes and reaches her destination of 22 kilometers. Calculate her speed for this journey in SI units.

Ans: $12.22 ms^{-1}$

- **Acceleration** and **Deceleration.** Acceleration and deceleration are basically opposite behavior. As a brief description, **accelerate means speeding** up while **decelerate means slowing down**.

Acceleration

- Acceleration is defined as the rate at which an object changes its velocity with time.
- It is a measure of how fast the velocity of an object changes in time.
- Vector quantity (which has magnitude and direction).
- Acceleration is experienced by an object if the **velocity increases** with time.
- ***Acceleration*** $= \frac{change\ of\ velocity\ (ms^{-1})}{time\ (s)}$
- Therefore,

$$\text{Acceleration, } \mathbf{a} = \frac{final\ velocity - initial\ velocity}{time\ taken}$$

$$\mathbf{a} = \frac{v - u}{t}$$

- SI unit = ms^{-2} @ m/s^2 @ $\frac{m}{s^2}$ @ meter per second ^{2}

QUICK TIPS

The **formula and units** for acceleration and deceleration is the **same.**

Deceleration

- Deceleration is the **opposite of acceleration**.
- Deceleration is experienced when an object slows down
- In other words, deceleration happens when the **velocity** of a moving object **decreases** with time.

Example 1

An athlete is accelerating from an initial velocity of 0 ms^{-1} to a final velocity of 4.5 ms^{-1} in 2 seconds. Calculate his acceleration.

Solution:

Initial velocity, u = 0 ms^{-1}

Final velocity, v = 4.5 ms^{-1}

Time taken, t = 2 s

Acceleration, **a** = $\frac{v-u}{t}$

= $\frac{4.5-0}{2}$

= 2.25 ms^{-2}

Example 2

A bus accelerates uniformly from an initial velocity of 3 ms^{-1} to a final velocity of 12 ms^{-1} in 5 seconds. Calculate the acceleration experienced by the bus.

Solution:

Initial velocity, u = 3 ms^{-1}

Final velocity, v = 12 ms^{-1}

Time taken, t = 5 s

Acceleration, **a** = $\frac{v-u}{t}$

= $\frac{12-3}{5}$

= 1.8 ms^{-2}

Example 3

A car decelerates uniformly from an initial velocity of 25 ms^{-1} until it stops 7 seconds later at a traffic light. Calculate the deceleration experienced by the car.

Solution:

Initial velocity, u = 25 ms^{-1}

Final velocity, v = 0 ms^{-1}

Time taken, t = 7 s

Acceleration, **a** = $\frac{0-25}{7}$

= $\frac{-25}{7}$

= -3.57 ms^{-2}

The negative sign of an acceleration simply means that the car is slowing down. The velocity is decreasing.

Example 4

Cody is riding his bicycle with an initial velocity of 15 ms^{-1}. He applied the brakes and the bicycle decelerates uniformly with 4.7 ms^{-2} until it finally stops. Calculate the time taken for the bicycle to stop in this situation.

Solution:

Initial velocity, u = 15 ms^{-1}

Final velocity, v = 0 ms^{-1}

Deceleration = 4.7 ms^{-2}

Deceleration, **a,** -4.2 = $\frac{0-15}{t}$

t = $\frac{-15}{-4.7}$

= 3.19 s

Use negative sign because to calculate deceleration, we use the same formula to calculate acceleration.

Example 5

A vehicle accelerates uniformly from an initial velocity of $3ms^{-1}$ to a final velocity of $11ms^{-1}$ in 9 seconds. It then slows down uniformly to a final velocity of $2ms^{-1}$ in 8 seconds. Calculate the acceleration of the vehicle

a. during the first 9 seconds and

b. during the last 8 seconds.

Solution:

a. During the first 9 seconds

Initial velocity, $u = 3ms^{-1}$

Final velocity, $v = 11ms^{-1}$

Time taken, $t = 9s$

Acceleration, $\mathbf{a} = \frac{v-u}{t}$

$= \frac{11-3}{9}$

$= 0.89\ ms^{-2}$

b. During the last 8 seconds

Initial velocity, $u = 11ms^{-1}$

Final velocity, $v = 2ms^{-1}$

Time taken, $t = 8s$

Acceleration, $\mathbf{a} = \frac{v-u}{t}$

$= \frac{2-11}{8}$

$= -1.125\ ms^{-2}$

Example 6

During a take-off, an airplane accelerates uniformly from $30kmhr^{-1}$ to $240kmhr^{-1}$ in 32 seconds before it lifts off the ground. Calculate the acceleration experienced by the airplane upon taking off. Give your answer in SI units.

Solution:

Initial velocity, $u = 30kmhr^{-1}$

Convert units to ms^{-1}

$= \frac{30\ km}{hr} \times \frac{1000\ m}{1\ km} \times \frac{1\ hr}{3600\ sec} = \mathbf{8.33\ ms^{-1}}$

Final velocity, $v = 240kmhr^{-1}$

Convert units to ms^{-1}

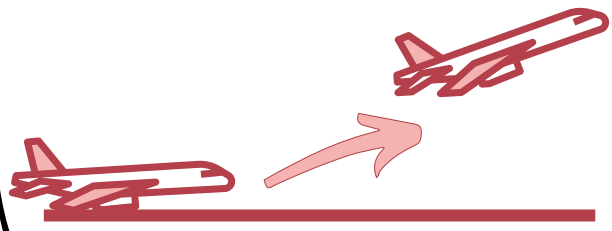
$= \frac{240\ km}{hr} \times \frac{1000\ m}{1\ km} \times \frac{1\ hr}{3600\ sec} = \mathbf{66.67\ ms^{-1}}$

Time taken, $t = 32s$

Acceleration, $\mathbf{a} = \frac{v-u}{t}$

$= \frac{66.67-8.33}{32}$

$= 1.823\ ms^{-2}$



Practice Question 1

A car accelerates from 10kmhr^{-1} to 110kmhr^{-1} n 15 seconds. Find the acceleration in SI unit.

Ans: 1.852ms^{-2}

Practice Question 2

An aircraft initially at rest accelerates at 2.51ms^{-2} in 32 seconds upon taking off. What is its final velocity for this movement?

Ans: 80.32ms^{-1}

Practice Question 3

A train starts from rest accelerates uniformly at 3.3ms^{-2} and reach its final velocity of 41ms^{-1}. How long is the duration of this movement?

Ans: 12.42s^{1}

Practice Question 4

A car with an initial velocity of 65 kmhr^{-1} takes 15 seconds to change its velocity to 12 kmhr^{-1}. Is this car experienced an acceleration or deceleration? Provide your answer with a calculation using suitable formula.

Ans: -0.982ms^{-2}

2.1.4 KINEMATIC FORMULA

- Problems related to uniformly accelerated motions can be solved using the kinematic formula.

KINEMATIC FORMULA

i. $v = u + at$

ii. $v^2 = u^2 + 2as$

iii. $s = ut + \frac{1}{2}at^2$

iv. $s = \frac{1}{2}(u + v)t$

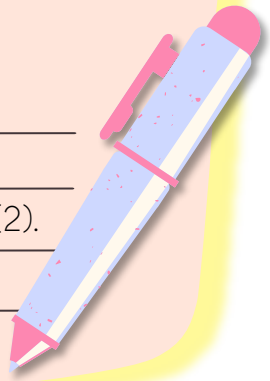
Variables used in the equations:

u = initial velocity
v = final velocity
t = time
a = acceleration
s = displacement

How do we choose a kinematic formula?

To choose which kinematic formula to use in solving a particular question, we can follow these simple steps:

1. List down all the variables given in the question
2. Identify which variable that we need to find
3. Choose suitable kinematic formula according to (1) and (2).
4. Rearrange the formula (if necessary)



Example 1

A cyclist is travelling at a constant velocity of 3.1 ms^{-1}. He suddenly accelerates at 0.65 ms^{-2} for 16 meters. Calculate his final velocity.

Solution:

List down all the variables given:

Initial velocity, u = 3.1 ms^{-1}
acceleration, a = 0.65 ms^{-2}
displacement, s = 16 m

Which variable that we need to find?

final velocity, v?

So we have u, a and s. And we need to find v.

$v^2 = u^2 + 2as$

$= (3.1)^2 + 2\ (0.65)\ (16)$

$v = \sqrt{30.41}$

$= 5.51\ ms^{-1}$

Example 2

A car slows down from a velocity of 15 ms-1 to 2 ms-1 in 8 seconds. Calculate:

a) The deceleration.
b) The distance travelled in 8 seconds.

Solution:

List down all the variables given:

Initial velocity, u = 15 ms-1
Final velocity, v = 2 ms-1
time taken, t = 8 s

So we have u, v and t. We need to find:

a) deceleration, a

$a = \frac{v-u}{t}$

$= \frac{2-15}{8}$

$= -1.625\ ms^{-2}$

b) distance, s

$s = \frac{1}{2}(u + v)\ t$

$= \frac{1}{2}(15 + 2)\ 8$

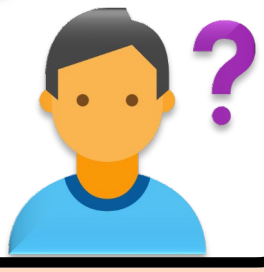
$= 68$ m

@ $s = ut + \frac{1}{2}at^2$

$= (15)(8) + \frac{1}{2}(-1.625)(8)^2$

$= 68$ m

This question can be solved using any of these two formulas as long as we have the value of related variables. As in example 2(a) the value of acceleration is obtained so it can be used to answer example 2(b).



Example 3

A man drove a car travelling at 105 km/hr decelerates uniformly at 3 ms^{-2} upon seeing a red traffic light and later comes to a halt. Calculate:

a) The time taken upon this deceleration process.
b) The distance travelled between the point where the brakes initially applied and the point where the car stops.

Solution:

List down all the variables given:

Initial velocity, u = 105 km/hr
Final velocity, v = 0 ms^{-1}
acceleration, a = -3 ms^{-2}

IMPORTANT

Be **alert with the units** provided for the variables.
To insert these variables into a formula, the **units must be in uniform condition**, preferably in SI units.
Therefore, a **conversion of units** might be needed before we solve the question.

Conversion of units:

$$105\ kmhr^{-1} = \frac{105\ km}{hr} \times \frac{1000\ m}{1\ km} \times \frac{1\ hr}{3600\ sec}$$

$$= 29.17\ ms^{-1}$$

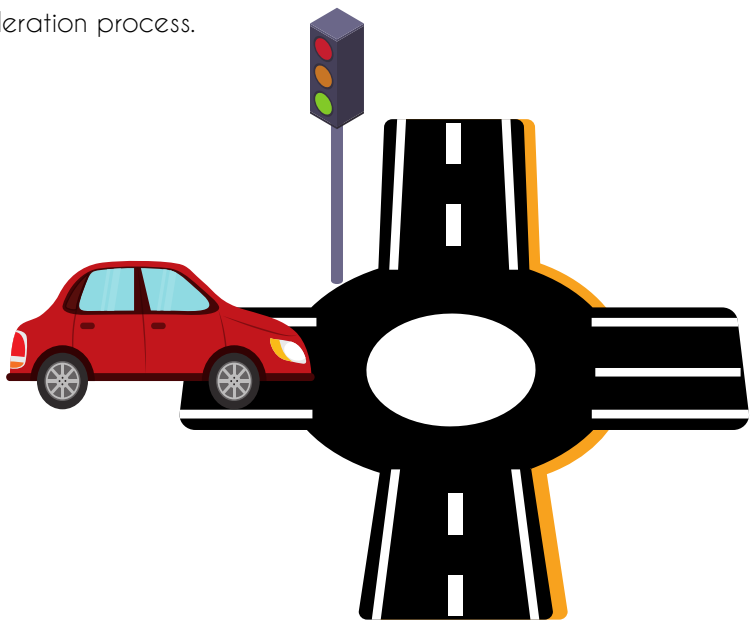
So we have u, v and a. We need to find:

a) The time taken upon this deceleration process.

$$a = \frac{v-u}{t}$$

$$t = \frac{0-29.17}{-3}$$

$$= 9.72\ s$$



b) Distance travelled, s

$$v^2 = u^2 + 2as$$

$$0 = (29.17)^2 + 2(-3)s$$

$$s = \frac{-850.89}{-6}$$

$$= 141.81m$$

Example 4

A ball is released free fall from the height of 5 meters. Calculate:

a) The final velocity just before it hits the ground.

b) The time taken for the ball to reach the ground.

Solution:

List down all the variables given:

Initial velocity, $u = 0\ ms^{-1}$

acceleration, $a = 9.81 ms^{-2}$

displacement, $s = 5\ m$

The initial velocity of the ball is zero since initially it was in a static position.

Every free falling objects experienced an acceleration of $9.81 ms^{-2}$ (positive value) which is due to the gravitational acceleration downwards.

So we have u, a and s. We need to find:

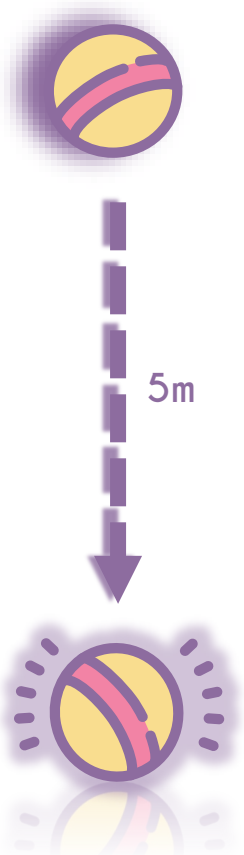
a) The final velocity just before it hits the ground.

