KEMENTERIAN PENGAJIAN TINGGI

POLITEKNIK MALAYSIA

KOLEJ KOMUNITI MALAYSIA

ENGINEERING SCIENCE

PENULIS:

ZAKIAH BT ADZMI

MATEMATIK SAINS DAN KOMPUTER

PENGHARGAAN

Alhamdulillah, puji dan syukur kehadrat Ilahi, kerana dengan izin dan limpah kurnia-Nya, eBook ini telah berjaya dihasilkan dan diterbitkan seperti yang telah dirancang.

Ebook Engineering Science ini dihasilkan bagi memudahkan pensyarah serta pelajar yang mengambil kursus Engineering Science untuk mengikuti kursus ini secara berstruktur dan sistematik. Melalui eBook yang dihasilkan ini juga diharapkan supaya dapat menjadi sumber penyebaran ilmu berdasarkan bidang yang dipilih di samping meningkatkan kemantapan intelek penulis sendiri.

Akhir kata, kami memohon kemaafan di atas kekurangan yang terdapat dalam penghasilan eBook ini. Sekalung penghargaan kepada pihak Pengurusan Politeknik Tuanku Syed Sirajuddin kerana telah memberi ruang dan peluang dalam penghasilan eBook ini.

Harapan kami agar pensyarah dan pelajar mendapat ilmu yang bermanfaat dan dapat dijadikan sebagai rujukan.

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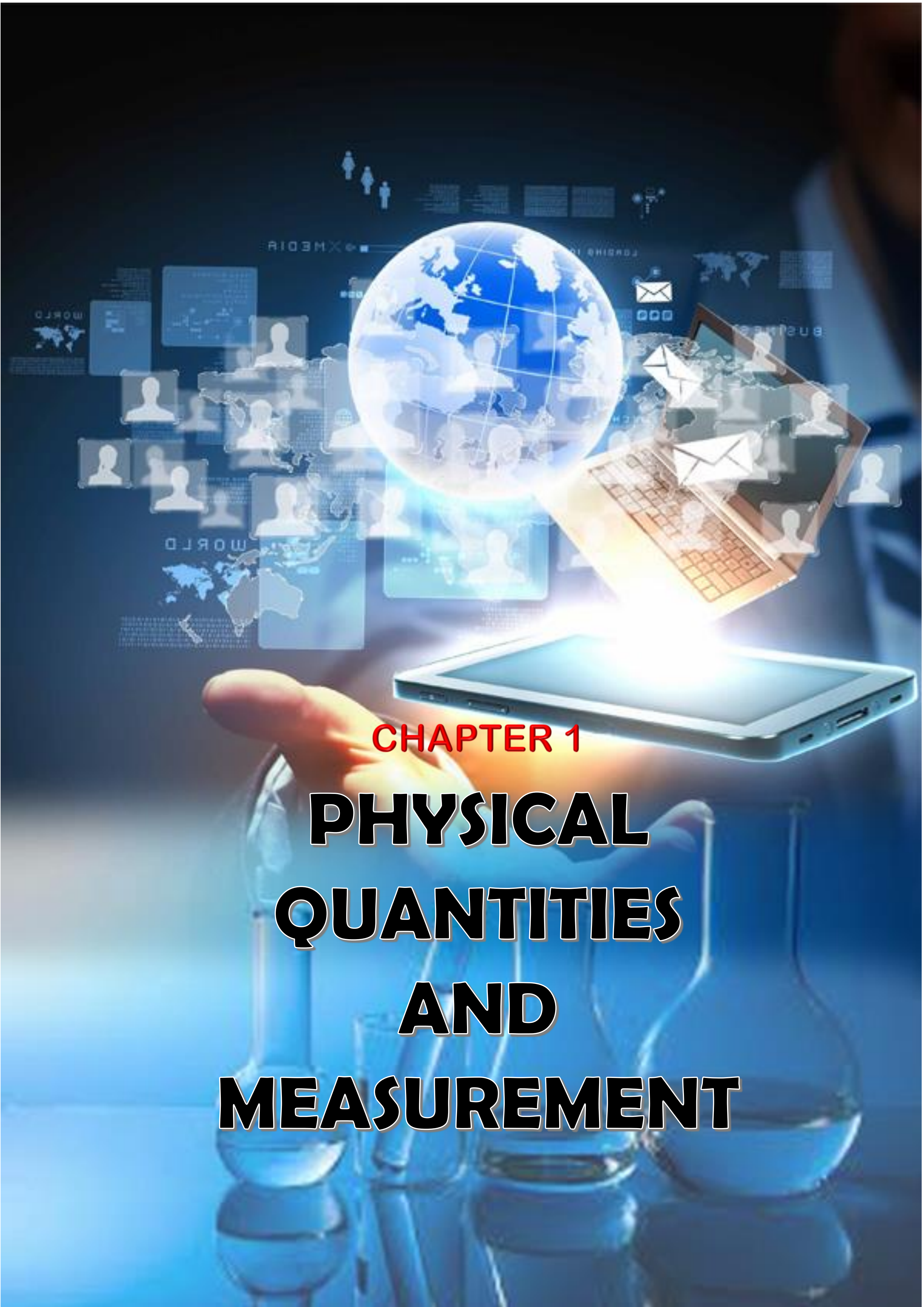
First Publishing 2021

Published By :

Politeknik Tuanku Syed Sirajuddin
Pauh Putra
02600, Arau
Perlis

CONTENT



CHAPTER 1

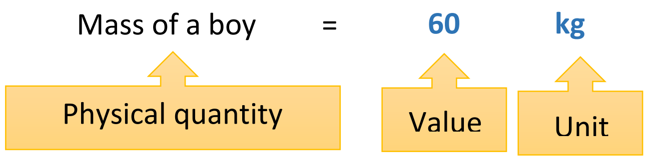
PHYSICAL QUANTITIES AND MEASUREMENT

1.0 INTRODUCTION

Physics is the study of material from the entire universe. The word 'physics' comes from the Latin word *physica*, which means 'the science of natural things'. The subdivisions of physics are mechanics, heat, sound, electricity, optics, waves, magnetism, and nuclear physics.

1.1 PHYSICAL QUANTITIES

- Physical quantity is a quantity that can be measured. Example of physical quantities are time, temperature, weight, volume, speed of a car, etc.
- All physical quantities are expressed as a numerical value in a particular unit of measurement. For example :



- Physical quantities are categorised into based quantities and derived quantities.
- Unit of measurement used is the International System of Units (SI units).

1.1.1 Based Quantities and Derived Quantities

- A **base quantity** is a physical quantity that cannot be defined in other terms.
- Table 1.1 shows the base quantities with their respective SI units.

Table 1.1

PHYSICAL QUANTITIES	SI UNITS	SYMBOLS
Length, ℓ	Meter	m
Mass, m	Kilogram	kg
Time , t	Seconds	s
Electric Current , I	Ampere	A
Temperature , θ	Kelvin	K

- A **derived quantity** is a physical quantity derived from based quantities by multiplication or division or both.
- Table 1.2 shows the derived quantities with their respective SI units.

Table 1.2

Derived Quantities	Symbol	Relationship with base quantities	SI units
Area	A	Length x Width	m^2
Density	ρ	$\frac{\text{Mass}}{\text{Volume}}$	kg/m^3
Velocity	v	$\frac{\text{Displacement}}{\text{Time taken}}$	m/s
Acceleration	a	$\frac{\text{Change in velocity}}{\text{Time taken}}$	m/s^2
Force	F	Mass x Acceleration	Kg ms^{-2} @ N
Energy	E_p E_k	Mass x gravity x height ½ x mass x velocity x velocity	J J

1.1.2 Prefixes

Prefixes are used to simplify the description of physical quantities that are either very big or very small. Table 1.3 shows the prefixes.

Table 1.3

Prefix	Power	Value
tera (T)	10^{12}	1000000000000
giga (G)	10^{9}	1000000000
mega (M)	10^{6}	1000000
kilo (k)	10^{3}	1000
hecto (h)	10^{2}	100
deka (da)	10	10
desi (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
mili (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000001
nano (n)	10^{-9}	0.000000001

1.1.3 Conversion Unit

A physical unit can be represent in several different unit, however its value remain the same.

EXAMPLE 1

Convert 5.6 km to m.

Solution:

$1 \text{ km} = 10^3 = 1000\text{m}$

Therefore,

$$5.6 \text{ km} = 5.6 \cancel{\text{km}} \times \frac{1000 \text{ m}}{1 \cancel{\text{km}}}$$

$$= 5.6 \times 1000 \text{ m}$$

$$= \mathbf{5600\ m}$$

PRACTICE 1

Convert the following questions.

a)	65cm to m
b)	5.7g to kg
c)	3.9kW to W

EXAMPLE 2

Convert 0.07 kW to mW

Solution:

$1\ \text{kW} = 1000\ \text{W}$

$1\ \text{W} = 1000\ \text{mW}$

Therefore,

$$0.07\ \text{kW} = 0.07\ \cancel{\text{kW}} \times \frac{1000\ \text{W}}{1\ \cancel{\text{kW}}} \times \frac{1000\ \text{mW}}{1\cancel{\text{W}}}$$

$$= \mathbf{70\ 000\ mW}$$

PRACTICE 2

Convert the following questions.

a) 3.58 mm to km	b) 8 kV to mV
c) 27.3 Mb to Gb	d) 600 mW to kW

EXAMPLE 3

i. Convert $2.5\ \text{cm}^2$ to m^2.

Solution:

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

Therefore,

$$2.5\ \text{cm}^2 = 2.5\ \text{cm}^2 \times \frac{1^2\text{m}^2}{100^2\text{cm}^2}$$

$$= \mathbf{2.5 \times 10^{-4}m^2}$$

ii. Convert $1.7\ \text{cm}^3$ to mm^3

Solution:

$$1.7\ \text{cm}^3 = 1.7\ \text{cm}^3 \times \frac{1^3\text{m}^3}{100^3\text{cm}^3} \times \frac{1000^3 mm^3}{1^3 m^3}$$

$$= \mathbf{1700\ mm^3}$$

PRACTICE 3

Convert the following questions.

a)	7.4mm^3 to m^3
b)	5.6mm^2 to cm^2
c)	$20.5\ \text{km}^2$ to cm^2

EXAMPLE 4

Convert 0.45g/cm^3 to kg/m^3.

Solution :

$$1\text{ kg} = 1000\text{ g}$$

$$1^3\text{m}^3 = 100^3\text{cm}^3$$

$$0.45\text{g/cm}^3 = 0.45\frac{\text{g}}{\text{cm}^3} \times \frac{1\text{kg}}{1000\text{g}} \times \frac{100^3\text{cm}^3}{1^3\text{m}^3}$$

$$= \mathbf{450\ kg/m^3}$$

PRACTICE 4

Convert the following questions.

a)	4520 kg/m^3 to g/cm^3
b)	25.7 g/cm^3 to kg/m^3
c)	2.5 kg/m^3 to g/cm^3

EXAMPLE 5

Convert 90km/h to m/s

Solution :

$1 \text{ km} = 1000 \text{ m}$

$1 \text{ h} = 3600 \text{ s}$

$$90 \text{ km/h} = \frac{90 \cancel{\text{km}}}{\cancel{\text{h}}} \times \frac{100\cancel{0} \text{ m}}{1 \cancel{\text{km}}} \times \frac{1 \cancel{\text{h}}}{36\cancel{0}0 \text{ s}}$$

$$= \mathbf{25 \ m/s}$$

PRACTICE 5

Convert the following questions.

a)	110 km/h to m/s
b)	876 km/h to m/s
c)	63 m/s^2 to km/h^2

1.2 MEASUREMENT

Some common measuring instruments:

- Meter ruler – to measure length a few centimeters to a meter. The measurement is accurate up to 0.1cm.

Figure 1.1: Meter ruler

- Micrometer screw gauge – to measure the thickness or diameter of a small object.

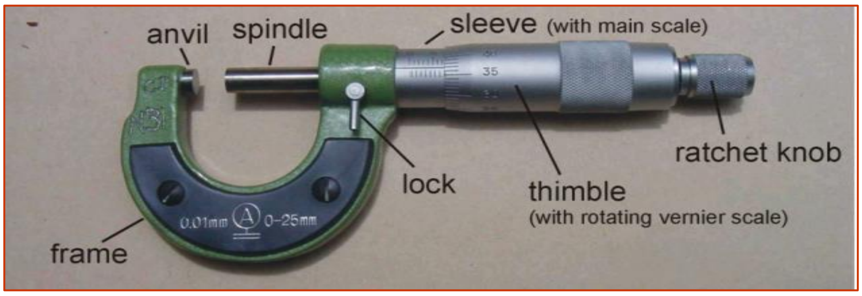


Figure 1.2: Micrometer screw gauge

(Image from https://www.miniphysics.com/how-to-read-a-micrometer-screw-gauge.html)

- Vernier calipers – to measure length of less than 10cm. suitable to measure internal and external diameter of round objects.

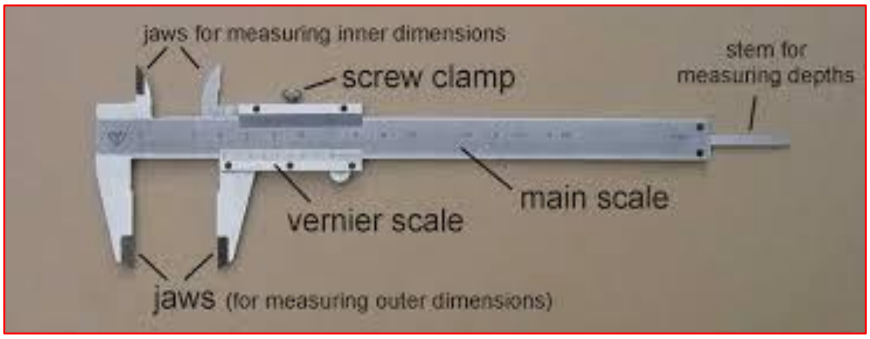
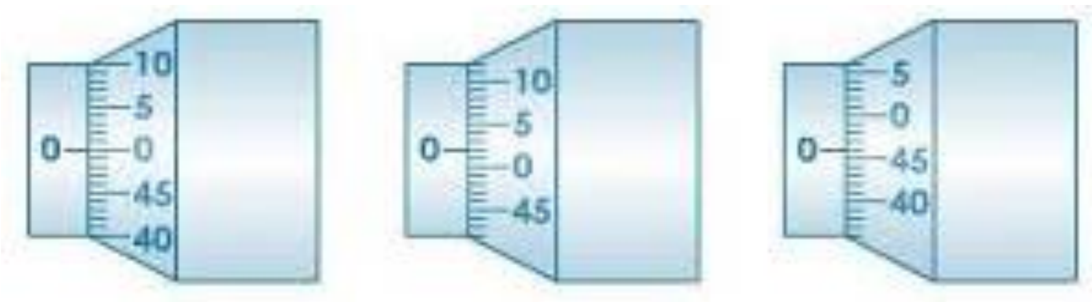


Figure 1.3: Vernier calipers

1.2.1 Zero Error Of A Micrometer Screw Gauge



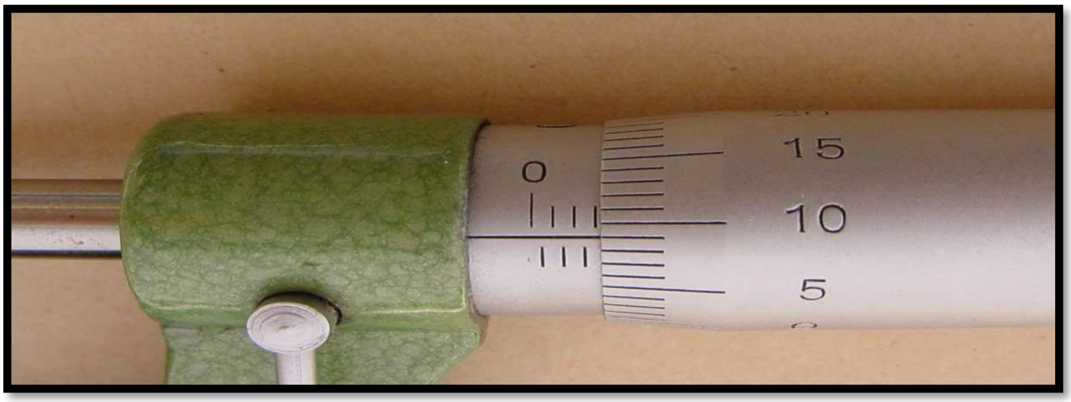
(a) No zero error

(b) Positive zero error

(c) Negative zero error

1.2.2 How to Read the Micrometre Screw Gauge

- Based on the figure below, calculate the **actual reading**



(Image from https://fdocuments.in/document/latihan-micrometer-screw-gauge.html)

Solution:

Actual reading = (reading) – (zero error)

= (3.0 + 0.09) – (0)

= 3.09mm

- Based on the figure below, calculate the **actual reading** if the zero error discovered is +0.01mm

(Image from https://fdocuments.in/document/latihan-micrometer-screw-gauge.html)

Solution:

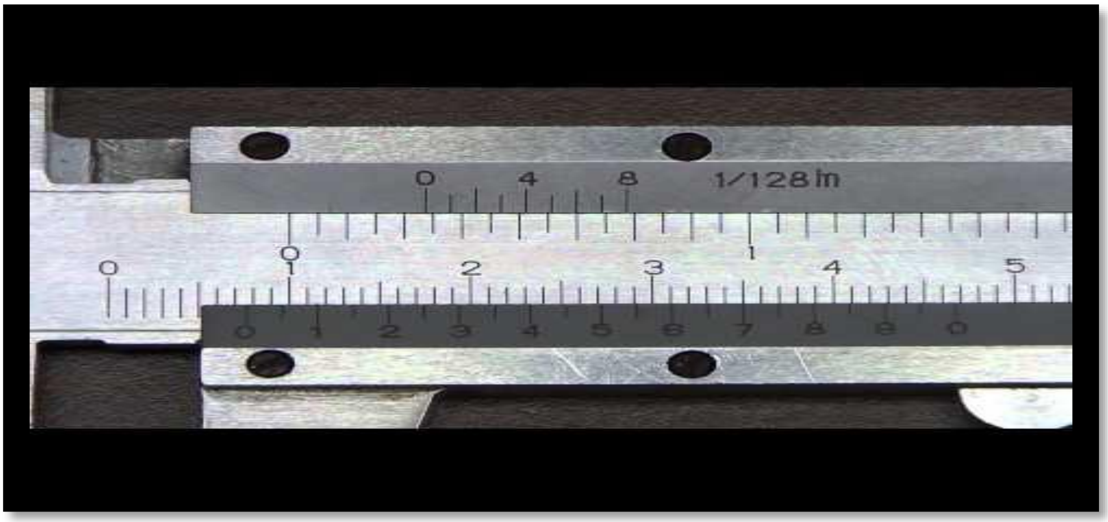
Actual reading = (reading) – (zero error)

= (5.5 + 0.30) – (+0.01)

= 5.79mm

1.2.3 How to Read the Vernier Caliper

- Based on the figure below, calculate the actual reading if there is NO zero error.



