KWAZULU-NATAL PROVINCE

EDUCATION
REPUBLIC OF SOUTH AFRICA

CURRICULUM GRADE 10 -12 DIRECTORATE

NCS (CAPS)

LEARNER SUPPORT DOCUMENT

GRADE 10

PHYSICAL SCIENCES REVISION DOCUMENT

2025

PREFACE

This support document serves to assist Physical Sciences learners on how to deal with curriculum gaps and learning losses. It addresses all the topics in the Grade 10 curriculum.

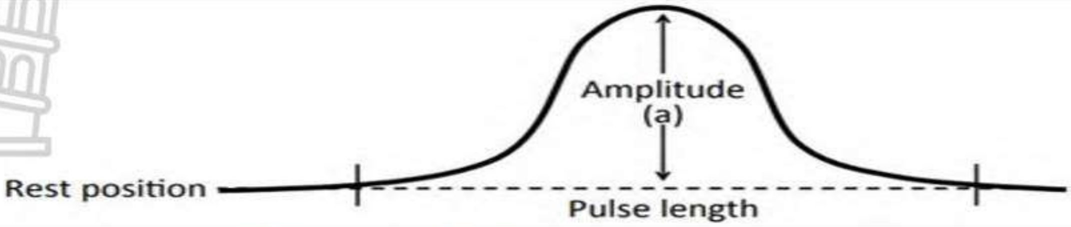
Activities serve as a guide on how various topics are assessed at different cognitive levels and to prepare learners for informal and formal tasks in Physical Sciences. It covers the following topics:

TERM 1 TOPICS
WAVES, SOUND AND LIGHT • ELECTROMAGNETIC RADIATION
ELECTRICITY AND MAGNETISM • ELECTROSTATICS AND ELECTRIC CIRCUITS
TERM 2 TOPICS
ELECTRICITY AND MAGNETISM • ELECTRIC CIRCUITS
MATTER AND MATERIALS • STATES OF MATTER & KMT • THE ATOM • THE PERIODIC TABLE • CHEMICAL BONDING
CHEMICAL CHANGE • PHYSICAL CHANGE AND CHEMICAL CHANGE • REPRESENTING CHEMICAL CHANGE • QUANTITATIVE ASPECTS OF CHEMICAL CHANGE
TERM 3 TOPICS
CHEMICAL CHANGE • QUANTITATIVE ASPECTS OF CHEMICAL CHANGE MECHANICS • VECTORS & SCALARS • MOTION IN ONE DIMENSION • INSTANTANEOUS SPEED AND VELOCITY & EQUATIONS OF MOTION
TERM 4 TOPICS
MECHANICS • ENERGY

WAVES, SOUND AND LIGHT

Pulse, amplitude

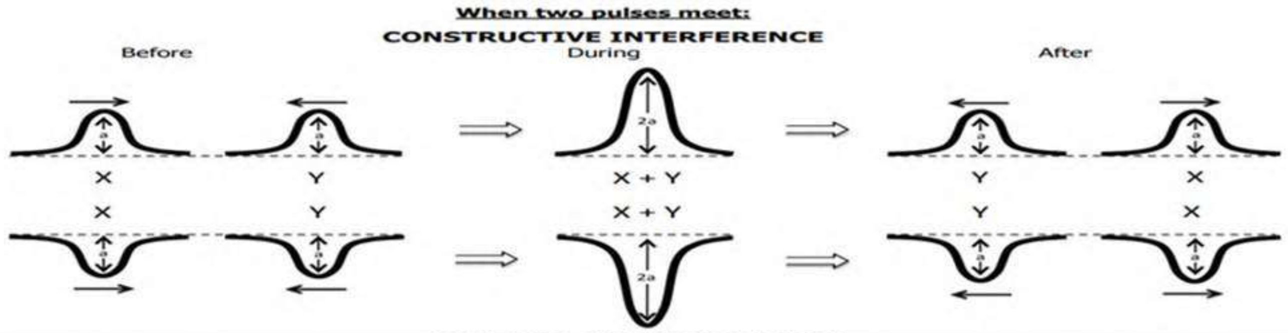
- Define a pulse as a single disturbance in a medium.
- Define a transverse pulse as a pulse in which the particles of the medium move at right angles to the direction of motion of the pulse.
- Define amplitude as the maximum disturbance of a particle from its rest (equilibrium) position.

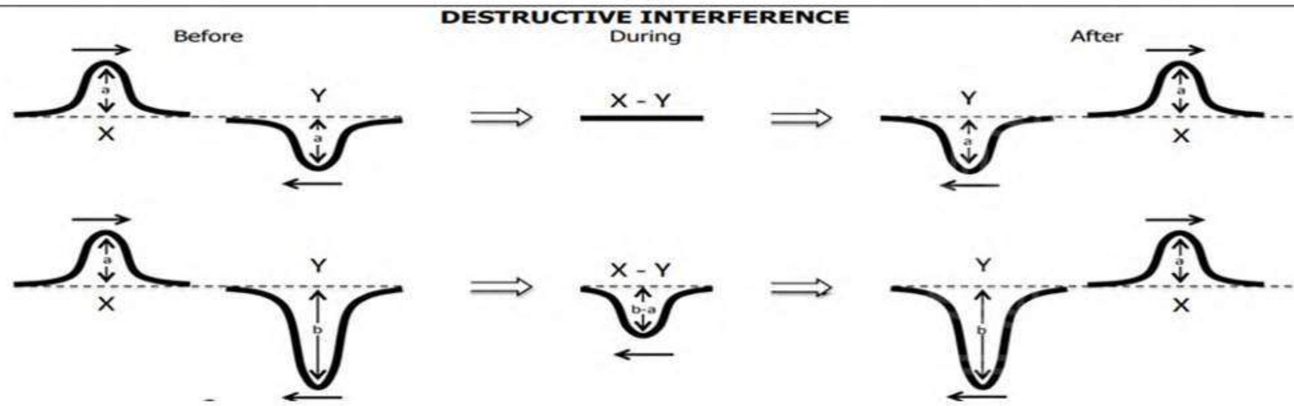


Superposition of pulses

- Define the principle of superposition as the algebraic sum of the amplitudes of two pulses that occupy the same space at the same time.
- Define constructive interference as the phenomenon where the crest of one pulse overlaps with the crest of another to produce a pulse of increased amplitude.
- Define destructive interference as the phenomenon where the crest of one pulse overlaps with the trough of another, resulting in a pulse of reduced amplitude.
- Apply the principle of superposition to pulses to explain, using diagrams, how two pulses that reach the same point in the same medium superpose constructively and destructively and then continue in the original direction of motion.

When two pulses meet:



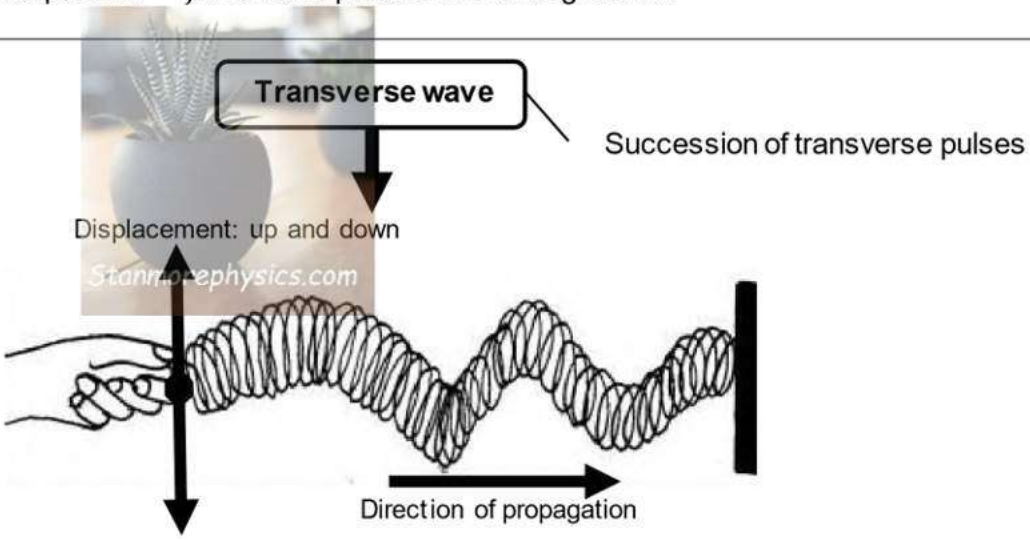


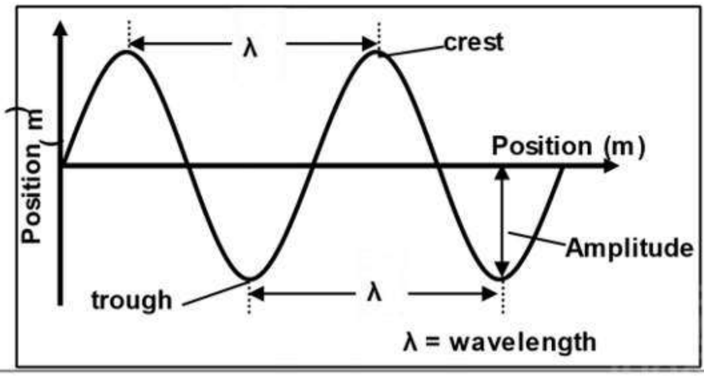
Transverse waves

Wavelength, frequency, amplitude, period, wave speed

- Define a transverse wave as a wave in which the particles of the medium vibrate at right angles to the direction of motion of the wave. A transverse wave is a succession of transverse pulses.
- Define the terms wavelength, frequency, period, amplitude, crest and trough of a wave.
- Wavelength: The distance between two successive points in phase.
- Frequency: The number of wave pulses per second.

• Period: The time taken for one complete wave pulse.
• Amplitude: The maximum displacement of a particle from its equilibrium position. Crest: Highest point (peak) on a wave.
• Trough: Lowest point on a wave.
• Explain the wave concepts in phase and out of phase.
• In phase: Two points in phase are separated by a whole number (1; 2; 3; …) multiple of complete wavelengths.
• Out of phase: Points that are not separated by a whole number multiple of complete wavelengths.
• Identify the wavelength, amplitude, crests, troughs, points in phase and points out of phase on a drawing of a transverse wave.
• Use the relationship between frequency and period, i.e. $f = \frac{1}{T}$ and $T = \frac{1}{f}$, to solve problems.
• Define wave speed as the distance travelled by a point on a wave per unit time.
• Use the wave equation $v = f\lambda$ to solve problems involving waves.





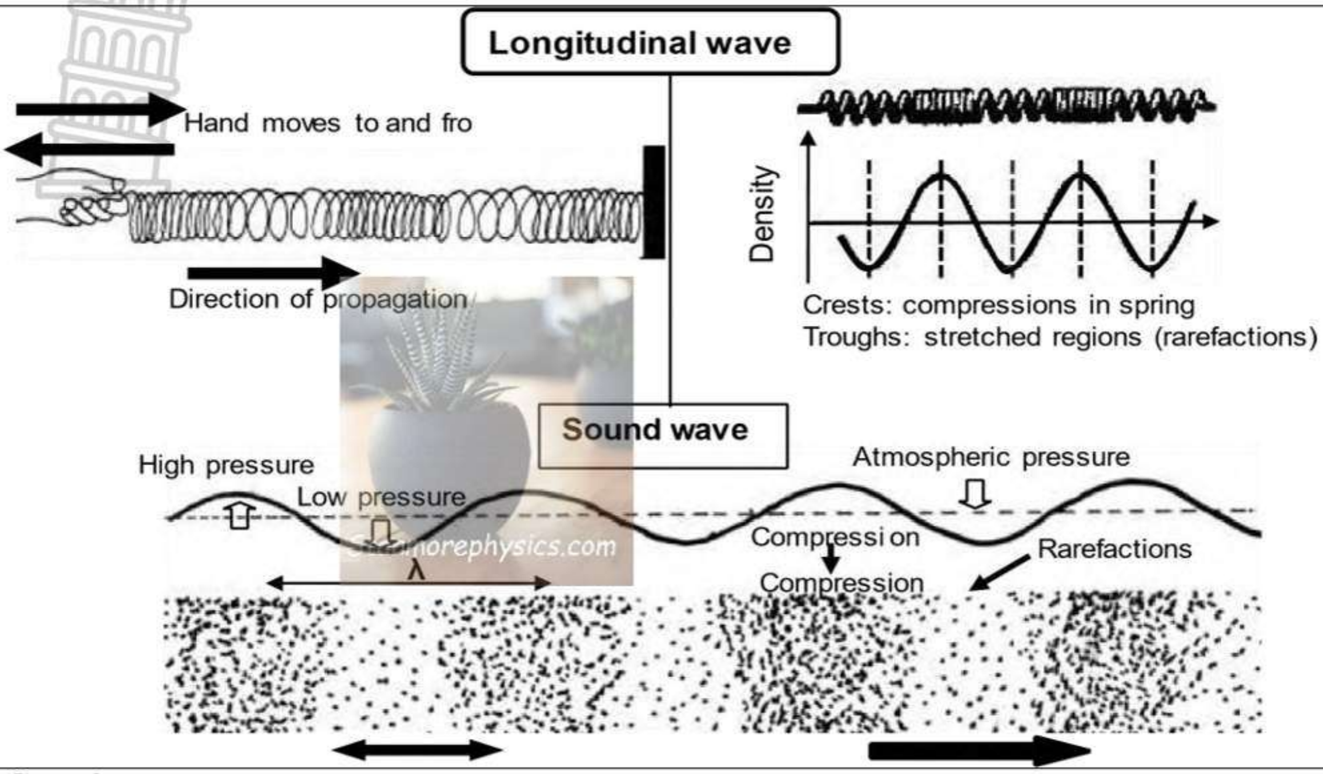
Longitudinal waves
On a spring

• Define a longitudinal wave as a wave in which the particles of the medium vibrate parallel to the direction of motion of the wave.
• Draw a diagram to represent a longitudinal wave in a spring, showing the direction of motion of the wave relative to the direction in which the particles move.

Wavelength, frequency, amplitude, period, wave speed

• Define the wavelength and amplitude of a longitudinal wave.
• Wavelength: The distance between two successive points in phase.
• Amplitude: The maximum displacement of a particle from its equilibrium position.
• Define a compression as a region of high pressure in a longitudinal wave.
• Define a rarefaction as a region of low pressure in a longitudinal wave.
• Differentiate between longitudinal and transverse waves.
• Define the period and frequency of a longitudinal wave.

- Frequency: The number of wave pulses per second.
- Period: The time taken for one complete wave pulse.
- Use the relationship between frequency and period, i.e. $f = \frac{1}{T}$ and $T = \frac{1}{f}$, to solve problems.
- Use the wave equation to solve $v = f\lambda$ to problems involving longitudinal waves.



Sound waves

- Sound waves are created by vibrations in a medium in the direction ofpropagation. The vibrations cause a regular variation in pressure in the medium. Sound waves are longitudinal waves

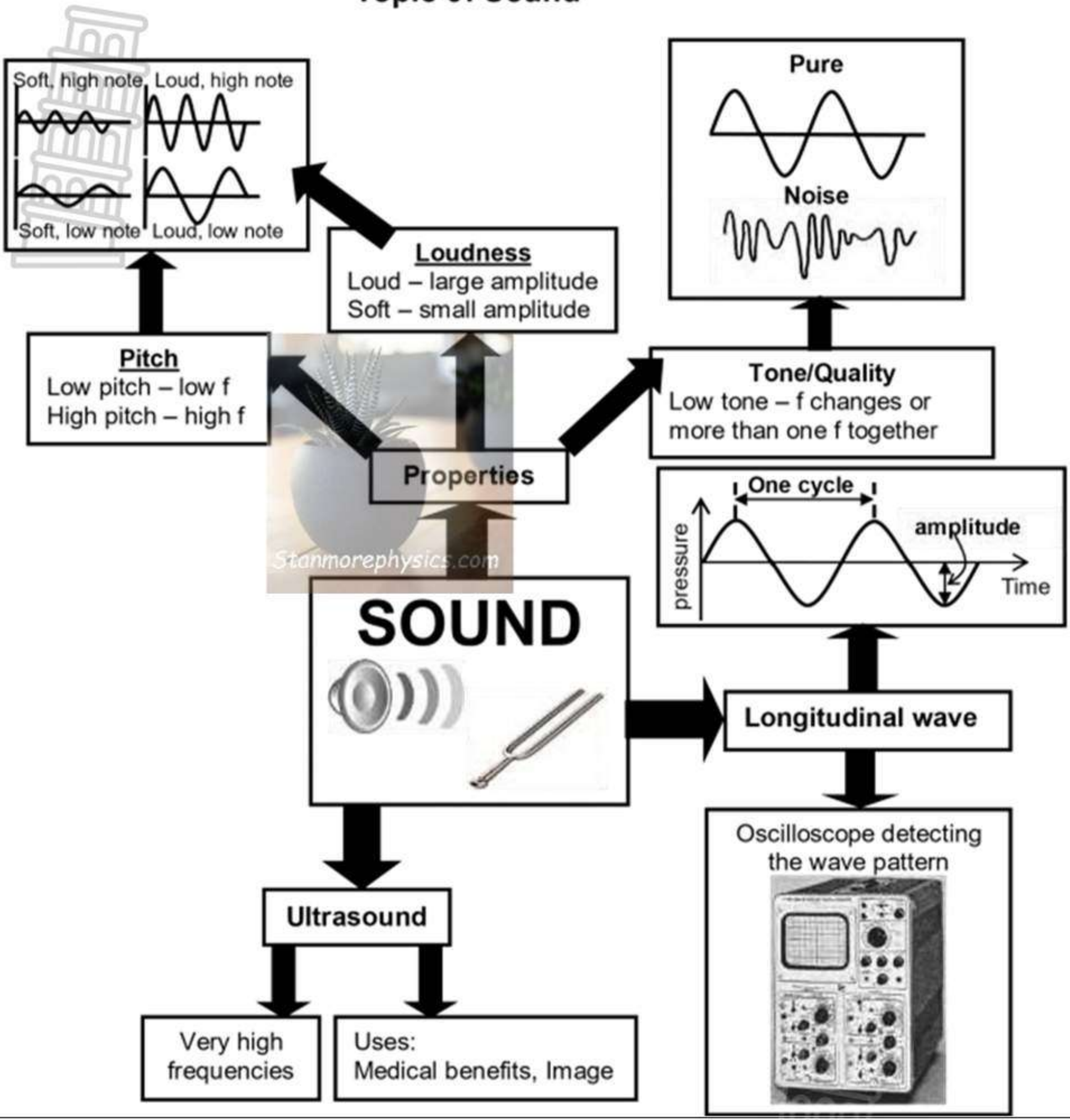
Pitch, loudness, quality (tone)

- Relate the pitch of a sound to the frequency of a sound wave. Pitch is the effect producedin the ear due to the sound of a particular frequency. Pitch is directly proportional to frequency.
- Relate the loudness of a sound to both the amplitude of a sound wave and the sensitivity of the human ear. Loudness is a subjective term describing the strength of the ear's perception of a sound. Loudness is directly proportional to amplitude.
- Relate quality of sound to the waveform as it appears to the listener. Two notes of the same pitch and loudness, played on different instruments do not sound the same because the waveforms are different and therefore differ in quality or tone.