$v^2 = u^2 + 2as$

$= 0 + 2(9.81)(5)$

$= \sqrt{98.1}$

$= 9.91\ ms^{-1}$



b) The time taken for the ball to reach the ground

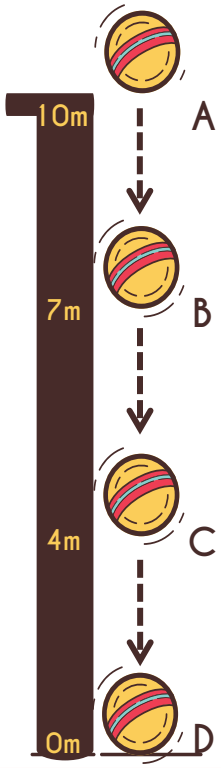
$v = u + at$

$9.91 = 0 + (9.81)\ t$

$t = 1.01\ s$

Example 5

An object is placed on a 10m height platform. It was then released free fall down as shown in the figure below. Calculate the velocity and the time taken at positions B, C and D.



Solution:

Note that at position B, the height is 7m from the ground. This means that the object has travelled 3 meters from its initial position.

So at position B; u = 0 ms-1
a = 9.81 ms-2
s = 3m

The velocity: $v^2 = u^2 + 2as$

$= 0 + 2(9.81)(3)$

$= \sqrt{58.86}$

$= \underline{7.67\ ms^{-1}}$

Time taken: $v = u + at$

$7.67 = 0 + (9.81)\,t$

$\therefore t = 7.67/9.81$

$= \underline{0.78\ s}$

Note that at position C, the height is 4m from the ground. This means that the object has travelled 6 meters from its initial position.

So at position C; u = 0 ms-1
a = 9.81 ms-2
s = 6m

The velocity: $v^2 = u^2 + 2as$

$= 0 + 2(9.81)(6)$

$= \sqrt{117.72}$

$= \underline{10.85\ ms^{-1}}$

Time taken:
Try using another formula to obtain the value of t.

$s = ut + \frac{1}{2}at^2$

$6 = (0)t + \frac{1}{2}(9.81)t^2$

$\therefore t^2 = \frac{6}{4.905}$

$t = \sqrt{1.223}$

$= \underline{1.11\ s}$

Note that at position D, the height is zero meter from the ground. This means that the object has travelled 10 meters from its initial position.

So at position D; u = 0 ms-1
a = 9.81 ms-2
s = 10m

The velocity: $v^2 = u^2 + 2as$

$= 0 + 2(9.81)(10)$

$= \sqrt{196.2}$

$= \underline{14.01\ ms^{-1}}$

Time taken:
Try using another formula to obtain the value of t.

$s = \frac{1}{2}(u + v)\,t$

$10 = \frac{1}{2}(0 + 14.01)\,t$

$\therefore t = \frac{10(2)}{14.01}$

$= \underline{1.43\ s}$

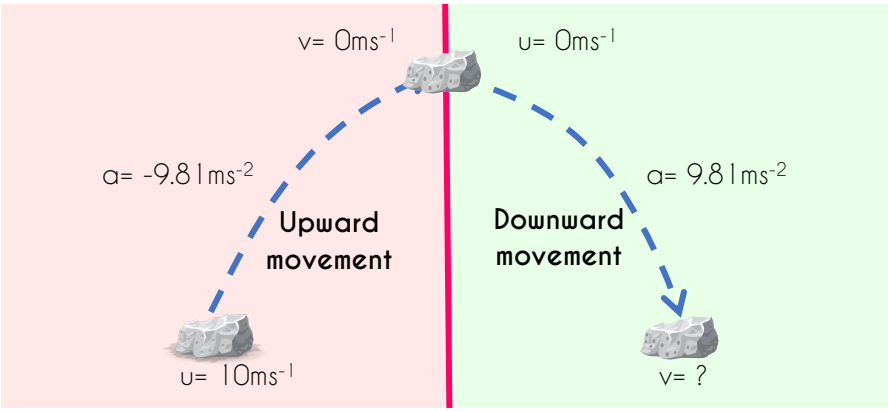
Example 6

A stone is thrown vertically upwards with an initial velocity of 10 ms^{-1}. Calculate the time taken and the total distance of the stone to go up and down the same height it was thrown.

Solution:

In this condition, an object thrown **upwards** experiences a **decreasing in velocity** (assuming there are no external forces acting on it, and neglecting the air friction). Therefore, the acceleration is negative when it moves upwards.

When it comes down, the velocity will increase and this means the acceleration is a positive value. Thus, we can divide the situation into 2 conditions:



Upward movement:

The stone thrown upwards will pause for a moment at the highest point of its travel before it falls again. Therefore, the final velocity for this movement is zero.

So we can use the formula:

$v = u + at$
$0 = 10 + (-9.81)\,t$
$-10 = -9.81\,t$
So $t = (-10)/(-9.81)$
$= \underline{1.019\ s}$

Distance s, $= ut + \frac{1}{2}at^2$
$= (10)(1.019) + \frac{1}{2}(-9.81)(1.019)^2$
$= \underline{5.097\ m}$

Downward movement:

Upon the downward movement of the stone, the initial velocity is zero. The distance traveled by the stone when thrown upwards is the **same distance as it travels back down**.

Using the same distance, we can find the time taken for the stone to fall back down. Now the initial velocity of this movement will be zero.

$s = ut + \frac{1}{2}at^2$
$5.097 = (0)(t) + \frac{1}{2}(9.81)\,t^2$
$t^2 = \frac{5.097}{4.905}$
$t = \sqrt{1.039}$
$= \underline{1.019\ s}$

Practice Question 1

A motorcycle travelling at 15 ms^{-1} stops after a distance of 150m. Calculate:

a) The deceleration

b) The time taken for it to stop.

Ans: a) 0.75 ms^{-2} b) 0.75 s

Practice Question 2

An object which initially at rest, moves in a straight line with uniform acceleration and covers 0.7 km in 1.8 minutes. Calculate:

a) The acceleration, and

b) The final velocity of the object.

Give your answers in SI units.

Ans: a) 0.12 ms^{-2} b) 12.96 ms^{-1}

Practice Question 3

A mango falls from its tree to the ground with an acceleration of 9.81 ms^{-2} for 0.8 seconds. Calculate:

a) The height from where the mango falls.

b) The final velocity just before it hits the ground.

Ans: a) 3.14 m b) 7.85 ms^{-1}

Practice Question 4

A boy throws a ball vertically upwards with an initial velocity of 3 ms^{-1}. Calculate the time taken for the ball to go up and come down again with the same height it travels.

Ans: 0.612 s

2.2 THE VELOCITY – TIME GRAPH

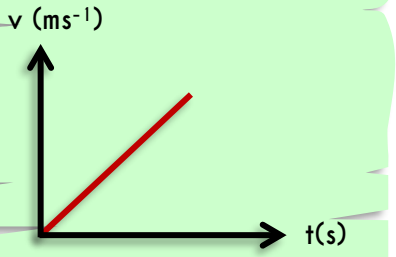
- The Velocity – Time graph is a linear graph showing how the velocity of an object changes with time.
- The **gradient** of graph indicates the **acceleration** of movement.

  Acceleration, a = gradient of graph
- The **area under the graph** indicates the **distance** travelled for the movement.

  Distance, s = Area under the graph

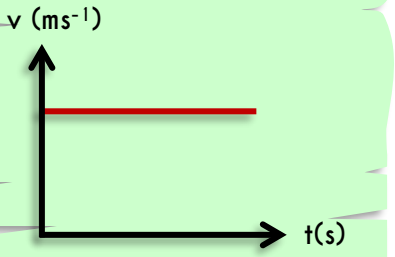
The Velocity – Time Graph in details

Uniform acceleration



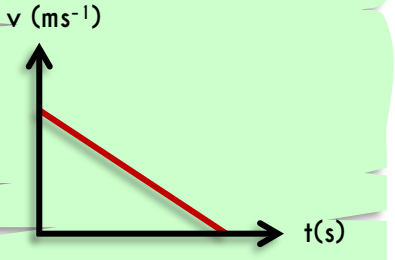
1. **Velocity**: Increases uniformly over a period of time.
2. **Acceleration**: Positive

Uniform velocity



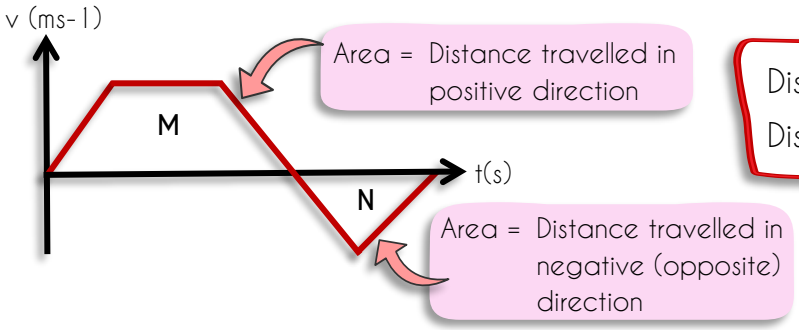
1. **Velocity**: Constant over a period of time.
2. **Acceleration**: Zero

Uniform deceleration



1. **Velocity**: Decreases uniformly over a period of time.
2. **Acceleration**: Negative

- If the graph shows that there is a negative value in v (as in the N area) this means that the whole M area, the object moves in positive direction while area N shows that the object moves in negative direction.



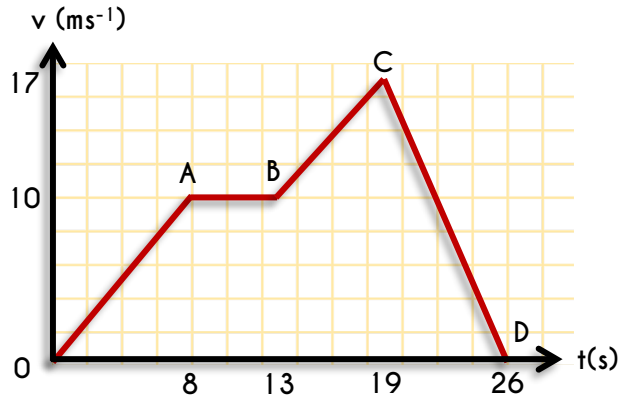
NOTES

Distance = Area M + Area N

Displacement = Area M – Area N

Example 1

The graph below shows the motion of a car on a straight road.



a) Describe the motion of the car represented by line OA, AB, BC and CD
b) Calculate the acceleration at point OA and BC
c) Calculate the deceleration at point CD
d) Calculate the total distance travelled for the whole 26 seconds movement.

Solution:

a) OA = Uniform acceleration
AB = Uniform velocity
BC = Uniform acceleration
CD = Uniform deceleration

b) Acceleration at Point OA:

a = gradient of graph

$= \frac{\Delta y}{\Delta x}$

$a = \frac{10-0}{8-0}$

$= 1.25\ ms^{-2}$

Acceleration at Point BC:

a = gradient of graph

$= \frac{\Delta y}{\Delta x}$

$a = \frac{17-10}{19-13}$

$= 1.17\ ms^{-2}$

c) deceleration at point CD

a = gradient of graph

$= \frac{\Delta y}{\Delta x}$

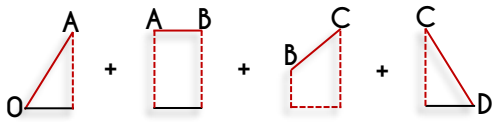
$a = \frac{0-17}{26-19}$

$= -2.43\ ms^{-2}$

d) Total distance travelled

Total distance = area under the graph

Divide the area into easier shapes



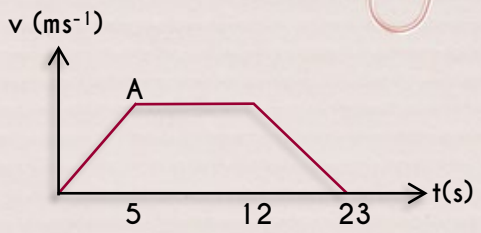
$= \left[\frac{1}{2}x10x8\right] + [10x5] + \left[\frac{10+17}{2}x6\right] + \left[\frac{1}{2}x17x7\right]$

$= 40 + 50 + 81 + 59.5$

$= 230.5\ m$

Practice Question 1

The graph below shows the velocity-time graph of an object.



Calculate:

a) The velocity at point A if its acceleration is 1.5 ms^{-2}.

b) The deceleration right before it stops.

c) The distance of the whole movement.

Ans: a) 7.5 ms^{-1} b) -1.25 ms^{-2} c) 112.5 m

Practice Question 2

A car starts from rest and accelerates at a constant acceleration of 2.3 ms^{-2} for 10 seconds. The car then travels at a constant velocity for 5 seconds. The brakes are then applied and the car stops in 8 seconds.

a) What is the maximum velocity of the car in this movement?

b) Plot the velocity – time graph for this movement.

c) Calculate the total distance travelled.

Ans: a) 23 ms^{-1} b) c) 322 m

Practice Question 3

A vehicle decelerates uniformly from 20 ms^{-1} to 10 ms^{-1} in a distance of 100 meters.

a) Sketch a velocity – time graph for this process.

b) Use the graph to determine the duration that is needed for the vehicle to slow down.

Ans: a) b) 6.67 s

Practice Question 4

A moving car initially decelerates from 30 ms^{-1} to 10 ms^{-1} in 10 seconds. The car then moves with uniform velocity for 7 seconds and finally accelerates for 5 seconds to reach a velocity of 25 ms^{-1}.

a) Sketch the velocity – time graph for this movement.

b) Calculate the acceleration of the car.