Solution:

Actual reading = (reading) – (zero error)

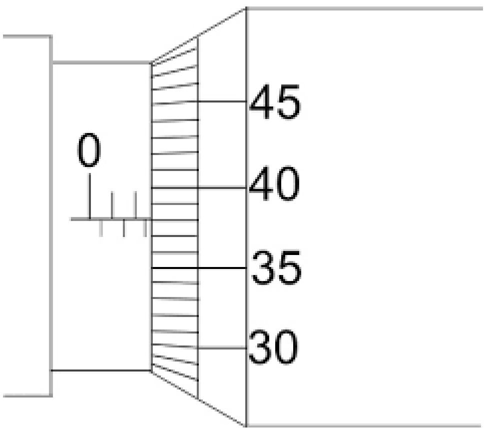
= (0.7 + 0.07) – (0)

= 0.77 cm

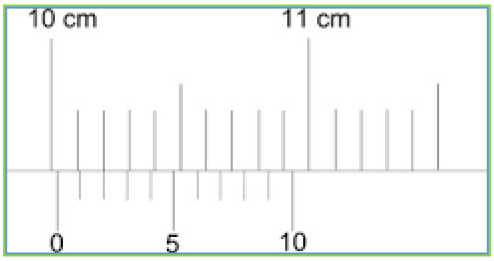
PRACTICE 6

Based on the figure below, calculate the actual reading if there is NO zero error.

a)



b)



c)

1.2.4 Error in Measurement

An error is the difference between the measured value and the actual value. There are TWO types of error in measurement which are:

- Systematic error
  - Error in measurements due to the condition of the measuring instrument or the state of the environment in which the measurements are taken.
  - It is cannot be minimized or reduced by repeated measurement.
  - Systematic error can be eliminated by varying the condition of measurement or suitable treatment of the measurement such as the correction for zero error.
- Random error
  - Occurs due to mistakes made by an observer when taking the measurement.
  - Repeating measurement and using statistical technique can be used to minimize the error.

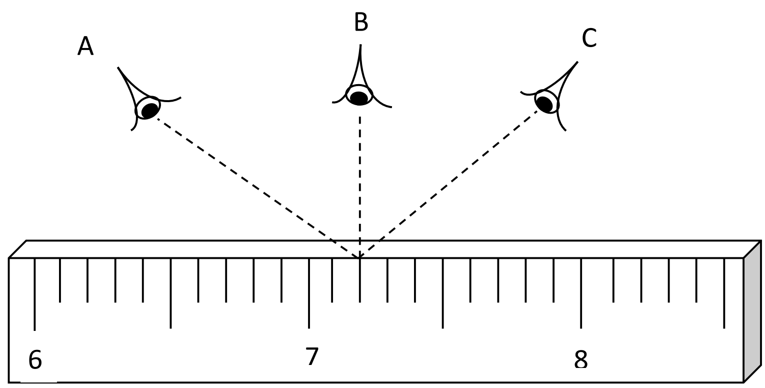
All these errors can be reduced by:

- Choosing the correct or suitable measuring instrument when making a measurement
- Using a proper technique in measurement
- Repeating the measurement, a number of times and find its mean (average)
- Measuring at different places or position of the object and calculate its average value.
- Checking a measuring instrument for zero error before using it.

MASTERY PRACTICE

1. List THREE (3) Base Quantities and THREE (3) Derived Quantities.
2. Convert:
    a. 60 cm to mm
    b. 45 cm to m
    c. 325 km/h to m/s
    d. 876 km/h to m/s
    e. 4520 kg/m^3 to g/cm^3
    f. 25.7 g/cm^3 to kg/m^3
    g. 67 cm^3/minute into m^3/h
    h. 2.95 km^2 into mm^2
    i. 0.2233 m^2 to mm^2
    j. 63 m/s^2 to km/h^2
3. State 2 measuring instruments for measuring thickness of object.

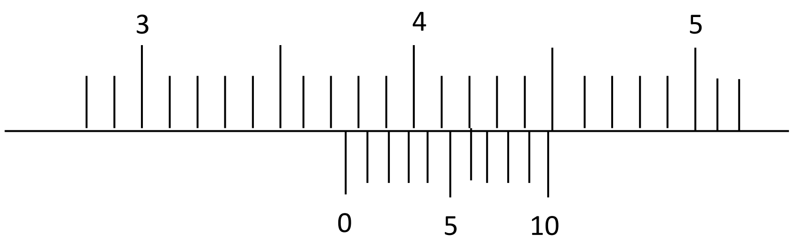
4.



From the figure above,

i) Choose the correct position while reading the scale
ii) State the type of error

5. Determine the reading of the Vernier caliper in figure below:



CHAPTER 2

LINEAR MOTION

2.0 UNDERSTAND THE CONCEPT OF LINEAR MOTION

2.1 DEFINE LINEAR MOTION

Linear motion also called **uniform motion** is the motion in a **straight line**.

	Linear Motion	Non – Linear Motion
Definition	Linear motion is the motion that reach and maintain its maximum speed on a straight line.	Non-uniform motion is the motion that undergoes a change in velocity, either by changing speed or changing direction.
Examples	- A passenger on moving an escalator - An athlete running a 100m race	- A spinning top - The earth orbits the sun - A roller coaster ride - A crawling snake

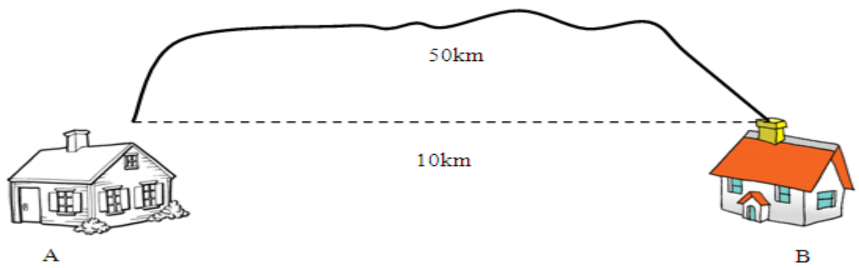
2.1.1 Scalar Quantity and Vector Quantity

	Scalar Quantity	Vector Quantity
Definition	Scalar quantity is a quantity which has magnitude only.	Vector quantity is a quantity which has both magnitude and direction.
Examples	- Distance - Time - Temperature - Mass - Volume	- Displacement - Velocity - Force - Acceleration - Momentum

2.2 DISTANCE AND DISPLACEMENT

	Distance	**Displacement**
Definition	Distance is the total path travelled by an object.	Displacement is defined as the shortest distance between two points in a specific direction.
Type of Quantity	Scalar quantity	Vector quantity
Unit	Meter (m)	Meter (m)

- Figure below shows the displacement and distance between two houses.



Displacement = 10 km

Distance = 50 km

EXAMPLE

A student walks to the south for 30 m, then to the east for 40 m and finally to the north for 30 m before he stops to rest. The total time taken by the student for the whole journey is 20 seconds.

a) What is the total distance travelled?

b) What is the displacement of the student?

Solutions:

a) Total distance = 30m + 40m + 30m = **100 m**

b) Displacement = **40m to the east**

PRACTICE 1

A car travels 600m due to west in ½ minute, and then travels 800m due to north in 1 minute 20 seconds. Calculate:

a) The total distance travelled	b) The total time taken for the journey	c) The displacement
(Ans: 1400m)	*(Ans: 110s)*	*(Ans: 1000m)*

2.3 SPEED AND VELOCITY

	Speed	Velocity
Definition	Speed is the rate of change of distance.	Velocity is the rate of change of displacement.
Formula	$speed = \frac{distance}{time}$ $v = \frac{s}{t}$	$speed = \frac{distance}{time}$ $v = \frac{s}{t}$
SI unit	$\frac{m}{s}$ @ms^{-1}	$\frac{m}{s}$ @ms^{-1}
Type of quantity	Scalar quantity	Vector quantity

EXAMPLE

An athlete runs 250m in 10s. What is his velocity?

Solution:

$$\text{velocity, } v = \frac{Displacement,s}{Time,t}$$
$$= \frac{250m}{10s}$$
$$= 25ms^{-1}$$

PRACTICE 2

A boy riding a bicycle travels 300m to the east in 10s and then 400m to the south in 15s.

a) What is the total distance he has travelled?	b) What is his displacement
c) What is his speed?	d) What is his velocity?

PRACTICE 3

Distance between school and Ali's house is 45km. If Ali took a bus and the bus moves with a constant velocity 50km/h, how long he took to reach his school?

2.4 ACCELERATION AND DECELERATION

	Acceleration	**Deceleration**
Definition	Acceleration is the rate of change of velocity.	Deceleration is the rate of change of velocity that has negative value.
Formula	$a = \frac{v-u}{t}$ $a = acceleration$ $v = final\ velocity$ $u = initial\ velocity$ $t = time$	
Unit	$ms^{-2} @ m/s^2$	
Type of quantity	Vector quantity	

EXAMPLE

A car accelerates at a constant rate from rest and reaches a velocity of 20m/s after 5s. What is the car acceleration?

Solution:

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

$$a = \frac{20-0}{5}$$

$$a = 4m/s^2$$

PRACTICE 4

a) A lorry is moving with constant velocity of 30 km/h. When the driver steps on the accelerator, the lorry accelerates uniformly until its velocity reaches 90 km/h in 1 minute. Determine the acceleration of the lorry in m/s^2? *(Ans: 0.28 m/s^2)*	b) A mass is moving with a velocity 3 m/s and it is under a constant acceleration of 4 m/s^2. Calculate the velocity of the mass after ½ minutes. *(Ans: 123 m/s)*

2.5 THE EQUATION OF MOTION

The table lists the equations can be used when solving problem involving linear motion.

PHYSIC QUANTITY	EQUATIONS
Displacement	$s = ut + \frac{1}{2}at^2$ $s = \frac{1}{2}(u + v)t$
Velocity	$v = u + at$ $v^2 = u^2 + 2as$
acceleration	$a = \frac{v - u}{t}$

EXAMPLE

a) A stone is thrown straight downward with initial speed of 8.0 m/s^{-1} from a height of 25m. Calculate:

i. The time it takes to reach the ground

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

$25 = 8t + \frac{1}{2}(9.81)t^2$

$4.905t^2 8t - 25 = 0$

$t_1 = 1.58s \quad t_2 = -3.22$

$\therefore t = 1.58s$

ii. The speed it strikes.

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

$v^2 = 8^2 + 2(9.81)(25)$

$v^2 = 64 + 490.5$

$v^2 = 554.5$

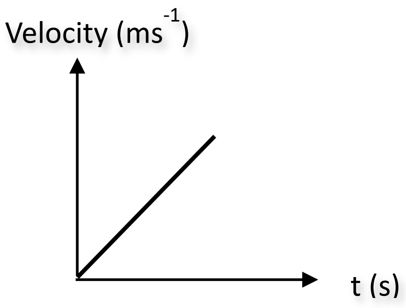
$v = 23.55ms^{-1}$

PRACTICE 5

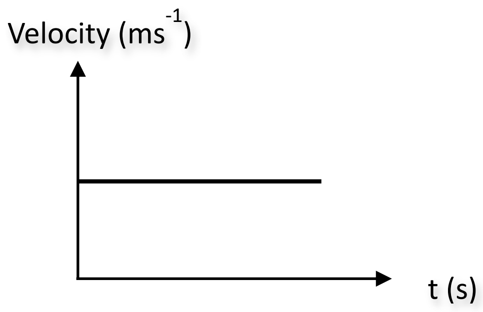
a) A car is accelerated at 8 m/s^2 from an initial velocity of 4 m/s for 10 s. Calculate: i. The final velocity. *(Ans : 84 m/s)* ii. The distance travelled by the car. *(Ans : 440 m)*	b) The speed of a car travelling along a straight road decreases uniformly from 50 m/s to 20 m/s over 100 m. Calculate: i. Deceleration of the car. *(Ans : -10.5 $m/s^{2)}$* ii. Time taken for the speed to decrease from 50 m/s to 20 m/s. *(Ans :2.86 s)*

2.6 THE VELOCITY TIME-GRAPH

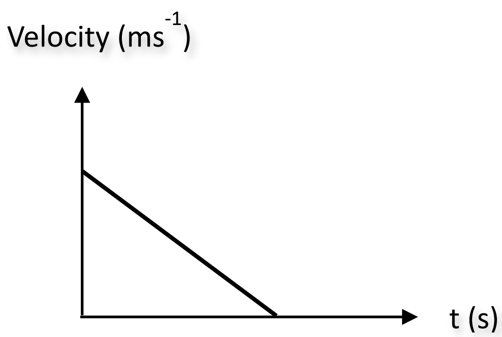
Types of velocity-time graph are as below:



- Increasing velocity
- Constant acceleration

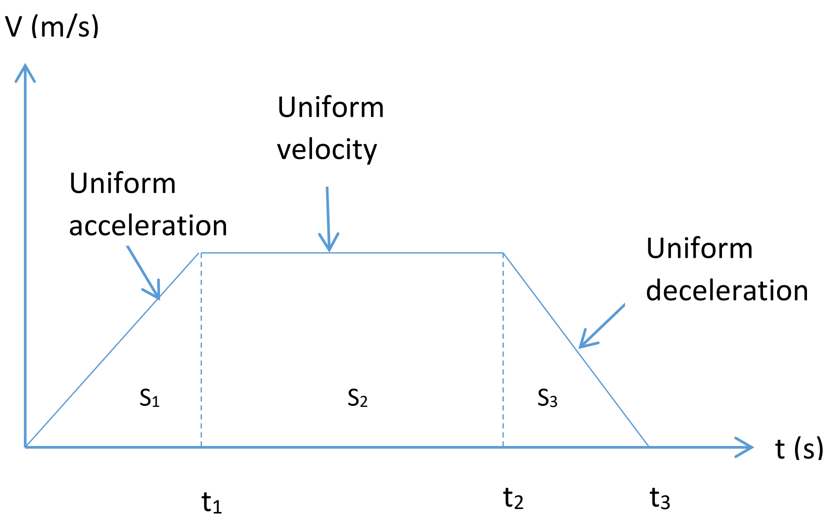


- Constant velocity
- Zero acceleration



- Decreasing velocity
- Constant deceleration.

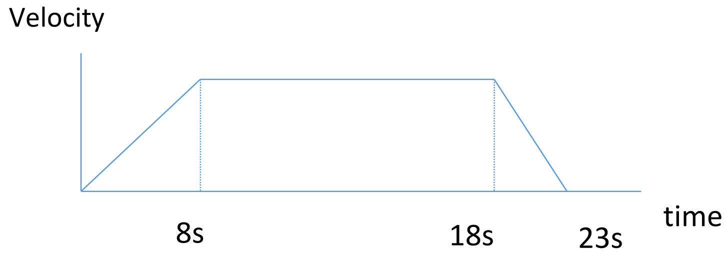
Figure 2.1 shows the combination of uniform acceleration, velocity and deceleration.