Ultrasound

- Sound with frequencies higher than 20 kHz up to about 100 kHz are ultrasound

Topic 9: Sound



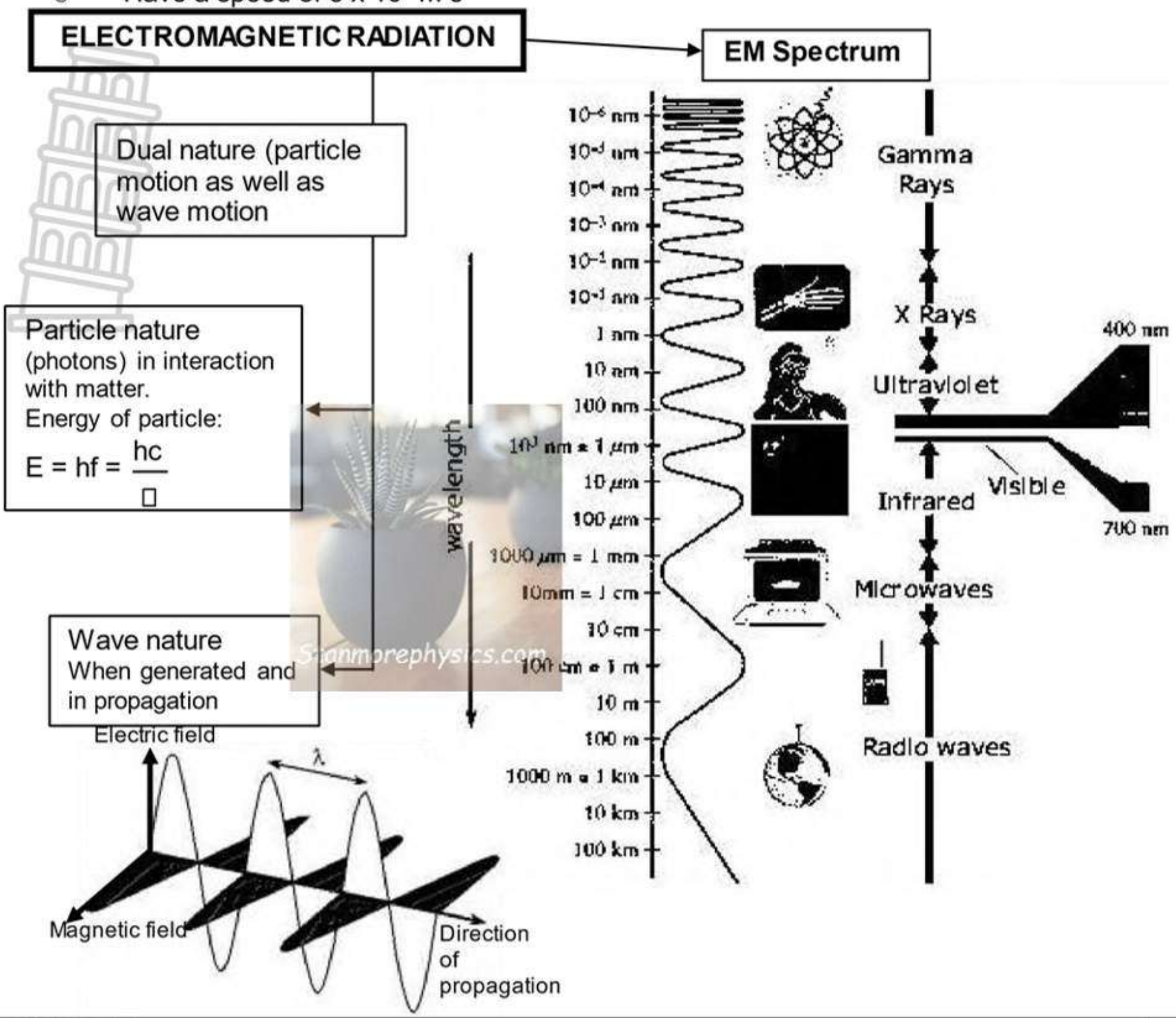
Electromagnetic radiation

Dual (particle/wave) nature of electromagnetic radiation
Light behaves as a particle and also as a wave.

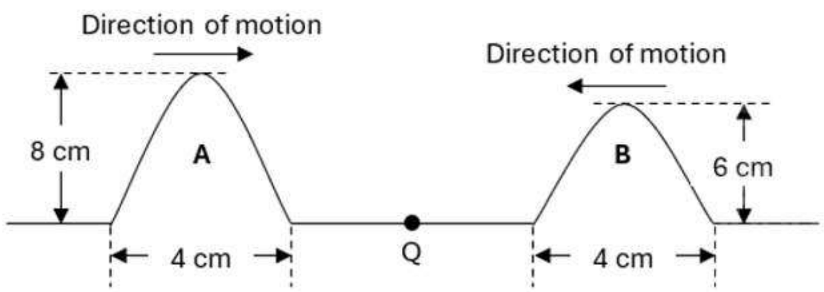
Nature of electromagnetic radiation

- The source of electromagnetic waves is an accelerating charge.
- The electromagnetic wave propagates when an electric field oscillating in one plane produces a magnetic field oscillating in a plane at right angles to it, which produces an oscillating electric field, and so on.
- The properties of electromagnetic waves:
  - Originate from accelerating electric charges
  - Propagate as electric and magnetic fields that are perpendicular to each other

- Can travel through a vacuum
- Have a speed of 3×10^8 m·s^{-1}

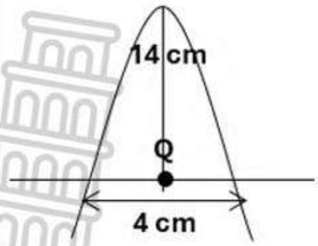


EXAMPLE 1		
The two pulses, **A** and **B**, in a string are approaching each other, as shown in the diagram below. The amplitudes of pulses **A** and **B** are 8 cm and 6 cm respectively and they meet at point **Q**. Assume that no energy is lost.		



1.1	What type of interference occurs when A and B meet at point Q?	(1)
1.2	Use the graph paper provided to draw a sketch that shows the resulting pulse when A and B meet at point Q. Show all relevant measurements	(3)
1.3	Write down the magnitude and direction of the amplitude of pulse B after A and B have met at point Q.	(1)

SOLUTIONS		
1.1	Constructive interference	(1)
1.2	(see diagram and criteria below)	(3)

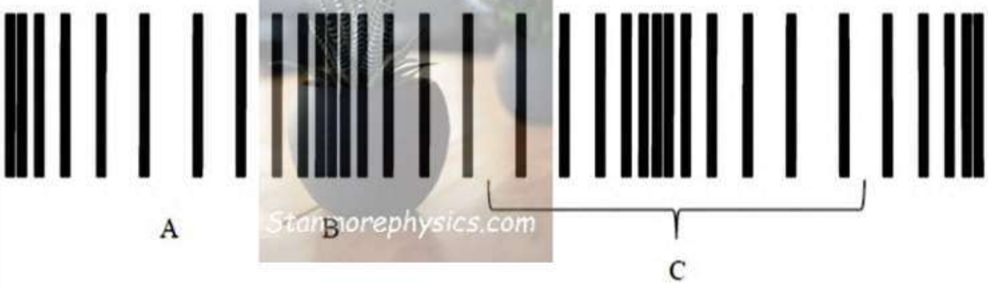


Criterion	Mark
• Correct size of pulse width	✓
• Correct new amplitude	✓
• Correct measurements	✓

1.3	8cm, to the left (or west or in the original direction.) ✓	(1)

EXAMPLE 2

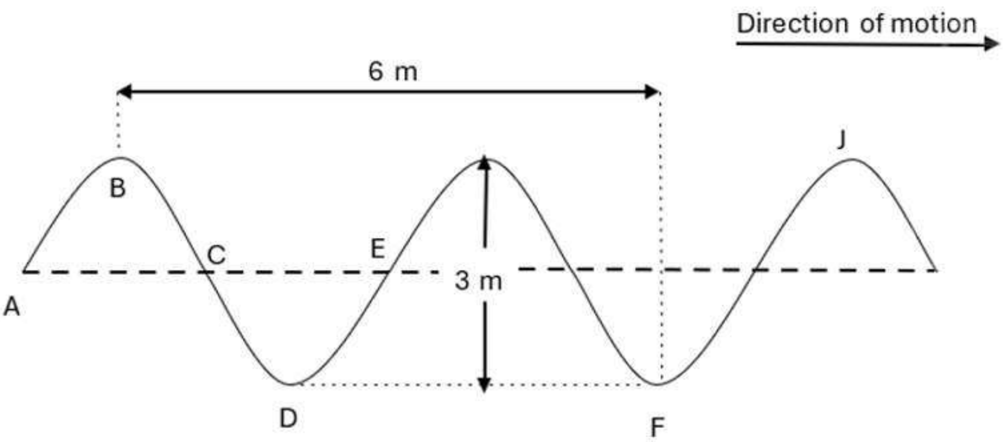
The diagram below shows different points on a longitudinal wave.



2.1	Write down the labels for A, B and C	(3)
2.2	Does this type of medium require a medium to propagate?	(1)
SOLUTION		
2.1	A: rarefaction ✓ B: compression ✓ C: wavelength ✓	(3)
2.2	YES ✓	(1)

EXAMPLE 3

The diagram below represents a water wave moving from left to right. The time between two consecutive crests is 0,5 s.



3.1	What type of wave is a water wave?	(1)
3.2	Write down the amplitude of the wave.	(1)
3.3	Determine the wavelength of the wave	(1)

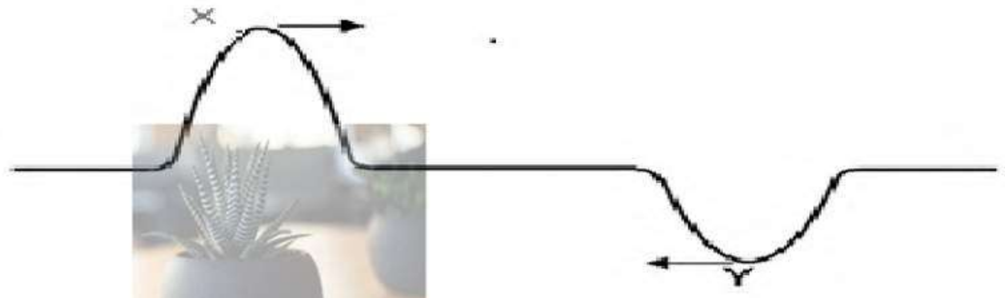
3.4	Name two points on the wave above that are in phase	(1)
3.5	Calculate the time taken for four crests to move past a certain point in the path of the wave	(2)
3.6	Calculate the speed of the wave	(3)
SOLUTIONS		
3.1	Transverse ✓	
3.2	1,5 m ✓	(1)
3.3	λ = 4 m (6 m =1,5 waves) ✓	(1)
3.4	Any one of: A and E; B and J; D and F ✓	(1)
3.5	4 crests implies 3 waves ✓ 3 x 0,5 = 1,5 s (3 waves x 0,5 seconds per wave) ✓	(2)
3.6	$v = f\lambda$ ✓ $= (1/T)\lambda$ $= (1/0.5)4$ ✓ $= 8\ m.s^{-1}$ ✓	(3)

QUESTION 1 (Multiple choice questions) (10 Marks)

1.1 Which ONE of the following statements is CORRECT?
All waves …

A	are transverse.	
B	are longitudinal.	
C	transmit energy.	
D	travel through a vacuum.	(2)

1.2 Two pulses are travelling towards each other along a string, as shown in the diagram below.



The points **X** and **Y** respectively are referred to as;

A	Trough and Crest.	
B	Crest and Trough.	
C	Crest and Crest.	
D	Trough and Trough.	(2)

1.3 The number of wave pulses per second is defined as the……… of the wave.

A	Speed	
B	Amplitude	
C	Wavelength	
D	Frequency.	(2)

1.4 Which ONE of the combinations below concerning the pitch and loudness of sound is CORRECT?

The pitch and loudness of sound depend on:

	PITCH	**LOUDNESS**
A	Frequency	Amplitude of vibration
B	Frequency	Speed of vibration
C	Amplitude of vibration	Frequency
D	Speed of vibration	Frequency

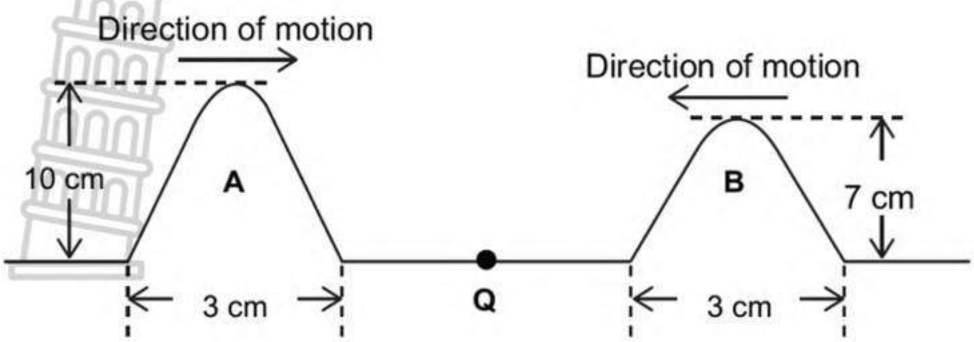
(2)

1.5 Doctors use certain equipment to check on the health of unborn babies.
This equipment uses ….

A	X-Rays	
B	Radio waves	
C	Ultrasound	
D	Microwaves	(2)

QUESTION 2 (13 marks)

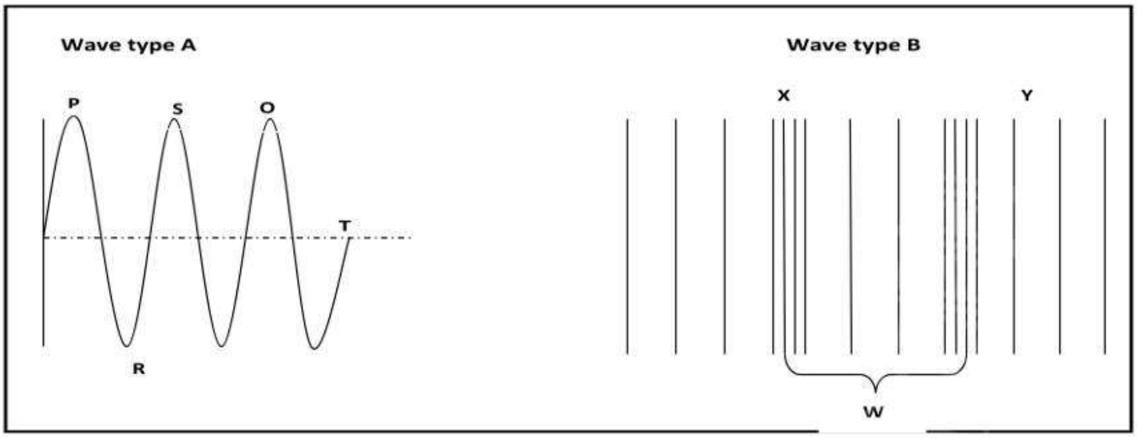
Two pulses, A and B , travelling along a string, approach each other. The amplitudes of the pulses are 10cm and 7cm respectively. They meet at point Q. Assume that no energy is lost.



2.1	Define the term *pulse*.	(2)
2.2	Name the phenomenon that occurs when A and B meet at point Q.	(2)
2.3	State *the principle of superposition*	(2)
2.4	Draw a sketch to show the resulting pulse when A and B meet at point Q. Show all relevant measurements.	(3)
2.5	What happens to pulse B AFTER pulse A and B met? Choose your answer from ONE of the following:	
	Moves to the right	(1)
	Becomes stationary OR	
	Moves to the left	
2.6	Pulse A travels a distance of 60m in 2 minutes. Calculate the speed of pulse A.	(3)

QUESTION 3 (23 Marks)

The two diagrams below, wave type A and wave type B represent the two types of waves. Study the waves and answer the QUESTIONs that follow.

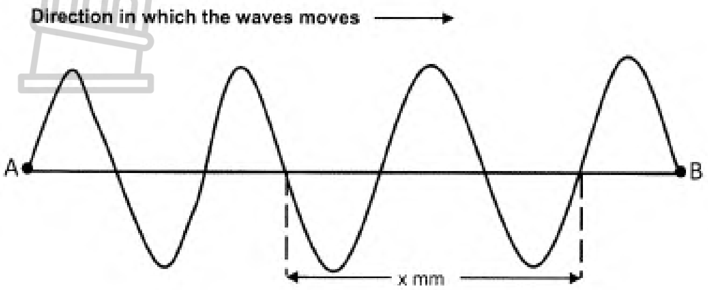


3.1	Identify and define wave type A.	(3)
3.2	Give one difference between wave types A and B.	(2)
3.3	Name the parts labelled R, O, W, and X.	(4)
3.4	How many complete waves cycles are in wave type A?	(1)
3.5	Calculate the frequency of the wave in type A if the time taken for the wave to reach point T in 0,3 s.	(3)
3.6	What time does it take for a wave in type A to complete one cycle?	(1)
3.7	Name the physical quantity described in 6.6.	(1)
3.8	Points O and S are in phase.	

	3.8.1	Explain what is meant by points in phase	(1)
	3.8.2	Identify any other two points that are in phase.	(1)
3.9		The amplitude in wave type A is 0; 2 m. Define the term amplitude.	(2)
3.10		What quantity of the sound wave is given by the amplitude?	(1)
3.11		If the distance OS is 0, 3 m, calculate the speed of this wave.	(3)

QUESTION 4 (11marks)

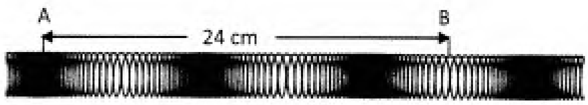
The following wave pattern is produced by a transverse wave that takes 4 seconds to complete on vibration.



4.1	Define the term transverse wave.	(2)
4.2	Determine the frequency of the wave.	(3)
4.3	If the speed of the wave is 0,5 $m.s^{-1}$ calculate the value of x in mm.	(5)
4.4.	How long (in seconds) does it take for a particle to move from point A to Point B	(1)

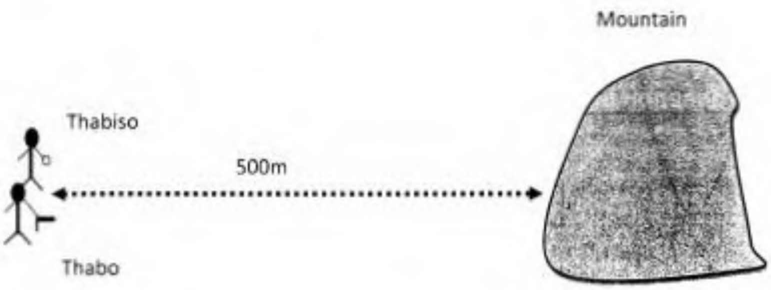
QUESTION 5 (12 Marks)

5.1 A longitudinal wave moves along a slinky spring. Position A and B are the centres of a compression and a rarefaction respectively.
A and B are 24 cm apart.



5.1.1	Define the term compression.	(2)
5.2.2	Use the diagram to determine the wavelength of the wave.	(2)
5.2.3	Determine the period of the wave if it takes 1,5 s for a particle to move from A to B.	(2)

5.2 Thabo and Thabiso conducted an experiment to determine the speed of sound in air. They stood 500m away from a mountain and Thabo fired a toy gun directly towards the mountain. Thabiso simultaneously started a stop-watch. He then recorded the time taken to hear the echo. The experiment was repeated three times and reading were recorded.

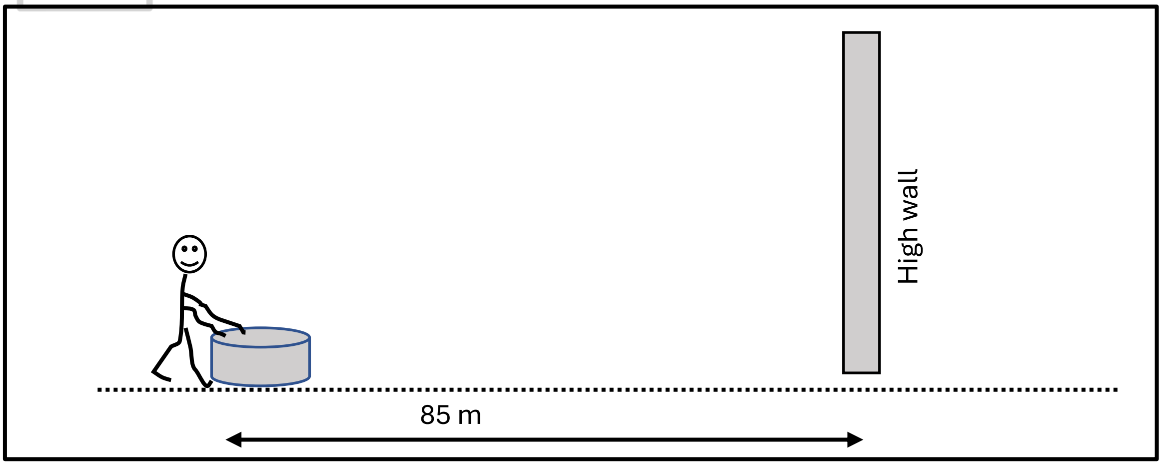


Experiment number	Time Taken (s)
1	3,01
2	2.95
3	3,04

	5.2.1	How an echo is produces?	(1)
	5.2.2	Determine the average time from the above readings.	(1)
	5.2.3	Calculate the speed of sound.	(2)
	5.2.4	How does the speed of sound in water compare to the speed of sound in air? (Choose from GREATER, LESS THAN or EQUAL TO). Give a reason.	(2)

QUESTION 6 (11 Marks)

Thembi stands 85 m from a high wall while she is beating a drum. She notices that the echo of each beat coincides exactly with the next beat of the drum if she strikes the drum every 0,5 s.



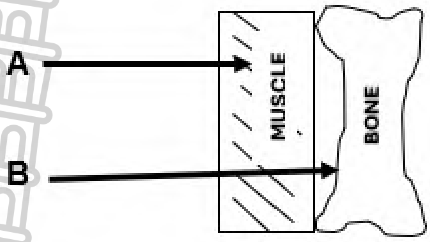
6.1	Use the information given above to calculate the following:		
	6.1.1	The speed of sound in the air	(3)
	6.1.2	The wavelength of the sound waves, if the drumhead vibrates at 100 Hz	(3)
6.2	Ultrasound is often used in the medical field to examine the internal parts of the human body.		
	6.2.1	What is meant by *ultrasound*?	(2)
	6.2.2	Give ONE non-medical use of ultrasound.	(1)
	6.2.3	Why is ultrasound often preferred to other types of body scanning?	(2)

QUESTION 7 (13 Marks)

Three types of electromagnetic radiation are given in the table below.