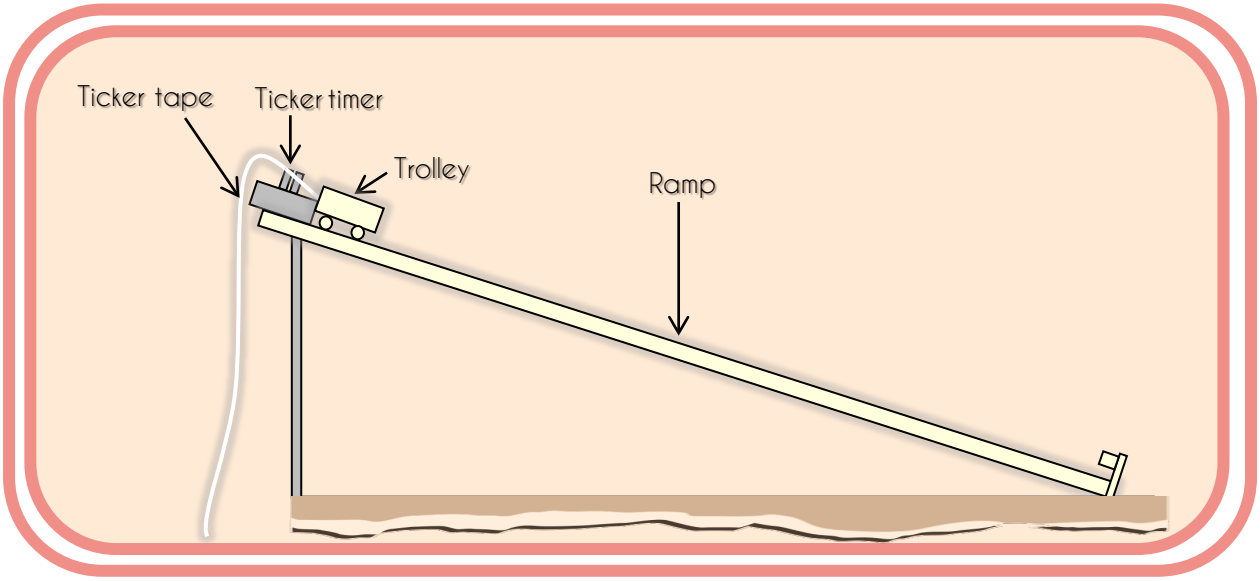
c) Calculate the deceleration of the car.

d) Calculate the total distance travelled for this whole journey.

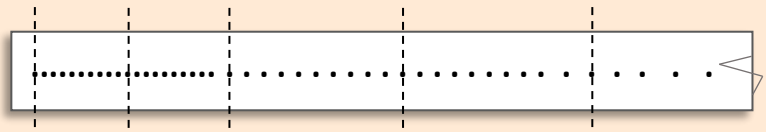
Ans: a) b) 3 ms^{-2} c) -2 ms^{-2} d) 357.5 m

2.3 EXPERIMENT RELATED TO LINEAR MOTION

- A common way to analyze the motion of an object is to use a ticker timer and a ticker tape.
- A ticker timer is usually connected to an alternating current (A.C) power supply.
- With a frequency of 50 Hz (hertz), it makes 50 dots per second on a ticker tape.



- By setting up the apparatus as illustrated above and perform the laboratory test, as a result, there will be several dots on the ticker tape.
- The time interval between two dots or 1 tick is 0.02 seconds.



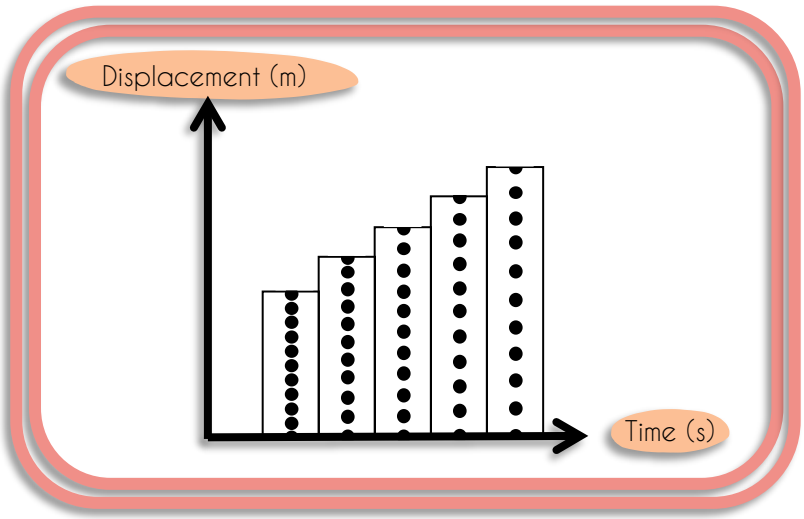
1 tick $= \frac{50Hz}{1\ second}$

$= 0.02$ s

So, 10 ticks = 0.2 s

- To analyze the motion of the trolley rolling down the ramp, a ticker tape is usually divided by a few strips, **each strip shows 10 ticks**.
- These strips will be arranged accordingly and it forms **a ticker tape chart**.

- From a ticker tape chart:
  - i. A Displacement vs Time chart can be formed.
  - ii. We can see that the distance between the dots increase with time.
  - iii. The length of the ticker tape strips increases uniformly.
  - iv. We can determine the displacement, velocity and acceleration of the trolley



1	Number of 10 dot strips	5
2	Total time, t_{total} = number of strips x 0.2	1 s
3	Total displacement of the trolley (total length of all strips)	0.85 m
4	Average velocity of the trolley $V = \frac{total\ displacement}{total\ time} = \frac{0.85}{1}$	0.85 m/s
5	Acceleration of the trolley	
	a. Initial velocity $u = \frac{length\ of\ first\ strip}{time\ for\ 10\ dots} = \frac{0.025}{0.2}$	0.125 m/s
	b. Final velocity $v = \frac{length\ of\ last\ strip}{time\ for\ 10\ dots} = \frac{0.226}{0.2}$	1.13 m/s
	c. Time for acceleration, t (number of strips – 1) x (time for 10 dots) = (5 – 1) x 0.2	0.8 s
	d. Acceleration $a = \frac{v-u}{t} = \frac{1.13 - 0.125}{0.8}$	1.256 m/s^2

EXERCISE

For more exercise on Linear Motion,
please scan the QR Code below:

CHAPTER 3

"FORCE"

Learning Objectives

Upon completion of this topic, students should be able to :

- ❑ Define force and its unit
- ❑ State the effect of force
- ❑ Differentiate between weight and mass
- ❑ Define Newton's Law
- ❑ Define force in equilibrium
- ❑ Calculate resultant force using resolution method
- ❑ Apply the concept of force in solving problems related to the equilibrium of forces
- ❑ Define moment of force and its unit
- ❑ Describe principle of moment of force
- ❑ Apply the concept and formula of moment of force in solving the related problems

WRITTEN BY:
MOHD SAIFUL BIN PAHRUDIN

3.1 Apply the concept of force

3.1.1 Define force and its units

FORCE

Definition(s)

- It is an action to push or pull , one objects on another object
- It is an action that alters the state of motion of a body in a straight line

Formula

F = m x a	F = force m = mass a = acceleration
W = m x g	W = weight m = mass g = gravity

*If the force acting on the object due to the gravity, it is known as **weight**.*

F = W = m x g

Unit

kg.m/s2 or Newton (N)

Physical Quantity

Derived quantity & Vector quantity

TIPS

A change of state of motion means a change in either the speed of an object or its direction of motion or both

3.1.2 Identify the type of force

Forces are classified as :

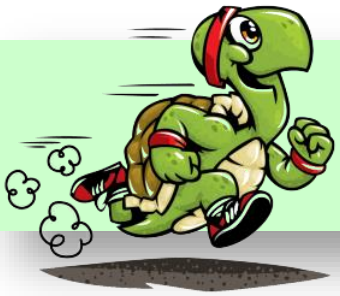
i. **Contact forces –** a force that can be applied only when it is in contact with an object

ii. **Non-contact forces –** a force that can be applied without any contact with two objects

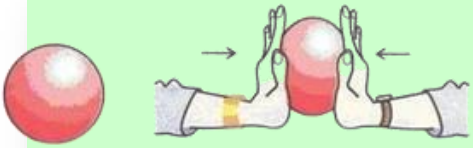
CONTACT FORCES	FRICTIONAL FORCE	the force exerted by a surface as an object moves across it or makes an effort to move across it
	TENSION FORCE	a force that is transmitted through a string, rope, cable or wire when it is pulled tight by forces acting from opposite ends.
	NORMAL FORCE	the support force exerted upon an object that is in contact with another stable object
	APPLIED FORCE	a force that is applied to an object by a person or another object
	SPRING FORCE	the force exerted by a compressed or stretched spring upon any object that is attached to it
	BUOYANT FORCE	this upward force exerted on objects submerged in fluids

NON-CONTACT FORCES	GRAVITATIONAL FORCE	the force with which the earth, moon, or other massively large object attracts another object towards itself. (Also known as WEIGHT)
	ELECTRICAL FORCE	the repulsive or attractive interaction between any two charged bodies
	MAGNETIC FORCE	attraction or repulsion that arises between electrically charged particles because of their motion

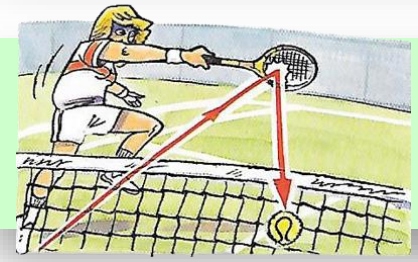
3.1.3 State the effect of the net force



change the speed of an object



change the shape of an object



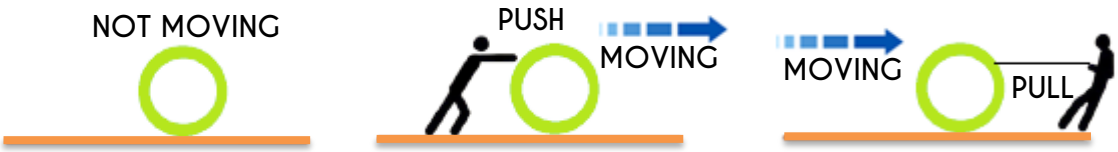
change the direction of motion of an object

can move a stationary object

can stop a moving object

3.1.4 Newton's Law

Newton's First Law



"An object at rest will remain at rest, forever, as long as nothing pushes or pulls it away. And an object in motion will remain in motion, travelling in a straight line, forever, until something pushes or pulls on it."

Newton's Second Law

"The force acting on an object is equal to the mass of that object tines its acceleration"

F (force) = **m** (mass) x **a** (acceleration)

Newton's Third Law

"For every action, there will be an equal and opposite reaction"

F(action) = **F**(reaction)

EXAMPLE 1

A motorcycle with a mass of 150kg accelerates at a rate of 30m/s^2. Calculate the force acting on the motorcycle.

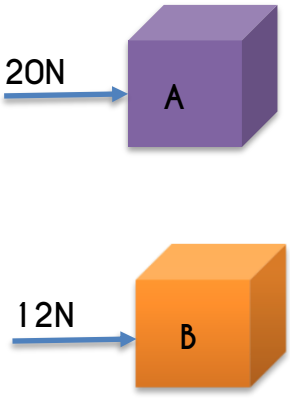
Answer:

m = 150 kg
a = 30m/s^2

$$F = m \times a$$
$$= (150) \times (30) = \mathbf{4500N}$$

EXAMPLE 2

Two value of forces is given to Box A and B respectively. It caused both boxes to move at the same acceleration at 2m/s^2. Find the value of mass for each box A and B. and caused both boxes to accelerate at 2m/s^2. IF the value of force and Find the value of mass for both box A and B.



Answer:

Box A
F = 20N
a = 2m/s^2

$$F = m \times a$$
$$m = \frac{F}{a}$$
$$m = \frac{20}{2} = \mathbf{10kg}$$

Box B
F = 12N
a = 2m/s^2

$$F = m \times a$$
$$m = \frac{F}{a}$$
$$m = \frac{12}{2} = \mathbf{6kg}$$

EXAMPLE 3

What is the net force required to accelerate $2x10^6$g of car at $5m/s^2$. (Neglect the friction force)

Answer:

m = $2x10^6$g = 2000kg
a = $5m/s^2$

$$F = m \times a$$
$$= (2000) \times (5) = \mathbf{10000N} = \mathbf{10kN}$$

EXAMPLE 4

A car is moving from it rest and gain a speed of 80km/hr in 60s. Given the mass of the car is $2.5x10^3$kg. Calculate:
i. Acceleration of the car.
ii. The nett force.

Answer:

i. v_f = 80km/hr , v_i = 0 (rest)
t = 60s

$$v_f = 80 \times 1000 \times \frac{1}{60} \times \frac{1}{60} = 22.2 \frac{m}{s}$$

$$a = \frac{(vf - vi)}{t} = \frac{(22.2 - 0)}{60} = \mathbf{0.37m/s2}$$

ii. m = $2.5x10^3$g = 2500kg
a = $0.37m/s^2$

$$F = m \times a$$
$$= (2500) \times (22.2)$$
$$= 55.5kN$$

TIPS

The state of **REST** is considered to be a state of **zero speed**

PRACTICE QUESTIONS 1

A girl pushes a table on a horizontal surface with a force of 45N. What is the acceleration of the table being pushed, if the mass of the table is 8kg?

Answer: 5.63m/s^2

PRACTICE QUESTIONS 2

A group of 3 boys run towards a 25kg cart, at rest. The force causes the cart to accelerate at 10m/s^2. Find the value of the force.

Answer: 250N

PRACTICE QUESTIONS 3

A customer pushes a trolley with a mass of 9kg with a constant acceleration of 3.2m/s^2. Calculate:

i. Force generated by the customer.
ii. The acceleration, if 15kg of items are loaded on the trolley, and the same value of force is applied.