EXAMPLE

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

i) Sketch a graph of v versus t to represent the motion.



ii) Calculate the maximum velocity attained by the car.

$$v = u + at$$
$$v = 0 + 5(8)$$
$$v = 40m/s$$

iii) Calculate the total distance travelled

$$Total\ distance = Area\ under\ graph$$

$$s1 = \frac{1}{2}(0 + 40)(8) = 160m$$

$$s2 = \frac{1}{2}(40 + 40)(10) = 400m$$

$$s3 = \frac{1}{2}(40 + 0)(5) = 100m$$

Total distance $= 160 + 400 + 100$
$= 660\text{m}$

PRACTICE 6

a) Figure 1 shows velocity-time graph of a car. From the graph, calculate:

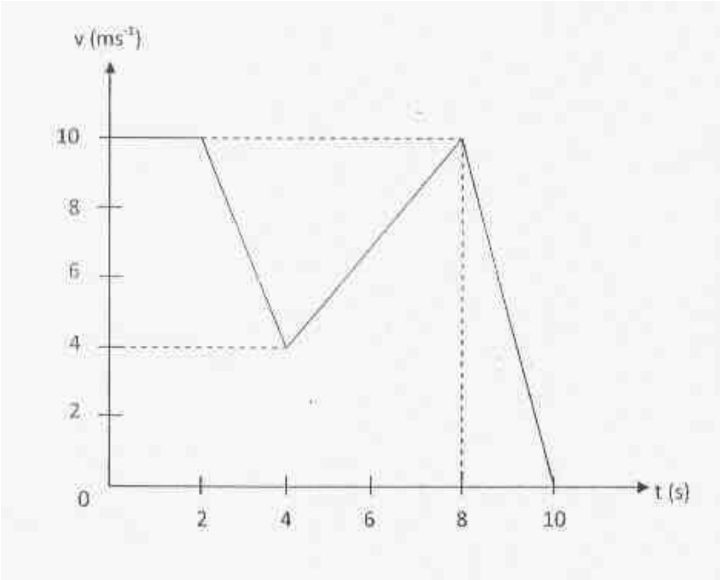


Figure 1

i. The initial velocity of the car.

ii. The acceleration of the car from t = 4s to t = 8s. (*Ans:1.5 m/s²*)

iii. The total distance travelled by the car. (*Ans:72 m)*

iv. The average velocity of the motion. (*Ans:7.2 m/s)*

b) A car starts from rest and accelerates at a constant acceleration of 5 m/s^2 for 10 s. The car then travels at a constant velocity for 15 s. The brakes are then applied and the car stops in 5 s.

i. Sketch a velocity - time graph for the whole journey.

ii. Calculate the maximum velocity attained by the car. (*Ans:50 m/s)*

iii. Calculate the total distance travelled. (*Ans:1125 m)*

MASTERY PRACTICE

1. Gives the definition of scalar quantity and vector quantity.

2. Define and state the SI units of the terms below:

   i. Acceleration
   ii. Displacement

3. Houses A and B as in Figure 1 are linked by two roads. The bold road is 50km while the dotted road is 10km. State which of the two roads represents distance and displacement.

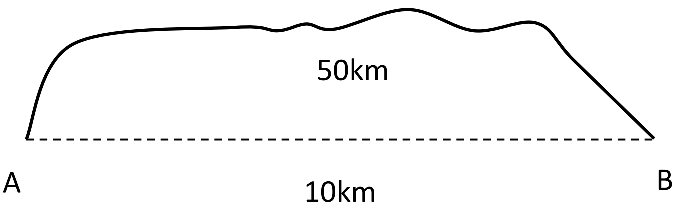


Figure 1

4. Calculate the acceleration of a car that moves from 80m/s and achieves a velocity of 432 km/h in 3 minute.

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

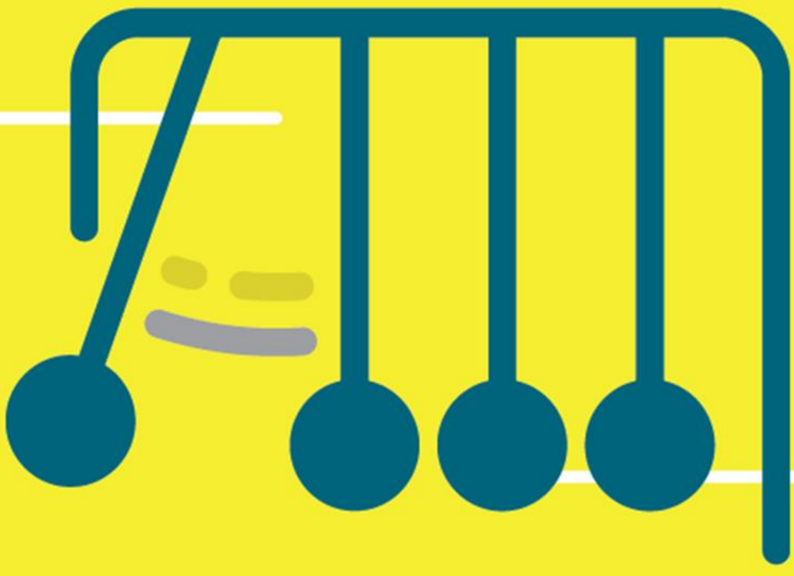
   i) Sketch a graph of v versus t to represent the motion.

   ii) Calculate the maximum velocity attained by the car.

   iii) Calculate the total distance travelled

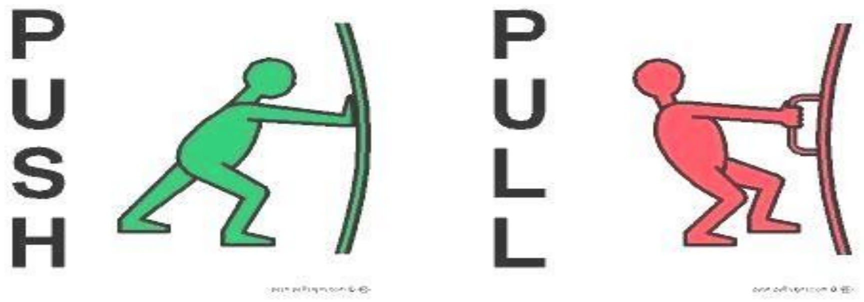
CHAPTER 3

FORCE



3.0 INTRODUCTION

- Force is a push or a pull.
- It is a vector quantity
- The SI unit of force is kgm/s^2 or Newton (N)



(Image from https://medium.com/theagency/why-pushing-will-get-you-slaughtered-in-advertising-and-pull-is-the-future-4f8879554398)

3.8 CONCEPT OF FORCE

3.8.1 Example situation when applied a force:

- Lifting luggage
- Playing football
- Stretching a spring

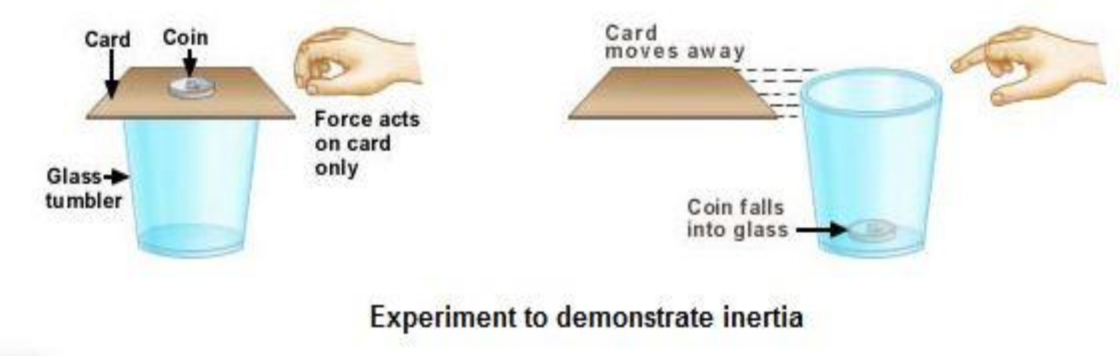
3.8.2 The effect of force on an object

- A stationary object to move
- A moving object to change its speed
- A moving object to change its direction of motion
- An object to change in size and shape

3.9 NEWTON'S LAW

Newton's First Law.

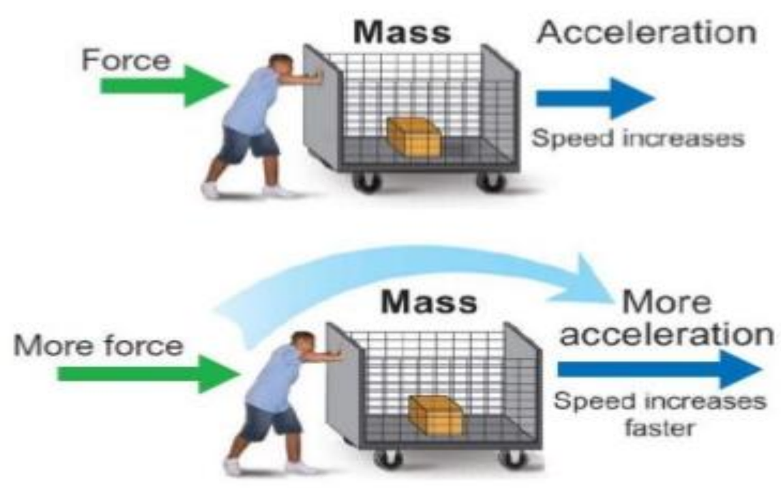
An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction until it is acted upon by an unbalanced force.



(Image from https://images.app.goo.gl/R7SQckQn4Rk91T3P9)

Newton's Second Law

When net force acting on an object is not zero, the object will accelerate at the direction of exerted force



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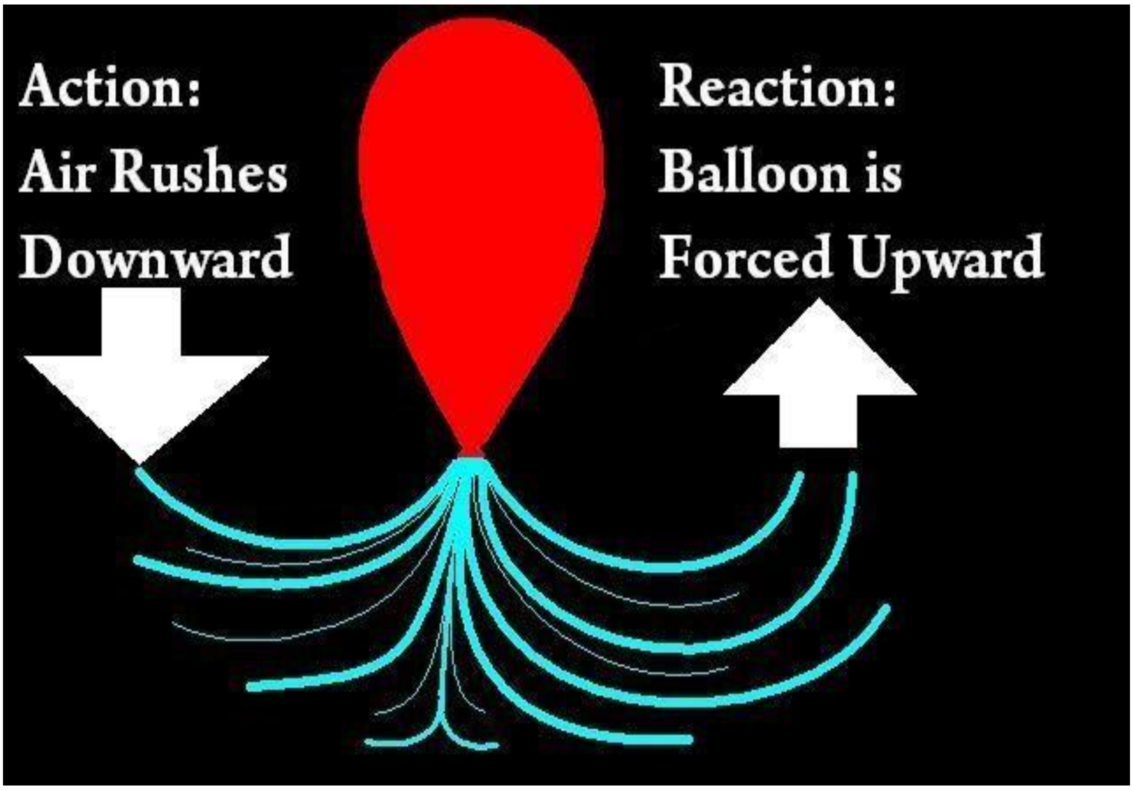
Newton's Third Law

For every action there is an equal and opposite reaction.



(Image from https://images.app.goo.gl/msdxeHHrZ5tMDd61A)

3.2.1 Application of force

$$F = m \times a$$

$$F = force$$

$$m = mass$$

$$a = acceleration$$

- The unit of force is **Newton(N)** or **kgms^{-2}**

EXAMPLE

If you apply a net force of 20N on 500g of ball, what is the acceleration of the ball?

Solution:

$F = ma \qquad\qquad\qquad 500g = 0.5kg$

$20N = 0.5kg \times a$

$a = \frac{20}{0.5}$

$a = 40N$

PRACTICE 1

a) A 200N force is required to accelerate a box at $15ms^{-2}$. What is the mass of the box? *(Ans : 13.33kg)*	b) A car of mass 900kg accelerates from rest to $15ms^{-1}$ in 10s. What is the accelerating force developed by the car engine? *(Ans : 1350N)*

3.3 WEIGHT

- The weight of an object is defined as the **force of gravity** which is exerted on an object by earth.

$$w = m \times g$$

$$w = weight$$

$$m = mass$$

$$g = gravitational\ acceleration\ (ms^{-2})$$

- The unit of weight is ***Newton, N***

3.3.1 Differences between Weight and Mass

	Weight, W	mass, m
Definition	Mass multiple by gravity	Amount of matter in an object
Value	The value changes according to gravitational field	The value is constant everywhere on the earth
Quantity of physics	Vector quantity	Scalar quantity
SI unit	Newton	kilogram

EXAMPLE

What is the mass of an object that has weight of 150N?

Solution :

$$W = mg$$

$$150 = m(9.81)$$

$$m = \frac{150}{9.81}$$

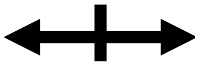
$$m = 15.29kg$$

PRACTICE 2

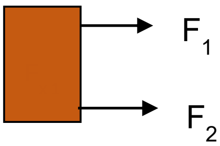
a) What is the weight of an object that has a mass of 70kg? ($g = 9.8 m/s^2$) *(Ans : 686.7N)*	b) What is your weight on moon and mars? *($g_{moon} = 1.622 m/s^2$, $g_{mars} = 3.711 m/s^2$)*
c) A 20N force gives a stone an acceleration of $4 m/s^2$. What is the weight of the stone? *(Ans : 49.05N)*	

3.4 FORCES IN EQUILIBRIUM

- Forces in equilibrium when the **resultant force is zero**, and if the object is at rest or is moving with constant velocity is a straight line.
- **The types of force**

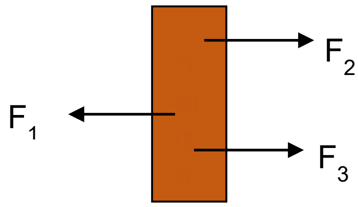
Balanced force	Unbalanced force
Pulling forces = pushing forces **10 N**  **10 N**	Pulling forces ≠ pushing forces **10 N**  **20 N**

3.5 THE TOTAL FORCE



Total net force

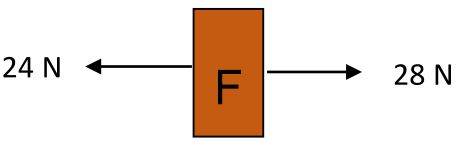
$$\sum F = F_1 + F_2$$



Total net force

$$\sum F = (F_2 + F_3) - F_1$$

EXAMPLE



$$\text{Total net force} = 28N - 24N$$

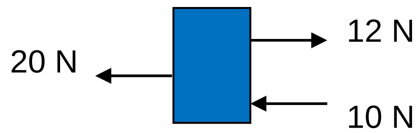
$$= 4N \; to \; the \; right$$

PRACTICE 3

a) Find the resultant force for the following:

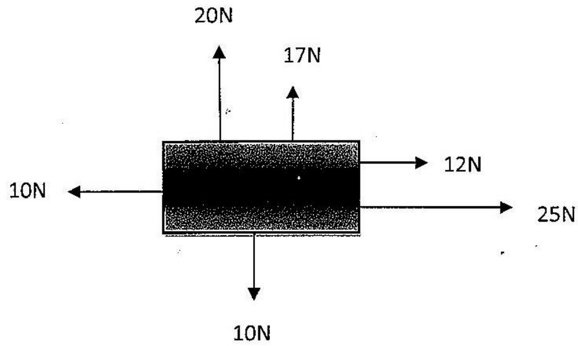
(Ans : -12N)

b) Find the resultant force for the following:



(Ans : -18N)

c) Calculate the net force acting on the x-axis and y-axis of an object in figure.