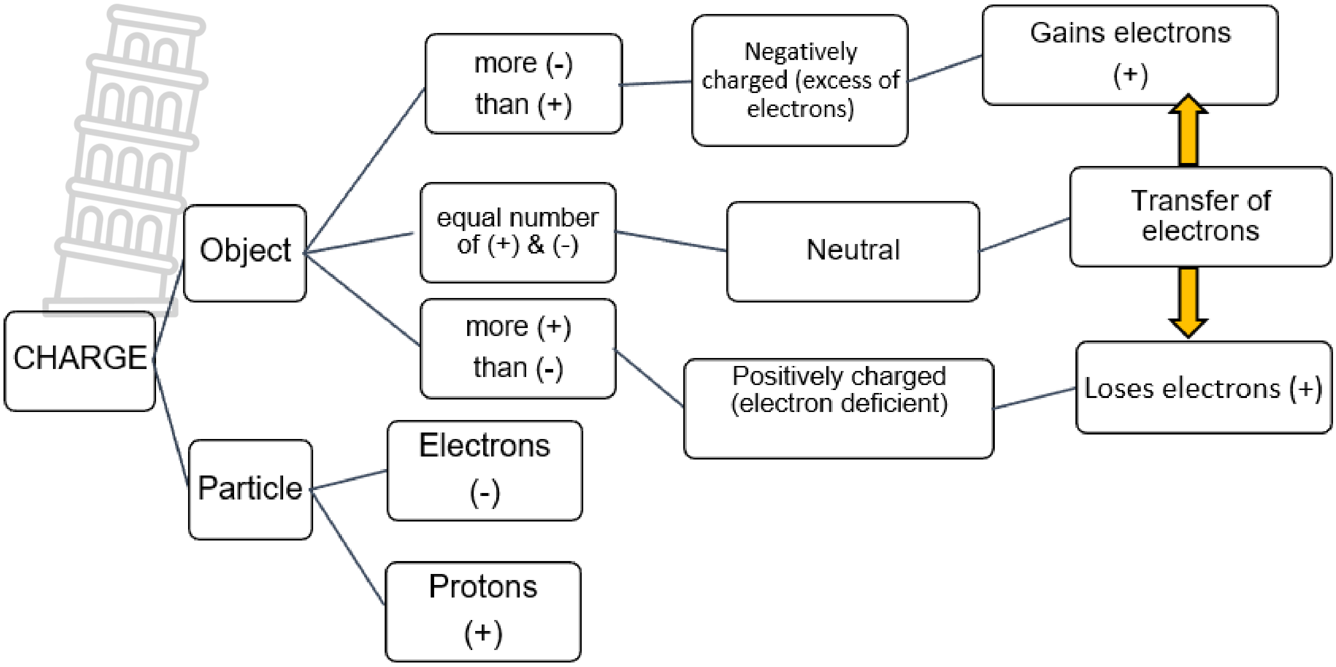
Radiation
X-rays
Ultraviolet
Infra-red

7.1	Write down the NAME of:		
	7.1.1	radiation with the longest wavelength from the given list	(1)
	7.1.2	ONE source of ultraviolet light	(1)
7.2	Calculate the energy of a photon of infra-red light if its wavelength is 4×10^{-5} m		(5)

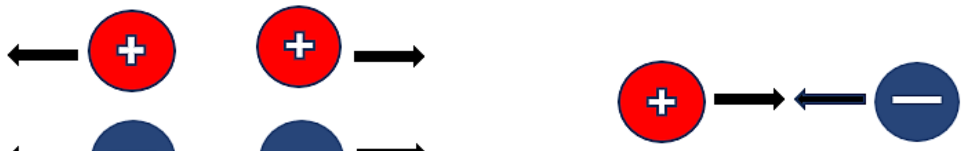
7.3	Learners are investigating the penetrating ability of ultraviolet radiation and X-rays. They shine electromagnetic radiation (ultraviolet and X-rays) using identical bulbs onto a muscle tissue and a bone tissue as shown below.  Rays of radiation **B** penetrate through the muscle tissue but they are stopped by the bone tissue. Rays of radiation **A** do not reach the bone tissue.		
	7.3.1	Which radiation (**A** or **B**) represents X-rays? Give a reason for your answer.	(3)
	7.3.2	Write down the independent variable for the investigation.	(1)
	7.3.3	Give a reason why it is necessary to use identical bulbs for the investigation.	(2)

ELECTROSTATICS (GRADE 10)

Electrostatics is study of charges at rest



Two kinds of charge

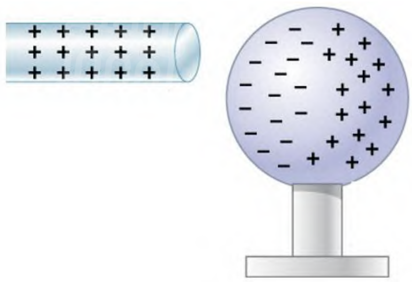


Like charges repel **Unlike charges attract**

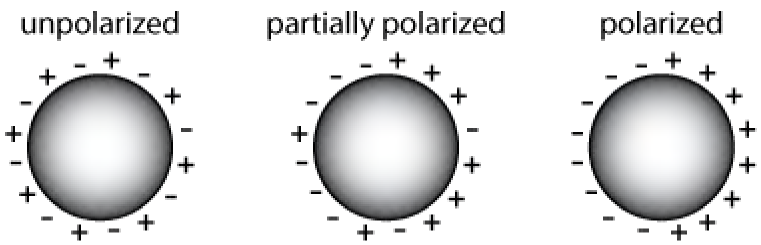
Objects become charged when electrons are either removed or added to them. This can be done by rubbing two materials together, called tribo-electric charging.

Tribo-electric charging: A type of contact electrification in which certain materials become electrically charged after they come into contact with different materials and are then separated (such as through rubbing)

Charged objects can attract uncharged objects due to the polarization of molecules inside the object.



Polarisation: The partial or complete polar separation of positive and negative electric charge in a system.



Charge conservation

- Symbol for electric charge: Q
- SI unit for electric charge: Coulomb (C)
- Principle of conservation of charge: The net charge of an isolated system remains constant during any physical process.
- During contact, electrons are transferred from the more negative object to the less negative object until both objects have the same charge.
- $Q = \frac{Q_1+Q_2}{2}$

Charge quantization

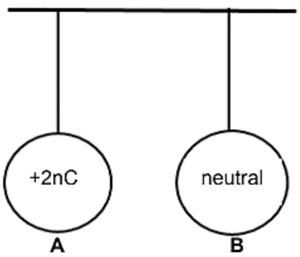
- Principle of charge quantization: All charges in the universe consist of an integer multiple of the charge on one electron.
- $Q = nq_e$
- The charge on one electron (q_e) is called the elementary charge ($q_e = -1,6 \times 10^{-19}$ C).

Conversion scale

1 milli-Coulomb (mC) = 1×10^{-3} C
1 micro-Coulomb (μC) = 1×10^{-6} C
1 nano-Coulomb (nC) = 1×10^{-9} C
1 pico-Coulomb (pC) = 1×10^{-12} C

WORKED EXAMPLE 1

Two identical insulated spheres, A and B, suspended by a light inextensible string from a ceiling, are held a distance apart, as shown below.



Sphere **A** carries a charge of + 2nC, while sphere **B** is neutral.

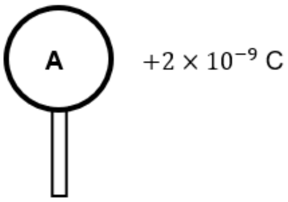
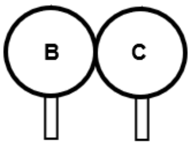
1.1	Explain what is meant by neutral object.	(2)

Sphere **A** is brought near the neutral sphere **B** and the spheres are allowed to touch each other. Immediately after touching, sphere **B** moves away from sphere **A**. Sphere **B** now has an excess of 20 electrons.

1.2	State the principle of conservation of charge in words.	(2)
1.3	Briefly explain how the neutral sphere **B** is attracted to sphere **A**.	(2)
1.4	Calculate the magnitude of the charge of sphere **B**.	(3)
1.5	Calculate the charge on each sphere after they have separated.	(3)
		[12]

SOLUTIONS

1.1	Neutral charge – an atom that has equal number of electrons and protons. ✓✓	(2)
1.2	The net charge of an isolated system remains constant during any physical process. ✓✓	(2)
1.3	Due to polarisation, a negative charge is developed on the side of sphere B near sphere A and a positive charge is developed on the side of sphere B that is away from sphere A ✓. Sphere B moves towards sphere A (attraction) as opposite charges attract. ✓	(2)

1.4	$Q = n.q_e$ ✓ $Q = 20 \times (-1,6 \times 10^{-19})$ ✓ $Q = -3,2 \times 10^{-18}$ C ✓	(3)
1.5	$Q_{new} = \frac{Q_1+Q_2}{2}$ ✓ $= \frac{(2\times10^{-9})+(-3,2\times10^{-18})}{2}$ ✓ $= 9,99 \times 10^{-10}$ C ✓	(3)
		[12]
WORKED EXAMPLE 2		
2.1	A small, metal sphere A carrying a charge of $+2 \times 10^{-9}$ C is placed on an insulated stand.  	
	2.1.1 How does the number of electrons compare to the number of protons in sphere **A**?	(1)
	10^{13} electrons are now added to sphere **A**	
	2.1.2 Calculate the new charge on sphere **A**	(4)
2.2	Two identical metal spheres **B** and **C** placed on insulated stands, carry charges $+4 \times 10^{-6}$C and -6×10^{-6} C respectively as shown in the diagram below.  The spheres are allowed to touch each other.  After touching the spheres are then separated and brought back to their original positions as shown in the diagram below.  	
	2.2.1 State the principle of conservation of charge	(2)
	2.2.2 Calculate the number of electrons transferred between the two spheres during contact.	(6)
		[13]
SOLUTIONS		
2.1.1	Less than ✓	(1)
2.1.2	$n = \frac{Q}{q_e}$ $10^{13} = \frac{Q}{-1,6\times10^{-19}}$ ✓ Q = - 1,6 x 10^{-19} C Q_{new}=(-1,6 x 10^{-19}) + (2 x 10^{-19}) ✓ = 4 x 10^{-20} C ✓	(4)

2.2.1 The net charge of an isolated system remains constant during any physical process. ✓✓ (2)

2.2.2

$$Q_{new} = \frac{Q_1+Q_2}{2} ✓$$

$$= \frac{(4\times10^{-6})+(-6\times10^{-6})}{2} ✓$$

$$= 1\times10^{-6} C ✓$$

$$n = \frac{\Delta Q}{e}$$

$$n = \frac{Q_f - Q_i}{e}$$

$$= \frac{(-1\times10^{-6} - (-6\times10^{-6}) ✓}{1{,}6\times10^{-19} ✓}$$

$= 3{,}13\times10^{13}$ electrons ✓ (6)

[13]

ACTIVITIES

QUESTION 1 (MULTIPLE CHOICE)

1.1. A neutral object has…

A	no charges	
B	no imbalance in charge	
C	more neutrons than protons and electrons	
D	no electric field	(2)

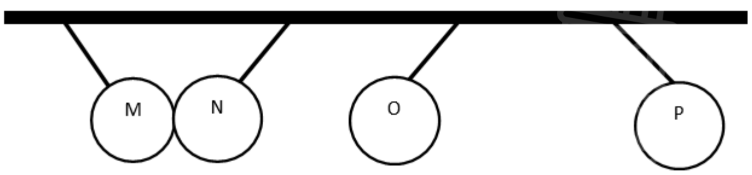
1.2 Which ONE of the following CANNOT be the charge of an object?

A	$3{,}2 \times 10^{-19}$ C	
B	$8{,}0 \text{ X } 10^{-19}$ C	
C	$6{,}4 \text{ X } 10^{-19}$ C	
D	7,2 x 10 – 19 C	(2)

1.3 A rubber balloon obtains a negative charge after it has been rubbed against human hair. Which ONE of the statements below best explains why this happens?

A	Negative charges are transferred from the rubber balloon to the human hair	
B	Positive charges are transferred from the rubber balloon to the human hair	
C	Negative charges are transferred from the human hair to the rubber balloon.	
D	Positive charges are transferred from the human hair to the rubber balloon.	(2)

1.4 Four identical balloons, each carrying a charge, are suspended from a ceiling, as shown in the diagram below.



Balloon **N** is negatively charged.
Which combination is CORRECT regarding the charges on the balloons?

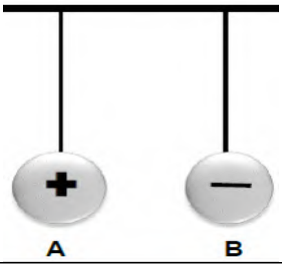
	SIGN OF CHARGE ON **M**	SIGN OF CHARGE ON **O**	SIGN OF CHARGE ON **P**
A	-	+	-
B	+	+	+
C	-	-	-
D	+	+	-

(2)

1.5	Two identical spheres, X and Y, on insulated stands, carry charges of 3 µC and -5 µC respectively. The spheres are brought into contact with each other and returned to their original positions. The charge on EACH sphere after contact is …				
	A	- 1 µC	B	-2 µC	
	C	-4 µC	D	8 µC	(2)
					[10]

QUESTION 2

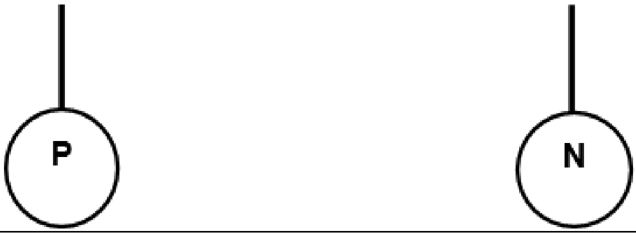
Two small, identical spheres A and B are suspended on long strings, as shown in the diagram below. The spheres carry charges of +5 x10 $^{-9}$ C and -2 x10 $^{-9}$ C respectively.



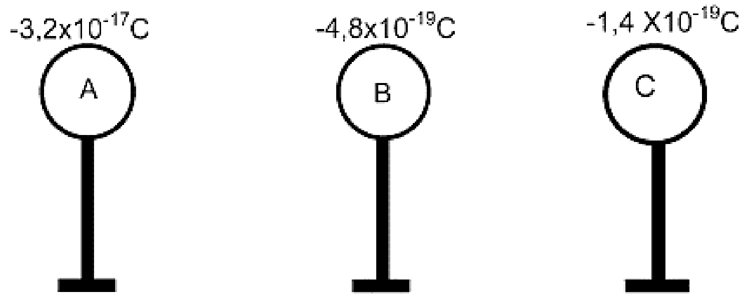
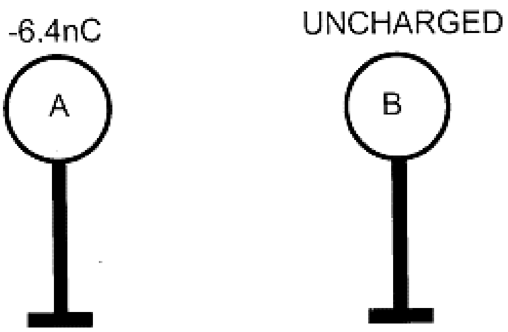
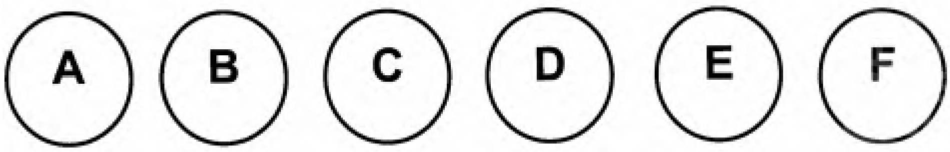
2.1	State the Principle of Conservation of Charge.		(2)
	The two spheres are brought into contact and then separated again		
2.2	Which sphere, **A** or **B**, will gain electrons? Motivate the answer		(2)
2.3	Calculate the:		
	2.3.1	Net charge of the two spheres during contact	(2)
	2.3.2	Charge on each sphere after separation.	(3)
	2.3.3	Number of electrons transferred during contact	(4)
2.4	What effect does bringing the charges closer to each other have on the magnitude of the electrostatic force. Write down only INCREASE, DECREASE or REMAIN THE SAME.		
			[13]

QUESTION 3

A NEUTRAL plastic ball, N, is suspended from an insulating string. An identical ball, P, is attached to a similar string and ball P has a charge of +9 x 10^{-9} C

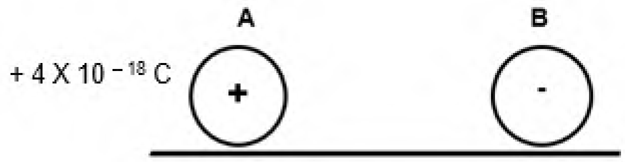


3.1	Are there any charged particles on ball N? Answer either YES or NO and explain your answer		(2)
3.2	Calculate the number of electrons that were removed from P to give it the positive charge.		(3)
3.3	Ball P is brought closer to N until a visible effect is observed in the case of ball N.		
	3.3.1	What happens to N?	(1)
	3.3.2	Draw a sketch to show the charge distribution that takes place on ball N	(2)
	3.3.2	Name the phenomenon as described in question 3.3.2	(1)
3.4	Ball P is allowed to TOUCH ball N and then TAKEN AWAY from N		
	3.4.1	Describe the movement of the charged particles when P and N are in contact. Refer to the type of charge and the direction in which they move.	(1)
	3.4.2	Calculate the charge on ball N after it has touched P and was separated again.	
			[13]

QUESTION 4		
4.1	What is meant by triboelectric charging?	(2)
4.2	Three metal spheres are placed on insulated stands and carry charges as shown below. 	
	4.2.1 Determine the number of excess electrons found on sphere A.	(3)
	4.2.2 Is it possible for the charge indicated on sphere C to exist? State Yes or No. Give a reason for the answer.	(2)
	4.2.3 Name the principle used to explain your answer to question 4.2.2.	(1)
4.3	Two identical metal spheres are placed on insulated stands as shown below.  Sphere A carries a charge of -6,4 nC and sphere **B** is UNCHARGED.	
	4.3.1 What is meant by sphere **B** is uncharged?	(1)
Sphere **A** is now brought CLOSE to sphere **B**. The spheres DO NOT touch,		
	4.3.2 Draw a sketch to show the charge distribution that takes place on sphere **B**.	(2)
	4.3.3 Name the phenomenon as described in question 4.3.2	(1)
The two spheres are now made to TOUCH each other, then separated.		
	4.3.4 State the principle of Conservation of Charge.	(2)
	4.3.5 Calculate the new charge on each sphere after touching	(3)
4.4	Refer to the six spheres A – F below. Sphere A is POSITIVELY charged. The charges on the other spheres are unknown.  A learner wishes to determine the nature of the charges on the other 5 spheres. She makes the following observations: • F attracts both A and B • D repels C • E attracts D but repels F • C attracts B Use the above information to determine the nature of the charges on spheres B, C, D, E and F.	(5)
		[23]

QUESTION 5

Two identical metal spheres, A and B, on an insulated surface, are held at a small distance apart, as shown in the diagram below.

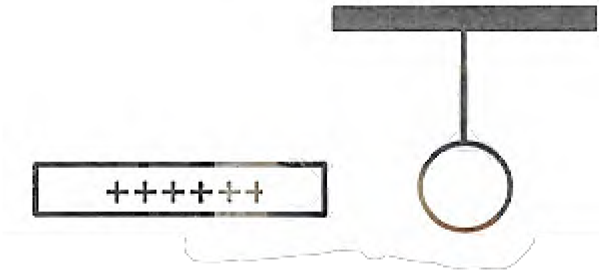
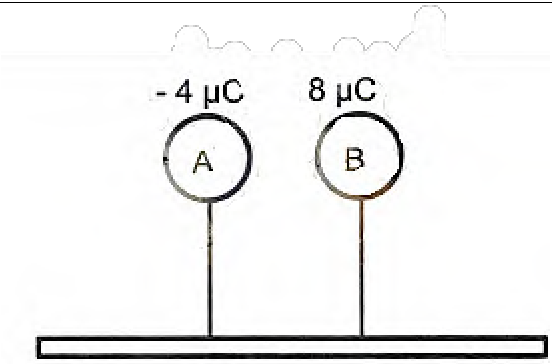


5.1	Sphere A carries a charge of + 4 x 10^{-18} C, while sphere B has an excess of 30 electrons		
	5.1.1	Calculate the magnitude of the charge on sphere B.	(3)
	5.1.2	Identify and state the principle used to answer question 5.1.1	(3)
5.2	The two spheres are now released and they move towards each other.		
	5.2.1	Give a reason why spheres A and B move towards each other.	(1)
	5.2.2	Is it possible for the charge indicated on sphere A to exist ? Write down YES or NO. Give a reason for the answer.	(2)
	5.2.3	Name the principle in which your answer to Question 5.2.2 is based.	(1)
5.3	The spheres are allowed to touch each other. After touching, they move away from each other.		
	5.3.1	Explain why the two spheres move away from each other after touching.	(2)
	5.3.2	State the principle of conservation of charge	(2)
	5.3.3	Calculate the number of electrons transferred	(4)
			[11]

QUESTION 6

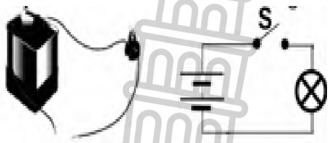
Two identical pith balls are suspended on light, inelastic cotton threads. Pith ball **A** has a positive charge of 5,4 nC. Pith ball **B** carries a negative charge of 8,2 nC.