Answer: i. 28.8N
ii. 1.2m/s^2

PRACTICE QUESTIONS 4

Given a mass of an object is 75kg.

i. What is the weight of the object.
ii. What is the weight of the object if it is placed on Mars. (Gravity of earth = 9.81m/s^2, Gravity of Mars = 3.721m/s^2)

Answer: i. 735.75N
ii. 279.08N

3.1.5 Describe between weight and mass

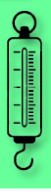
Mass

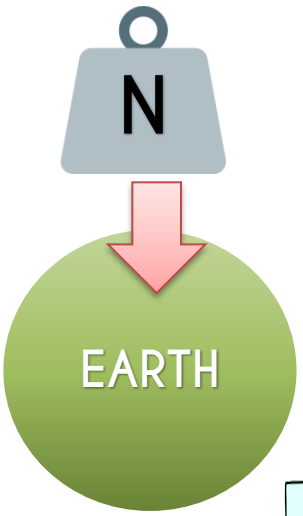
- a measure of how much matter there is in a body
- constant quantity and does not change of position or location

Weight

- the measure of the heaviness of an object
- variable quantity and change with the change in position and location due to the gravity

Differences between weight and mass

	MASS	 WEIGHT
Definition	A measure of how much matter there is in a body	The measure of the heaviness of an object
SI Unit	kilogram, kg	Newton, N
Symbol	mass, m	weight, W
Physical Quantities	Scalar Quantity Base Quantity	Vector Quantity Derive Quantity
Effect of Gravity	Not affected by gravity, and mass is always constant at any place and time	The weight of an object depends on the gravity at that particular place

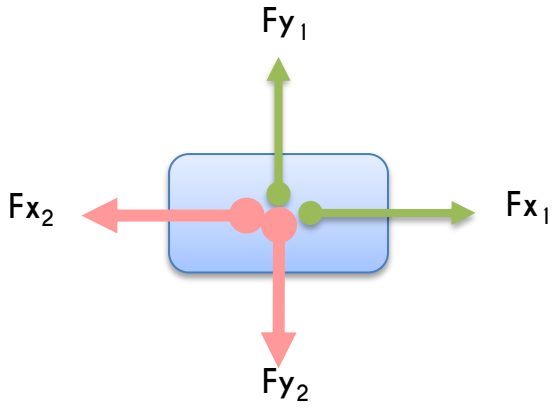


3.1.6 Define forces in equilibrium

BALANCED and UNBALANCED FORCES

- **BALANCED FORCES**
  - does not cause any change in motion
  - the net force acting on an object is ZERO ($F_{net} = 0$)

- **UNBALANCED FORCES**
  - always causes changes a change in motion
  - there is a value of net force acting on an object (F_R)

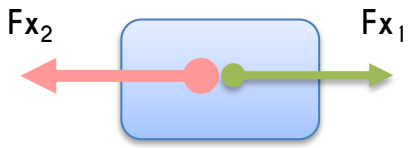
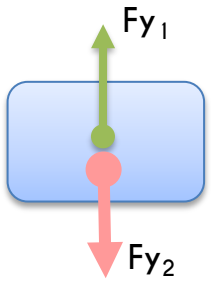


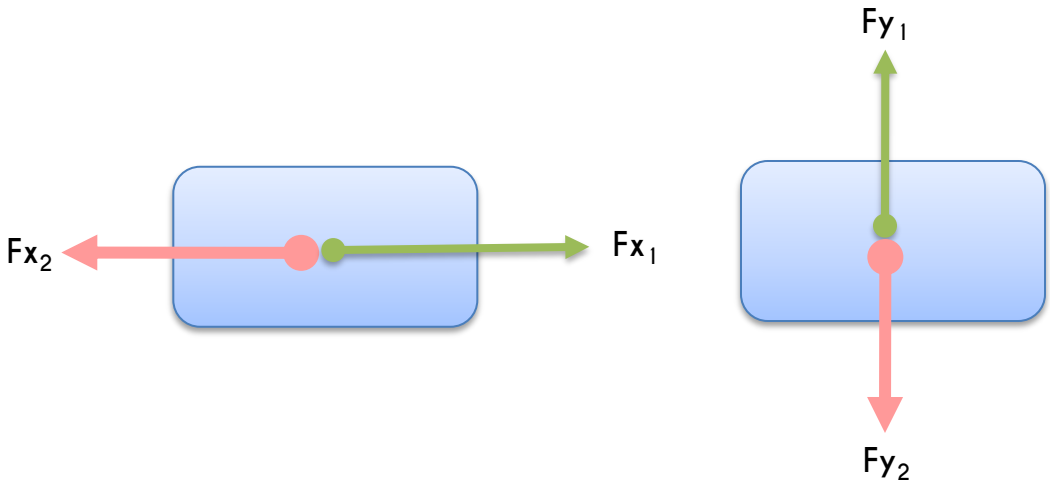
TIPS

A body is in **EQUILIBRIUM** if it does **NOT MOVE**

OBJECT IN EQUILIBRIUM

'The resultant/net force acting on an object is equal to ZERO'

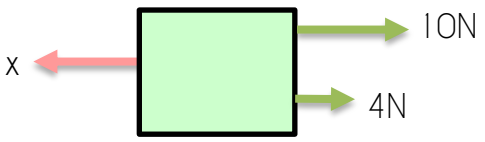
	Sum of all horizontal components of the forces is equal to zero Horizontal component Fx1 = Fx2 Therefore, Fx1 – Fx2 = 0
	Sum of all vertical components of the forces is equal to zero Vertical component Fy1 = Fy2 Therefore, Fy1 – Fy2 = 0



Horizontal component	Vertical component
Resultant Force, $F_R = Fx_1 - Fx_2 = 0$	Resultant Force, $F_R = Fy_1 - Fy_2 = 0$

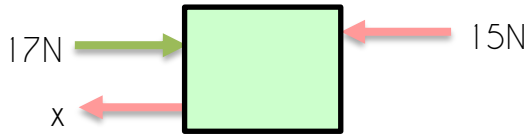
EXAMPLE

Calculate the value of 'x', if the box is in balanced condition.



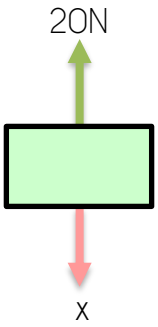
Answer:

$$F_R = Fx_1 - Fx_2 = 0$$
$$x - (10 + 4) = 0$$
$$x = 14N$$



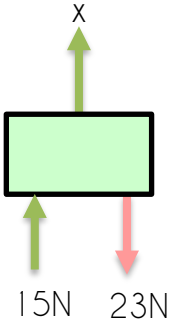
Answer:

$$F_R = Fx_1 - Fx_2 = 0$$
$$17 - (x + 15) = 0$$
$$x = 2N$$



Answer:

$$F_R = Fy_1 - Fy_2 = 0$$
$$20 - x = 0$$
$$x = 20N$$

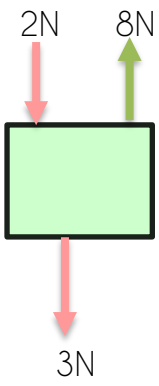


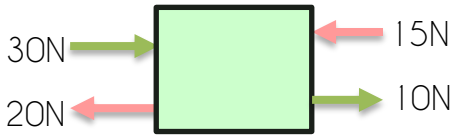
Answer:

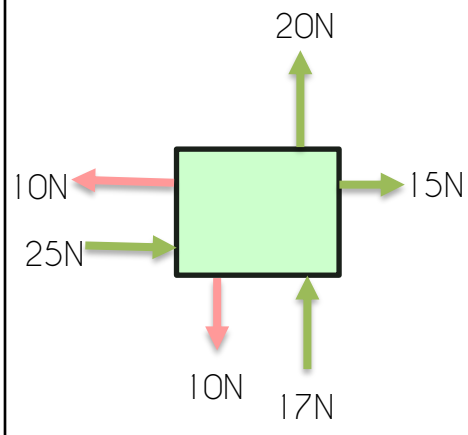
$$F_R = Fy_1 - Fy_2 = 0$$
$$(x + 15) - 23 = 0$$
$$x = 8N$$

EXAMPLE

Find the resultant forces

<table>
<tr>
<td> 
</td>
<td>F_R = F(upward) + F(downward)

$F_R = 8 + (-2) + (-3)$
$= 3N$ (upward)</td>
</tr>
<tr>
<td> 
</td>
<td>F_R = F(right) + F(left)

$F_R = 30 + 10 + (-15) + (-20)$
$= 5N$ (to the left)</td>
</tr>
<tr>
<td> 
</td>
<td>Vertical components

F_R = F(upward) + F(downward)

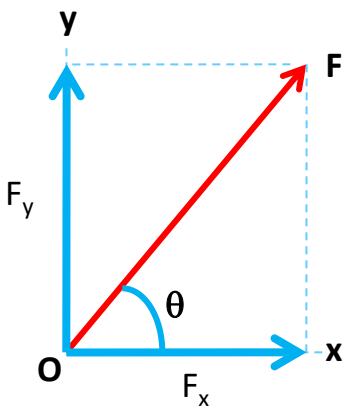
$F_R = 20 + 17 + (-10)$
$= 27N$ (upward)

Horizontal components

F_R = F(right) + F(left)

$F_R = 15 + 25 + (-10)$
$= 30N$ (to the right)</td>
</tr>
</table>

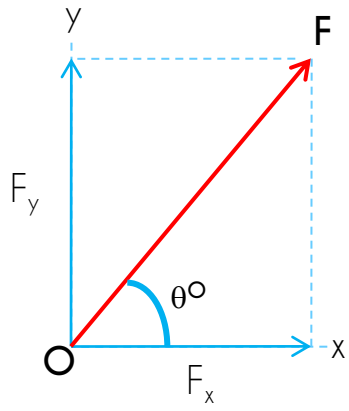
3.1.7 Calculate resultant force by using resolution method



Resultant force is a single force that can be resolved into two perpendicular components

F_x = Horizontal vector component
F_y = Vertical vector component
F = Resultant Force (The force, F at the angle of θ)

$F_x = F. \cos\theta$	$\cos\theta = F_x / F$
$F_y = F. \sin\theta$	$\cos\theta = F_y / F$



Horizontal component

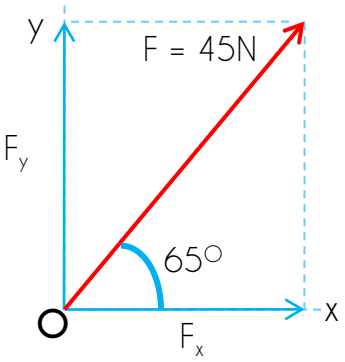
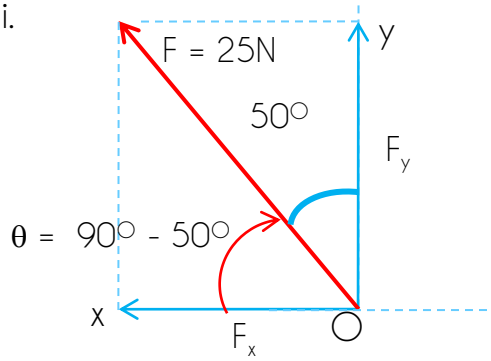
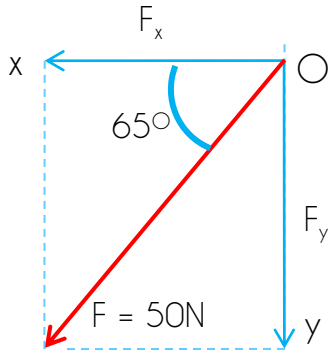
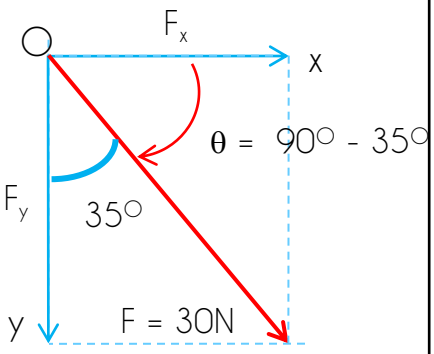
$F_x = F. \cos\theta$

Vertical component

$F_y = F. \sin\theta$

EXAMPLE

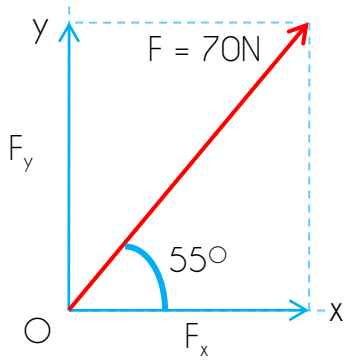
Find the components of force.

i. 	Horizontal component F_x = F. cosθ = (45) x cos 65 = 19.02 N Vertical component F_y = F. sinθ = (45) x sin 65 = 40.78 N
ii. 	Horizontal component - F_x = F. cosθ = - (25) x cos (90 - 50) = -19.2 N Vertical component F_y = F. sinθ = (25) x sin (90 – 50) = 16.06 N
iii. 	Horizontal component - F_x = F. cosθ = - (50) x cos (65) = - 21.1 N Vertical component - F_y = F. sinθ = - (50) x sin (65) = -45.3 N
iv. 	Horizontal component F_x = F. cosθ = (30) x cos (90 - 35) = 17.21 N Vertical component - F_y = F. sinθ = - (30) x sin (90 – 35) = - 24.57 N

PRACTICE QUESTIONS

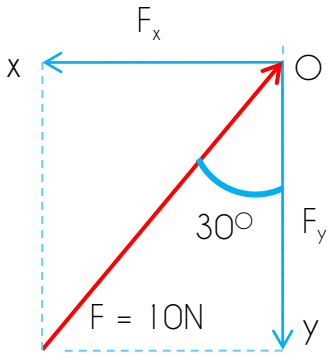
Find the components of force.

i.