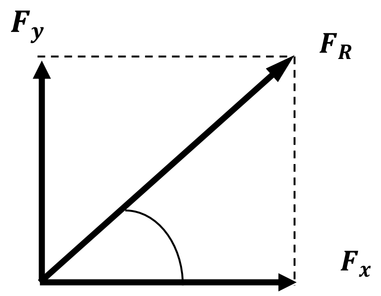


(Ans :x-axis = 27 N, y-axis = 27 N)

3.5.1 RESOLUTION OF FORCES

The resolution of forces is a single force with an angle, θ can be resolved into two components :

- Horizontal component, F_x
- Vertical component, F_y



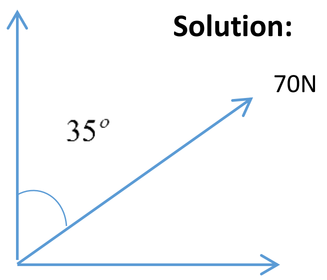
With that,

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

Resolution Force

EXAMPLE

Find the horizontal and vertical for each of the following forces.



Solution:

$F_x = F\cos\theta$

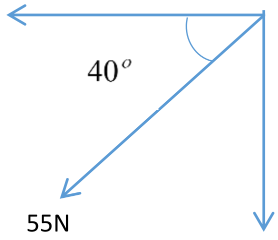
$= 70\cos(90 - 35)$

$= 40.15N$

$F_y = F\sin\theta$

$= 70\sin(90 - 35)$

$= 57.34N$



Solution:

$F_x = F cos\theta$

$= 55\cos(180 + 40)$

$= -42.132N$

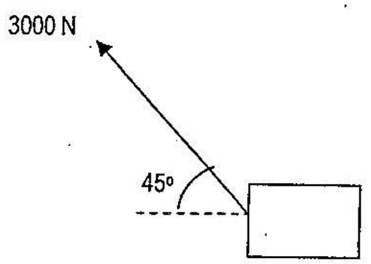
$F_y = F sin\theta$

$= 55\sin(180 + 40)$

$= -35.353N$

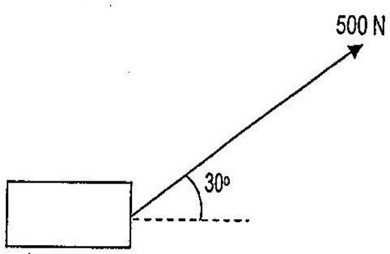
PRACTICE 4

a) Calculate the horizontal and vertical components for the forces in the figures below:



(Ans : Fx = 2121.3N, Fy = 2121.3N)

b) Calculate the horizontal and vertical components for the forces in the figures below:



(Ans : Fx = 433.01 N, Fy = 250 N)

3.6 RESULTANT FORCE

- A **resultant force** is a single force that represents the combined effect of two or more forces with **magnitude** and **direction.**

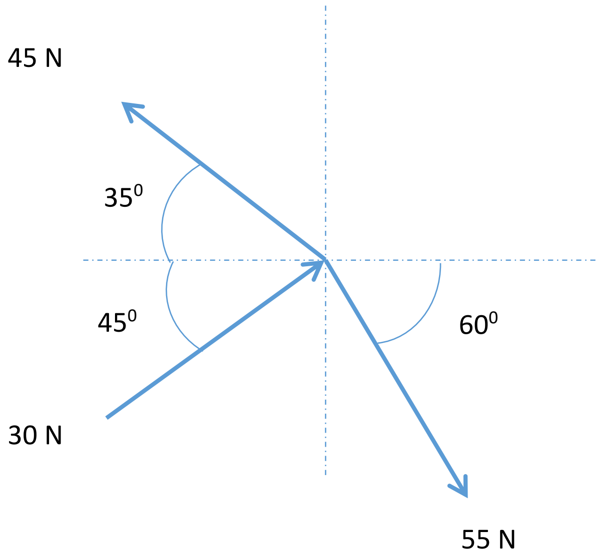
Resultant Force

$$F_R = \sqrt{\left(\sum F_x\right)^2 + \left(\sum F_y\right)^2}$$

$$\theta = tan^{-1}\left(\frac{\sum F_y}{\sum F_x}\right)$$

EXAMPLE

Determine the resultant **Force (F_R)** and its **direction** for figure below.



Solution:

Resolution method

Force (N)	Angle	F_x	F_y
45	145°	$45cos145° = -36.86$	$45sin145° = 25.81$
−30	225°	$-30cos225° = 21.21$	$-30sin225° = 21.21$
55	300°	$55cos300° = 27.5$	$55sin300° = -47.63$
Total		11.85	−0.61

Resultant force

$$F_R = \sqrt{(\sum F_x)^2 + \left(\sum F_y\right)^2}$$

$$= \sqrt{(11.85)^2 + (-0.61)^2}$$

$$= 11.86N$$

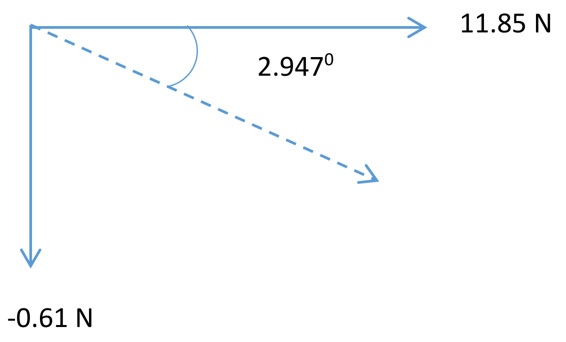
Direction of force

$$\theta = tan^{-1}\left(\frac{\sum F_y}{\sum F_x}\right)$$

$$= tan^{-1}\left(\frac{-0.61}{11.85}\right)$$

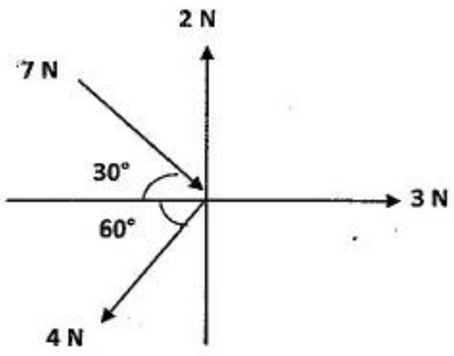
$$= -2.947°$$

Force diagram



PRACTICE 5

a) Determine resultant force, F_R for the system of forces shown in the Figure below.

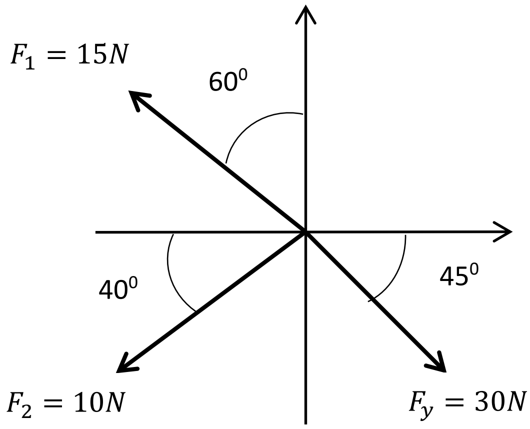


(Ans : 8.63N)

b) From the figure below

i. Find the total force of $\sum Fx$ and $\sum Fy$

ii. Calculate the magnitude F_R and direction $\boldsymbol{\theta}$ of Resultant Force.

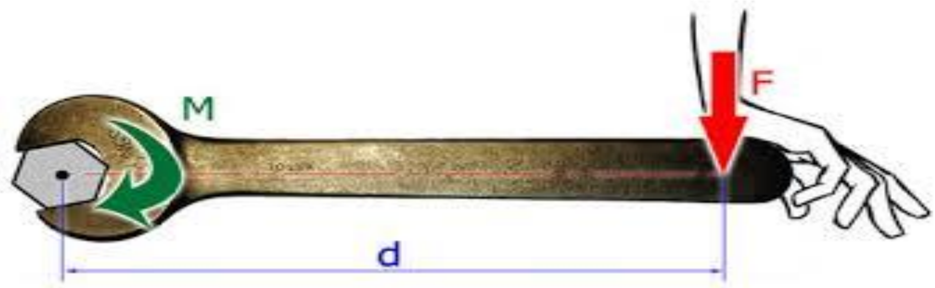


(Ans: F_x= 0.56 N, F_y= -20.14 N,FR = 20.14N, ϑ = 88.39°)

3.7 MOMENT OF FORCE

3.7.1 Definition of Moment of Force

- The moment of force is a measure of its turning points.
- The moment of force about a point is the product of the force and perpendicular distance of its line of action.



(Image from https://images.app.goo.gl/Ro57aj1aWdWHwuJm7)

The Figure shows the force and distance produce the moment of force for the object.

3.7.2 The ability of force to make an object turn depends on TWO factors:

- The size of the force that acts at right-angles to a line through the turning point of the object you wish to turn
- The perpendicular distance the force is applied from the turning point.

3.7.3 Formula of Moment

- MOMENT = Force X Perpendicular distance (arm)

= F x d

= (Newton) x (meter)

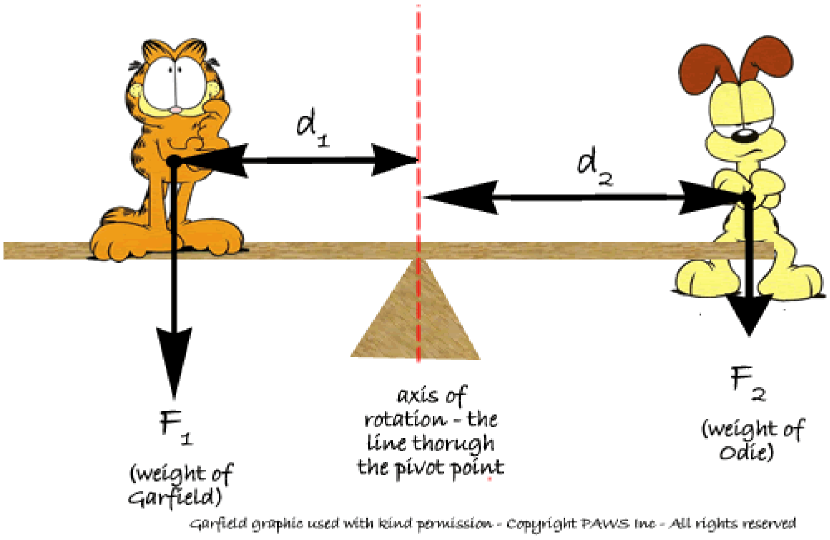
= Nm

- **Nm** is unit SI for **MOMENT**

3.7.4 Principle of Moment

- For a body in equilibrium (balanced) the sum of the clockwise moments is equal to the sum of the anticlockwise moments.

$\sum$**clockwise moments** = $\sum$**anticlockwise moments**



Simple balance see saw

(Image from https://images.app.goo.gl/jzJG2aofGjW9Z9BAA)

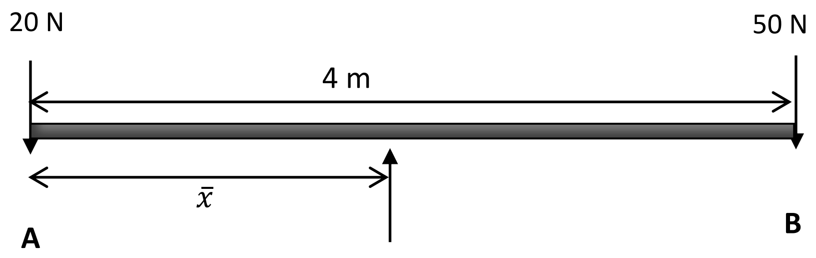
- Balancing moment - In a simple balances see-saw, the forces acting on the left and right-hand sides of the pivot are the same.
- Unbalancing moment – when moving the load at one end, will cause the see saw to become unbalanced.
- Principle of moment – to regain balance, the load on the opposite side must either be increased or its position changed.

3.7.5 Centre of Gravity

- There are two methods to find centre of gravity, $\bar{x}$ for forces to ensure "bar" on the horizontal balance or in equilibrium.
  - **Force moment method**
  - **Resultant moment method**

EXAMPLE

Determine the centre of gravity for force action, so that the bar remains in horizontal equilibrium



Solution :

Method 1: Force Moment Method

Given the Centre of gravity at $\bar{x}$ from A is,

The total of anti-clockwise moment = the total of clockwise moment

$$20\bar{x} = 50(4 - \bar{x})$$

$$20\bar{x} = 200 - 50\bar{x}$$

$$70\bar{x} = 200$$

$$\bar{x} = \frac{200}{70} = 2.86m$$

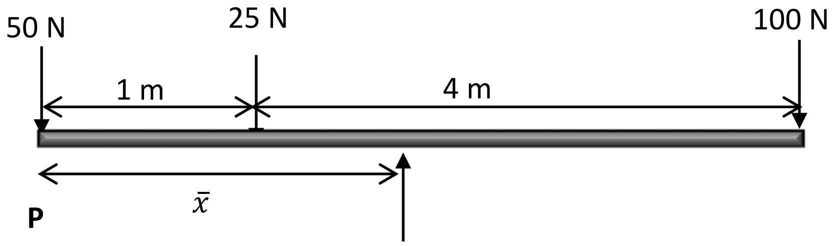
Method 2: Resultant Moment Method

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

$$= \frac{200}{70} = 2.86m$$

EXAMPLE

Determine the centre of gravity for force action, so that the bar remains in horizontal equilibrium.



Solution :

Method 1: Force Moment Method

Given the Centre of gravity at $\bar{x}$ from P is,

The total of anti-clockwise moment = the total of clockwise moment

$$50\bar{x} + 25(\bar{x} - 1) = 100(5 - \bar{x})$$

$$50\bar{x} + 25\bar{x} - 25 = 500 - 100\bar{x}$$

$$50\bar{x} + 25\bar{x} + 100\bar{x} = 500 + 25$$

$$175\bar{x} = 525$$

$$\bar{x} = \frac{525}{175}$$

$$= 3m$$

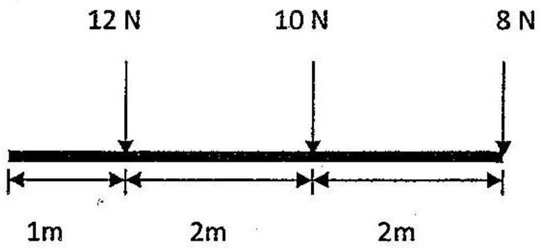
Method 2: Resultant Moment Method

$$\bar{x} = \frac{50(0)+25(1)+100(5)}{50+25+100}$$

$$= \frac{525}{175} = 3m$$

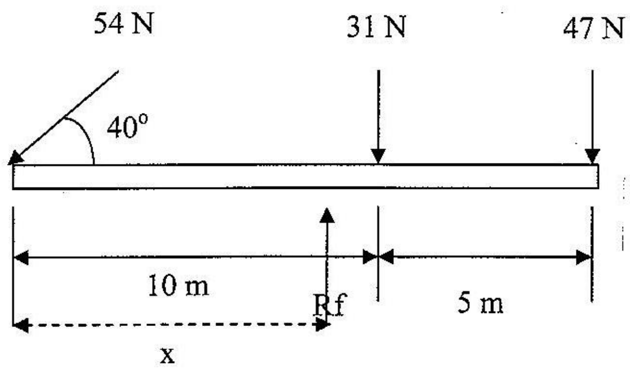
PRACTICE 6

a) Determine the gravitational point to balance the bar below by using the moment force method and resultant moment method.



(Ans : 2.733m)

b) Calculate the centre of gravity for the condition given in Figure below by using the moment force method and resultant moment method. Assume the object is in equilibrium.

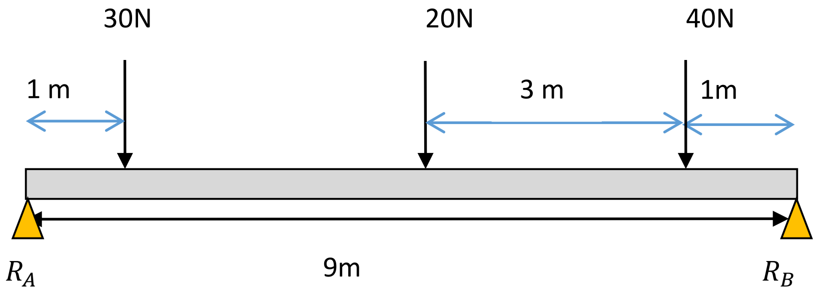


(Ans : 9.0m)

3.7.6 Interaction Force

EXAMPLE

Calculate the interaction Force for the both points R_A and R_B.