6.1	6.1.1	State the principle of quantization of charge.	(2)
	6.1.2	Calculate the number of extra electrons added to pith ball **B**.	(4)
	6.1.3	Two pith balls **A** and **B** are brought together, and then separated again to hang at the same original distance apart. Describe the type of force that pith ball **B** exerts on pith ball **A**.	(1)
	6.1.4	State the law of conservation of charge	(2)
	6.1.5	Calculate the charge on pith ball B after it has touched pith ball A and is separated and hangs back at its original position.	(3)
	6.1.6	How many electrons were transferred from pith ball B to pith ball A when the pith balls touched each other?	(4)
6.2	Explain each of the following phenomena using your knowledge of electrostatics		
	6.2.1	When the air is very dry, your hand feels a small sharp electric shock when you touch a metal doorknob after walking along the carpet to the door.	(3)
	6.2.2	When a charged plastic ruler is brought close to small pieces of paper the paper pieces are attracted to the ruler.	(3)
			[22]

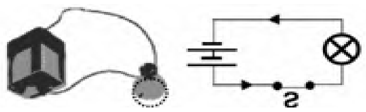
QUESTION 7			
7.1	An uncharged glass road is rubbed with a silk cloth resulting in the rod becoming positively charged.		
	7.1.1	explain how the rod becomes positively charged.	(2)
In the diagram below, the positively charged rod is now held to the left of a neutral sphere suspended by a light insulated string, causing the sphere to move.			
			
	7.1.2	Define the term polarization in words	(2)
	7.1.3	Will the sphere move to the LEFT or to the RIGHT	(1)
7.2	A and B are two identical spheres, mounted on insulated stands, carrying charges of -4 µC and 8 µC respectively.		
			
	7.2.1	Determine the number of excess electrons on sphere A	(3)
	The spheres are allowed to touch and then separated.		
	7.2.2	In which direction will electrons flow when the spheres are in contact with each other? Choose from: A to B or B to A	(1)
	7.2.3	State the principle of conservation of charge in words.	(2)
	7.2.4	Calculate the new charge on sphere A.	(3)
	A third sphere, C, caring a charge of – 6 µC, is now brought into contact whip sphere B.		
	7.2.5	Calculate the number of electrons transferred when these spheres are in contact with each other.	(5)
			[19]

Electric circuit

Open circuit: No flow of charge



Closed circuit: Charges flow

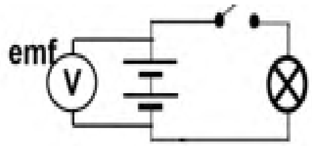


Current
Rate of flow of charge.

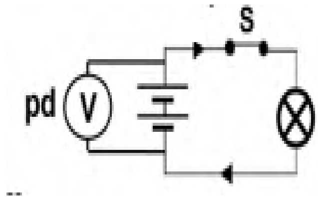
$$I = \frac{Q}{\Delta t}$$

Unit: Ampere (A)
Measuring instrument:
Ammeter connected in series.
Conventional current from positive to negative

Emf: potential difference across the battery in an open circuit.



Terminal potential difference: the potential difference in a closed circuit.



Potential difference
Unit: Volt (V)
Measuring instrument: Voltmeter connected in parallel.
Definition: The potential difference between the ends of a conductor is equal the energy transferred per unit electric charge flowing through it. In symbols:

$$V = \frac{W}{Q}$$

Parallel circuits

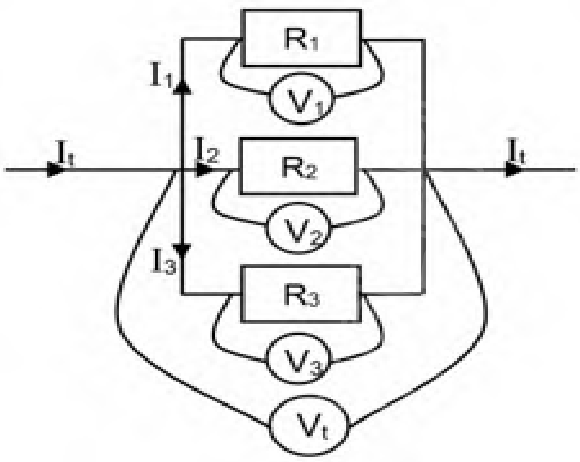
- More than one pathway for charges (One or more branches)

Resistors in parallel

- Current dividers
  $I_{total} = I_1 + I_2 + I_3$
- Total resistance

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

- Potential difference everywhere the same.

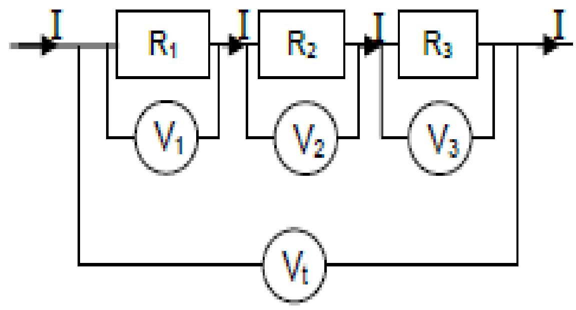


Series circuit

- Only one pathway for charges (no branches)

Resistors in series

- Potential dividers
  $V_t = V_1+V_2+V_3$
- Total resistance
  $R_{tota} = R_1+R_2+R_3$
- Current everywhere is the same



Ohm's Law

- The current in a conductor is directly proportional to the potential difference across it, provided its temperature remains constant.

$$\boxed{V=IR}$$

Definition of an ohm: A resistor has a resistance of 1 ohm if it allows a current of 1 ampere when the potential difference across it is 1 volt. *So, an ohm is a volt per ampere.*

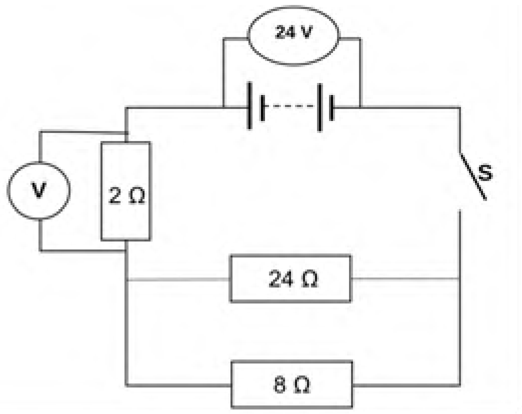
Resistance

- Resistance (R) is the extent to which a resistor limits the flow of charge in it. When connected to the same potential difference, the higher the resistance of the resistor, the smaller the current.
- Resistance is measured in ohms (Ω).

Factors affecting resistance: Resistance depends on: the **type of metal**, **length**, **thickness**, and **temperature**.
Resistance increases as the length of the resistor increases.
Resistance decreases as the thickness of the resistor increases.

Worked examples 1

In the circuit below, the connecting wires and the battery have negligible resistance.



1.1	Define the term resistance.		(2)
	Calculate the:		
1.2	1.2.1	Equivalent resistance of the resistors connected in parallel	(3)
	1.2.2	Total resistance of the circuit	(2)
1.3	When the switch is closed, the voltmeter connected across the 2 Ω resistor measures 6 V. Determine the potential difference across the parallel combination.		(1)
1.4	A charge of 18 C flows through the battery in 6 s. calculate the current in the 2 Ω resistor.		(3)

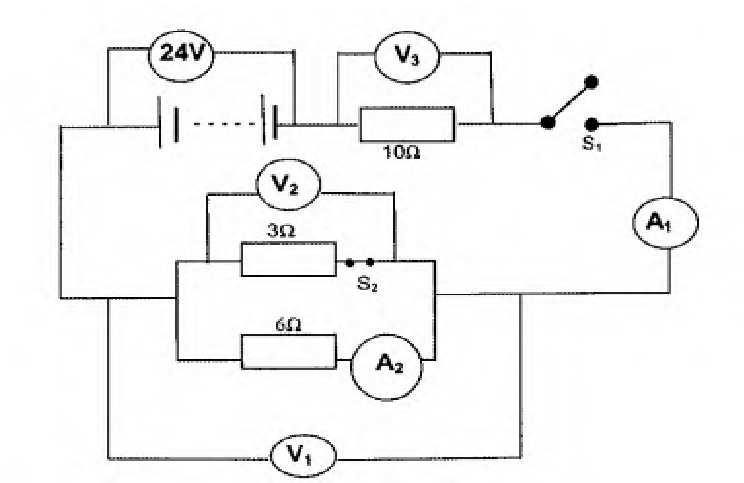
Solutions

1.1	The ratio of the potential difference across a resistor to the current in the resistor.□□	
1.2.1	$\frac{1}{Rp} = \frac{1}{R1} + \frac{1}{R2}$ ✓ $\frac{1}{Rp} = \frac{1}{24} + \frac{1}{8}$ ✓	

	$R_p = 6\ \Omega$✓	
1.2.2	$R_p = R_s + R_p$✓ $= 2 + 6$✓ $= 8\ \Omega$✓	
1.3	$V_p = 24V - 6V$ $=18V$✓	
1.4	$Q = It$✓ $18 = I(6)$ ✓✓ $I = 3A$✓	

Worked example 2

A battery is made of an unknown number of cells. Each of cells in the battery is labelled 3V. The battery is connected in a circuit as shown. Ignore the resistance of the battery and the wires. Initially switch S_1 is open, and the voltmeter connected across the ends of the battery reads 24V.



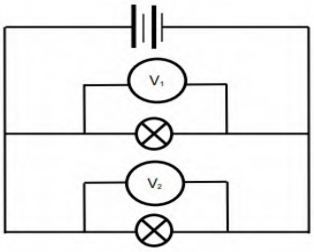
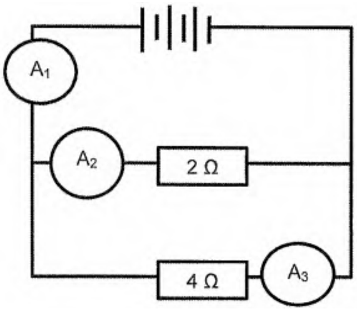
2.1	Does the reading of 24V represent emf or the terminal potential difference? Give a reason for your answer.		(2)
2.2	Determine the number of cells in the battery?		(1)
When switch S_1 is now closed, the ammeter A_1 reads 2 A and V_3 reads 20V.			
2.3	What will be the reading on:		
	2.3.1	V_1	(1)
	2.3.2	V_2	(1)
2.4	What will the reading on A_2 be if 1.33 A of current flows through the 3 Ω resistor?		(1)
2.5	How many coulombs of charge flows through A_1 in 1 second?		(1)
2.6	Calculate the total resistance in the circuit.		(1)
2.7	Calculate the total resistance in the circuit.		(4)
2.8	How long (in minutes) will it take 4 800J of electrical energy to flow though the 10 Ω resistor?		(5)
2.9	If switch S_2 is now opened (while S_1 remains closed) how will this affect the reading on V_3? Explain. (Choose from INCREASES, DECREASES or REMAINS THE SAME)		(4)
			[20]

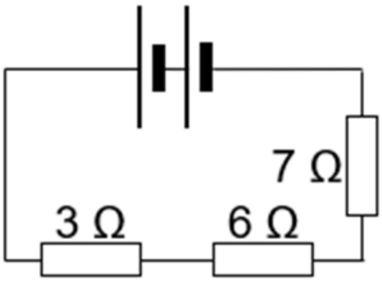
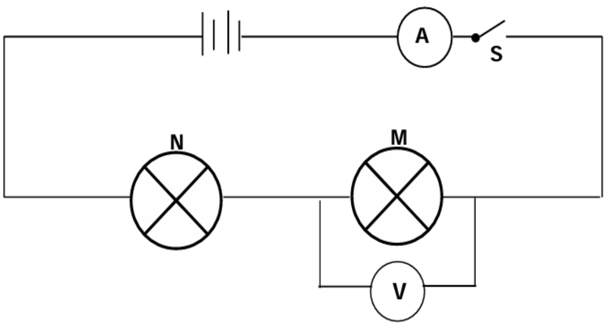
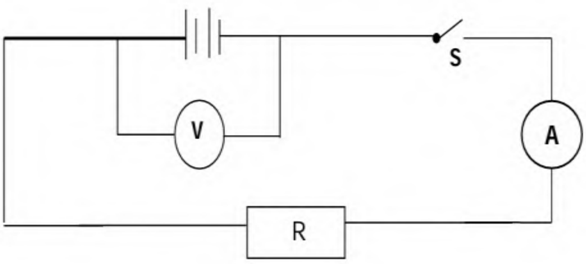
Solutions

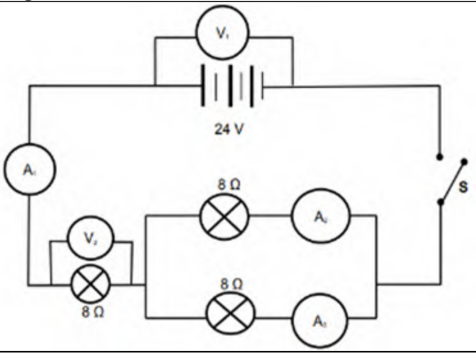
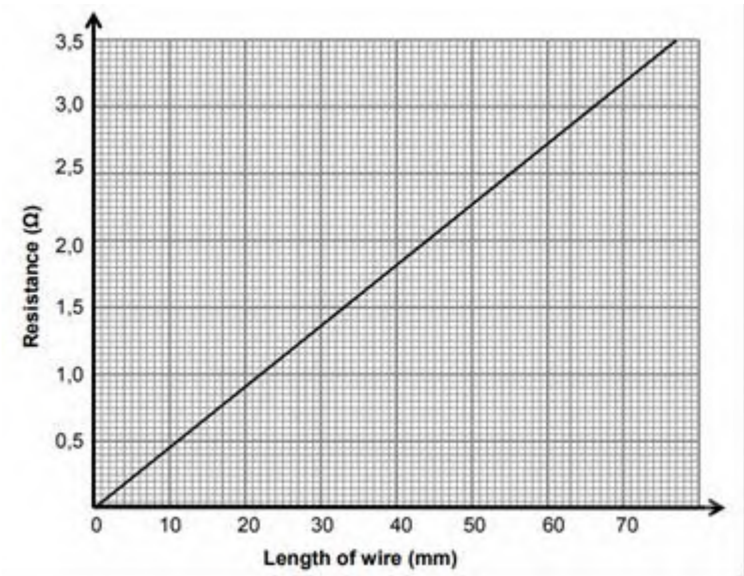
2.1	Emf ✓	
2.2	8 cells ✓	
2.3.1	4V✓	
2.3.2	4V✓	
2.4	0.67A ✓	

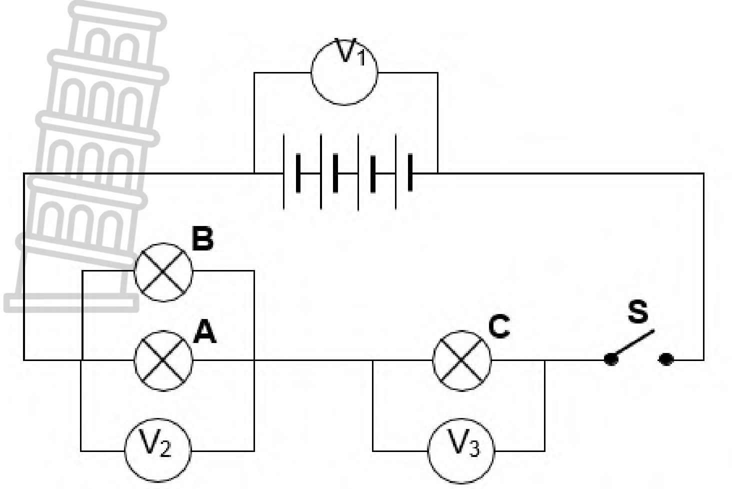
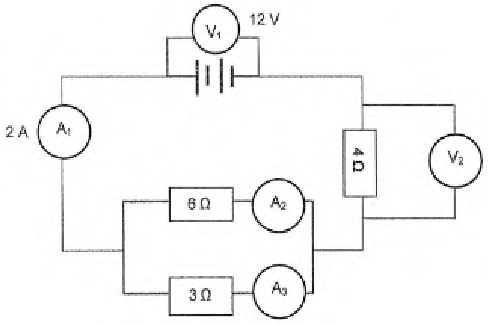
2.5	2 C ✓	
2.6	$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ ✓ $\frac{1}{R_P} = \frac{1}{3} + \frac{1}{6}$ ✓ R_p = 2 Ω ✓ R_{total} = 2+10 = 12 Ω ✓	
	$V = \frac{W}{Q}$ ✓ $20 = \frac{4800}{Q}$ ✓ Q = 240 C ✓ Q = IΔt 240 = 2Δt ✓ Δt = 120 seconds Δt = 2 minutes ✓	
2.7	Apply Negative Marking • Decreases ✓ • total resistance will increase ✓ • causing total current to decrease✓ • which causes V_3 to decrease since $V_3 \alpha I$	

Question 1 [8 marks]

1.1	Which one of the following statements regarding conventional current is TRUE?		
	A	The direction of current is the same as the direction of flow of electrons.	
	B	The direction current is perpendicular to the direction of flow of electrons.	
	C	The direction of current is opposite to the direction of flow of electrons.	(2)
1.2	Which one of the following is a unit of measurement of electric current.		
	A	Volt	
	B	Coulomb	
	C	Ohm	
	D	Ampere	(2)
1.3	Two identical light bulbs are connected in parallel, as shown in the circuit diagram below. Voltmeters V_1 and V_2 are connected across each light bulb. 		
	Which ONE of the following voltmeter readings is CORRECT?		
	A	$V_1 = V_2$	
	B	$V_1 = 2V_2$	
	C	$V_1 = ½V_2$	
	D	$V_1 = ¼V_2$	(2)
1.4	Consider the circuit diagram below. 		

	How will the readings on ammeters A_1, A_2 and A_3 compare with each other?		
	A	$A_1 = A_2 = A_3$	
	B	$A_1 = A_2 + A_3$	
	C	$(A_2 + A_3) > A_1$	
	D	$A_2 < A_3 < A_1$	(2)
Long questions			
Question 1 (10 marks)			
1.1	A learner connects a battery, a wire, a voltmeter, and an ammeter to form a circuit. The reading on the voltmeter is 4 V and the reading on the ammeter is 3 A.		
	1.1.1	How must the learner connect the ammeter in the circuit?	(1)
	1.1.2	How must the learner connect the voltmeter to measure the potential difference between the ends of the wire?	(1)
	1.1.3	Calculate the total resistance of the circuit.	(3)
1.2	Study the circuit diagram below.		
			
	1.2.1	Define the term resistance.	(2)
	1.2.2	Calculate the total resistance of the circuit.	(3)
			[10]
2.	Two IDENTICAL bulbs, **M** and **N** and devices **A** and **V**, are connected as shown in the circuit below. Switch **S** is initially open.		
			
2.1	Define the term emf.		(2)
2.2	Which physical quantity do the following devices measure when the switch is closed?		
	2.2.1	Device **A**	(1)
	2.2.2	Device **V**	(1)
2.3	Device **V** and component **R** are connected in the circuit as shown below.		
2.3			
	Switch s is now closed.		

	2.3.1	Define the term potential difference.	(2)
	2.3.2	Calculate the current flowing through the circuit if electric charge of 6 C passes through component **A** in 2 s.	(3)
	2.3.4	The potential difference across resistor **R** is 4 V when a charge of 6 C flows through it. Calculate the energy transferred in resistor **R**.	(3)
Question 3 (12 marks)			
3.	Consider the circuit diagram below.		
			
	Switch S is OPEN.		
3.1	Write down the reading on the following:		
	3.1.1	Voltmeter (V_1)	(1)
	3.1.2	Ammeter (A_1)	(1)
	Switch S is now CLOSED.		
3.2	Calculate the:		
	3.2.1	Equivalent resistance of the circuit.	(4)
	3.2.2	Voltmeter reading on V_2.	(3)
3.3	How do the readings on ammeters A_2 and A_3 compare with each other?		(1)
3.4	The graph below shows the relationship between the resistance and the length of the conducting wire.		
			
	3.4.1	Write down the relationship between the resistance and the length of the conducting wire.	(1)
	3.4.2	Determine the resistance of wire with a length of 30 mm.	(1)

Question 4 (11 marks)			
	Learners set up a circuit as shown in the diagram below. The emf of each cell is 1,5 V. Each of bulb **A** and bulb **B** has a resistance of 2 Ω and bulb C has a resistance of 3 Ω.		
			