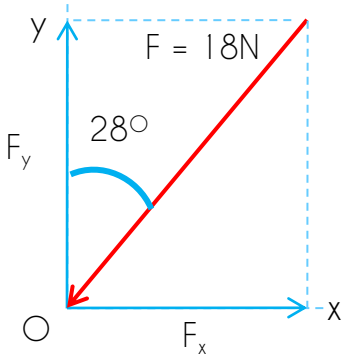
Answer: Fx = 40.15N
Fy = 57.34N

ii.



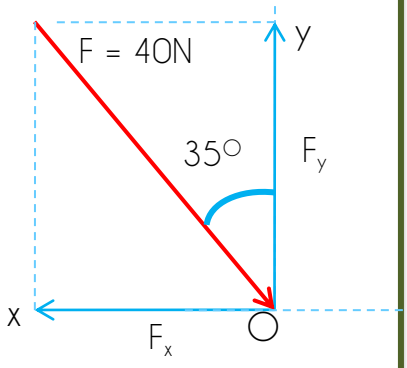
Answer: Fx = 5N
Fy = 8.66N

iii.



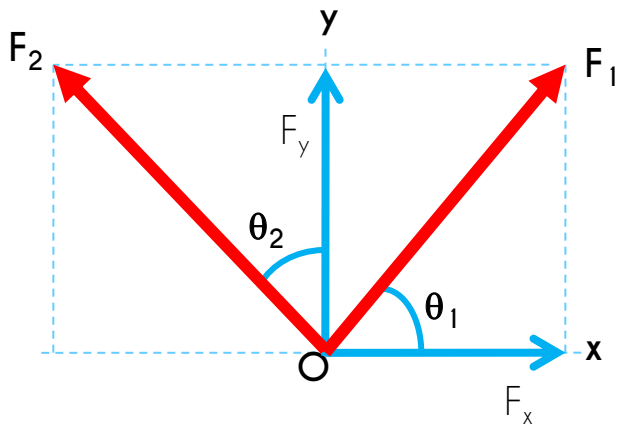
Answer: Fx = - 8.45N
Fy = -15.89N

iv.



Answer: Fx = 22.94N
Fy = 32.77N

3.1.8 Apply the concept of force in solving problems related to equilibrium of forces



Resultant force is a single force that represents the combination of two or more force by taking into account both magnitude and direction of each particular forces.

F_{x1} = Horizontal vector component 1
F_{y1} = Vertical vector component 1
F_1 = Resultant Force for component 1
F_{x2} = Horizontal vector component 2
F_{y2} = Vertical vector component 2
F_2 = Resultant Force for component 2

F_R is the symbol representing the resultant force.

To find the resultant force and the direction,

$F_R = \sqrt{F_{x1}{}^2 + F_{x2}{}^2}$	$\tan\theta = \frac{F_{x2}}{F_{x1}}$

TIPS

To find the angle **θ**

O° is measured from x-axis (reference angle)

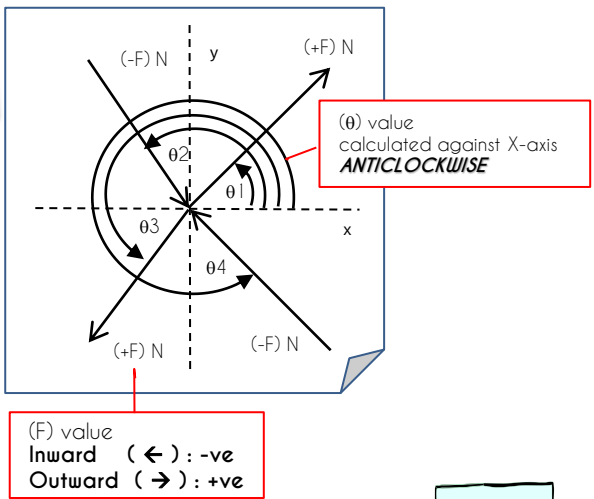
TIPS

Sum of Fx and Fy

ΣFx = Fx1 + Fx2 +... + Fn

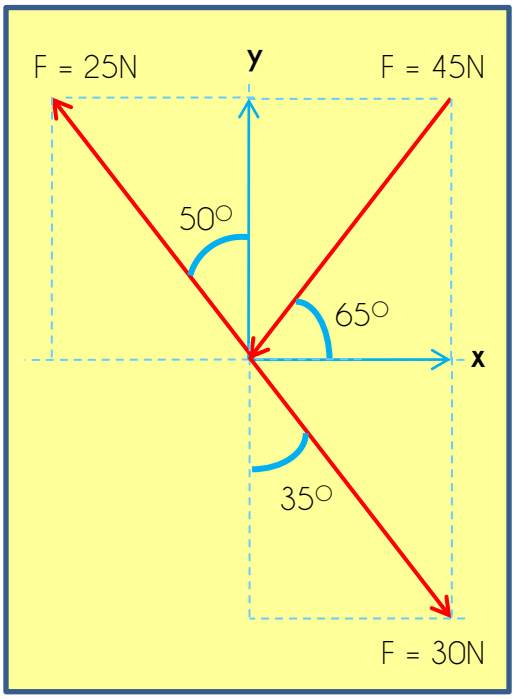
ΣFy = Fy1 + Fy2 +... + Fn

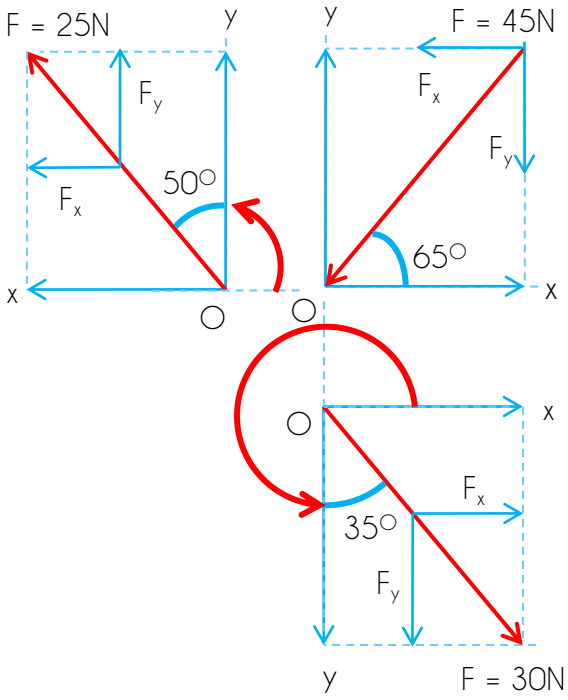
Important Information



EXAMPLE 1

Find the magnitude and direction of the resultant force.





Answer :

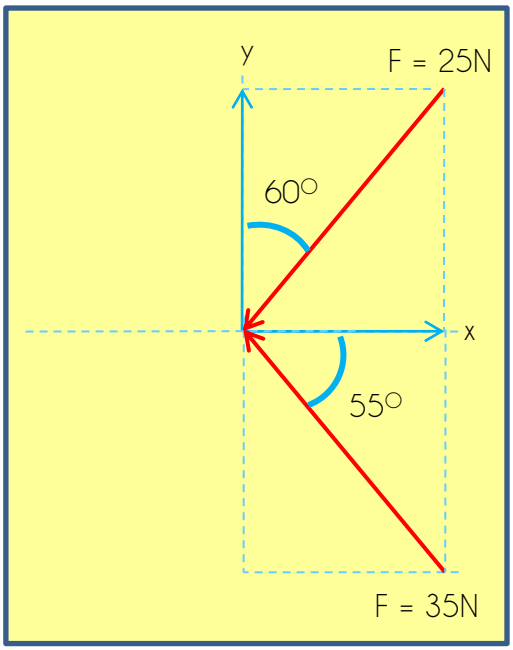
F	θ	F_X = F. cos θ	F_Y = F. sin θ
- 45	65	-19.02N	-40.78N
25	50 + 90 = 140	-19.15N	16.07N
30	270 + 35 = 305	17.21N	-24.57N
		ΣF_x = -20.96N	**ΣF_y = -49.28N**

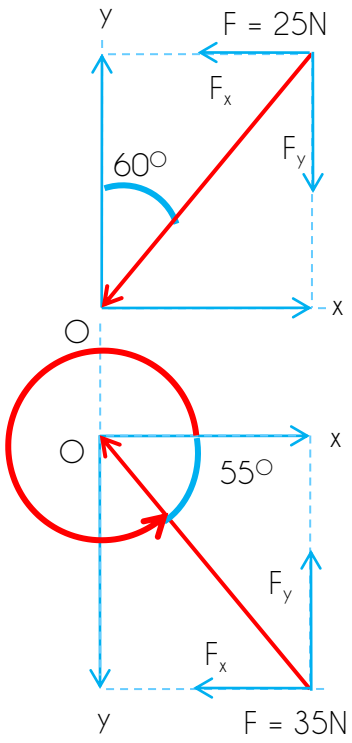
$$F_R = \sqrt{(-20.96)^2 + (-49.28)^2}$$
$$= 53.55\ N$$

$$\theta = \tan^{-1}\frac{(-49.28)}{(-20.96)}$$
$$= 66.96^0$$

EXAMPLE 2

Find the magnitude and direction of the resultant force.





Answer :

F	θ	F_X = F. cos θ	F_Y = F. sin θ
- 25	90 – 60 = 30	-21.65N	-12.5N
- 35	360 – 55 = 305	-20.08N	28.67N
		ΣF_x = - 41.73N	**ΣF_y = 16.17N**

$$F_R = \sqrt{(-41.73)^2 + (16.17)^2}$$

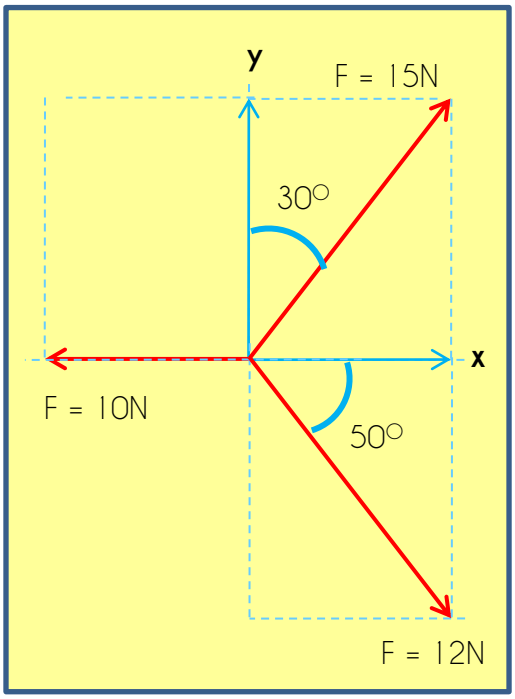
$$= 44.75\ N$$

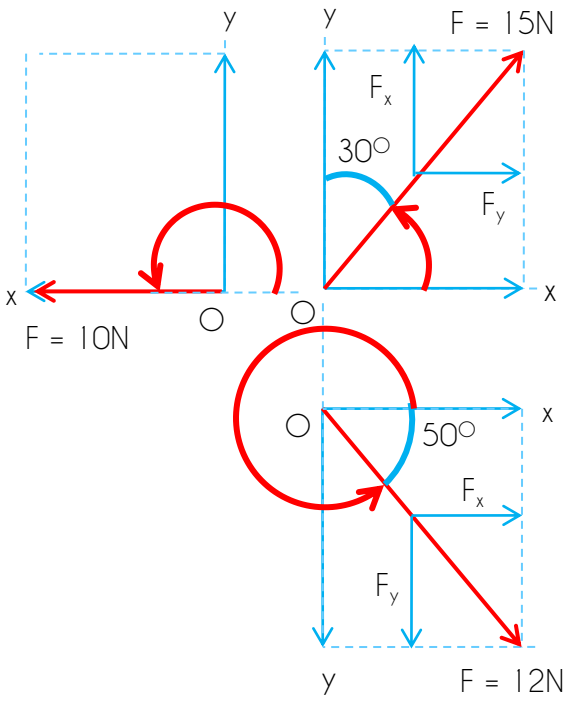
$$\theta = \tan^{-1}\frac{(16.17)}{(-41.73)}$$

$$= -21.18^0$$

EXAMPLE 3

Find the magnitude and direction of the resultant force.





Answer :

F	θ	F_X = F. cos θ	F_Y = F. sin θ
15	90 – 30 = 60	7.5N	12.99N
10	180	-10N	0
12	360 – 50 = 310	7.71N	-9.19N
		ΣF_x = 5.21N	**ΣF_y = 3.8N**

$$F_R = \sqrt{(5.21)^2 + (3.8)^2}$$

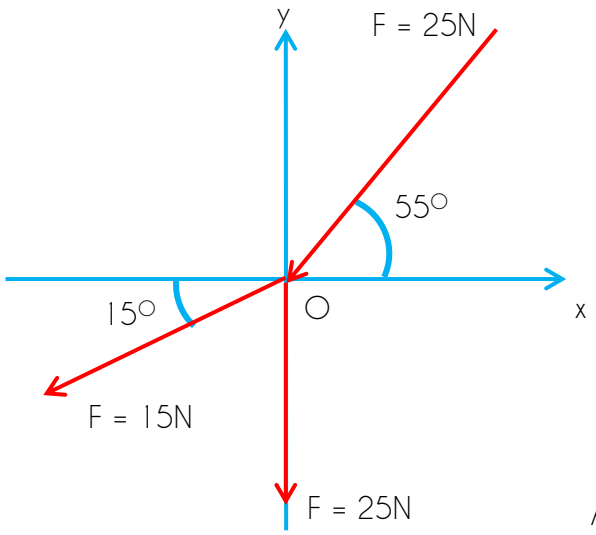
$$= 6.45\ N$$

$$\theta = \tan^{-1}\frac{(3.8)}{(5.21)}$$

$$= 36.12^o$$

PRACTICE QUESTION 1

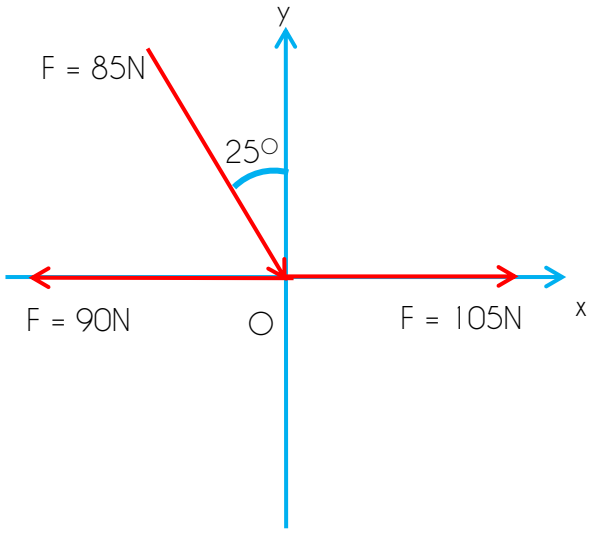
Find the magnitude and direction of the resultant force.