Solution:

$$\boldsymbol{Moment} \downarrow = \boldsymbol{moment} \uparrow$$

$$30(1) + 20(5) + 40(8) = R_A(0) + R_B(9)$$

$$30 + 100 + 320 = 9R_B$$

$$450 = 9R_B$$

$$R_B = 50N$$

$$\boldsymbol{Force} \downarrow = \boldsymbol{Force} \uparrow$$

$$30 + 20 + 40 = R_A + R_B$$

$$90 = R_A + 50$$

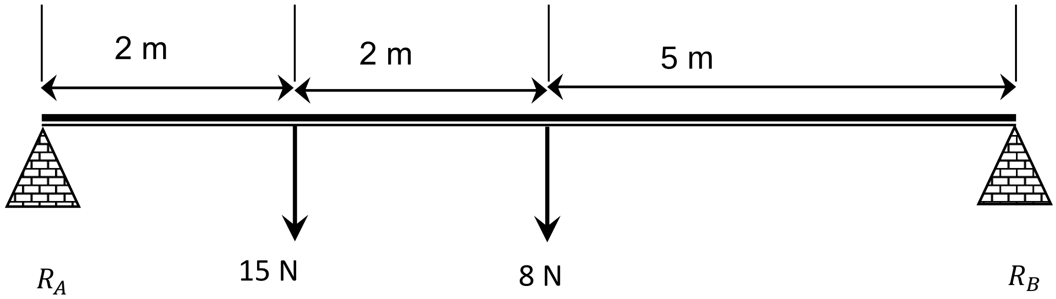
$$R_A = 90 - 50$$

$$R_A = 40N$$

PRACTICE 7

Find the interaction for both of following points, R_A and R_B.

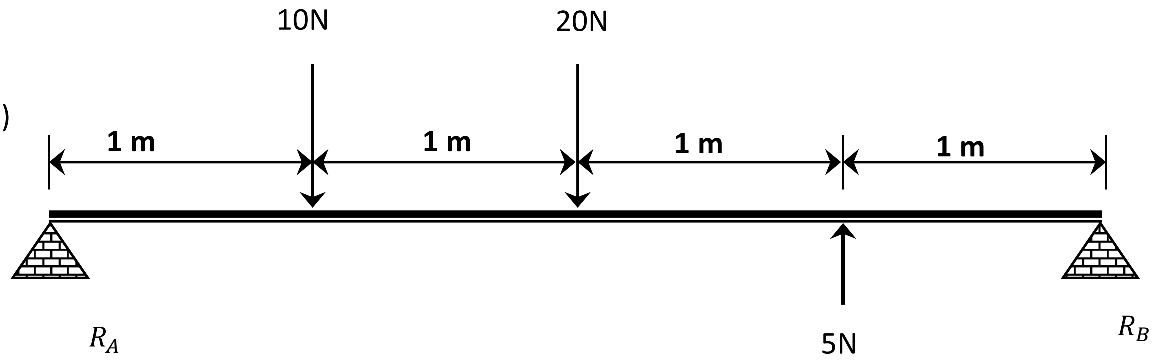
a)



(Ans: R_A =16.11N, R_B =6.89N)

Find the interaction for both of following points, R_A and R_B .

b)



(Ans: R_A =16.25N, R_B = 8.75N)

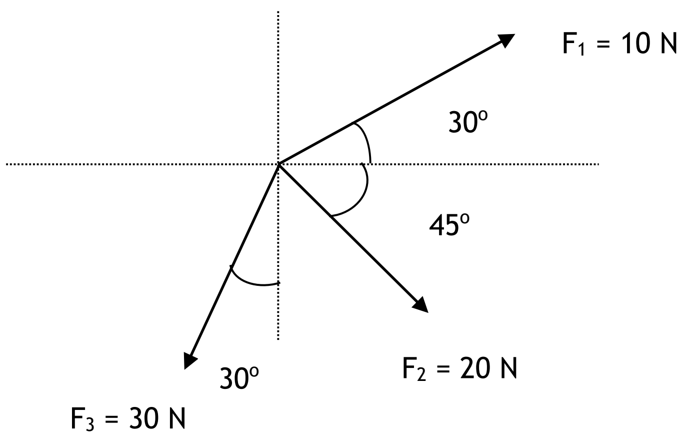
MASTERY PRACTICE

1. (i) Define FORCE

   (ii) Differential between weight and mass.

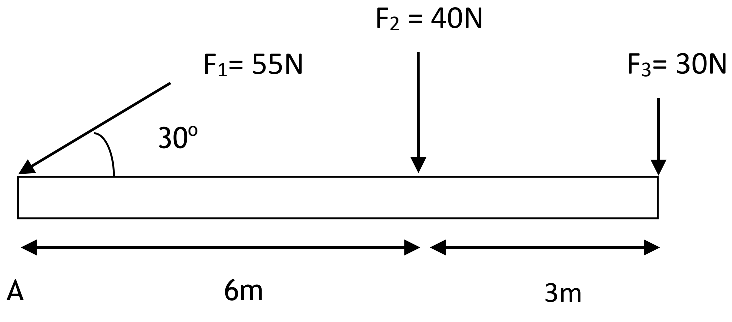
2. A car with a mass of 1000kg accelerates from rest to $60kmh^{-1}$ in 5s. What is the accelerating force developed by the car engine.

3. Determine the resultant force and its direction from the figure below.



4. Give definition and formula of moment.

5. Calculate center of gravity from point A based on figure below.



CHAPTER 4

WORK

ENERGY

POWER

4.1 WORK

- Work, W is defined as the product of the force and displacement of an object in the direction of the force.

- Work is scalar quantity and its unit is Joule(J) or Nm

$$w = F \times s$$

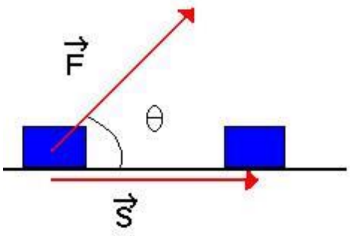
Where,

$w = work$

$F = force$

$s = displacement$

- When the applied force on an object and the direction of movement of the object is not the same, then work done can be calculated by the formula.



$$w = F\ cos\theta \times s$$

EXAMPLE

Nina pushed a box on the floor with a force 15N for a distance of 7m. Calculate the work done by Nina.

Solution:

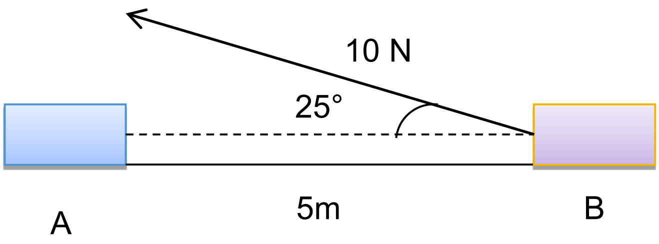
$w = F \times s$

$w = 15 \times 7$

$w = 105\ J$

EXAMPLE

Determine the work done to pull a wood block for the given situation:



Solution:

$w = F \times s$

$w = (10cos25^0) \times (5)$

$w = \ 45.32J$

PRACTICE 1

a)	A boy pulling a cart with a horizontal force of 30N distances of 5m along a horizontal surface. What is the work done by him? *(Ans:150J)*	b)	A boy pushing his bicycle with a force of 25N through a distance of 3m. What is the work done by the boy? *(Ans:75J)*
c)	Calculate the work done, when a force of 12N acting a distance of 60cm. *(Ans:7.2J)*	d)	A roller is pulled along the horizontal by a force of 30N in the direction of the holder that makes a 60^0 angle with the horizontal line. How much work is needed to move the roller as far as 25m the horizontal? *(Ans:375J)*

EXAMPLE

A garage lift raises a 1300kg car a vertical distance of 2.3m at constant speed. How much work do you do?

Solution:

$w = F \times s$

$w = mg \times s$

$w = (1300)(9.81) \times (2.3)$

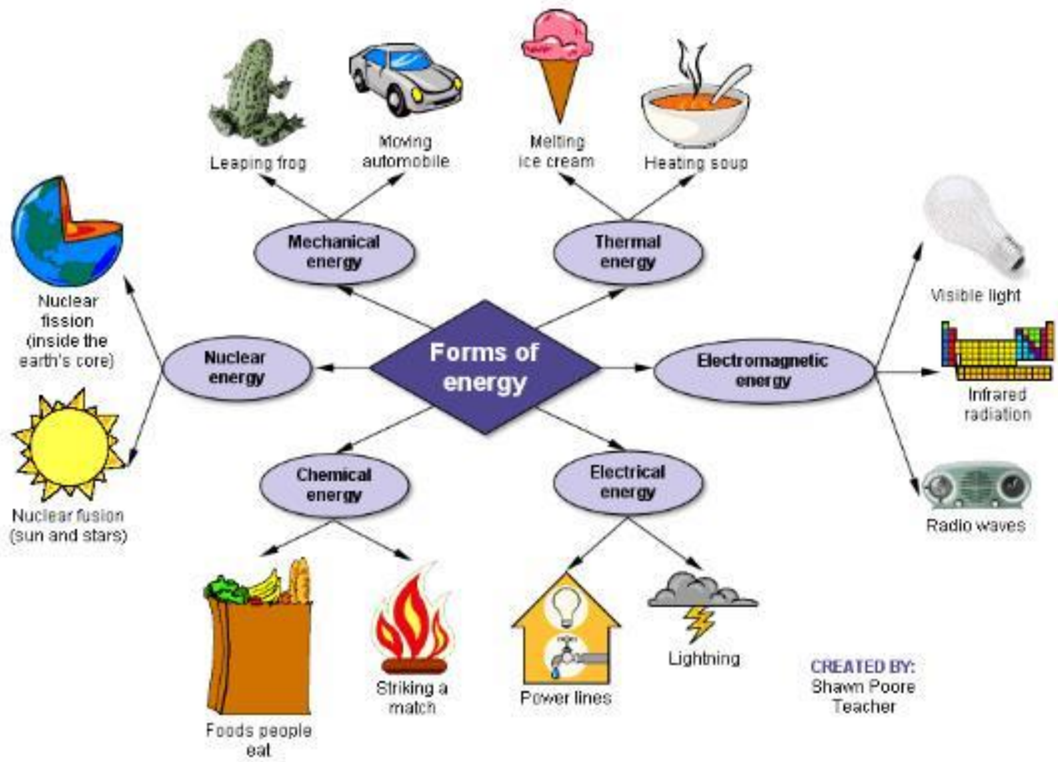
$w = 29331.9J$

PRACTICE 2

a) A girl lifting up a 3kg flower pot steadily to a height of 4.0m. What is the work done by the girl? *(Ans:117.72J)*	b) Find in Joule, work that has been done for the situations below: *10kg mass carried up to the height of 2500m.* *(Ans:245250J)*

4.2 ENERGY

- Energy is defined as **ability to do work.**
- Energy can exist in various forms.
- Example of energy is Potential Energy, Electrical Energy, Sound Energy, Heat Energy, Kinetic Energy and etc.
- Energy is a scalar quantity and its unit is **Joule** or **Nm**



(Image from https://images.app.goo.gl/2bdvUTWL1tiPeiF3A)

4.2.1 Potential Energy

- Potential energy is the energy possessed by an object due to its position or state.

$$E_p = mgh$$

Where,

$E_p = potential\ energy$

$m = mass$

$g = acceleration\ due\ to\ gravity$

$h = height$

.

EXAMPLE

A stone of mass 2kg is dropped from the window of a high building, 45m above the ground. What is the initial gravitational potential energy of the stone?

Solution:

$E_p = mgh$

$E_p = (2)(9.81) \times (45)$

$E_p = 882.9J$

PRACTICE 3

a) An object with a mass of 30kg is lifted up 6m from the earth and is released to fall under the action of gravity. Calculate the potential energy. *(Ans:1765.8J)*	b) A 50kg rock is released from a height of 85m. Calculate the potential energy of the rock at the moment. *(Ans:41692.5J)*
c) A 10 000J of work is needed to raise up a box vertically. If the mass of the box is 20kg, calculate the height that can be reached by the box. *(Ans:50.97m)*	

4.2.2 Kinetic Energy

- Kinetic energy is the energy possessed by an object due to its motion.

$$E_k = {}^1/_2\, mv^2$$

Where,

$E_k = kinetic\ energy$

$m = mass$

$v = velocity$

EXAMPLE

Cyclist mass and his bicycle total 75kg are moving on the flat road with constant velocity 25ms^{-1}. Find the kinetic energy producing during on the flat road.

Solution:

$$E_k = {}^1/_2\, mv^2$$

$$E_k = {}^1/_2\,(75)(25)^2$$

$$E_k = 23437.5J$$

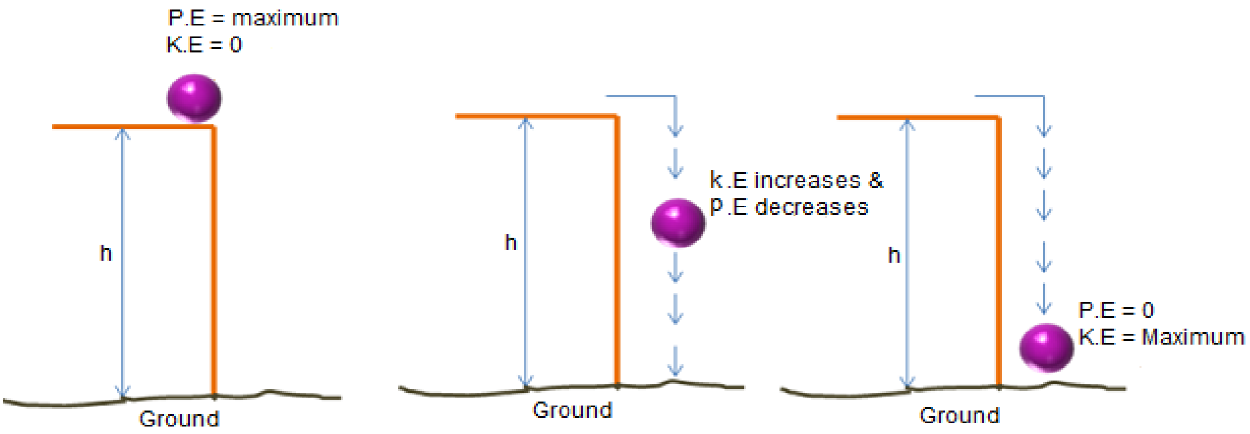
PRACTICE 4

a) An object of mass 4 kg having a kinetic energy of 500 J. Calculate the velocity of the object. *(Ans :15.81 m/s)*	b) A car is moving with a velocity of 20 m/s. if the mass of the car is 3000 kg; calculate the kinetic energy possessed by the car. *(Ans: 600 000J)*

4.2.3 Principle of Conservation of Energy

The principle of conservation of energy states that energy can neither be destroyed nor created, but it can change from one to another.

EXAMPLE



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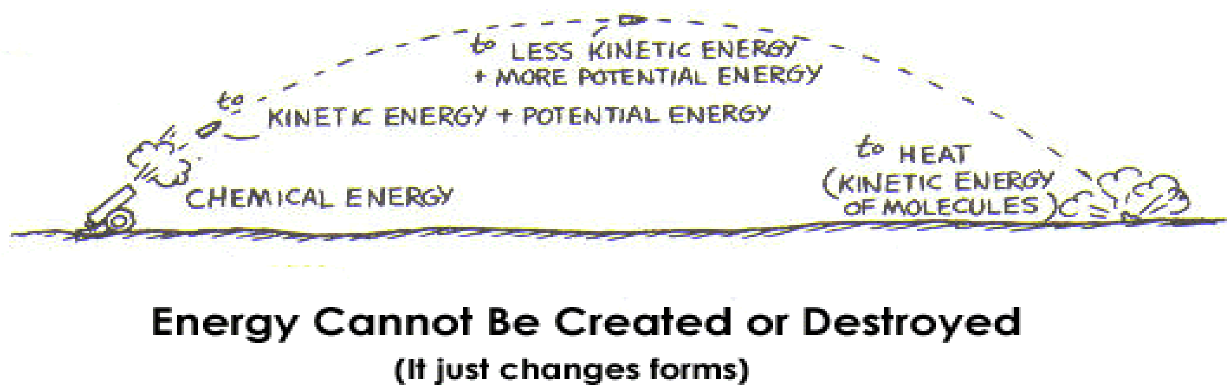

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$$KE_i + PE_i = KE_f + PE_f$$

EXAMPLE

Just before striking the ground, a 200g box has 400J of kinetic energy.

i) Determine the velocity of the box before it hits the ground

$$m = 200g = 0.2kg$$

$$KE = {}^{1}/_{2}\, mv^2$$

$$400 = {}^{1}/_{2}\,(0.2)v^2$$

$$v^2 = 4000$$

$$v = 63.245m/s$$

ii) What height is the box was dropped.

$$PE = mgh$$

$$400 = (0.2)(9.81)(h)$$

$$h = 203.874m$$

PRACTICE 5

a) An aero plane of mass 4.0 x 10^5 kg is flying at a height of 8000 m at a velocity of 240 ms^{-1}. Calculate the kinetic energy and gravitational potential energy of the aero plane. *(Ans: $E_k = 1.152 \times 10^{10} J$, $E_p = 3.139 \times 10^{10} J$)*	b) A jackfruit falls from a height of 22m. What is the velocity just before it hits the ground? Assume g= 9.81ms^{-1}. *(Ans: 20.8 ms^{-1})*
c) An object of mass 50kg thrown at a velocity of 20ms^{-1}. Find the kinetic energy and the height of the object. *(Ans: 10000J, 20.3874 m)*	

4.3 POWER

- Power, P is the rate of doing work.
- The unit of power is **Watt** or J/s or Nm/s.

$$P = \frac{w}{t} = \frac{Fs}{t} = Fv$$

Where,

$P = power$

$w = work$

$t = time$

$F = force$

$s = distance$

$v = velocity$

EXAMPLE

A weightlifter get uplifting 250kg burden as high as 1.6m within 0.15 minute. Calculate:

i) Work done by the weightlifter

$$w = F \times s = mg \times s$$

$$w = (250)(9.81) \times 1.6m$$

$$w = 3924J$$

ii) Power produced by the weightlifter

$$0.15\ min = 9\ sec$$

$$P = \frac{w}{t}$$

$$P = \frac{3924}{9}$$

$$P = 436W$$

PRACTICE 6

a) A motorcycle uses to lift up a mass of 100kg at height 20m in 5 minutes. Calculate the power needed. *(Ans:65.4 W)*	b) A student with a weight of 650 N is going up a staircase of 60m height within 1.5 minutes. How much power is needed by the student to go up the stairs? *(Ans:433.34 W)*
c) A 500N force is applied to an object. If the object travels with a constant velocity of 20m/s. Calculate the power expended on the object. *(Ans:10 000W)*	d) A crane with an output power of 12kW is used to lift a steel bar of mass 400kg to a height of 20m. What is the time taken by the crane to do this work? *(Ans:6.54s)*

4.4 EFFICIENCY

- The efficiency of a device is defined as the **percentage of the input energy that is transformed into useful energy.**

$$Efficiency(\%) = \frac{P_{output}}{P_{input}} \times 100\%$$

- Efficiency also can be described in term of **work** and **energy**

$$Efficiency(\%) = \frac{W_{output}}{W_{input}} \times 100\%$$

$$Efficiency(\%) = \frac{E_{output}}{E_{input}} \times 100\%$$

EXAMPLE

A crane is used to lift a steel bar of mass 400kg to a height of 20m in 2s. If the efficiency of the crane is 75%, what is the power input of the crane?