4.1	Calculate the effective resistance of bulbs **A** and **B**.		(3)
	Switch **S** is now closed for a short time.		
4.2	Determine the reading on:		(1)
	4.2.1	Voltmeter V_1	(2)
	4.2.2	Voltmeter V_3	
4.3	Calculate the energy transferred in bulb C in 3 seconds if the current in the circuit is 2 A.		(4)
4.4	ALL the bulbs are now connected in parallel. How will the total current in the circuit be affected? Write down only INCREASES, DECREASES or REMAINS THE SAME.		(1)
Question 5 (17 marks)			
In the circuit diagram below the reading on voltmeter V1 is 12V and the reading on ammeter A1 is 2A. 			
5.1	Calculate the:		
	5.1.1	Total resistance of the circuit.	(4)
	5.1.2	Reading on V_2.	(3)
	5.1.3	Reading on A_2	(3)
	5.1.4	Amount of charge that flows through ammeter in A_1 in 120 s.	(3)
5.2	How will the reading on ammeter A_1 be affected if the 6Ω resistor is removed from the circuit? Write down only INCREASE, DECREASE or REMAIN THE SAME.		(1)
5.3	Explain the answer to Question 5.2 without any calculations.		(3)

MATTER AND MATERIALS

Matter and its classifications

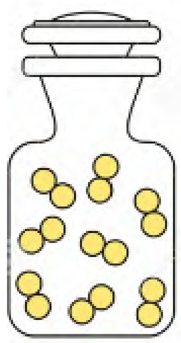
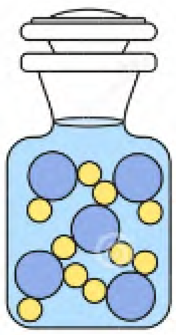
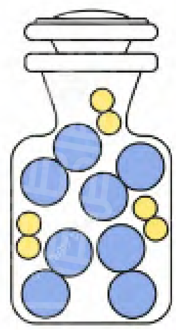
The Material(s) of Which an Object is Composed

- Materials can be divided into mixtures and pure substances
- Pure substances can be elements which consist of only one type of atom, or compounds which consist of more than one type of atom, bonded together in definite proportions.
- Elements can be metals, metalloids or non-metals.
- Metals are usually solids at room temperature. They are shiny, malleable and ductile and are good conductors of heat and electricity.
- Malleable substances can be hammered or pressed into shape without breaking or cracking.
- Ductile substances can be stretched into a wire.
- Non-metals are often gases at room temperature or soft or brittle elements.
- They are insulators of both heat and electricity.
- Metalloids have some properties of metals and some properties of non-metals.
- Magnetic materials are attracted by magnets. The only three magnetic elements are: iron, cobalt and nickel.
- Brittle substances are hard but likely to break easily.
- Density is the mass of a substance divided by its volume. Units are $g.cm^{-3}$.
- Boiling point of a substance is the temperature of a liquid at which its vapour pressure equals the external (atmospheric pressure).
- Melting point is the temperature at which a solid, given sufficient heat, becomes a liquid.

Pure Substances: Elements and Compounds

- Pure substances can be either elements or compounds
- Elements are pure substances which cannot be broken down into simpler substances by chemical methods.
- A compound is defined as a pure substance consisting of two or more different elements.
- Compounds contain more than one type of atom. They can be broken down into simpler substances by chemical methods.

Properties of Elements, Compounds and Mixtures

Elements	**Compounds**	**Mixture**
Consist of one kind of atom	Composition is constant	Composition can vary and consists of two or more elements or compounds
		

Elements

- Elements can be metals, non-metals or metalloids.
- Scientists use symbols to represent elements.
- Elements are made up of individual particles called atoms. The atom is the basic unit of matter

Compounds

- When two or more elements react compounds are formed.
- When carbon burns in oxygen for example, a compound called carbon dioxide is formed.
- The properties of carbon dioxide are different from those of oxygen and carbon.
- The formula of a compound tells us the elements which are found in that compound and the number of atoms of each element that are in each molecule or unit of the compound

The following table gives examples of compounds with their formulae:

Compound	***Formula***	***Elements making up the compound***
Water	H_2O	Hydrogen; Oxygen
Carbon dioxide	CO_2	Carbon, Oxygen
Sodium nitrate	$NaNO_3$	Sodium, Nitrogen, Oxygen

Metals, Metalloids and Non-metals

- Substances can be classified as metals, metalloids and non-metals using their properties.
- Metals are found on the left hand side of the Periodic Table.
- Non-metals are found on the top right hand side of the Periodic Table
- Metalloids have properties of metals and non-metals.
- There are seven elements that are classified as metalloids on the Periodic Table and they are: boron, silicon, germanium, arsenic, antimony, tellurium and polonium.
- Metalloids have increasing conductivity with increasing temperature (the reverse of metals), e.g. silicon.
- Metals have a decreasing conductivity with an increase in temperature.

Electrical Conductors, Semiconductors and Insulators

- Electrical conductors are materials that allow the flow of charge.
- Semiconductors are substances that can conduct electricity under some conditions, but not others, making them a good medium for the control of electrical current.
- Electrical insulator: is a material that prevents the flow of charge.
- All materials fall under one of the following categories: electrical conductors, semiconductors or insulators.

Thermal Conductors and Insulators

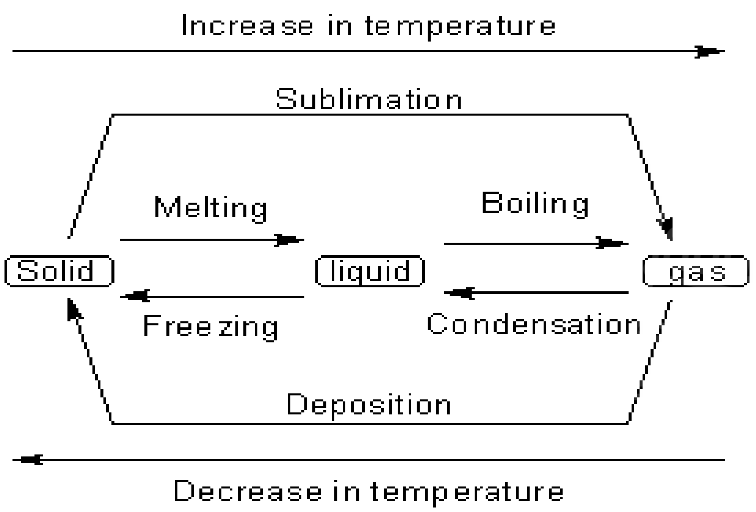
- A thermal conductor is a material that allows heat to pass through easily, whilst a thermal insulator does not allow heat to pass through it.
- The following materials are examples of thermal insulators: Air, cork, wool rubber wood, polystyrene.
- The following materials are examples of thermal conductors: silver, copper, aluminium, steel.

State of matter and kinetic molecular theory

- Matter consists of small particles.
- Particles of matter are in a constant state of random motion called Brownian motion.
- This random movement of microscopic particles suspended in a liquid or gas, caused by collisions between these particles and the molecules of the liquid or gas.
- Particles collide (with the sides of the container and with each other) and exert pressure
- Diffusion is the movement of atoms or molecules from an area of higher concentration to an area of lower concentration.
- Matter exists in any one of the following three states i.e. liquids, solids and gases
- The properties of the states are summarised in the following table:

	Solids	Liquids	Gases
Forces	Strong forces between the particles	Forces between particles are weaker than in solids	Virtually no forces between particles
Space	Small spaces between particles i.e. particle density is high	Spaces between particles slightly larger than in solids i.e. particle density is lower	Large spaces between particles i.e. particle density is very low
Movement	Particles vibrate in their fixed positions	Particles move about more vigorously	Particles move about at high speed.

- Liquids and solids are called condensed states because particles are very close together.
- Liquids and gases are called fluids because particles can move past one another.
- Temperature is a measure of the average kinetic energy of a substance.
- A phase change may occur when the energy of particles changes
- Boiling point is the temperature at which the vapour pressure of a substance equals the atmospheric pressure
- Freezing point is the temperature at which a liquid changes to a solid by the removal of heat.
- Melting point is the temperature at which a solid, given sufficient heat, becomes a liquid.
- Melting is the process during which a solid changes to a liquid by the application of heat.
- Evaporation is the change of a liquid into a vapour at any temperature below the boiling point.
- Evaporation takes place at the surface of a liquid, where molecules with the highest kinetic energy are able to escape.
- When evaporation happens, the average kinetic energy of the liquid is lowered, and its temperature decreases.
- Freezing is the process during which a liquid changes to a solid by the removal of heat.
- Sublimation is the process during which a solid changes directly into a gas without passing through an intermediate liquid phase.
- Condensation is the process during which a gas or vapour changes to a liquid, either by cooling or by being subjected to increased pressure.



Atomic structure

- When one or more electrons are removed from an atom, the atom becomes positively charged (cation).
- When one or more electrons are added to an atom, it becomes negatively charged (anion).

Isotopes

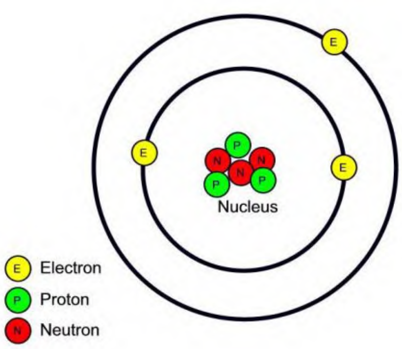
- Isotopes are atoms of the same element having the same number of protons, but different numbers of neutrons.
- Relative atomic mass is the mass of a particle on a scale where an atom of carbon-12 has a mass of 12.
- The atomic number (Z) is the number of protons in the nucleus of an atom
- The mass number (A) is the number of protons and neutrons in the nucleus of an atom
- The notation ${}^{A}_{Z}E$ is used to represent an isotope of an element where E is the symbol of the element, Z is the atomic number and A is the mass number.

Example: write down the ${}^{A}_{Z}E$ notation of lithium

Solution: ${}^{7}_{3}Li$

Electron configuration

- The term electron configuration refers to the way that electrons are arranged around the nucleus.
- Electrons move around the nucleus in specific energy areas that are called energy levels.
- Atomic orbitals are the most probable regions in space where electrons that have the specific energy corresponding to the orbital are found.
- The arrangement of electrons, neutrons and protons of Lithium are shown below.



- The following rules are used in order to distribute electrons into energy levels
  - Energy levels are filled from the lowest energy to the highest energy (Aufbau Principle).
  - There can only be two electrons of opposite spin in any one orbital (this is called Pauli's exclusion principle).
  - When there is more than one orbital of the same energy, each orbital must be filled singly before it can be occupied by two electrons (this is called Hund's rule).
- The electron configurations of a few elements are shown below:

  Hydrogen (H): $1s^1$

  Helium (He): $1s^2$

  Oxygen (O): $1s^2\ 2s^2\ 2p^4$

  Sodium (Na): $1s^2\ 2s^2\ 2p^6\ 3s^1$

Example: write down the sp notation for neon(Ne)

Solution: (Ne) $1s^2\ 2s^2\ 2p^6$

The Periodic Table of elements

The positions of the elements in the periodic table related to their electronic arrangements

- The periodic table display the elements in order of increasing atomic number.
- The periodic table shows how periodicity of the physical and chemical properties of the elements relates to atomic structure.
- Groups are the vertical columns in the periodic table.
- Some groups have names, e.g. alkali metals (group I), earth-alkaline metals (group 2), halogens (group 17) and noble gases (group18).
- Periods are the horizontal rows in the periodic table.
- The position of an element in the periodic table is related to its electronic structure and vice versa.
- Periodicity is the repetition of similar properties in chemical elements, as indicated by their positioning in the periodic table
- Moving from Li to Ne, properties of elements in terms of atomic radius, ionisation energy, electron affinity and electronegativity are repeated from Na to Ar.
- Atomic radius is the mean distance from the nucleus to the border of the outer orbital.
- Ionisation energy is the energy needed per mole to remove an electron(s) from an atom in the gaseous phase
- First ionisation energy is the energy needed per mole to remove the first electron from an atom in the gaseous phase.
- Electron affinity is the energy released when an electron is attached to an atom or molecule to form a negative ion
- Electronegativity is a measure of the tendency of an atom in a molecule to attract bonding electrons
- Metals are found on the left-hand side of the periodic table
- Non-metals are found on the right-hand side of the periodic table.
- Group 1 elements are called alkali metals. They form positive ions, and they react strongly with oxygen and water.
- Group 2 elements are called alkaline-earth metals. They form positive ions with a +2 charge, and they react with oxygen and water.
- Group 1 oxides are soluble in water, but group 2 oxides are not.
- Group 17 elements are called halogens. They are the most reactive non-metals, and they form an ion with a charge of -1.
- Group 18 elements are called noble gases, and they are unreactive.
- In groups 1 and 2, chemical reactivity increases from top to bottom.
- In group 17, chemical reactivity decreases from top to bottom.
- Elements in the same group have the same number of electrons in their outer energy levels
- Elements in the same period have their outer electrons in the same energy level

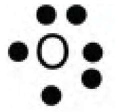
	Across the period	**Down the group**
Atomic radius	Decreases	Increases
Ionisation energy	Increases	Decreases
Electron affinity	Increases	Decreases
Electronegativity	Increases	Decreases

Chemical bonding

- Define a chemical bond as a mutual attraction between two atoms resulting from the simultaneous attraction between their nuclei and the outer electrons.
- There are three types of chemical bonding:
  Non-metal + non-metal = covalent bond

Non-metal + metal = Ionic bond
Metal +metal = metallic bond

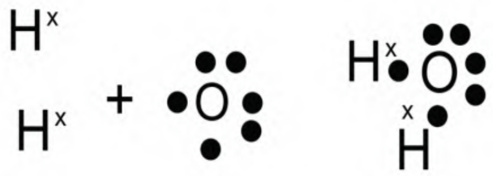
- The energy of the combined atoms is lower than that of the individual atoms resulting in higher stability.
- A Lewis dot diagram is a structural formula in which valence electrons are represented by dots or crosses. It is also known as an electron dot formula, a Lewis formula, or an electron diagram.
- The following are examples of Lewis structures of two elements:

Oxygen: 

Hydrogen: 

Covalent bonding

- A covalent bond is the sharing of electrons between atoms to form molecules
- A molecule is a group of two or more atoms that are covalently bonded and that functions as a unit.
- In a Lewis dot diagram two dots between atoms represent a covalent bond. These two electrons are known as a bonding pair, whilst non-binding electron pairs are called lone pairs.
- The formation of a covalent bond between two hydrogen atoms and one oxygen atom can be represented by means of Lewis structures as follows:



- The bonding pair of electrons between each hydrogen atom and the oxygen atom, are share by hydrogen and oxygen.

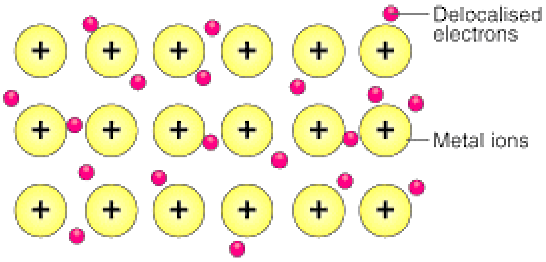
Ionic bonding

- Ionic bonding is the transfer of electrons to form cations (positive ions) and anions (negative ions) that attract each other to form a formula-unit
- The formation of an ionic bond between sodium and chlorine can be represented by means of Lewis structures as follows:

- A formula-unit is the simplest empirical formula that represents the compound.
- An ion is a charged particle made from an atom by the loss or gain of electrons
- A crystal lattice is an orderly three-dimensional arrangement of particles (ions, molecules or atoms) in a solid structure.
- In a crystal of sodium chloride each sodium ion is surrounded by six chloride ions to form a cubic structure. Each chloride ion is also surrounded by six sodium ions.

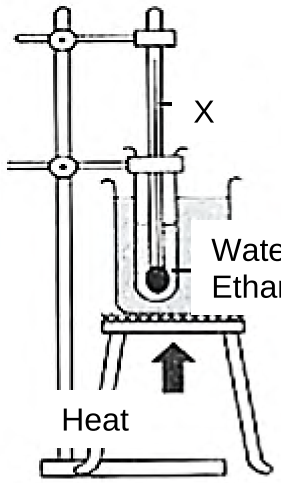
Metallic bonding

- Metallic bonding is the bond between positive ions and delocalised valence electrons in a metal.
- Valence electrons or outer electrons are the electrons in the highest energy level of an atom in which there are electrons.

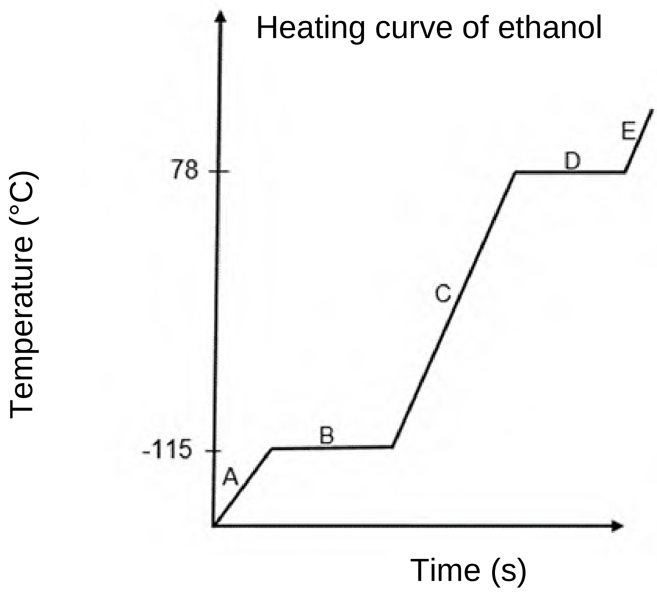


Worked Example: 1 (heating and cooling curve)

1. The grade 10 learners conducted an experiment to investigate the effect of the increase in temperature on ethanol over a period of time at standard pressure.



The graph below was drawn using the results obtained



1.1 Define the term melting point. (2)

1.2 Write down the value of standard pressure. (1)

1.3 Give the name of apparatus X. (1)
1.4 In what phase is ethanol at 0 °C? (1)
1.5 Explain, using the kinetic molecular theory, what is happening at section D. (3)
1.6 Will water or ethanol boil first at standard pressure? Explain the answer. (3)
[11]

Worked Example 1 solutions

1.1 The temperature at which a solid, given sufficient heat, becomes a liquid. ✓✓ (2)

1.2 1,013 x 10^5 Pa or 101,3 kPa or 1 atm or 1 bar or pressure at sea level ✓ (1)

1.3 Thermometer ✓ (1)

1.4 Liquid ✓ (1)

1.5
- Temperature remains constant, phase change is taking place (liquid to gas). ✓
- All the heat absorbed is used to weaken the intermolecular forces. ✓
- Kinetic energy remains constant, but potential energy increases. ✓

(3)

1.6
- Ethanol will boil faster than water. ✓
- Ethanol boils at 78 °C and water boils at a higher temperature, 100 °C at standard pressure. ✓
- The water molecules need more energy to overcome the stronger forces. ✓

(3)
[12]

Worked example 2 (Isotopes

2.1 Describe the difference between atomic mass and relative atomic mass. (3)

2.2 The element potassium has three naturally occurring isotopes with the following abundance:

$^{39}K = 93,26\%$

$^{40}K = 0,2\%$

$^{41}K = 6,57\%$

Calculate the relative atomic mass of potassium. (4)

2.3 What is meant by an atomic orbital, and how does it differ from an orbit? (4)

2.4 Naturally occurring neon has three isotopes with following abundance:

$^{20}Ne = 90,48\%$

$^{x}Ne = 0,233\%$

$^{22}Ne = 9,25\%$

By means of a calculation, determine the mass number x, if the relative atomic mass of neon is 20,18 (5)

Worked Example 2 solutions

2.1 Relative atomic mass is the mass of a particle on a scale where an atom of carbon-12 has a mass of 12g while atomic mass is the sum of the number of protons and neutrons in the atom. ✓✓ (2)

2.2

$$RAM = \frac{\overset{\checkmark}{(39 \times 93.26)} + \overset{\checkmark}{(40 \times 0.2)} + \overset{\checkmark}{(41 \times 6.57)}}{100}$$

= 39.15g ✓ (4)

2.3 Atomic orbitals are the most probable regions in space where electrons that have the specific energy corresponding to the orbital are found✓✓ while an orbit is a fixed path along which electrons move around the atom's nucleus. ✓✓

(4)

2.4

$$20.18 = \frac{\overset{\checkmark}{(20 \times 90.48)} + \overset{\checkmark}{(x \times 0.233)} + \overset{\checkmark}{(22 \times 9.25)}}{100}$$

x = 21.03g ✓

(4)

Matter and materials activities

Question 1: Multiple-choice questions

1.1 From which of these atoms in the ground state can a valence electron be removed using the least amount of energy?

A Nitrogen
B Oxygen
C Carbon
D Fluorine (2)

1.2 Which one of the following is an unreactive gas?

A O_2
B He
C H_2
D CO (2)

1.3 Covalent bonding is the ...

A sharing of protons between atoms to form molecules.
B transfer of electrons to form cations and anions.
C sharing of electrons between atoms to form molecules.
D transfer of protons to form cations and anions. (2)

1.4 A neutral atom of an element has an electron configuration of $1s^2 2s^2 2p^5$.
In which group and period of the periodic table is this element located?