Answer: $F_R = 57.16\ N$
$\theta = 59.71^o$

PRACTICE QUESTION 2

Determine the resultant force and its direction.



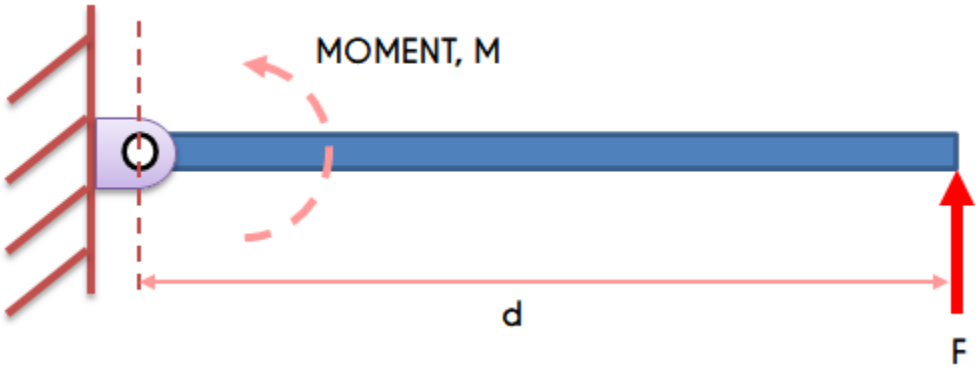
Answer: $F_R = 92.35\ N$
$\theta = -56.54^o$

3.2 Apply the concept of moment of force

3.2.1 Define moment of force and its unit

MOMENT

- a turning effect produced by a force acting at a distance on an object
- can be expressed as the product of the force and the distance from its line of action to a given point.



The magnitude of a moment can be calculated using the equation:

M(Moment) = **F**(Force) **x d**(distance)

This is when:

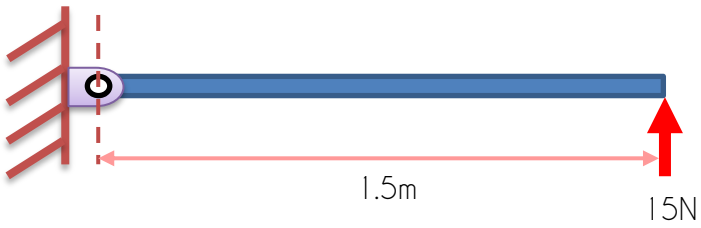
- moment (M) is measured in **newton-metres (Nm)**
- force (F) is measured in **newtons (N)**
- distance (d) is measured in **metres (m)**

NOTE

It is important to remember that the distance (d) is the perpendicular distance from the pivot to the line of action of the force

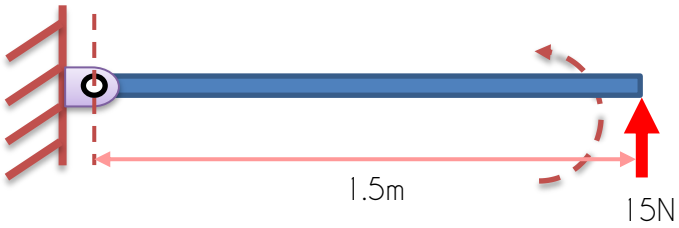
EXAMPLE 1

Calculate the moment acting on the pivot.



Answer:

The force acting on the beam causing the moment COUNTER-CLOCKWISE:



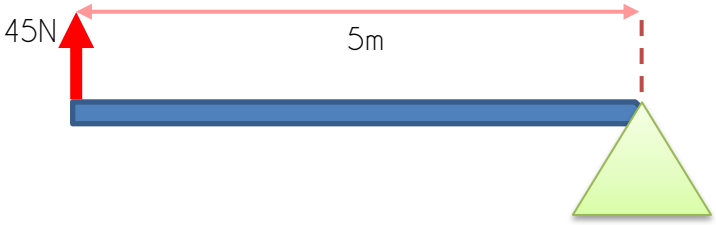
F = 15N
d = 1.5m

Moment, M = F x d

$= 15 \times 1.5 = \mathbf{22.5Nm}$ COUNTERCLOCKWISE

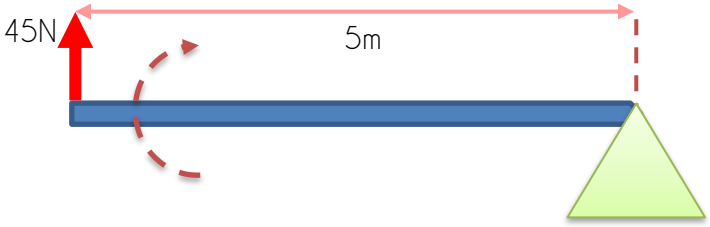
EXAMPLE 2

Calculate the moment acting on the pivot.



Answer:

The force acting on the beam causing the moment CLOCKWISE:



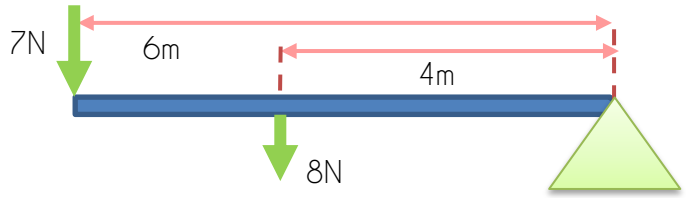
F = 45N
d = 5m

Moment, M = F x d

$= 45 \times 5 = \mathbf{225Nm}$ CLOCKWISE

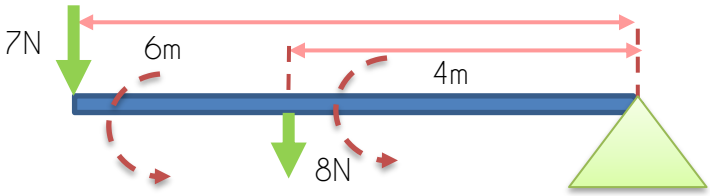
EXAMPLE 3

Calculate the moment acting on the pivot.



Answer:

The overall force acting on the beam causing the moment COUNTER-CLOCKWISE:

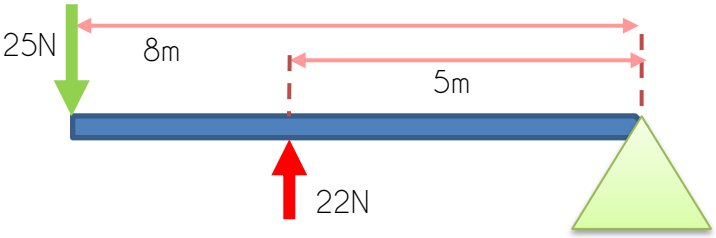


Moment, $M = (F_1 \times d_1) + (F_2 \times d_2)$

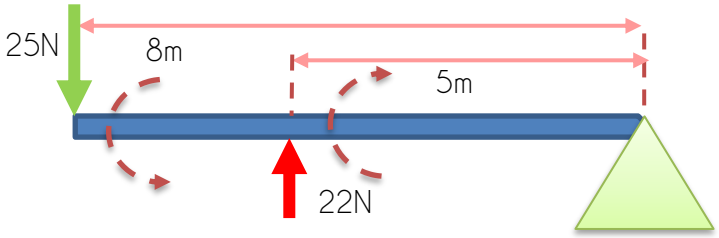
$= (7 \times 6) + (8 \times 4) = \mathbf{74Nm}$ **COUNTERCLOCKWISE**

EXAMPLE 4

Calculate the moment acting on the pivot.



Answer:



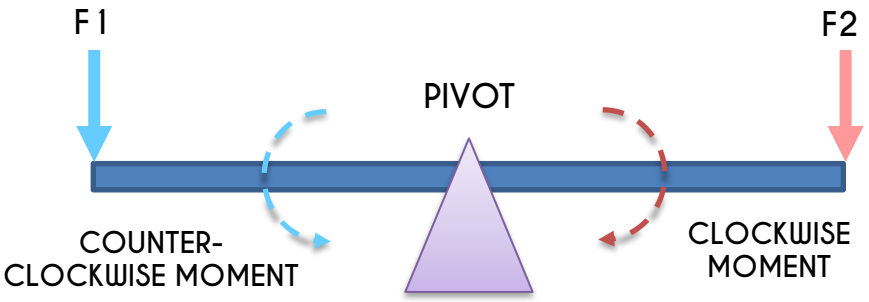
Moment, $M = (F_1 \times d_1) + (F_2 \times d_2)$

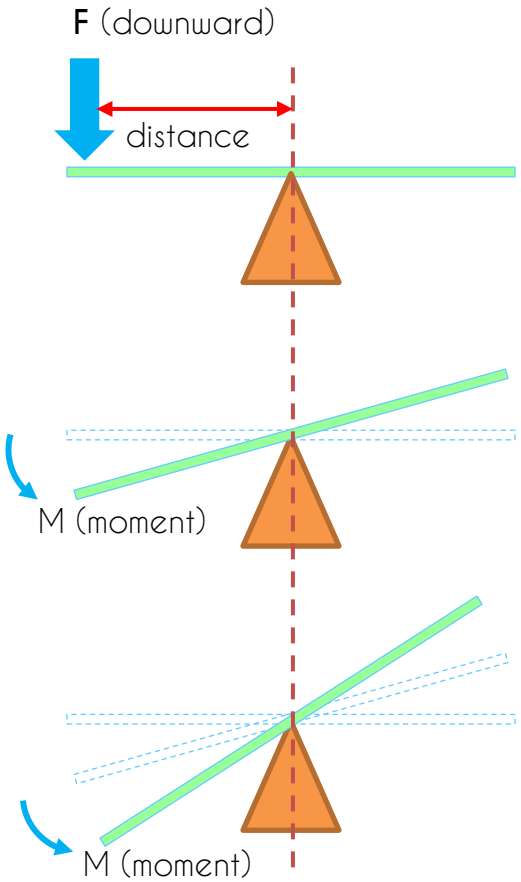
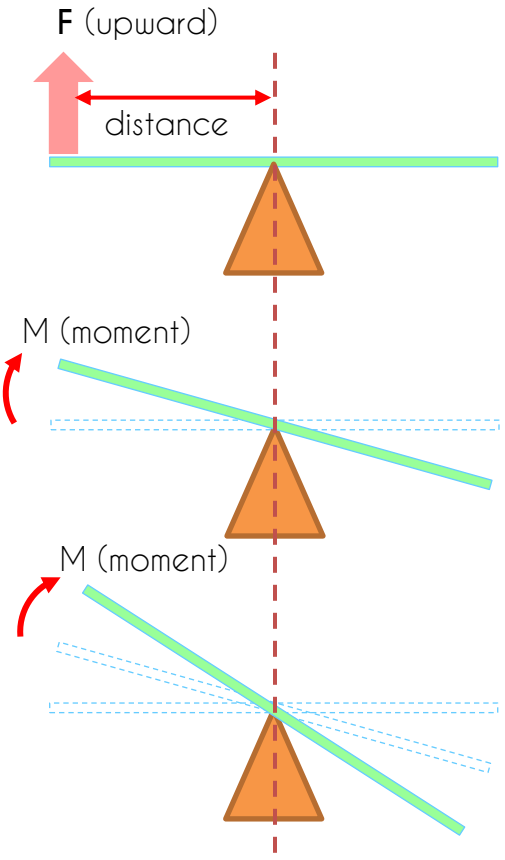
Moment, $M = M_{CCW} + M_{CW}$

$= (25 \times 8) + (-22 \times 5) = \mathbf{90Nm}$

3.2.2 Describe principle of moment of force

MOMENT OF FORCE is a measure of its tendency to cause a body to rotate about a specific point or pivot.