Solution:

$$P_{out} = \frac{mgh}{t}$$

$$P_{out} = \frac{(400)(9.81)(20)}{2}$$

$$P_{out} = 39240\ W$$

$$P_{in} = \frac{P_{out}}{efficiency} \times 100\%$$

$$P_{in} = \frac{39240}{75} \times 100\%$$

$$P_{in} = 52320\ W$$

PRACTICE 7

a) A crane's efficiency to lift a load 3000kg through a vertical height of 10m in 2s is 70%. Determine the input power of the crane. *(Ans: 210214W)*	b) A petrol engine has a work output of 96kJ per minute. What is the power input if the engine efficiency is 20%? *(Ans: 8000W)*
c) A petrol engine has a work output of 78 000J per minute. What is the power input if the efficiency of the engine is 30%? *(Ans:4333.33 J/s)*	

MASTERY PRACTICE

1. State the **definition** and **SI units** for the following terms:

    i) Kinetic Energy

    ii) Potential Energy

2. State **THREE (3)** examples of energy.

3. An object with a mass of 30kg is lifted up 6m from the ground and is released to fall under the action of gravity. Calculate:

    i) Kinetic Energy just as it released.

    ii) Potential Energy just as it released.

4. A weightlifter get uplifting 150kg burden as high as 1.8m within 0.15 minute. Calculate:

    i) Work done by the weightlifter

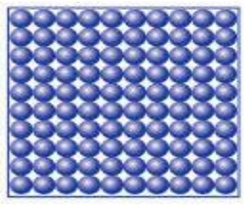
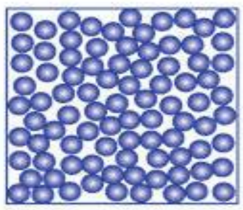
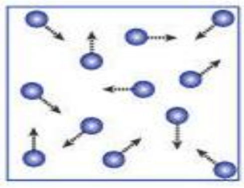
    ii) Power produced by the weightlifter

CHAPTER 5

SOLID AND FLUIDS

5.1 MATTER AND ITS PROPERTIES

- All around us is a matter. Matter is anything that has mass and occupies space (volume). For example; woods, books, water, air and others.
- A matter is made up of tiny particles which are known as molecule.
- The molecules of a matter consist of an atom.
- Matters exist in three different states. They are solid, liquid and gas.
- Table below show differentiate three states of matter.

Characteristic	Solid	Liquid	Gas
Arrangement of particle	 Very closely packed	 Closely packed	 Widely spaced
Shape and Volume	Fixed shape and volume	Takes the shape and volume of its container	Takes the shapes and volume of its container
Movement	Vibrate and spin about their fixed position	Vibrate and move randomly but not freely	Move freely and randomly.
Compressibility	Cannot be compressed	Can be compressed	Can be easily compressed

(Image from https://images.app.goo.gl/jFbNoPCR8AVEU2cm8)

5.2 DENSITY OF MATTER

- Density of matter, ρ is defined as mass per unit volume.

$$\rho = \frac{m}{v}$$

Where,

$\rho = density$

$m = mass$

$v = volume$

- The S.I unit is kg/m^3or g/cm^3.

EXAMPLE

A metal has a mass of $2.5kg$ and occupies a volume of $0.23cm^3$.Calculate the density of the brick.

Solution:

$v = 0.23cm^3$

$$v = 0.23cm^3 \times \frac{1m^3}{(100)^3cm^3} = 2.3 \times 10^{-7}m^3$$

$\rho = \frac{m}{v}$

$\rho = \frac{2.5}{2.3\times10^{-7}} = 1.087 \times 10^7\ kg/m^3$

PRACTICE 1

The density of air is 1.29 kg/m^3. Calculate the mass of air in a room with a dimension of $10m \times 8m \times 24m$. *(Ans: m = 2476.8 kg)*	The density of pure gold is $19.3gcm^{-3}$. A piece of jewellery that is completely made of gold has a mass of $5g$. What is the volume of the jewellery? *(Ans: 0.26 cm^3)*
Air has a density of 1.29 under standard conditions. What is the mass of air in a room with dimensions $7.5m \times 10m \times 2m$? *(Ans: 193.5kg)*	A solid metal cylinder has radius, $r = 0.45\ cm$ and length, $L = 5cm$. Its mass is 60 $gram$. Find the density of the cylinder. *(Ans:18 868 kg/ m^3)*

5.2.1 Relative density

- Relative density also known as a specific gravity of matter.
- Relative density is a dimensionless ratio of the density of two substances or materials.

$$RD = \frac{\rho_{substance}}{\rho_{water}}$$

Where,

$RD = relative\ density$

$\rho_{substance} = density\ substance$

$\rho_{water} = density\ of\ water\ (1000\ \ kg/m^3)$

Table 5.1: The density of substance

Substance	Density(kg / m^3)	Density(g / cm^3)
Water	1000	1
Ice	917	0.917
Alcohol	790	0.790
Oxygen	1.43	0.00143
Air	1.29	0.00129

EXAMPLE

An object has a density of $4\ g/cm^3$. Calculate its relative density with respect to water, which has a density of $1\ g/cm^3$.

Solution:

$$RD = \frac{4g/cm^3}{1g/cm^3} \quad or \quad RD = \frac{40000kg/m^3}{1000kg/m^3} = 4$$

PRACTICE 2

a) Calculate the density and relative density of a rectangular block with the following measurements:$(\rho_{water} = 1000\, kg/m^3)$

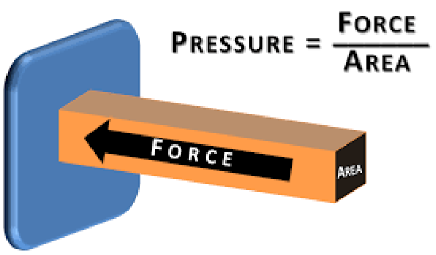
Length : 28 cm	Width : 18 cm
Height : 17 cm	Mass : 7800 g

(Ans: ρ = 910.364 kg/m^3, relative ρ = 0.910)

b) A metal has a volume and mass of 3.18 X 10^{-6} m^3 and 60g respectively. Find the density of metal and its specific density. Given the density of water is 1000 kgm^{-3}

(Ans: 18868 kg/m^3, 18.868)

5.3 PRESSURE



(Image from https://images.app.goo.gl/TWp5YkG6KGYZkbNS7)

- Pressure is force per unit area.

$$P = \frac{F}{A}$$

Where,

$P = pressure$

$F = force$

$A = area$

- The SI unit for pressure is **Nm^{-2}** or **Pascal (Pa)**
- Application in involving high pressure

A sharp knife has a very small surface area its cutting edge so that high pressure can exert to cut the meat

The studs on football boot have only a small area of contact with the ground. The pressure under the studs is high enough for them to sink into the ground, which gives extra grip.

(Image from https://images.app.goo.gl/Vnz1Ezbp3Cw9JdwH6)

EXAMPLE

On a table is a full box of apples which has a weight of 100 N. The area of the box is 0.4 m^2. What is the pressure between the box and the table top?

Solution:

$$P = \frac{F}{A}$$

$$P = \frac{100}{0.4}$$

$$P = 250\ Pa$$

PRACTICE 3

a)	A metal cube of mass 40 kg and surface area of 0.08 m^2 is placed on a floor. Determine the pressure exerted on the floor?
	(Ans:4905 Pa)

b) Yasmin uses a knife with a sharp edge and a cross-sectional area of 0.025 cm^2 to cut open honeydew.

i. If the force applied on the knife is 15 N, what is the pressure exerted by the knife on the honeydew? *(Ans:6x10^6 Pa)*

ii. After that, she cuts open a pineapple using the same knife by exerting a pressure of 3 x 10^5 Pa. Calculate the magnitude of force applied to cut the pineapple.

(Ans:0.75 N)

5.3.2 Pressure in Liquid

- The pressure, P, of a fluid at a particular depth in the fluid is given by the formula:

$$P = \rho g h$$

Where,

$P = pressure$

$\rho = density$

$g = gravitational\ field\ strength$

$h = depth$

EXAMPLE

A cylinder contains mercury to a depth of 60 cm. Find the pressure it exerts at the base. (Density of mercury = 13 600 kg/m^3).

Solution:

$60cm = 0.6\ cm$

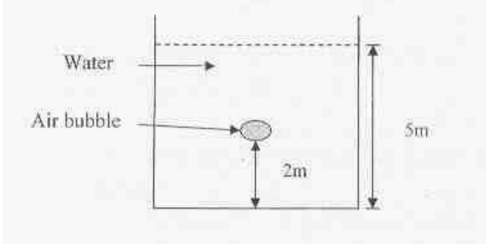
$P = \rho g h$

$P = (13600)(9.81)(0.6)$

$P = 80049.6\ Pa$

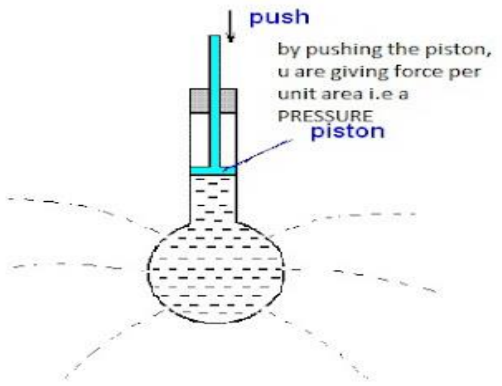
PRACTICE 4

a) What is the total pressure experienced by Kevin if he dives 25 meters below the surface of the ocean? (Neglect the pressure due to the atmosphere) $(\rho_{seawater} = 1.025 \times 10^3\ kg/m^3)$ $(g = 9.81\ m/s^2)$ *(Ans:251381.25 Pa @ $2.5\text{x}10^5$ Pa)*	b) Calculate the pressure and force acting on the cylindrical bone with diameter of 0.85 m located at the bottom of an 8 m tank filled with oil of density 875 kg/m^3. *(Ans:P = 68670 N/m^2, F = 38970.23 N)*

c) A submarine has submerged to a depth of 68 m below the sea. Calculate the force acting on the submarine, if the surface area of the submarine is 15×10^6 cm^2. $(\rho_{seawater} = 1.03 \times 10^3\ kg/m^3)$ *(Ans:1.0306x10^9 N)*	d) From Figure 4 below, find the pressure exerted on air bubble in the water. $(\rho_{water} = 1000\ kg/m^3)$  Figure 4 *(Ans:29430 Pa)*

5.4 PASCAL'S PRINCIPLE

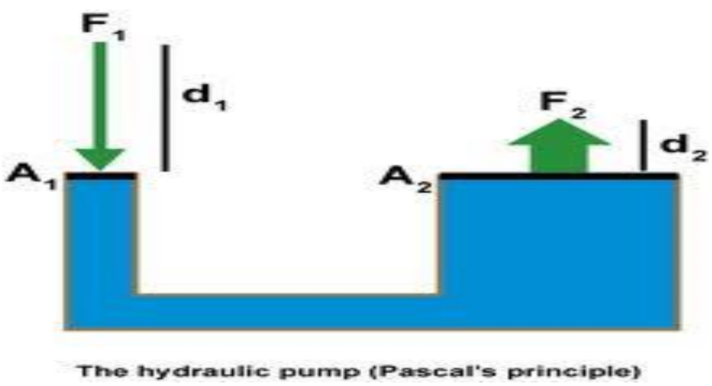
Pascal's principle states that the pressure exerted on a confined liquid is transmitted equal in all direction.



(Image from https://images.app.goo.gl/nrzaqXjBoTrsig21A)

The figure show the plunger is pushed in, the pressure of water at the end of the plunger will cause water to spurt out in directions.

5.4.1 Hydraulic Systems



Input pressure = Output pressure

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$A_1 d_1 = A_2 d_2$$

(Image from https://images.app.goo.gl/ZLgdzH2ERCHKdzZr5)

Where,

$$F = force$$

$$d = distance$$

$$A = area$$

EXAMPLE

Figure A shows a hydraulic pump. The cross-section areas of piston P and piston Q are 10 cm^2 and 100 cm^2 respectively.

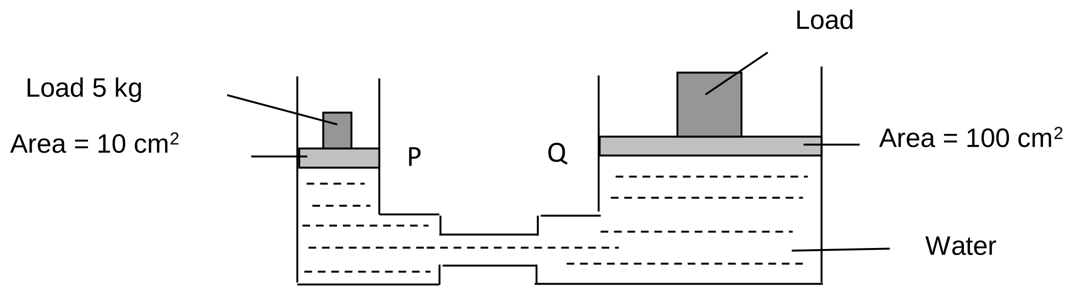


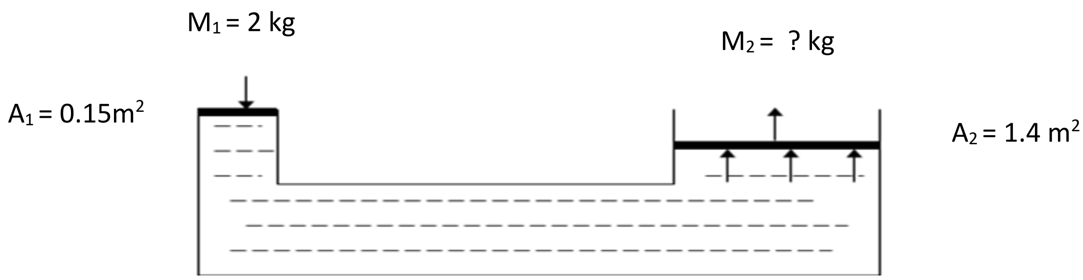
Figure A / Rajah A

Solution:

a) What is the force which is applied on piston P? $F = mg$ $F = (5)(9.81)$ $F = 49.05\ N$	b) Find the pressure which is exerted on piston P. $10cm^2 = 0.001\ m^2$ $P = \frac{F}{A}$ $P = \frac{49.05}{0.001}$ $P = 49050\ Pa$
c) Calculate the weight of the load that can be lifted by piston Q $P_1 = P_2$ $P = \frac{F}{A}$ $F = 49050\ (0.01)$ $F = 490.5\ N$	d) If the water level at Q rises by 0.001 cm, how much will pistons P will go down. $(Ad)_P = (Ad)_Q$ $10d = 100(0.001)$ $d_P = \frac{0.1}{10}$ $d_P = 0.01\ cm$

EXAMPLE

The figure below shows a hydraulic system in equilibrium. What is the value of the mass, M_2.