A Group II, Period 7
B Group V, Period 2
C Group VII, Period 2
D Group VII, Period 5 (2)

1.5 Which of the following statements best describes the forces found in metallic lattices?

A Electrostatic forces between positive ions and electrons.
B Electrostatic forces between positive ions and negative ions.
C London forces between non-polar molecules.
D Hydrogen bonds between (2)

1.6 Which one of the following statements about the trends down Group VII (lowest to highest atomic number) in the Periodic Table is correct?

A The atomic size increases
B The ionisation energy increases
C The non-metallic character increases
D The number of valence electrons (2)

1.7 Consider the following elements:
potassium (K); zinc (Zn); phosphorous (P); antimony (Sb); argon (Ar)

Which of the following statements is true?

A All are metals.
B All are non-metals.
C All are chemically reactive.
D One is a metalloid (semi-conductor). (2)

1.8 What is the percent by mass of oxygen in H_2SO_4?

A 16%

B 33%

C 65%

D 98% (2)

1.9 The electron configuration of sodium ion (Na+) is:

A $1s^22s^22p^6$

B $1s^22s^22p^63s^1$

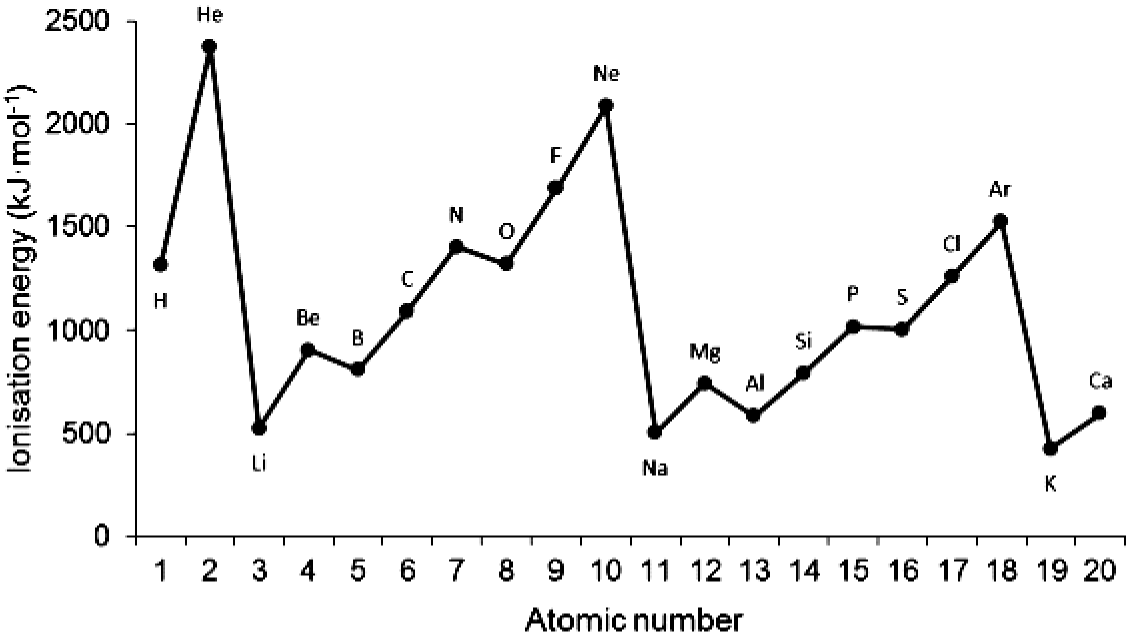
C $1s^22s^22p^63s^2$

D $1s^22s^22p^63s^23p^6$ (2)

[18]

Question 2

Consider the graph of the first ionisation energy and answer the questions that follow.



2.1 Define the term *ionisation energy*. (2)

2.2 State the general trend in ionisation energy from left to right across a period on the periodic table. (1)

2.3 There is a drop in ionisation energy from beryllium to boron.

2.3.1 Write down the sp- notation for beryllium AND boron. (2)

2.3.2 Explain this drop in ionisation energy. (2)

2.4 Is the following statement TRUE or FALSE? If false, rewrite the statement correctly. *The ionisation energy of noble gases is high because of the half- filled s- and p-orbitals.* (2)

2.5 Study the ionisation energy of the group (I) elements in the graph above and answer the questions that follow.

2.5.1 Give the general name of the group (I) elements. (1)

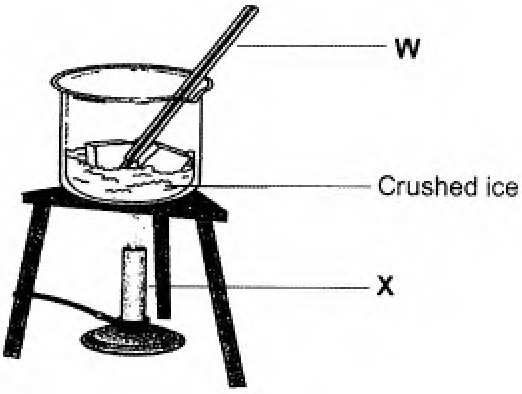
2.5.2 State the trend in the reactivity of elements in group (I). (1)

2.5.2 Explain the reason for the trend in QUESTION 2.5.2 by using the graph of ionisation energy (2)

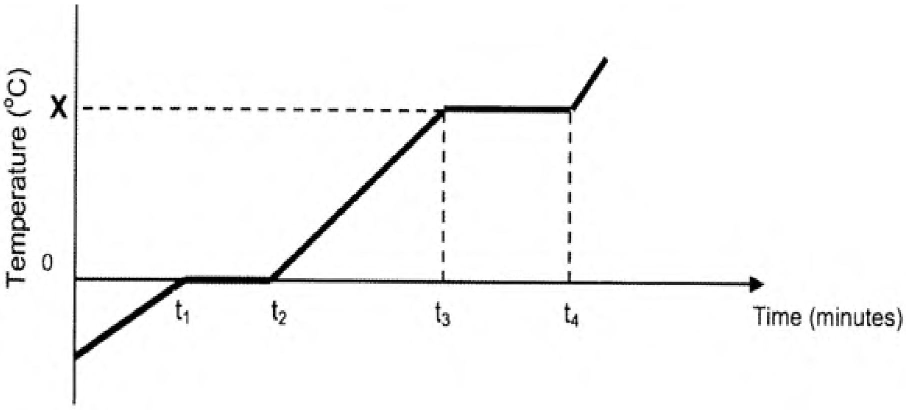
[13]

Question 3

Grade 10 learners conducted an experiment to determine the heating curve of water by using crushed ice at standard pressure, as shown in the figure below



3.1	define the boiling point	(2)
3.2	Write down the name of an instrument labelled W	(1)
3.3	Explain why crushed ice was used instead of ice cubes?	(2)
3.4	The graph below, not drawn into scale, shows the results obtained.	



3.4.1	Write down the value represented by **X**	(1)
3.4.2	Name the predominantly phase of this substance between t_2 and t_3.	(1)
3.4.3	Write down the process taking place between t_3 and t_4.	(1)
3.4.4	Explain increase in temperature between t_2 and t_3.	(2)
3.4.5	How will the above graph be affected if a larger quantity of crushed ice was used?	(2)

Question 4

4.1 Calcium (Ca) reacts with Chlorine (Cl) to form Calcium Chloride.

4.1.1	Write down the number of electrons in Ca^{2+} ion.	(1)
4.1.2	Draw the Aufbau diagram and provide the electron configuration (sp-notation) for chlorine.	(3)
4.1.3	Identify the type of bond that forms when calcium and chlorine combine.	(1)
4.1.4	Draw the Lewis structure for calcium chloride.	(2)

4.2 Copper (Cu) has two stable isotopes. Copper – 65 has percentage abundance of 25%. The relative atomic mass of copper is 63.5 amu. Determine the number of neutrons in the most abundant isotope of copper.

(6)

4.3 Write down the chemical formula for:

4.3.1 Magnesium oxide (2)

4.3.2 Ammonium dichromate (2)

4.4 Write down the chemical name of $Cu(NO_3)_2$. (2)

[17]

Question 5

Magnesium metal reacts readily with oxygen when it is burned in air.

5.1 Write down a word equation for the reaction of magnesium with oxygen (3)

5.2 Write down the chemical formula for the substance formed in QUESTION 6.1 (2)

5.3 Write down the valence electron configuration for magnesium. (2)

5.4 Write down the valence electron configuration for oxygen. (2)

5.5 Write down the symbol for the cation formed when magnesium loses its valence electrons. (1)

5.6 Write down the symbol for the anion formed when oxygen accepts two electrons into its valence shell (1)

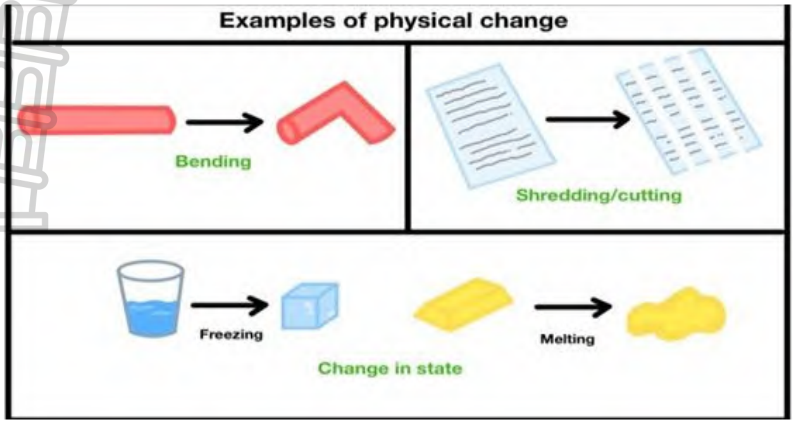
[11]

PHYSICAL AND CHEMICAL CHANGE

Physical change: No **new substances** are formed, mass, numbers of atoms and molecules are conserved

- A change in the form of the substance but not the substance itself
- In other words: a change in the property of matter but not a change in the matter itself

Example of Physical Changes



Chemical change: Involves **change of materials** into another, **new materials** with **different properties** and one or more than one substance formed

Chemical change: Involves **change of materials** into another, **new materials** with **different properties** and one or more than one substance formed

Chemical Change Event	Substance before Chemical Change	Substance after Chemical Change
Burning firewood	Firewood	Ash
Iron rusting	Iron	Rust
Souring of milk	Milk	Soured milk
Frying an egg	Raw egg	Cooked agg

Differences between physical and Chemical Change

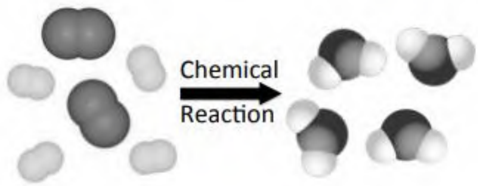
	Physical Change	**Chemical Change**
Differences	No new substances are formed.	New substances are formed.
	Mass, number of atoms and molecules are conserved.	Mass and number of atoms are conserved, but **molecule numbers may change**.
	Energy is released or absorbed during **PHASE change**.(Melting, evaporation & sublimation)	Energy is absorbed when chemical bonds are broken and it is released when chemical bonds are formed.
	Have no direct effect on chemical bonds or number of molecules	Have effect on the chemical bonds of molecules – chemical bonds are broken and new bonds are formed
Examples	Ice melting, salt dissolving in water, breaking glass into fragments, water evaporating into air, mixing oil with water	• hydrogen burns in oxygen to form water. • hydrogen peroxide decomposes into hydrogen and oxygen. • hydrochloric acid reacted with sodium hydroxide to form sodium chloride and water.

Water can undergo chemical and physical changes as shown below.

CHEMICAL CHANGE

EXAMPLE: Synthesis of water

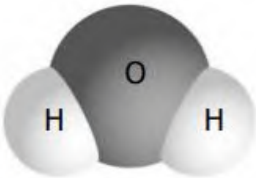
	Reactants		Products
Word Equation	Hydrogen + oxygen	forms	Water
Balanced chemical equation	$2\,H_2 + O_2$	→	$2\,H_2O$
Particle diagram			

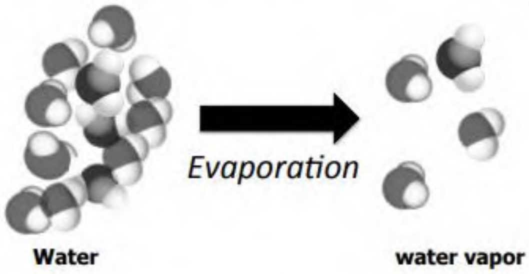


PHYSICAL CHANGE

Example of Physical change: Water

Consider liquid water evaporating to form water vapour. Each water molecule consists of one oxygen atom bonded to two hydrogen atoms.





Representing Chemical Change

- Phases in a chemical reaction: (g) Gas; (s) Solid; (l) liquid; (aq) aqueous
  A typical aqueous solution involves ions dissolved in water.
  e.g. Na^+ and Cl^- ions in water is referred to as $Cl^-_{(aq)}$ and $Na^+_{(aq)}$

- Word equations
  Sodium + water ⟶ sodium hydroxide + hydrogen
  Reactants Products

- Symbolic representation
  $Na + H_2O \longrightarrow NaOH + H_2$

- Balancing the equation
  The number of atoms on the RHS should balance those on the LHS.
  $2Na + 2H_2O \rightarrow 2NaOH + H_2$

Law of conservation of matter

In a chemical reaction, the sum of the mass of the reactants equal the sum of the mass of the products.
Total mass of reactants = total mass of products.

This can also be expressed as "Matter is neither created nor destroyed in a chemical reaction." Another name for the "law of indestructible of matter" is the law of conservation of mass.

Worked example: Verify the law of conservation of mass in a reaction between Nitrogen reacting with Hydrogen to form Ammonia solutions.

Answer:

The reaction must be balanced.

Total relative mass before and after the reaction:

$Pb(NO_3)_{2(aq)} + 2NaI_{(aq)} \longrightarrow PbI_{2(s)} + 2NaNO_{3(aq)}$

$331,2 + (2 \times 149,9) \longrightarrow 461,0 + (2 \times 85)$

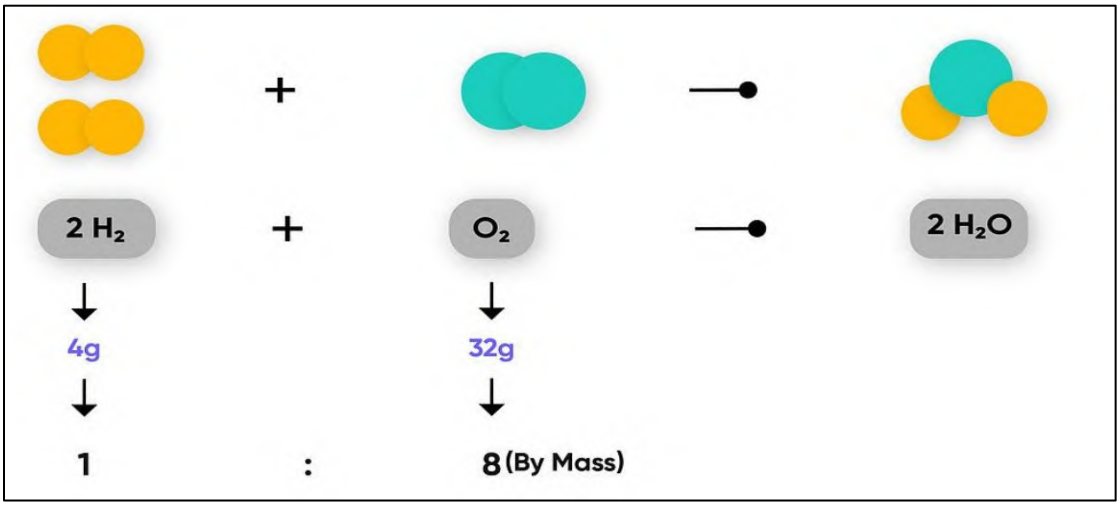
$631,0 \longrightarrow 631,0$

The mass of the reactants is equal to the mass of the products.

Matter (in this case atoms) are neither created nor destroyed but they are simply combined or arranged differently.

Mass of reactants = mass of products.

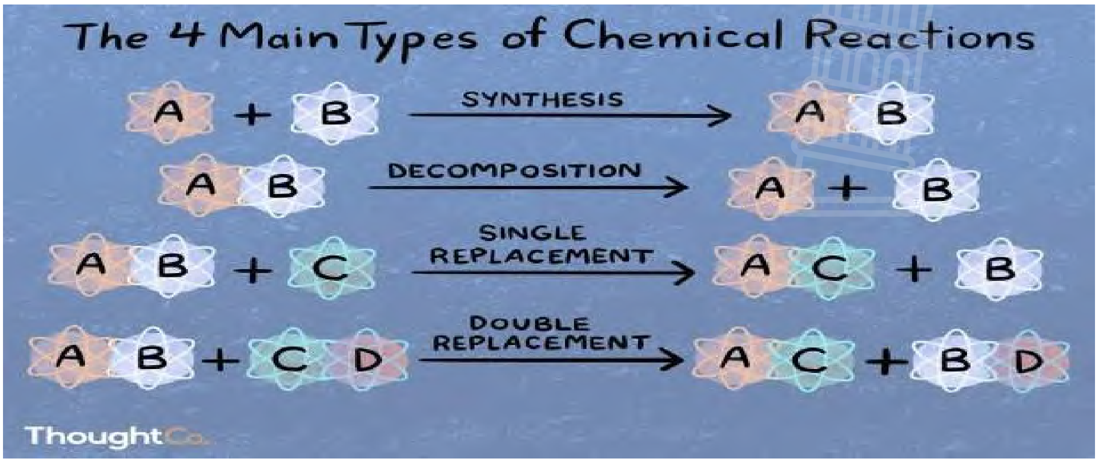
The law of Constant Composition



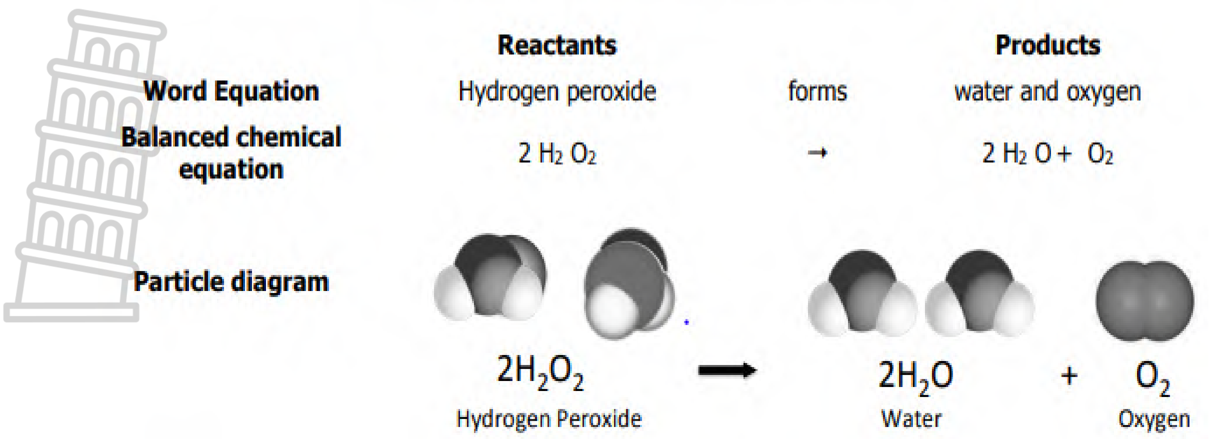
No matter how a chemical compound is prepared, it always contains the same elements in the same ratio.

Synthesis- means to make something or build

Decomposition- means to break something down



EXAMPLE: Decomposition of Hydrogen peroxide



QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer.