COUNTER-CLOCKWISE MOMENT	CLOCKWISE MOMENT
	

PRINCIPLE MOMENT OF FORCE states that the moment of any force is equal to the sum of the moments of the components of that force

Total applied force, F (upward force) ⇧ **= Total reaction force, F (downward force)** ⇩

Furthermore, if a body is in equilibrium, the sum of the clockwise moments is equal to the sum of the anticlockwise moments

Sum of moment counter-clockwise, M_{CCW} ↺ **= Sum of moment clockwise, M_{CW}** ↻

NOTE

The principle of moment of force is used to solve :
- Determining the centre of gravity
- Finding the reaction force
- Determining the distance of the reaction force

3.2.3 Apply the concept and formula of moment of force in solving the related problem

There are **TWO (2)** methods of solving problems:

1. Moment of force (Force moment)
2. Resultant moment of force

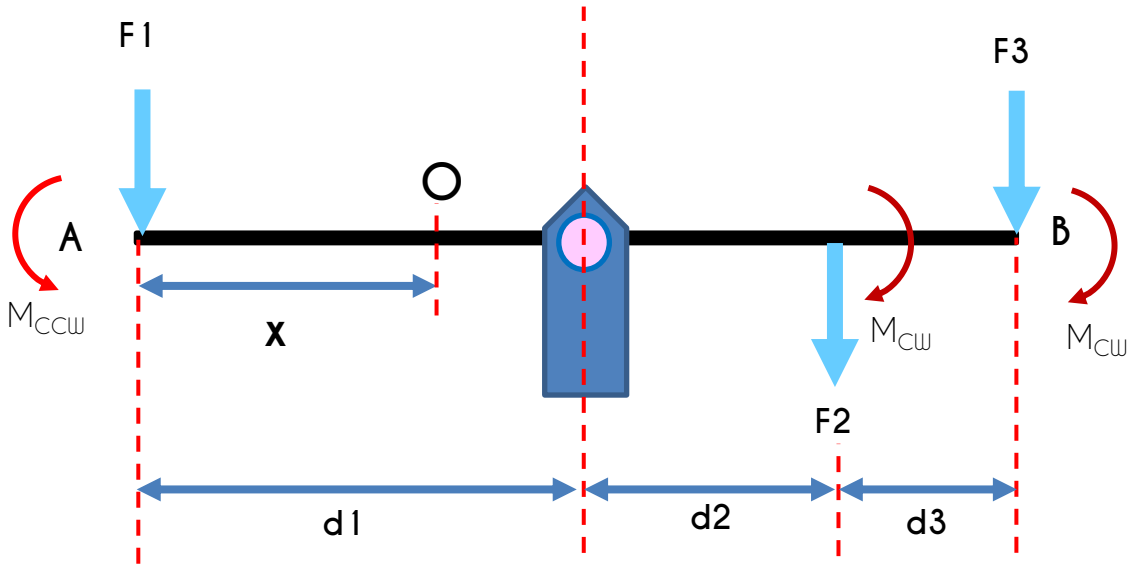
Moment of force (Force moment)

For an object to be in equilibrium,

Sum of moment counter-clockwise, M_{CCW} = Sum of moment clockwise, M_{CW}

To solve the problems :

1. Identify the forces that will cause the clockwise and counter-clockwise moments
2. Find the clockwise and counter-clockwise moments
3. Placed any point on the beam as the pivot of the system (if it is not given)
4. Equate the clockwise and counter-clockwise moments to solve the problems



Assume the position of the centre of gravity is at Y from end A with length of x.

SUM OF MOMENT CLOCKWISE = SUM OF MOMENT COUNTER-CLOCKWISE

$$F2\big((d1+d2)-x\big)+F3\big((d1+d2+d3)-x\big) = (F1)(x)$$

$$(F2)(d1)+(F2)(d2)-(F2)(x)+(F3)(d1)+(F3)(d2)+(F3)(d3)-(F3)(x) = (F1)(x)$$

$$(F2)(x)+(F3)(x)+(F1)(x) = (F2)(d1)+(F2)(d2)+(F3)(d1)+(F3)(d2)+(F3)(d3)$$

$$x = \frac{[(F2)(d1)+(F2)(d2)+(F3)(d1)+(F3)(d2)+(F3)(d3)]}{F2+F3+F1}$$

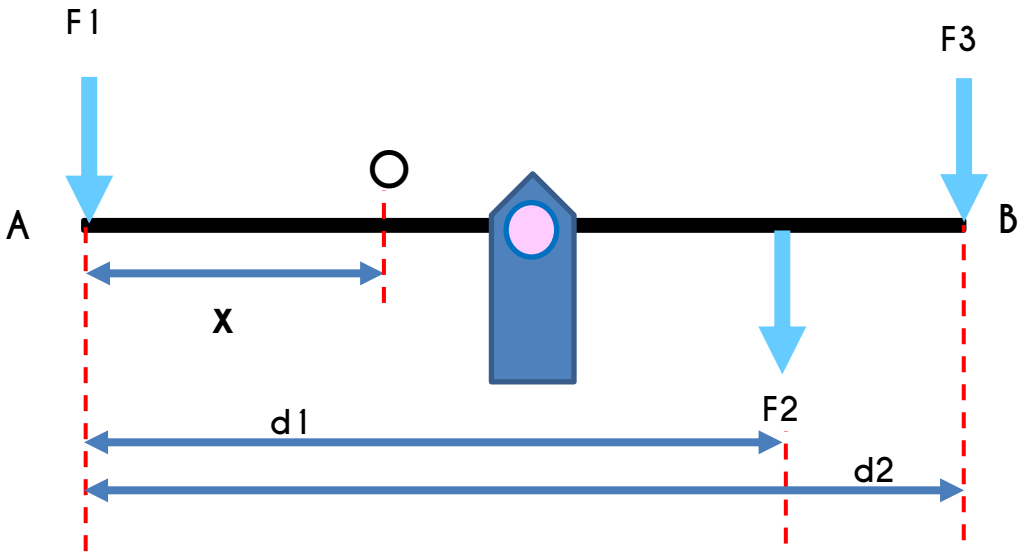
Resultant moment of force

For an object to be in equilibrium,

Resultant moment of force = sum of moment of a force action

To solve the problems :

1. Placed any point on the beam as the centre of gravity(if it is not given) and assume any end of the beam as the pivot
2. Identify upward and downward forces applied
3. Identify the forces that will cause the clockwise and anticlockwise moments
4. Find the resultant moment of force
5. Find the sum of moment of force action
6. Equate the resultant moment of force and the sum of moment of force to solve for the centre of gravity.



Assume the position of the centre of gravity is at Y from end A with length of x (A as the pivot).

RESULTANT MOMENT , $M_R = (F1 + F2 + F3)(x)$

SUM OF MOMENT OF FORCE , $\sum M = (F1)(d0) + (F2)(d0 + d1) + F3)(d0 + d1 + d2)$

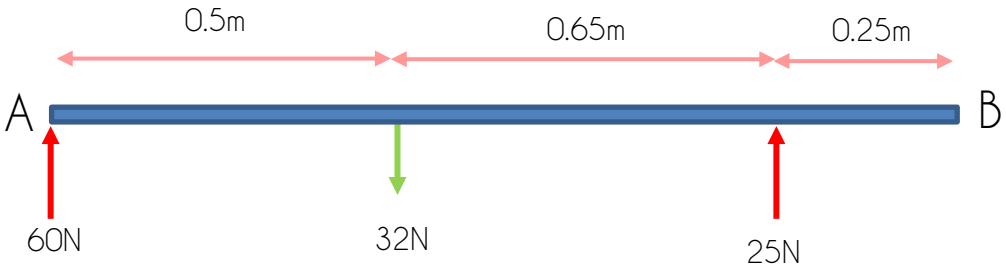
RESULTANT MOMENT , M_R = SUM OF MOMENT OF FORCE , $\sum M$

$(F1 + F2 + F3)(x) = (F1)(d0) + (F2)(d0 + d1) + F3)(d0 + d1 + d2)$

$$x = \frac{[(F1)(d0) + (F2)(d0 + d1) + F3)(d0 + d1 + d2)]}{(F1 + F2 + F3)}$$

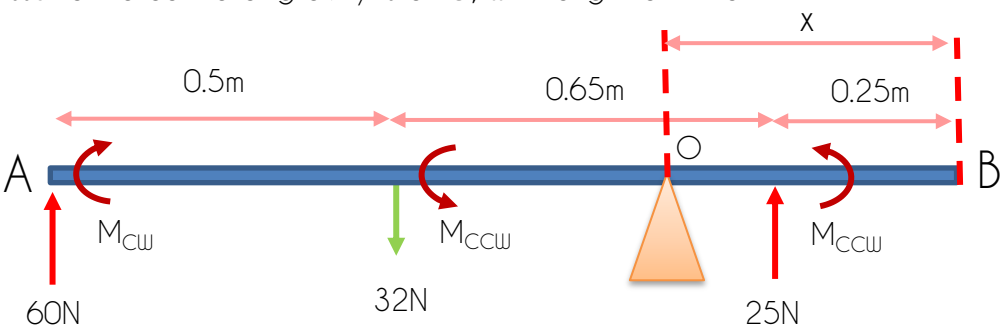
EXAMPLE 1

Find the centre of gravity of the bar, to make sure it is in equilibrium by using *moment of force.*



Answer:

Assume the centre of gravity is at O, with length of 'x' from B



Moment of force (Force moment)

TOTAL CLOCKWISE MOMENT = TOTAL COUNTER-CLOCKWISE MOMENT

$$60((0.5 + 0.65 + 0.25) - x) = 32((0.65 + 0.25) - x) + (25(x - 0.25))$$

$$84 - 60x = 28.8 - 32x + 25x - 6.25$$

$$32x - 60x - 25x = 28.8 - 84 - 6.25$$

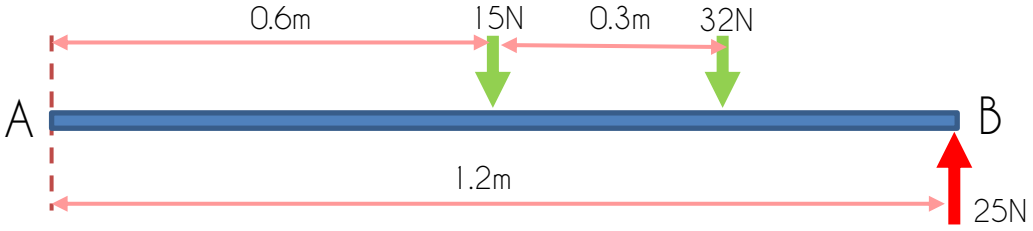
$$x = \frac{-61.45}{-53} = \mathbf{1.16m\ \ from\ B}$$

TIPS

Centre of gravity of a beam.
If you calculate from end A, and calculate from end B. You can add both lengths from the end A and B, to get the total length of a beam.

EXAMPLE 2

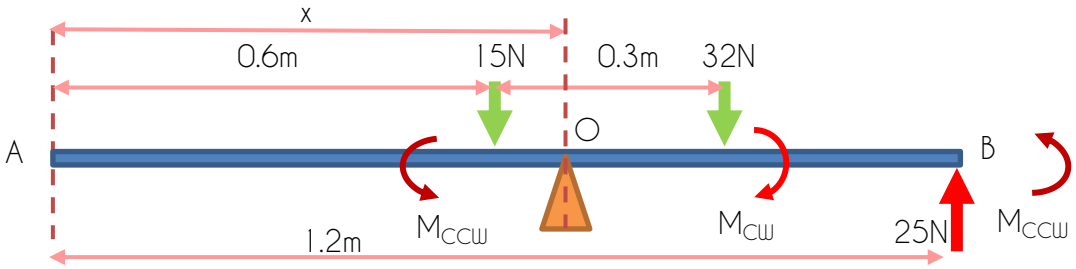
Find the centre of gravity of the bar, to make sure it is in equilibrium by using *moment of force* and *resultant moment of force*.



Answer:

Moment of force (Force moment)

Assume the centre of gravity is at O, with length of 'x' from A



TOTAL CLOCKWISE MOMENT = TOTAL ANTICLOCKWISE MOMENT

$$32((0.3 + 0.6) - x) = (15(x - 0.6)) + (25(1.2 - x))$$

$$28.8 - 32x = 15x - 9 + 30 - 25x$$

$$-32x - 15x + 25x = -28.8 - 9 + 30$$

$$x = \frac{-7.8}{-22} = \mathbf{0.35m\ from\ A}$$

Resultant moment of force

Assume the centre of gravity is at O, from A

RESULTANT MOMENT , $M_R = (15 + 32 + (-25))(x)$

SUM OF MOMENT OF FORCE , $\sum M = (15)(0.6) + (32)(0.6 + 0.3) + (25)(1.2)$

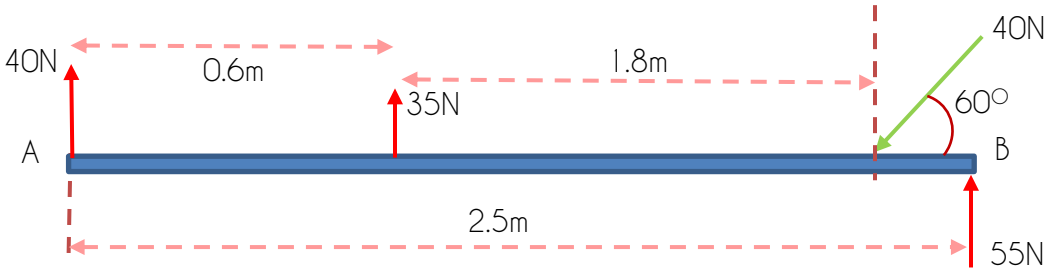
RESULTANT MOMENT , M_R = SUM OF MOMENT OF FORCE , $\sum M$

$$(15 + 32 + (-25))(x) = (15)(0.6) + (32)(0.6 + 0.3) + (-25)(1.2)$$

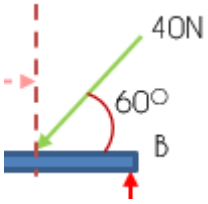
$$x = \frac{7.8}{22} = \mathbf{0.35m\ from\ A}$$

EXAMPLE 3

Find the centre of gravity of the bar, to make sure it is in equilibrium by using *moment of force* and *resultant moment of force*.