Solution:

$F = mg$

$F_1 = (2)(9.81) = 19.62\ N$

Pascal Principle

$\frac{F_1}{A_1} = \frac{F_2}{A_2}$

$\frac{19.62}{0.15} = \frac{F_2}{1.4}$

$F_2 = 183.12N$

$F = mg$

$183.12 = m(9.81)$

$m = 18.667\ kg$

PRACTICE 5

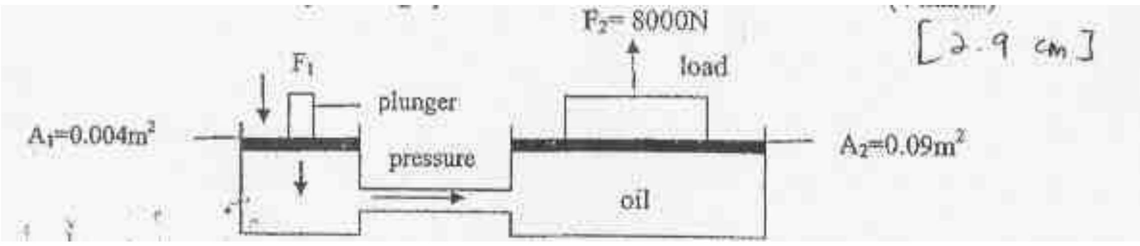
a) The cylindrical piston of a hydraulic jack has a cross-sectional area of 0.09 m^2 and the plunger has a cross-sectional area of 0.004 m^2.

i. Given the upward force for lifting a load placed on top of the large piston is 8000 N. calculate the downward force on the plunger required.

(Ans:356 N)

ii. If the distance moved by the plunger is 65 cm, what is the distance moved by the large piston?

(Ans:2.9 cm)



b) According to Pascal's Principle, a force exerted on piston. It can lift a car at piston B as shown in Figure 4(d). The diameter of piston A and piston B is 0.05 m and 0.20 m respectively, calculate the force must be exerted on the piston A to lift a 15000 N car.

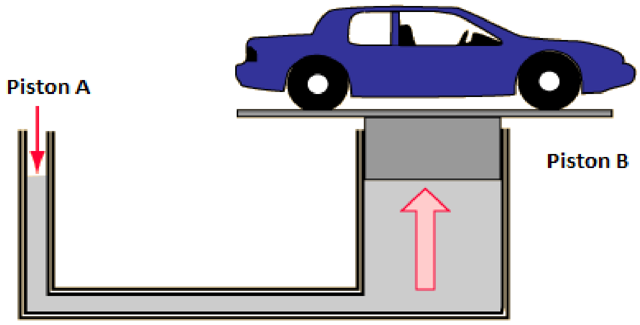


Figure 4 (d)

(Ans:937.5 N)

c) Figure 2 shows a hydraulic lift with a force F_1 acting on a circular piston with an area of 0.02 m^2. The pressure generated is transmitted through a liquid to a second piston with area of 0.12 m^2. Calculate the minimum force F_1 which need to be applied so that a load of 5000 N is lifted.

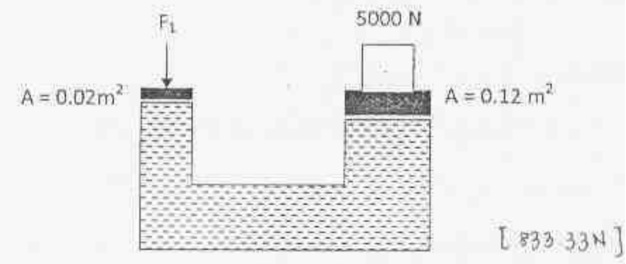
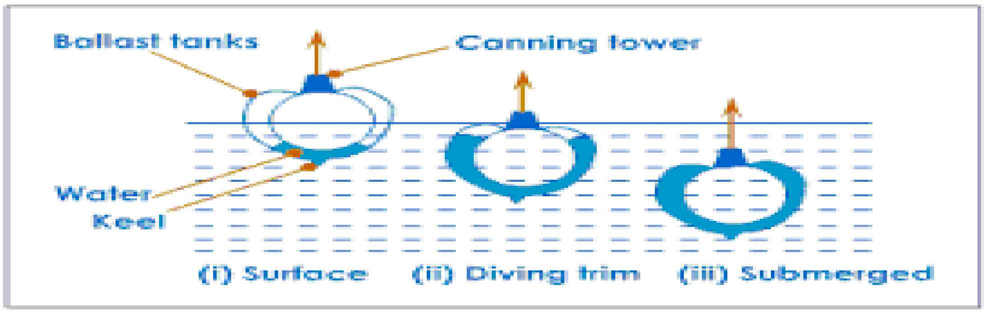


Figure 2

(Ans:833.33 N)

5.5 ARCHIMEDES'S PRINCIPLE

- An immersed body is buoyed up by a force equal to the weight of the liquid it displaces.
- Application of Archimedes' Principle is well known with submarine, hot-air balloon, ship etc.



(Image from https://images.app.goo.gl/qVtNAoGLvno1yTXx5)

Buoyant force = F_b= weight of liquid displaced

F_b = weight of immersed body

$F_b = m_{of\ displaced}g$

$F_b = \rho g V$

*Volume of liquid displaced = volume of object.

5.5.1 Law of Floatation

- A floating object displaces its own weight of the fluid in which it floats.
  - weight of floating = weight of fluid displaced
  - mass of floating object = mass of fluid displaced

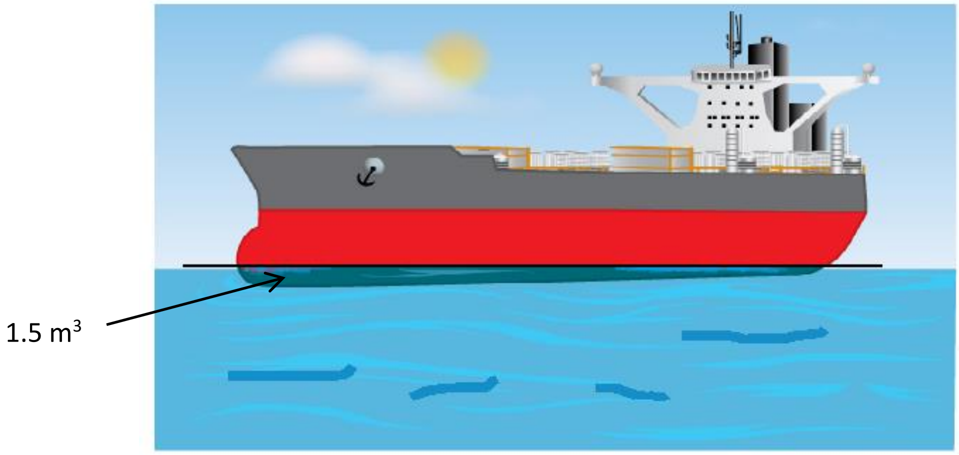
- Buoyant force **>** Weight of object
  - object moves to the surface of the water

- Buoyant force **<** Weight of object
  - object sinks to the bottom

- Buoyant force **=** Weight of object
  - Object floats or remain stationary in the water

EXAMPLE

Figure below shows a ship loaded with some goods floating on a sea. The density of the sea water is 1020 kg/m^3. Calculate the weight of the ship.



(https://www.aplustopper.com/understanding-buoyancy-using-archimedess-principle/)

Solution:

$$weight\ of\ the\ ship = weight\ of\ sea\ water$$

$$weight\ of\ the\ ship = \rho V g$$

$$weight\ of\ the\ ship = 1020 \times 1.5 \times 9.81$$

$$weight\ of\ the\ ship = 15009.3\ N$$

EXAMPLE

A concrete block has a actual weight of 163 N. When it is fully submerged under the sea, its apparent weight is 115 N. Calculate the density of the sea if the volume of the sea water displaced by the concrete block is 4800 cm^3. (g = 9.81N/kg)

Solution:

$$4800cm^3 \times \frac{1^3m^3}{100^3m^3} = 4.8 \times 10^3m^3$$

Buoyant force = Actual weight – apparent weight

= 163 N – 115 N

= 48 N

According to Archimedes' Principle:

Buoyant force = weight of sea water displaced

Thus,

$$F_B = \rho V g$$

$$\rho = \frac{F_B}{Vg}$$

$$\rho = \frac{48}{(4.8\times10^3)\times(9.81)}$$

$$\rho = 1019 \ kg/m^3$$

PRACTICE 6

a) A stone weight 2.5 N. When it is fully submerged in a solution, its apparent weight is 2.2 N. Calculate the density of the solution if its volume displaced by the stone is 25 cm^3. [$g=9.8\ Nkg^{-1}$] *(Ans: 1223.24 kg/m^3)*	b) A rock with weight of 52N is found to have an apparent weight of 36N when completely submerged in water. The density of water is $1000kgm^{-3}$. i. Calculate the buoyant force acting on the rock when it is submerged in water. *(Ans: 16N)* ii. What is weight of the water displaced by the rock? *(Ans: 16N)* iii. Calculate the volume of the rock *(Ans: $1.6 \times 10^{-3}\ m^3$)*

MASTERY PRACTICE

a. State **3 differences** between solids, liquids and gases.

b. A metal has a mass of 2600 g and occupies a volume of $0.123m^3$.Calculate the density of the brick.

c. The wind blow and exerts a pressure of 145 Pa on a wall surface. If the surface area of the wall is $6m^2$, find the force which acts on the wall

d. Figure A shows a hydraulic pump. The cross-section areas of piston P and piston Q are 20 m^2 and 100 m^2 respectively.

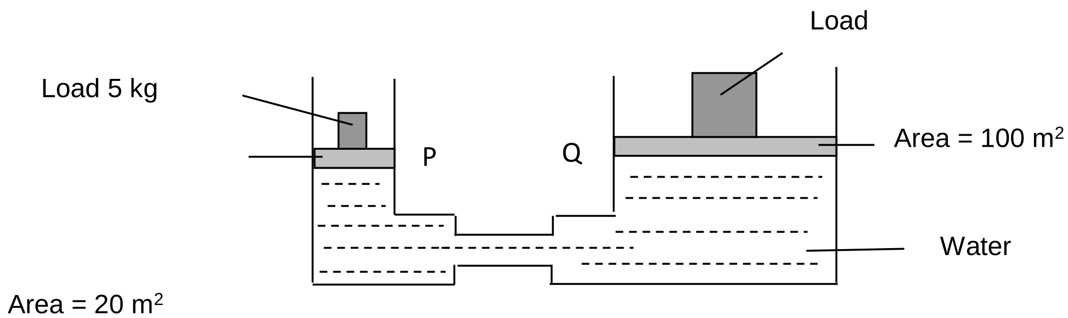
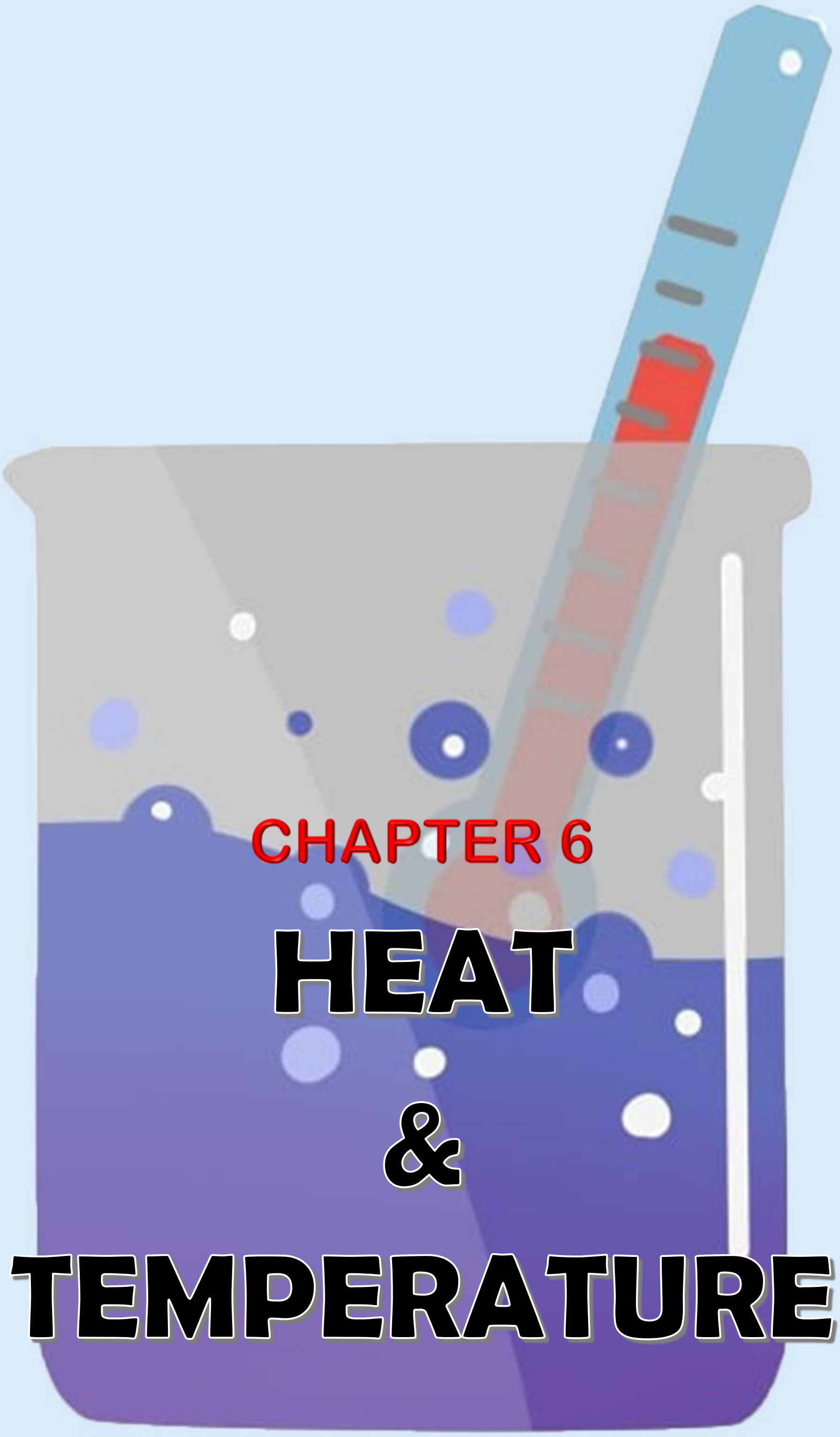


Figure A / Rajah A

e. Calculate the weight of the load that can be lifted by piston Q

f. If the water level at Q rises by 0.001 cm, how much will piston P go down.



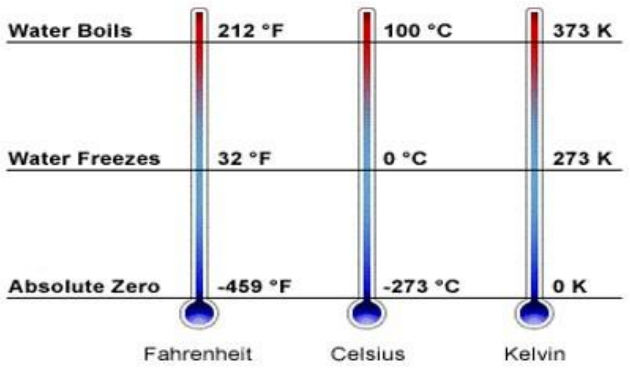
CHAPTER 6

HEAT & TEMPERATURE

6.1 TEMPERATURE

- Temperature is a physical quantity that measure degree of hotness of a body.
- SI unit of temperature is Kelvin(K)
- Other unit is Celsius (℃), Fahrenheit (℉).

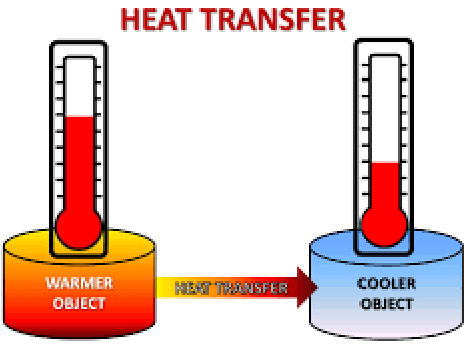
- Temperature is measured with **thermometer.**



(Image from https://images.app.goo.gl/DzrYUEutEJx9zUnp9)

6.2 HEAT

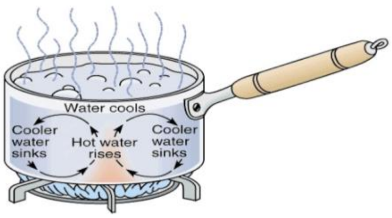
- Heat is an energy (thermal) that flows naturally from hot body to cold body.
- SI unit is **Joule(J)**



(Image from https://images.app.goo.gl/3MGRbTFAik7Q5fHE6)

6.2.1 Heat Transfer

- Heat can be transfer in **conduction**, **convection** or **radiation**.