1.1 A physical change is a change in which...

A New chemical substances are formed
B Mass and atoms are conserved; number of molecules is not
C Mass, numbers of atoms and molecules are conserved
D A large amount of energy is absorbed or released (2)

1.2 Which one of the following is an indication that a chemical change is taking place?

A Salt dissolves in water and becomes invisible.
B Chocolate is heated until it melts.
C The temperature remains constant during the change.
D A gas is released while the change is occurring (2)

1.3 Which ONE of the following is true for a physical change?

A $2Hg + O_2 \rightarrow HgO$
B $2Hg + 2O_2 \rightarrow 4HgO$
C $Hg + O_2 \rightarrow HgO$
D $2Hg + O_2 \rightarrow 2HgO$ (2)

1.4 The law of constant composition states that:

A Molecules combine in a specific ratio in any chemical reaction.
B Atoms combine in a fixed ratio to form a specific compound.
C Atoms combine in a specific mass ratio when they react.
D The number of molecules in a specific reaction is conserved. (2)

1.5 The law of conservation of mass states that

A the mass of the reactants is equal to the mass of the products.
B the number of molecules of reactants is equal to the number of molecules of
C the number of atoms of reactants is equal to the number of atoms in the products.
D the number of atoms of each element in the reactants is equal to the number of atoms of each element in the product. (2)

1.6 What are the missing coefficients for the following equation?

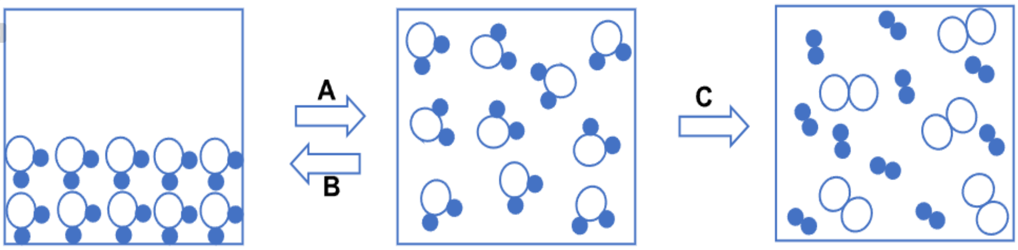
$$Al(SO_4)_3(aq) + KOH(aq) \rightarrow Al(OH)_3(aq) + K_2SO_4(aq)$$

A 1, 3, 2, 3
B 2, 12, 4, 6
C 4, 6, 2, 3
D 1, 6, 2, 3 (2)

[12]

Question 2

2.1 Study the illustration below and answer the questions that follow.



2.1.1 Is process A showing a physical or chemical change? **(1)**
2.1.2 Give 2 reasons for the answer to Question 3.1.1. **(2)**
2.1.3 Is process B showing a physical or chemical change? **(1)**
2.1.4 Is process C showing a physical or chemical change? **(1)**
2.1.5 Give a reason for the answer to question 3.1.4 **(1)**

2.2 A chemical reaction is carried out in the laboratory. The chemical equation for the reaction is

$$\mathbf{AgNO_3 + KI \rightarrow AgI + KNO_3}$$

What mass of **silver nitrate reacts** completely with potassium iodide, when 16,6 g of KI reacts to form 23,5 g of AgI and 10,1 g of KNO_3?

(3)

2.3 Consider the following chemical reaction:

$$\mathbf{4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O}$$

2.3.1 Show, by using relative atomic masses that mass is conserved during the reaction **(7)**
2.3.2 Show by using relative atomic masses that mass is conserved during the reaction **(7)**

2.4 Explain why the number of molecules is not conserved during a chemical change **(3)**

Question 3

3.1 Sulfur consists of S_8 molecules. Describe the rearrangement of molecules that occurs in each of the following changes:

3.1.1 sulfur is heated until it melts. **(3)**
3.1.2 liquid sulfur is heated until it boils. **(4)**

3.2 For each of the changes mentioned in question 4, state whether a physical or chemical change is happening **(2)**

3.3 Compare the energy required to bring about these changes with the energy needed to break the covalent bonds between sulfur atoms in S_8 molecules. Explain your answer **(4)**

Question 4

Balance the following reactions and describe each reactions whether is synthesis or decomposition

4.1 **$2Na + C\ell_2 \rightarrow 2NaC\ell$** **(2)**

4.2 **$KClO_3 \rightarrow KCl + O_2$** **(2)**

PHYSICAL AND CHEMICAL CHANGE: SOLUTIONS

Question 1

1.1 **C** No new substances are formed,

1.2 **D** Release of a gas indicates that a chemical change is occurring. During a chemical change there is always a change in temperature

1.3 **D**

1.4 **B** The law of constant composition states that atoms of elements combine in fixed ratios to produce a specific compound. Note that it is not a mass ratio in which elements combine. The last statement is correct, but it is not the law of constant composition.

1.5 **A** The number of molecules being conserved is not what occurs in a chemical change

Question 2

2.1 Physical Change

2.1.1 No new substances are formed

2.1.2 The number of atoms, molecules and mass is conserved

2.1.3 Physical Change

2.1.4 Chemical Change

2.1.5 New substances are formed

The numb2.2er of have molecules changed

2.2 By the law of conservation of mass, the total mass of reactants and products must be the same.✓ So,

reactants = products

X + 16,6 = 23,5 + 10,1✓

X = 17,0 g✓

2.3.1 a. Reactants:

NH_3: m = 4(14 + 1 X 3)
= 68 ✓

O_2: m = 5(2 x 16)
= 160 ✓

Total reactants = 228 ✓

Products:

NO: m = 4(14 + 16)
= 120 ✓

H_2O: m = 6(2 X 1 + 16)
= 108 ✓

Total products = 228 ✓

∴ reactants = products ✓

2.3.2 a. Reactants: N = 4 atoms✓
H = 4 X 3 = 12 atoms✓
O = 5 X 2 = 10 atoms✓
Products: N = 4 X 1 = 4 atoms✓
O = 4 X 1 + 6 X 1 = 10 atoms✓
H = 6 X 2 = 12 atoms✓

Number of atoms of each element is the same in reactants and products .

∴ conserved. ✓

2.4 The number of molecules of each substance is not conserved in a chemical change because the molecules of the reactants each break up✓ when they react and form different molecules in the products✓. The number of molecules may increase or decrease.✓

3.1.1 In solid sulfur, the molecules are held in place in a crystal lattice by intermolecular forces. ✓ When the sulfur melts, the molecules become disordered✓ because the intermolecular forces can no longer keep them in the crystal lattice arrangement. ✓

3.1.2 In liquid sulfur there are still intermolecular forces in place ✓so the molecules are not totally free to move. ✓When the sulfur absorbs more energy, the intermolecular forces are broken completely ✓and the sulfur molecules are totally free to move.✓

QUANTITATIVE ASPECTS OF CHEMICAL CHANGE

knowledge base:

- Writing chemical formula
- Calculation of Relative Formula Mass
- Balancing chemical equations

Atomic mass and the mole concept

- one mole refers to the amount of substance having the same number of particles as there are atoms in 12 g carbon-12.
- Relative atomic mass (RAM) is **the mass of a particle on a scale where an atom of carbon-12 has a mass of 12**

Relationship between Avogadro's number(N_A), Number of particles, number molecules, number of atoms, number of formula units(N) and the number of moles(n)

This is the number of particles (atoms, molecules, formula units) present in one mole of a substance.
(N_A = 6,02 x 10^{23} mol^{-1})

Converting a given number of particles of a substance to moles: $n = \frac{N}{N_A}$

n: number of moles
N: number of particles (atoms, molecules, formula-units)
N_A: Avogadro's Number

Worked examples

1. Determine the number of moles of H_2O in 1,806 x 10^{24} molecules of water.

Solution: $n = \frac{N}{N_A}$

$$n = \frac{1{,}806 \times 10^{24}}{6{,}02 \times 10^{23}} = 3 \text{ moles}$$

2. Calculate the total number of atoms in 0,5 moles of CO_2.

Solution:

Number of CO_2 molecules: = n x N_A = 0,5 x 6,02x10^{23} = 3,01 x 10^{23}.

<u>BUT each CO_2 has 1 Carbon atom and 2 Oxygen atoms</u>

Number of C atoms = 1 x 3,01x10^{23} = 3,01x10^{23} atoms

Number of O atoms = 2 x 3,01x10^{23} = 6,02x10^{23} atoms

Total number of atoms = 3,01x10^{23} + 6,02x10^{23} = 9,03x10^{23} atoms

OR

Total number of atoms = 3 x 3,01x10^{23} = 9,03x10^{23} atoms

1C atom + 2O atoms

Molar mass: The mass of one mole of a substance measured in gmol-1

Formula : $n = \frac{m}{M}$

n: number of moles of a substance in moles(mol)

m: mass of substance in grams(g)

M: molar mass of substance in grams per mole($g \cdot mol^{-1}$)

Calculating the molar mass

The molar mass is calculated using the atomic mass numbers in the periodic table

Example

M(Ne)= 20 $g \cdot mol^{-1}$

M(NaCl) = 23+35,5 = 58,5 $g \cdot mol^{-1}$

Worked Examples

Calculate the Molar mass of each of the following

1. Copper(Cu)
2. Oxygen gas (O_2)
3. Carbon dioxide gas(CO_2)
4. Sulphuric acid(H_2SO_4)
5. Sucrose ($C_{12}H_{22}O_{11}$)
6. Copper Sulphate crystals ($CuSO_4.5H_2O$)

Solutions

1. Cu = 63,5 $g \cdot mol^{-1}$
2. O_2 2(16) = 32 $g \cdot mol^{-1}$

3. CO_2 — $12 + 2(16) = 44\ g\cdot mol^{-1}$
4. H_2SO_4 — $2(1)+32+4(16) = 92\ g\cdot mol^{-1}$
5. $C_{12}H_{22}O_{11}$) — $12(12)+22(1)+11(16) = 342\ g\cdot mol^{-1}$
6 ($CuSO_4.5H_2O$) — $63,5 +32+4(16) + 5[2(1)+16)] = 249,5\ g\cdot mol^{-1}$
7. $Mg_3(PO_4)_2$ — $3(24)+[31+4(16)]2 = 262\ g\cdot mol^{-1}$

NB* 1)In $CuSO_4.5H_2O$, the dot(.) does not mean multiplication. It means addition.
2 In $Mg_3(PO_4)_2$ the "2" outside the bracket is ONLY used to find the number of each atom within the bracket.

Activity 1

Calculate the molar mass for each of the following:

1. Ca
2. Cl_2
3. H_2O
4. $KMnO_4$
5. C_4H_{10}
6. $Na_2CO_3.10H_2O$
7. $Mg(NO_3)_2$

Relationship between number of moles (n), mass (m) and molar mass(M)

Formula: $n = \frac{m}{M}$

n: number of moles

m: mass in g

M: molar mass in $g.mol^{-1}$ (obtained by adding the atomic masses (A) from periodic table)

Mass conversions

1000 mg = 1 g

1000g = 1 Kg

Example

840 mg = 840 ÷ 1000

= 0,84 g

1,5 Kg = 1,5 × 1000

= 1500 g

Worked Example 1

1. Calculate the number of moles of water in 100 g of water

Solution

Chemical formula of water is H_2O

$Mr(H_2O) = 2(1)+16 = 18\ g\cdot mol^{-1}$

$$n = \frac{m}{M} = \frac{100}{18} = 5,56\ mol$$

Worked Example 2

1. What is the molar mass of a substance if 5 moles of the substance have a mass of 295, 5 g?

Solution

$$n = \frac{m}{M}$$

$5 = \frac{295,5}{M}$ (Cross multiply and let M be the subject of the formula)

$$M = \frac{295}{5} = 58,5\ \mathrm{g \cdot mol^{-1}}$$

Worked Example 3
Calculate the mass of 0,2 mol of NH_3

$$n = \frac{m}{M}$$

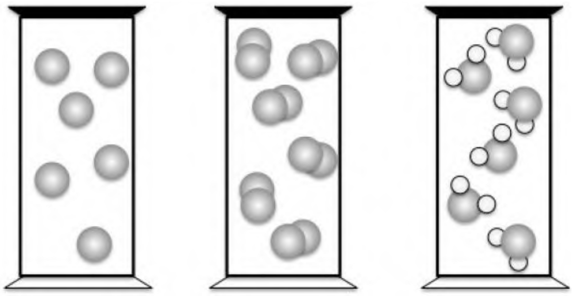
$$0,2 = \frac{m}{17}$$

$$m = 3,4\ g$$

Activity 2

1. Determine the mass of 2,5 moles of Na_2SO_4
2. Calculate the number of moles in 50 g magnesium chloride
3. moles of a diatomic element has a mass of 84 g. Identify the diatomic element using a suitable calculation

Molar Volumes of Gases
Avogadro's Law: One mole of any gas occupies the same volume at the same temperature and pressure



We refer to the volume of 1 mole of a gas as the <u>Molar Volume</u> (V_m).
Therefore, the Molar Volume of a gas depends on the Temperature and Pressure.

<u>Standard Temperature and Pressure (STP)</u>
Standard Temperature: 273 K or 0°C
Standard Pressure: 1atm or 101,3 kPa
The Molar Volume (V_m) of any gas at STP is 22,4 dm^3.

Note: If the temperature is not 273 K or pressure is not 101,3 kPa, the V_m cannot be taken as 22,4 dm^3.

The volume of a gas at STP can be obtained from the Molar Volume using the formula below:

$V = n \times V_m$ = n x 22,4 (Gases at STP ONLY)

V: volume of the gas in dm^3
n: number of moles of the gas.
V_m: Molar Volume of the gas in dm^3

Worked Example
Determine the volume of 2 moles of Oxygen gas at STP

Solution:
$V = n \times V_m = 2 \times 22.4 = 44.8\ dm^3$

The Volume of the gas sample (V) must always be measured in

dm^3(1 dm^3 = 1000 cm^3 = dm^3 1000ml = 1 litre)
1 Litre = 1 dm3

Worked Example 3

1. Determine the volume of 0,2 moles of H_2 at STP.
2. Determine the mass of 60 cm^3 of NH_3 at STP.

Solutions

1. $n = \frac{V}{Vm} = 0{,}2 \times 22.4 = 0{,}448\ dm^3$
2. [convert units first]
   V=60/1000 =0.06dm^3
   $$n = \frac{V}{Vm} = \frac{0.06}{22.4} = 0.0027\ mol$$
   $$n = \frac{m}{M}$$
   $$m = 0.0027 \times 17.03 = 0.046g$$

Activity 3

1. What volume will 0,75 moles of nitrogen gas occupy at STP (3)
2. How many moles are contained in 2,5 Litres of methane(CH_4) at STP (3)
3. What volume will 10 g ammonia(NH_3) occupy at STP

Concentration

Concentration is defined as the number of moles of solute per cubic decimetre of solution.

Concentration is calculated using one of the following formulae:

$c = \frac{n}{V}$ ……1 $c = \frac{m}{MV}$ ……2

c: concentration in $mol.dm^{-3}$
n: number of moles of solute.
m: mass of solute in g

M: molar mass of solute in $g \cdot mol^{-1}$
V: final volume of solution in dm^3

Formula 1 above is useful when working with concentration and number of moles.
Formula 2 above is useful when working with mass and concentration.

Common volume conversions:
$1m^3 = 1000dm^3$
$1dm^3 = 1000cm^3$
$1litre = 1dm^3$
$1000ml = 1000cm^3 = 1dm^3$ (convert ml or cm^3 to dm^3 by dividing by 1000)

Worked Example

1 Calculate the concentration of 2 moles of HCl dissolved in a volume of 5 dm^3 of water.

Solution:

$$c = \frac{n}{V}$$

$$c = \frac{2}{5} = 0.4\ mol \cdot dm^{-3}$$

2 32g of ammonium nitrate (NH_4NO_3) is added to sufficient water to obtain a 250 cm^3 solution. Calculate the concentration of the solution.

Solution:

$M(NH_4NO_3) = 14 + 4x1 + 14 + 3x16 = 80\ g \cdot mol^{-1}$

$$c = \frac{m}{MV}$$

$$c = \frac{32}{80 \times 0.25} = 1.6\ mol.dm^{-3}$$

Activity 4

1 Calculate the concentration of a solution of calcium chloride made by dissolving 5.55g of dry $CaCl_2$ crystals in enough water to make 750 cm^3 of solution. (4)

2 What mass of copper (II) sulphate must be dissolved in 200ml water to yield a 0.4 $mol.dm^{-3}$ solution? (4)

Percentage Composition

This is the mass of each atom present in a compound expressed as a percentage of the total mass of the compound. (Note: Remember to take into account the number of times the atom appears in the compound).

$$Percentage\ Composition\ of\ Atom = \frac{Atomic\ Mass\ of\ Atoms}{Molar\ Mass\ of\ Compound} \times 100$$

Worked Example

Find the percentage composition of each atom in Na_2SO_4.

Solution:
$M(Na_2SO_4) = 2(23) + 1(32) + 4(16) = 142\ g \cdot mol^{-1}$

$$\%Na = \frac{23 \times 2}{142} \times 100 = 32.39\%$$

$$\%S = \frac{32}{142} \times 100 = 22.54\%$$

$$\%O = \frac{16 \times 4}{142} \times 100 = 45.07\%$$

(Note: The sum of the percentage of all atoms in the compound is 100)

Worked example 2
Determine the percentage composition of water (H_2O) in hydrated copper sulphate $CuSO_4.5H_2O$
Solution
$M(CuSO_4.5H_2O) = 63,5+32+4(16)+ 5(18)$
$= 249,5\ g \cdot mol^{-1}$

$\%\ H_2O = \frac{90}{249,5} \times 100$
$= 36,07\%$

Activity
1. Find the percentage composition of each atom in $C_6H_{12}O_6$ (2)

2. Find the percentage composition of water in $Na_2CO_3.10H_2O$ (2)

Empirical formula
It is the simplest whole number ratio of atoms in a compound
Steps to determine the Empirical formula from percentage composition
Step 1: Take 100 g of the substance, so that the mass of each element is the given percentage.
Step 2: Calculate the number of moles using the formula $n = \frac{m}{M}$
Step 3: Determine the simplest ratio by dividing the number of moles of each element by the smallest number from step 2. If all values are not whole numbers, multiply throughout by a suitable constant to obtain whole numbers.
Step 4: Write the empirical formula.

Worked Example
An organic acid made up Carbon(C), hydrogen(H), and oxygen(O) only has the following percentage composition by mass. Determine the empirical formula of the compound

Element	**Percentage Composition**
Carbon(C)	48,65%
Hydrogen(H)	8,11%
Oxygen(O)	43,24%

Solution

Element	Mass 100(g)	n = $\frac{m}{M}$	Simplest ratio	Simplest ratio x 2
C	46,65	$\frac{48,65}{12}$ = 4,05	$\frac{3,8875}{2,7025} = 1,5$	$1,5\ (\times 2\ ) = 3$
H	8,11	$\frac{8,11}{1}$ = 8,11	$\frac{8,11}{2,7025}$= 3,0	$3,0\ \ (\times 2\ ) = 6$
O	43,24	$\frac{43,24}{16}$ = 2,7	$\frac{2,7025}{2,7025} = 1$	$(1\ \ \times\ \ 2\ ) = 2$

Empirical formula $C_3H_6O_2$

Example 2

An unknown organic compound, with a perfume like smell has a formula of $C_xH_yO_z$. The molar mass of this compound is 88 $\mathrm{g \cdot mol^{-1}}$

A 2 g sample of this compound contains 1,09 g carbon and 0,18 g hydrogen

1. Calculate the mass of oxygen in the sample
2. Determine the empirical formula for the compound
3. Determine the molecular formula for the compound

Solution

1. Mass of oxygen = 2 – (1,09+ 0,18)
   = 0,73 g

2.

Element	Mass in (g)	n = $\frac{m}{M}$	Simplest ratio
C	1,09	$\frac{1,09}{12}$ = 0,0908	$\frac{0,0908}{0,04563}$ = 2
H	0,18	$\frac{0,18}{1}$= 0,18	$\frac{0,04563}{0,18}$= 4
O	0,73	$\frac{0,73}{16}$ = 0,04563	$\frac{0,04563}{0,04563}$=1

The empirical formula is C_2H_4O

3. n = $\frac{molar\ mass\ of\ compound}{empirical\ molar\ molar\ mass}$

   n is an integer that is used to multiply the number of atoms in the empirical formula to get the molecular formula

   n = $\frac{88}{44}$ = 2

   therefore, the molecular formula is $C_4H_8O_2$

Activity 6
Determine the empirical formula of a compound containing 49,31% Carbon, 9,59% Hydrogen, 19,18% Nitrogen and 21,92% Oxygen.

Hydrated salts
water of crystallisation: water that is stoichiometrically bound into a crystal, e.g. the H_2O in $CuSO_4 \cdot 5H_2O$.

Worked example 1
The experimental setup below is used to dry 10 g of blue hydrated copper (II) sulphate crystals, $CuSO_4.xH_2O$, to form 6,4 g of anhydrous salt.
Determine the number of moles of, x, of waters of crystallization
Solution
$CuSO_4 \cdot x\,H_2O \rightarrow CuSO_4 + xH_2O$

$m(CuSO_4 \cdot x\,H_2O) = 10$ g
$m(CuSO_4) = 6,4$ g
$m(xH_2O) = 10 - 6,4$
$= 3,6$g

$n(H_2O) = \frac{m}{M}$
$= \frac{3,6}{18}$
$= 0,2$ mol
$n(CuSO_4) = \frac{m}{M}$
$= \frac{6,4}{159}$
$= 0,04$ mol

Simplest mol ratio
$CuSO_4 : H_2O$
0,04 : 0,2
1: 5
$\therefore x = 5$

Activity 7
14.3 g of a sample of hydrated sodium carbonate, $Na_2CO_3 \cdot xH_2O$, was strongly heated until no further change in mass was recorded. On heating, all the water of crystallisation evaporated as follows

$$Na_2CO_3 \cdot xH_2O \rightarrow Na_2CO_3 + xH_2O$$

Calculate the number of moles of water of crystallisation, x, in the sodium carbonate sample, if 5.3g of solid remained after strong heating.

BASIC STOICHIOMETRIC CALCULATIONS

Limiting Reaction

- In a reaction between two substances, one reaction is likely to be used up completely before the other and this limit the amount of product formed.
- Limiting reagent: substance that get used up completely in a reaction.
- The amount of limiting reactant will determine :

- The amount of product formed.
- The amount of other (**excess)** reactant used.