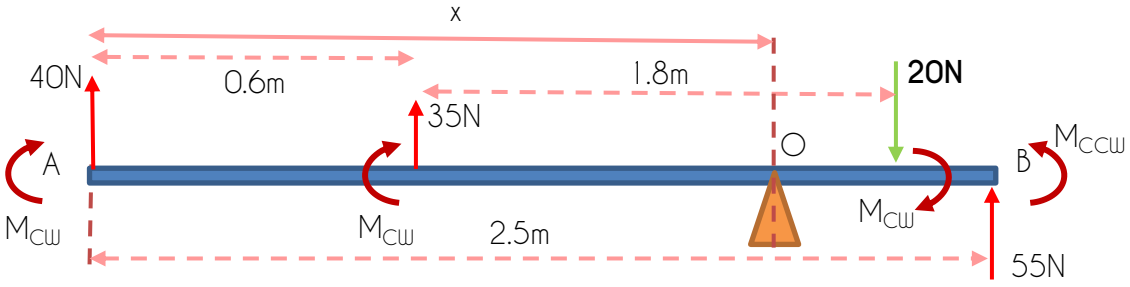


Answer:



$$Fx = F.\cos\theta$$
$$= (40).\cos 60 = 20N$$

Assume the centre of gravity is at O, with length of 'x' from A



Moment of force (Force moment)

TOTAL CLOCKWISE MOMENT = TOTAL ANTICLOCKWISE MOMENT

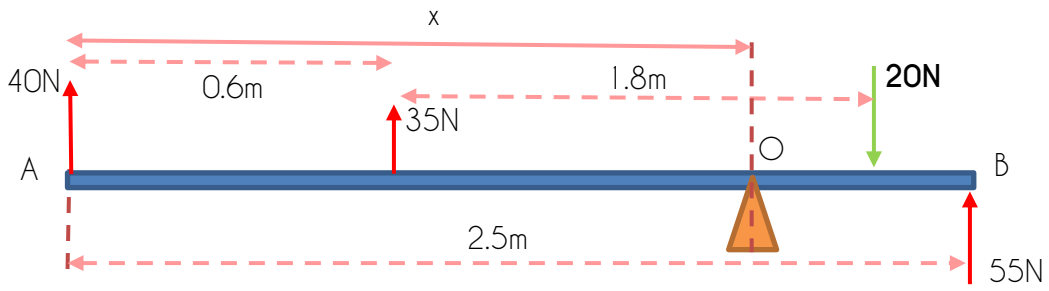
$40(x) + 35(x - 0.6) + 20((1.8 + 0.6) - x) = 55(2.5 - x)$

$40(x) + 35x - 21 + 48 - 20x = 137.5 - 55x$

$40x + 35x - 20x + 55x = 21 + 48 + 137.5$

$x = \frac{110.5}{110} = \mathbf{1.00m\ \ from A}$

Assume the centre of gravity is at O, with length of 'x' from A



Resultant moment of force

RESULTANT MOMENT , $M_R = (-40 + 35 + (-20) + 55)(x)$

SUM OF MOMENT OF FORCE , $\sum M = (40)(0) + (35)(0.6) + (-20)(1.8 + 0.6) + (55)(2.5)$

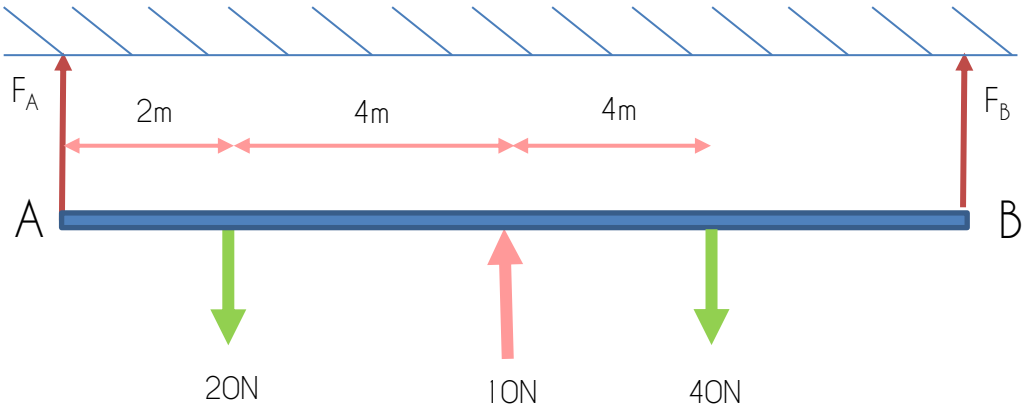
RESULTANT MOMENT , $M_R =$ SUM OF MOMENT OF FORCE , $\sum M$

$(40 + 35 + (-20) + 55)(x) = (40)(0) + (35)(0.6) + (-20)(1.8 + 0.6) + (55)(2.5)$

$$x = \frac{110.5}{110} = \mathbf{1.00\,m\ from\ A}$$

EXAMPLE 4

Given the length of the beam is 13m. Calculate the reaction forces in both of the supporter.



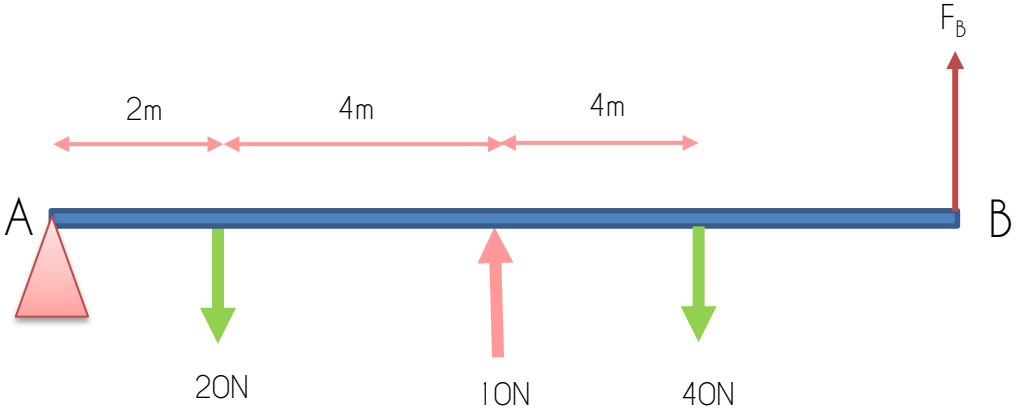
Answer:

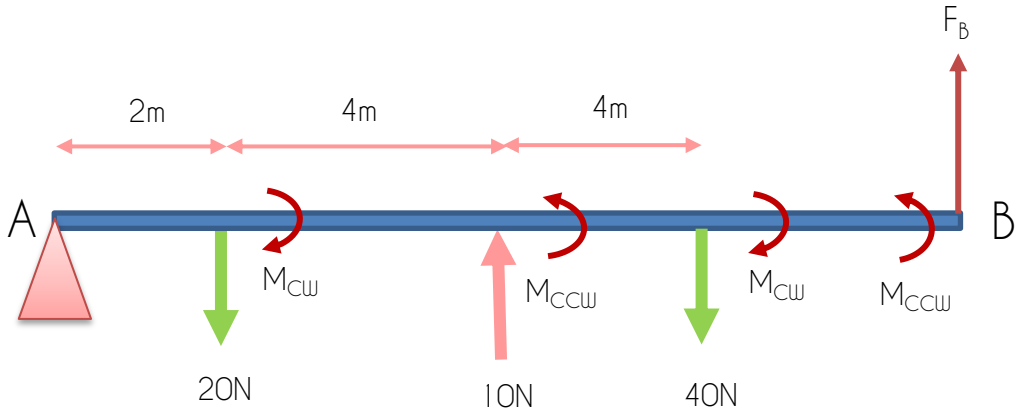
From the Principle Moment of force, $\sum F(upward) = \sum F(downward)$

$$F_A + F_B + 10 = 20 + 40$$

$$F_A + F_B = 20 + 40 - 10 = 50N$$

Let one of the supporters as the pivot, for example point F_A at A.





TOTAL CLOCKWISE MOMENT = TOTAL COUNTER-CLOCKWISE MOMENT

$$20(2) + 40(4 + 4 + 2) = 10(4 + 2) + F_B(13)$$

$$F_B = \frac{380}{13} = 29.23 \text{ N}$$

Answer:

From the Principle Moment of force, $\sum F(upward) = \sum F(downward)$

$$F_A + F_B = 50N$$

Let F_B = 29.23N

$$F_A + 29.23 = 50N$$

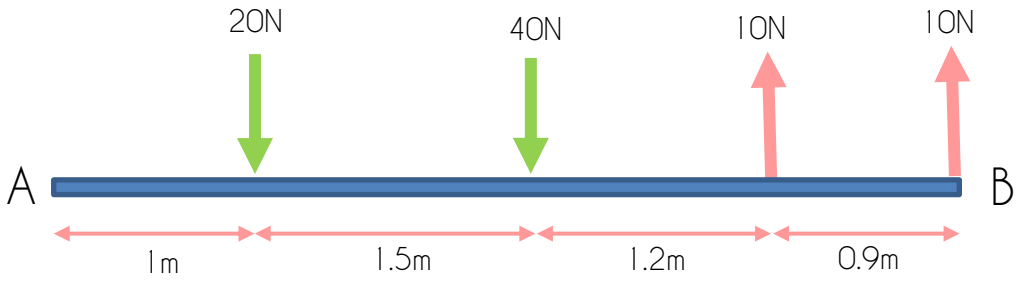
$$F_A = 50 - 29.23 = 20.77 \text{ N}$$

$$F_A = \mathbf{20.77\,N}$$

$$F_B = \mathbf{29.23\,N}$$

PRACTICE QUESTION 1

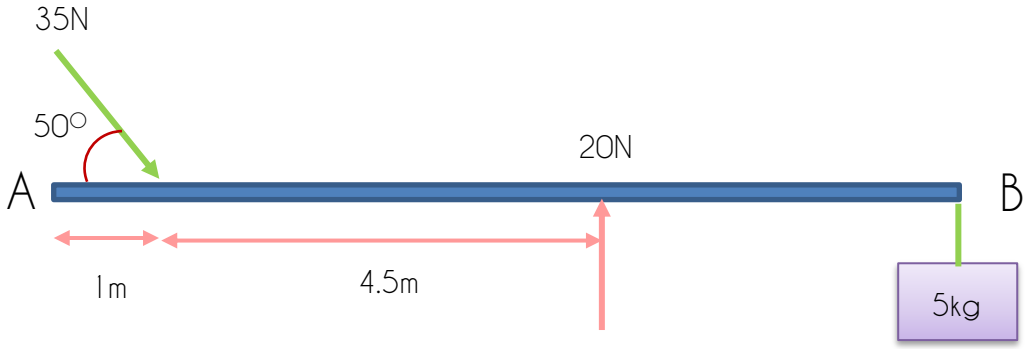
Find the centre of gravity from end B, by assuming the bar is in equilibrium state by using *moment of force* and *resultant moment of force*.



Answer: $x = 0.925m\ from\ left$

PRACTICE QUESTION 2

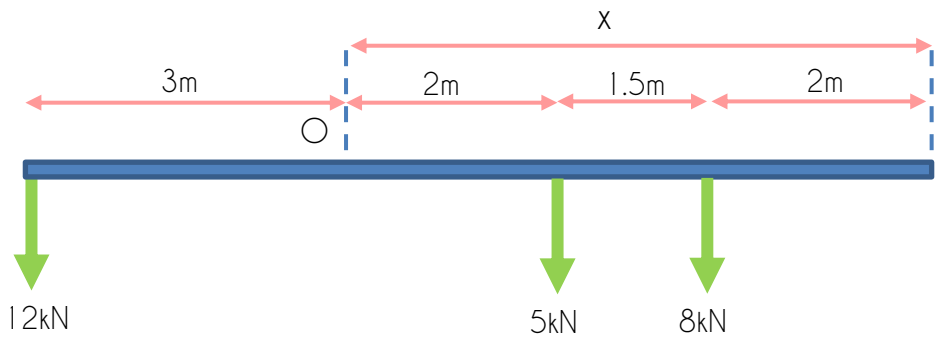
Find the centre of gravity of the bar, to make sure it is in equilibrium by using *moment of force* and *resultant moment of force*. Given the total length of the bar is 8.5m.



Answer: $x = 6.39m\ from\ left$

PRACTICE QUESTION 3

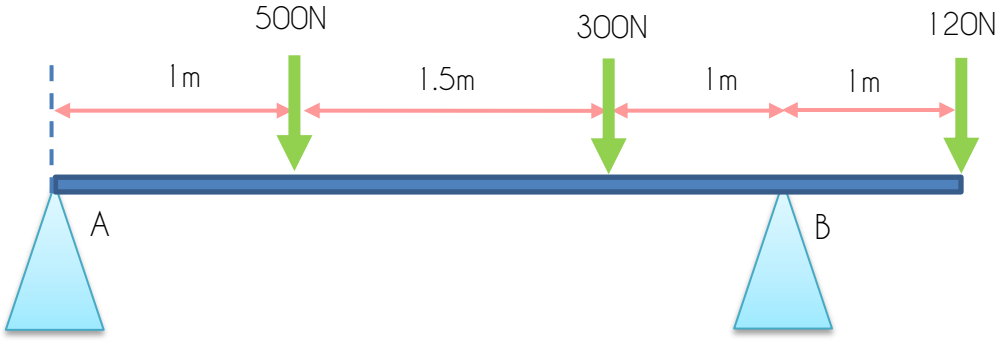
Calculate the centre of gravity, 'x', so that the beam is in equilibrium by using *moment of force* method.



Answer: $x = 5.42$

PRACTICE QUESTION 4

Find the value of force at point A and B for the beam, if the system is in equilibrium.



Answer: $F_A = 408.57N$
$FB = 511.43N$

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