Types of Heat Transfer	Process	Diagram
Conduction	• A process of transferring heat from a region of higher temperature to a region of lower temperature within a body by collisions of particle and diffusion. • Conduction works the best in solids.	 (Image from https://images.app.goo.gl/EUXDDaoxVubQNmEHA)
Convection	• Convection is up and down movement of gases and liquid caused by heat transfer • Example water boiling.	 (Image from https://images.app.goo.gl/37EyLiTwUbtkmZqaA)
Radiation	• Transfer of heat by electromagnetic waves travel through space • Examples of radiation are microwave oven, heat from the sun reaching the earth.	 (Image from https://images.app.goo.gl/jJhUHKsWw8bD7NZc6)

6.2.2 Heat Capacity

- Heat capacity of a substance is the amount of heat required to raise its temperature by 1°C.

$$C = \frac{Q}{\Delta\theta}$$

Where, $C = heat\ capacity$

$Q = heat\ energy$

$\Delta\theta = temperature\ change\ (\theta_{final} - \theta_{initial})$

6.2.3 Specific Heat Capacity (c)

- Specific heat capacity of a substance is the heat required to raise the temperature of 1kg of the substance by 1°C.
- Its unit SI $Jkg^{-1}C^{-1}$

$$Q = mc\Delta\theta$$

Where,

$Q = heat\ energy\ (\ heat\ received\ or\ lost)$

$m = mass$

$c = specific\ heat\ capacity$

$\Delta\theta = temperature\ change\ (\theta_{final} - \theta_{initial})$

Table 1: Specific heat capacity of substances

Substance	Specific heat capacity, c ($J\ kg^{-1}\ °C^{-1}$)	Substance	Specific heat capacity, c ($J\ kg^{-1}\ °C^{-1}$)
Solids		**Liquids**	
Ice	2100	**Water**	4200
Aluminium	900	**Alcohol**	2400
Concrete	800	**Paraffin**	2100
Glass	700	**Mercury**	140
Iron	500	**Steam (110 °c)**	2010
Copper	400		

EXAMPLE

Calculate :

i) The amount of heat required to raise the temperature of 8 kg water from 20°C to 60°C.

Solution:

$$m = 8kg$$

$$C = 4200\ Jkg^{-1}°C^{-1}$$

$$\theta = 40°C$$

$$Q = mc\Delta\theta$$

$$Q = (8)(4200)(40°)$$

$$Q = 1344000J$$

ii) The specific heat capacity if the metal heat capacity is $880kJ$ for a $2.5kg$ metal with temperature of $250°C$.

Solution:

$$Q = 880\ kJ$$

$$\theta = 250°$$

$$m = 2500g = 2.5kg$$

$$Q = mc\Delta\theta$$

$$880k = (2.5)(c)(250°)$$

$$880k = 625c$$

$$c = 1.408kJ/kg^{-1}°C^{-1}$$

$$c = 1408\ J/kg^{-1}°C^{-1}$$

PRACTICE 1

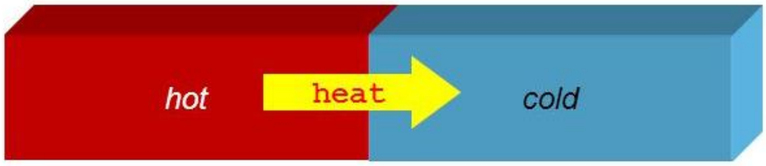
a) An aluminium plate with mass of $600g$ is heated from 28°C to 45°C. Calculate the quantity of heat of the aluminium plate if the specific heat capacity of aluminium is $950\ Jkg^{-1}°C^{-1}$. *Ans:* $9690J$	e) The temperature of an object with the mass of $2.5kg$ increases from 30°C to 75°C when it absorbs $54000J$ of heat. Calculate the specific heat capacity for the object. *Ans:* $480Jkg^{-1}°C^{-1}$
f) Calculate the amount of heat required to raise the temperature of $350g$ of copper from 37°C to 54°C. (Given that specific heat capacity of copper is $390Jkg^{-1}°C^{-1}$) *(Ans:*$2320.5J$*)*	g) The specific heat capacity of water is $4200Jkg^{-1}°C^{-1}$. Find the heat lost from $3.5kg$ of water when its temperature is dropped from 100°C to 30°C. *Ans:*$1029000J$

6.3 THERMAL EQUILIBRIUM

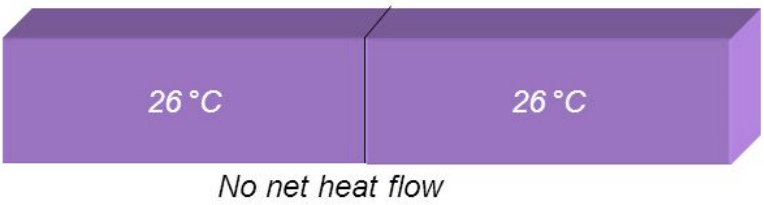
- Thermal equilibrium happens when two bodies which are different temperatures are placed in contact with each other.

(Image from https://images.app.goo.gl/835bkg6WD6VgSvji6)

- Then, heat is transferred from the hotter body to cold body.



- Heat transfer process continues until the temperatures of two bodies are equal.



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$$Heat\ lost = Heat\ gained$$

$$-Q_{lost} = Q_{received}$$

$$-mc\theta = mc\theta$$

EXAMPLE

$550g$ of copper at temperature of $120°C$ is put in $330g$ of water with initial temperature $25°C$. If there is no heat exchange with the outside, find the final temperature.

(Specific heat capacity of copper: $390Jkg^{-1}°C^{-1}$)

(Specific heat capacity of water: $4200Jkg^{-1}°C^{-1}$)

Solution:

$$m_{copper} = 0.55\ kg$$

$$m_{water} = 0.33\ kg$$

$$-Q_{lost} = Q_{received}$$

$$-(mc\theta) = mc\theta$$

$$-(0.55)(390)(\theta_f - 120) = (0.33)(4200)(\theta_f - 25)$$

$$-214.5(\theta_f - 120) = 1386(\theta_f - 25)$$

$$-214.5\theta_f + 25740 = 1386\theta_f - 34650$$

$$-214.5\theta_f - 1386\theta_f = -34650 - 25740$$

$$-214.5\theta_f - 1386\theta_f = -34650 - 25740$$

$$-1600.5\theta_f = -60390$$

$$\theta_f = \frac{-60390}{-1600.5}$$

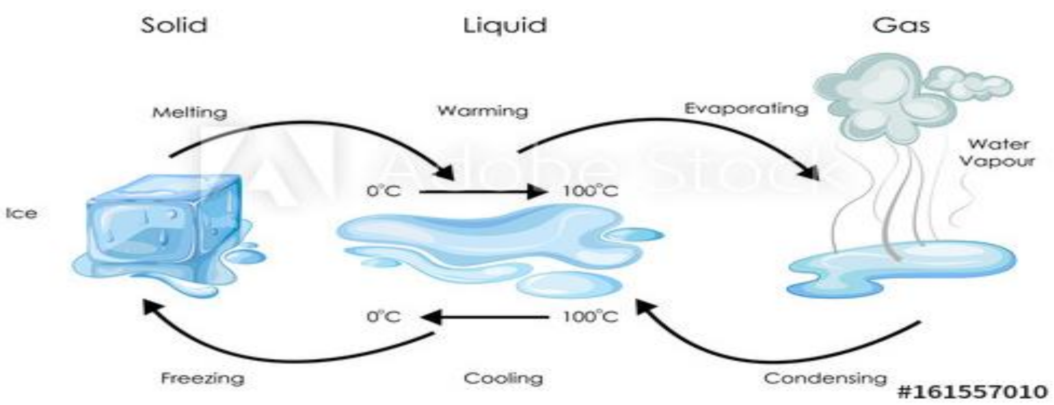
$$\theta_f = 37.73°C$$

PRACTICE 2

a) A $350\,g$ copper block at 25°C is immersed in a container filled with $200g$ of water at 65°C. Final temperature of 60°C is reached. There is no heat lost, what is the copper's specific heat capacity? $(c_{water} = 4200Jkg^{-1}°C^{-1})$ *Ans:* $342.86Jkg^{-1}°C^{-1}$	b) A cube of plumbum with a mass of $1.5kg$ and at temperature of 80°C is put into water with a mass of $2kg$ and at temperature of 25°C. After these two materials are mixed together, find the final temperature of the mixture. $\begin{pmatrix} c_{water} = 4200Jkg^{-1}°C^{-1}, \\ c_{plumbum} = 1300Jkg^{-1}°C^{-1} \end{pmatrix}$ *Ans:* 35.36°C

6.4 SPECIFIC LATENT HEAT *(HABA PENDAM TENTU)*

- **Latent heat**, energy absorbed or released by a substance during a change in its physical state (phase) that occurs without changing its temperature.
- Unit : Jkg^{-1}



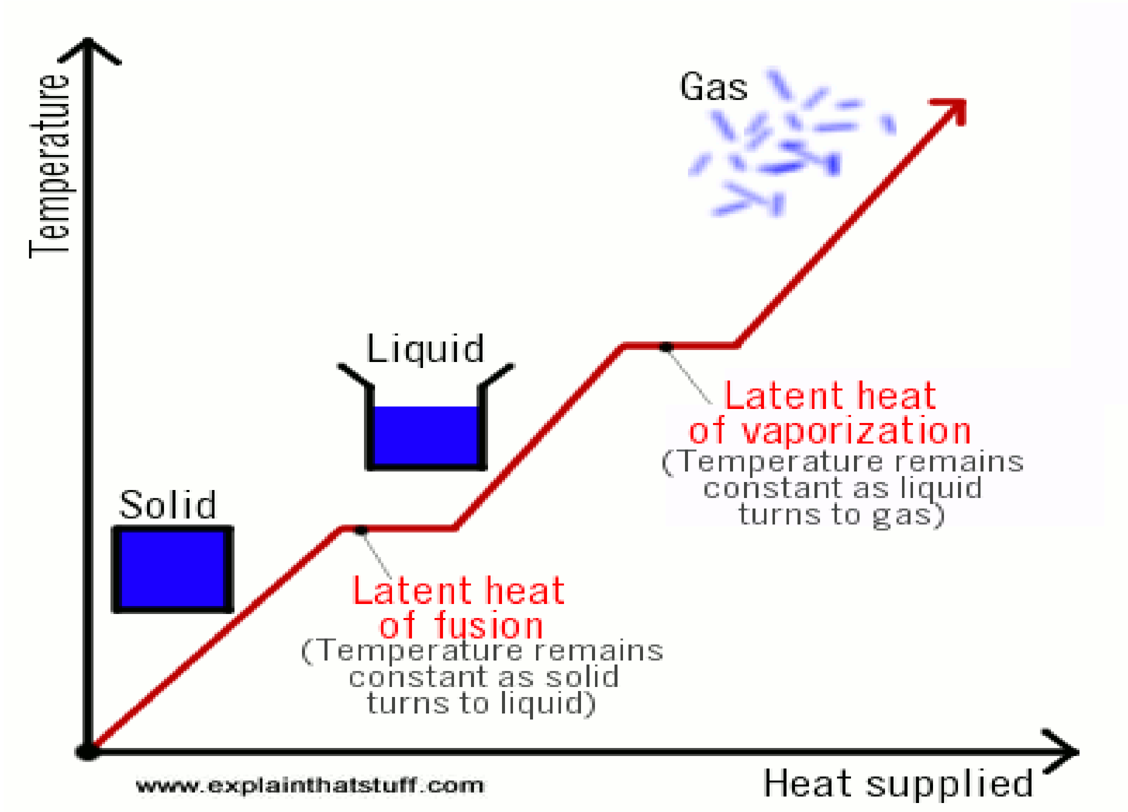
(Image from https://images.app.goo.gl/vvFHV3vXcfTLVqfx9)

- Heat of fusion : The latent heat associated with melting a solid or freezing a liquid
- Heat of vaporization : that associated with vaporizing a liquid or a solid or condensing a vapour .

Specific Latent Heat — Heat Energy — Mass

$$L = \frac{Q}{m}$$

LATENT HEAT



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EXAMPLE

(Image from https://images.app.goo.gl/BHn1cqhHN8r43peu6)

Calculate the amount of heat needed to change $1kg$ water at $100°C$ to water vapour at $100°C$.

$(latent\ heat\ of\ fusion = 3.36\ \times 10^5 Jkg^{-1})$

$(latent\ heat\ of\ vapourization = 2.26 \times 10^6 Jkg^{-1})$

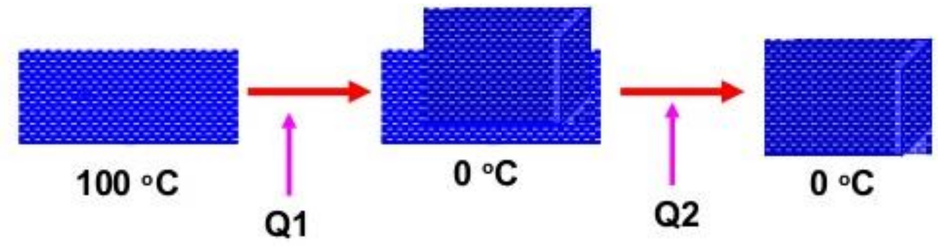
Solution:

$Q = mL$

$Q = 1 \times 2.26 \times 10^6$

$Q = 2.26 \times 10^{6\ J}$

EXAMPLE



(Image from https://images.app.goo.gl/o2br25gmQK33pBKa8)

500g of boiled water were put into the freezer. Calculate the amount of heat released when the the water change into the ice cube.

$(latent\ heat\ of\ fusion = 3.36\ \times 10^5 Jkg^{-1})$

$(latent\ heat\ of\ vapourization = 2.26 \times 10^6 Jkg^{-1})$

$(specific\ heat\ capacity = 4200\ Jkg^{-1}C^{-1})$

Solution:

$Q = Q1 + Q2$

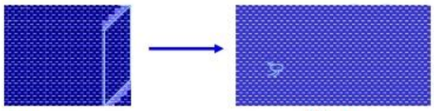
$Q = mc\theta + mL$

$Q = (0.5 \times 4200 \times 1000) + (0.5 \times 3.36 \times 10^5)$

$Q = 210000 + 1.68 \times 10^5$

$Q = 3.78 \times 10^5 J$

PRACTICE 3

a) Calculate the amount of heat needed to change $1kg$ of ice at $-5°C$ to $0°C$ of water. $(latent\ heat\ of\ fusion = 3.36 \times 10^5 Jkg^{-1})$ $(latent\ heat\ of\ vapourization = 2.26 \times 10^6 Jkg^{-1})$ $(specific\ heat\ capacity = 4200\ Jkg^{-1}C^{-1})$  *(ans :* 3.57×10^5)	b) Calculate the amount of heat needed to change $500g$ of $0°C$ ice to $20°C$. $(latent\ heat\ of\ fusion = 3.36 \times 10^5 Jkg^{-1})$ $(specific\ heat\ capacity = 4200\ Jkg^{-1}C^{-1})$ *(ans :* $2.09 \times 10^5 J$)

c) $0.5kg$ of water at 30°C is heated until $0.2kg$ steamed is produced. How much heat energy is supplied to the water? $(latent\ heat\ of\ vapourization = 2.26 \times 10^6 Jkg^{-1})$ $(specific\ heat\ capacity = 4200\ Jkg^{-1}C^{-1})$ *(ans :* $5.99 \times 10^5 J)$	d) How much heat is needed to convert 4g of ice to steam at 100°C $(latent\ heat\ of\ fusion = 3.36\ \times 10^5 Jkg^{-1})$ $(latent\ heat\ of\ vapourization = 2.26 \times 10^6 Jkg^{-1})$ $(specific\ heat\ capacity = 4200\ Jkg^{-1}C^{-1})$ *(ans :* $1.21 \times 10^4 J)$

MASTERY PRACTICE

1. Define and state the SI units for each of the following:

   i. Heat

   ii. Temperature

   iii. Heat capacity

2. State and explain **THREE (3)** ways of heat transfer.

3. What is the specific heat of a substance that absorbs $2.5 \times 10^3 J$ of heat when a sample of $20g$ of the substance increases in temperature from $10°\text{C}$ to$70°\text{C}$?

4. $10kg$ of water is allowed to cool after reaching its boiling point. Calculate the final temperature of the quantity of water after $480kJ$ of heat energy has been released. (Given that the specific heat capacity, *c* of water is $4200Jkg^{-1}°\text{C}^{-1}$)

5. A $30g$ cube of aluminium at temperature of $120°\text{C}$ is put into water at temperature of $30°\text{C}$. After the two materials are mix together, the final temperature of the mixture is $40°\text{C}$. Calculate the mass of the water. (Given that the specific heat capacity, *c* for aluminium = $900\ Jkg^{-1}°\text{C}^{-1}$and specific heat capacity, *c* of water = $4200Jkg^{-1}°\text{C}^{-1}$)

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Terbitan

POLITEKNIK MALAYSIA
TUANKU SYED SIRAJUDDIN

e ISBN 978-967-2258-40-7

9789672258407