Determining limiting reactants

- Calculate the number of moles of each element.
- Determine the ratio between reactants.
- Determine limiting reactant using the ratio.

NOTE: If one reactant is in excess, it means that there is more enough of it. If there are only two reactants and one is in excess, it means that the other is the limiting reactant.

Worked example

1. A 8,4g sample of nitrogen reacts with 1,5g of hydrogen. The reaction is represented with the unbalanced equation below.

$$N_2(g) + H_2(g) \rightarrow NH_3(g)$$

   1. Balance the equation.

2. Which reactant is a limiting reactant?
3. The mass of ammonia that can be produced.

Solutions

1. $N_2 + 3H_2 \rightarrow 2NH_3$

2.n$(N_2) = \frac{m}{M} = \frac{8,4}{28} = 0,3\ mol$

n$(H_2) = \frac{m}{M} = \frac{1,5}{2} = 0,75\ mol$

N_2 : $3H_2$

1 : 3

0,3 : x

x= 0,9 mol

If all nitrogen is used, 0,9mol of hydrogen is needed, however, only 0,75 mol of hydrogen is available. The hydrogen will run out first therefore **hydrogen is the limiting reactant**.

1.2.2. Because the hydrogen is the limiting reactant, it will determine the mass of ammonia produced:

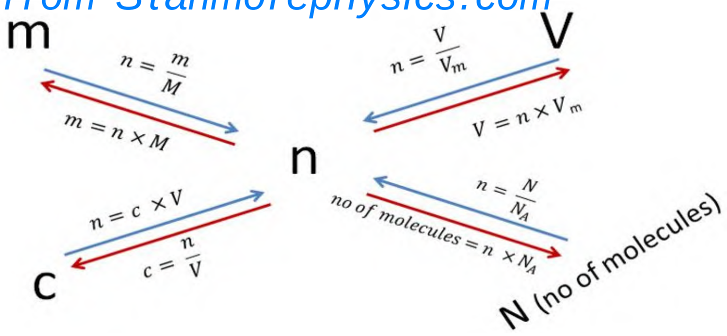
$3H_2$: $2NH_3$

3 : 2

0,75 : x = 0,5 mol

n$(NH_3) = \frac{m}{M}$

m= (0,5)(17) = 8,5 g



Activity 8

The reaction between magnesium and dilute hydrochloric acid is represented by the balanced equation below:

$$Mg(s) + 2HC\ell(aq) \rightarrow MgC\ell_2(aq) + H_2(g)$$

During an experiment, 1250 cm^3 hydrochloric acid of concentration 0,1 mol.dm^{-3} reacts with excess magnesium to produce hydrogen gas at STP.

Calculate the:

1. mass (in grams) of hydrogen gas that is expected. (4)

2.number of hydrogen atoms formed.

Excess steam, $H_2O(g)$, reacts with methane, $CH_4(g)$, industrially according to the reaction: (5)

$$H_2O(g) + CH_4(g) \rightarrow 3H_2(g) + CO(g)$$

In a reaction, 41,4 dm^3 of methane was reacted with steam, producing 55,89 dm^3 of hydrogen gas, $H_2(g)$.
Calculate the percentage yield of hydrogen gas.

Nitrogen gas reacts with excess Hydrogen gas according to the following balanced reaction: (6)

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

In the reaction, ***x*** grams of N_2 was reacted with excess H_2 and produced 12.5 grams of ammonia gas. If the percentage yield for the reaction is 75%, calculate the mass of N_2 gas required for the reaction

Activity 9

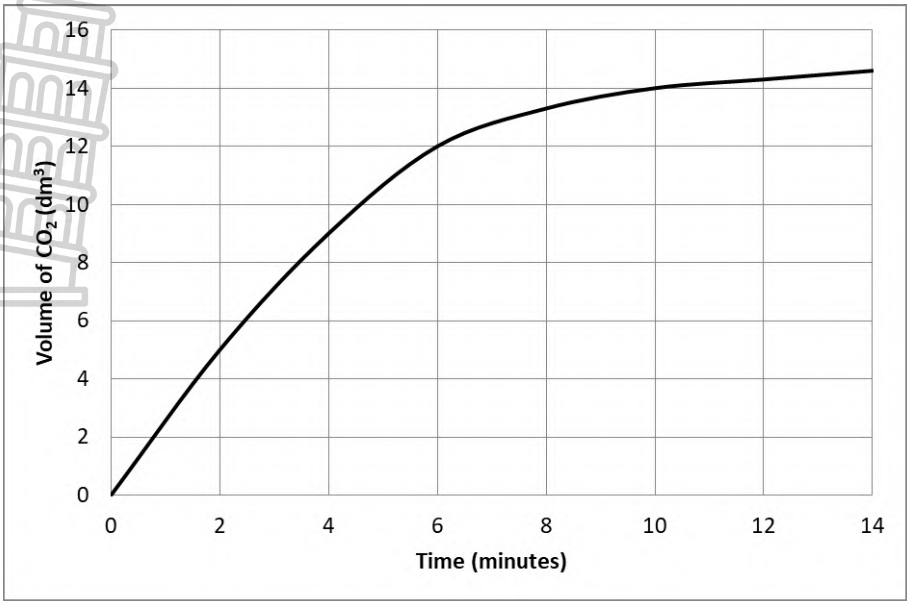
Propane(C_3H_8) reacts with oxygen (O_2) to form carbon dioxide (CO_2) and water (H_2O), as indicated in the balanced equation below.

$$C_3H_8\ (g) + 5O_2\ (g) \rightarrow 3CO_2\ (g) + 4H_2O\ (g)$$

In one such reaction 5 dm^3 propane(C_3H_8) reacts with excess oxygen at standard temperature and standard pressure (STP).

1 Calculate the TOTAL volume of gas (in dm^3) formed at the end of the reaction. **(4)**

The graph below shows the **volume of CO_2 formed** as the reaction above progresses. The reaction has not reached completion.



2. Determine the mass of C_3H_8 (in grams) that reacted after 6 minutes

MECHANICS

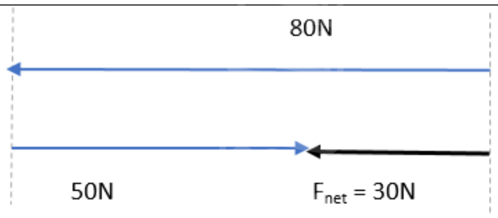
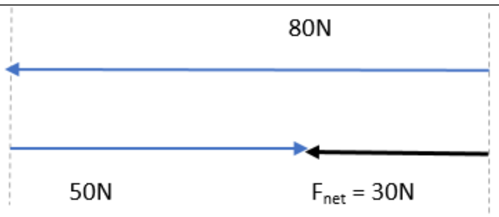
VECTORS AND SCALARS

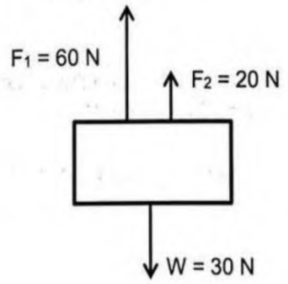
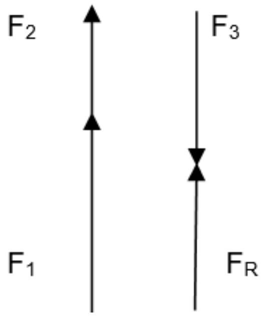
Scalar Quantity	Vector Quantity
A physical quantity with **magnitude only**	A physical quantity with both **magnitude and direction**
examples: mass (kg), distance (m), speed ($m.s^{-1}$), time (s), energy (J), temperature (K)	Examples: force (N), weight (N), displacement (m), velocity ($m.s^{-1}$), acceleration ($m.s^{-2}$)

Vector quantities are represented by arrows called vectors.
In a drawing to scale:

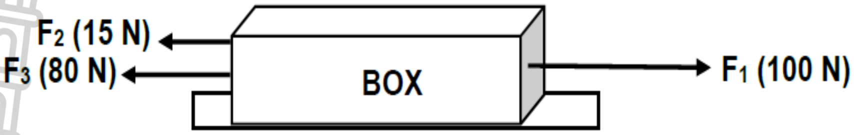
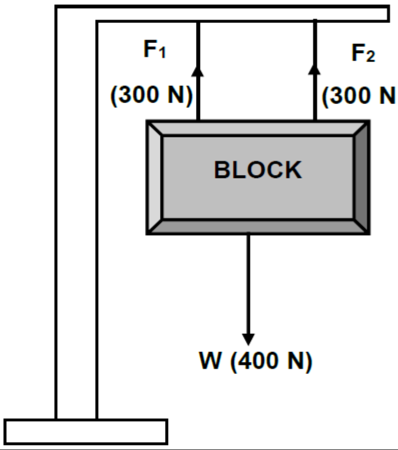
- magnitude of a vector quantity is represented by length of vector
- Direction is indicated by arrowhead.

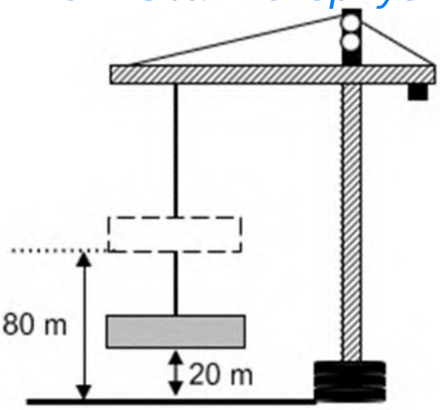
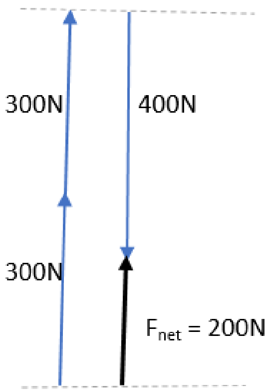
Equal vectors have the same length and direction.
Negative vectors act in opposite direction to chosen positive direction.

Worked examples			
Worked example 1			
1.	Find the resultant of two forces F_1 = 50 N and F_2 = 80 N graphically:		
	1.1	if they both act to the right	(3)
	1.2	if the 50 N vector acts to the right and the 80 N vector acts to the left	(3)
	1.3	if the 50 N vector acts to the left and the 80 N vector acts to the right	(3)
	Solutions		
1.1			(3)
1.2			(3)
1.3			(3)
Worked example 2			

Two forces, F_1 and F_2 of magnitude 60 N and 20 N respectively act on a suspended box of weight 30 N as shown in the diagram below.			
			
2.1	Using the tail to head and a scale of 1 cm represents 10 N, draw an accurate vector diagram to determine the magnitude of the resultant force acting on the box.		(4)
	SOLUTION:		
			(4)
<u>ACTIVITIES [6 marks]</u>			
1.1	Which ONE of the following physical quantities is a scalar?		
	A	Weight	
	B	Displacement	
	C	Mass	
	D	Velocity	(2)
1.2	Which ONE of the following combinations includes TWO vector quantities and ONE scar quantity?		
	A	Displacement, time, speed.	
	B	Velocity, distance, Force.	
	C	Speed, time, acceleration.	
	D	Displacement, acceleration, velocity.	(2)
1.3	Two forces Y and Z act on an object which does not move. Which statement below is correct? The two forces:		
	A	Are equal.	
	B	Act in the same direction.	
	C	Act in opposite directions.	
	D	Are equal and act in opposite directions.	(2)

QUESTION 2 [15 marks]

2.1	In the diagram below, a box which is on a smooth surface start moving when three forces F_1, F_2 and F_3 acts on it.		
			
	2.1.1	Define the term resultant of a number of forces.	(2)
	2.1.2	Calculate the magnitude and direction of the resultant force acting on the box.	(3)
	2.1.3	In which direction will the box move? Write only LEFT or RIGHT.	(1)
2.2	A rectangular block is vertically suspended by two forces F_1 (300 N) and F_2(300 N) in the strings as shown below.		
			
	The weight of the block lifted is 400 N.		
	2.2.1	Give a reason why the forces in the diagram above are referred to as vectors.	(2)
	2.2.2	Using a scale of 1cm representing 100 N, draw a scale diagram to determine the resultant of forces F_1, F_2 and W. Label all for forces clearly including the resultant force.	(3)
2.3		The crate is lifted to a vertical height of 80 m above the ground and then lowered to a height of 20 m above the ground as shown in the diagram below.	

			
	2.3.1	Total distance travelled by the crate	(2)
	2.3.2	Displacement of the crate	(2)
SOLUTIONS: VECTORS AND SCALARS			
1.1	C✓✓		(2)
1.2	B✓✓		(2)
1.3	D✓✓		(2)
QUESTION 2 [15 marks]			
2.1.1	Resultant vector is the single vector that has the same effect as two or more vectors acting together. ✓✓		(2)
2.1.2	$F_{net} = F_1 + F_2 + F_3$ $= 100 + (-15) + (-80)$ ✓✓ $= 5N$ to the right✓		(3)
2.1.3	RIGHT✓		(1)
2.2.1	Vector quantities have both magnitude and direction✓✓		(2)
2.2.2	 (1 mark for each force drawn correctly)		(3)
2.3.1	Distance = 80 + 60 ✓ = 140 m ✓		(2)
2.3.2	Upward positive: Displacement = +80 + (-60) = 20 m ✓ upwards Upward negative: Displacement = -80 + 60		(2)

= 20 m ✓ upwards

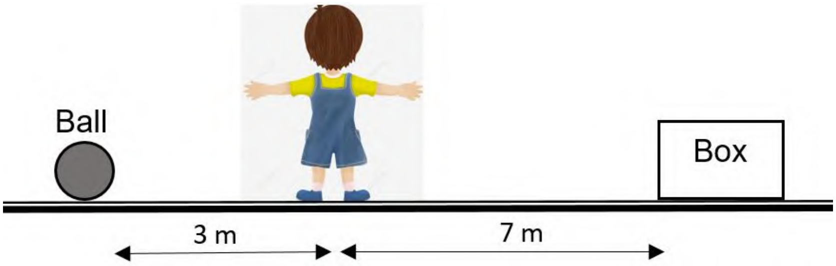
MOTION IN ONE DIMENSION

Frame of reference

Coordinate system used to represent and measure properties of objects, such as position.
A frame of reference has an origin and a set of directions, such as East and west, up and down …

Position

The location of an object relative to a reference point.
Position is a vector. It will be denoted by **x**.
Example: A ball, a boy and a box are stationary on straight horizontal floor.



- Taking the ball as reference point (Zero position):

The boy is 3 m to the right of the ball and the box is 10 m to the right of the box.

- Taking the boy as zero position:

The ball is 3 m to the left of the boy and the box is 7 m to the right of the boy.

One-dimensional motion

A motion along a straight line. The object may move forward or backward along this line.

Distance

The total path length travelled.
Distance is a **scalar** quantity, expressed in metres (m). It is denoted by D.

Displacement

The change in position of an object.
It is the length of a straight line joining the initial to the final position.
Displacement is a **vector** quantity, also expressed in metres. It is denoted by Δx.
$\Delta x = x_f - x_i$ (x_f: final position and x_i: initial position).

Average speed

The total distance travelled per total time.

$$average\ speed = \frac{Distance}{time}$$

Average speed is a **scalar** quantity, expressed in metres per second ($m.s^{-1}$).

Average velocity

The rate of change of position. (vector quantity)

$v = \frac{\Delta x}{\Delta t}$

Average velocity is a **vector** quantity, expressed in metres per second ($m.s^{-1}$).

Acceleration

The rate of change of velocity.

$$a = \frac{\Delta v}{\Delta t}$$

Acceleration is a **vector** quantity, expressed in metres per second squared ($m.s^{-2}$).

Positive acceleration:

An object moving in the positive direction is experiencing an increase in speed and an object moving in the negative direction is experiencing a decrease in speed.

Negative acceleration:

An object moving in the positive direction is experiencing a decrease in speed and an object moving in the negative direction is experiencing an increase in speed.

Deceleration:

An object is experiencing a decrease in speed.

Conversion of units

- Converting cm to m, divide by 100.
- Converting mm to m, divide by 1000.
- Converting minutes to seconds, divide by 60.
- Converting hours to seconds, divide by 3600.
- Converting $km.h^{-1}$ to $m.s^{-1}$, Multiply by $\frac{1000}{3600}$

E.g. 25 $km.h^{-1}$= $25\ x\ \frac{1000}{3600} = 6{,}94\ m \cdot s^{-1}$

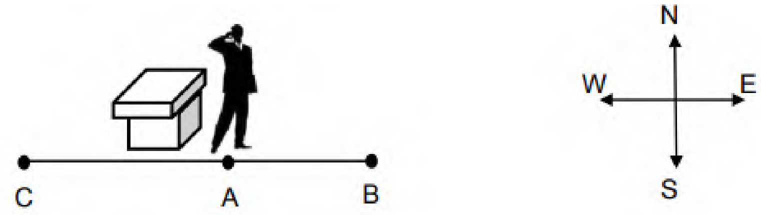
- Converting $m.s^{-1}$ to $km.h^{-1}$, multiply by $\frac{3600}{1000}$

30 $m.s^{-1}$= $30\ x\ \frac{3600}{1000} = 108\ km \cdot h^{-1}$

WORKED EXAMPLES [MOTION IN ONE DIMENSION]

EXAMPLE 1 [12 marks]

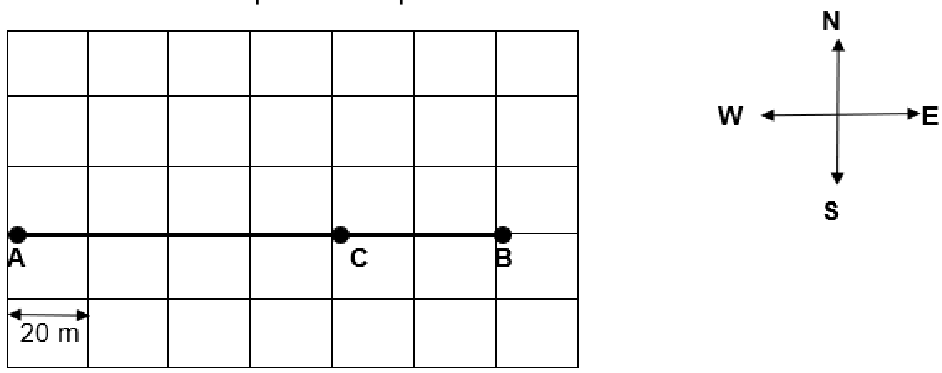
An impatient businessman paces up and down while making a business call on his Cell phone.

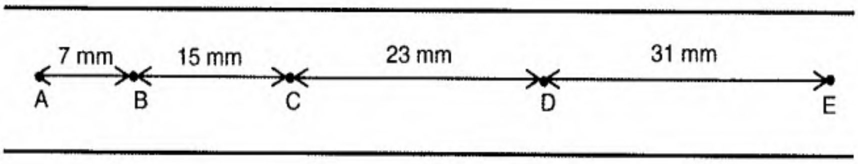
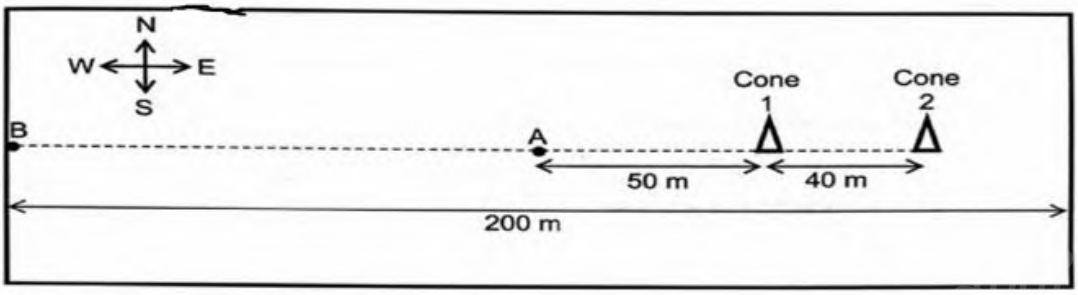


He starts at his desk and walks 5 m east (from A to B) and then walks 7 m west (from B to C). This process takes him 20 s.

1.1	What is the businessman's change in position at C relative to A?	(2)
1.2	Calculate the total distance the man covers.	(2)
1.3	Explain why the value calculated in QUESTION 1.1 differs from the one calculated in QUESTION 1.2	(2)
1.4	Define the term velocity.	(2)

1.5	Calculate the man's average velocity.	(4)
SOLUTIONS [12 marks]		
1.1	2 m ✓ to the left ✓	(2)
1.2	Total distance = 5 + 7 ✓ = 12 m ✓	(2)
1.3	For the total distance, the whole path length travelled is considered.✓ For change in position, only the original position and final position ✓ of the man are considered.	(2)
1.4	Velocity is the rate of change of displacement. ✓✓	(2)
1.5	$v = \frac{\Delta x}{\Delta t}$ ✓ $= \frac{2}{20}$ ✓ $= 0{,}1\ m \cdot s^{-1}$ ✓ west / to left ✓	(4)

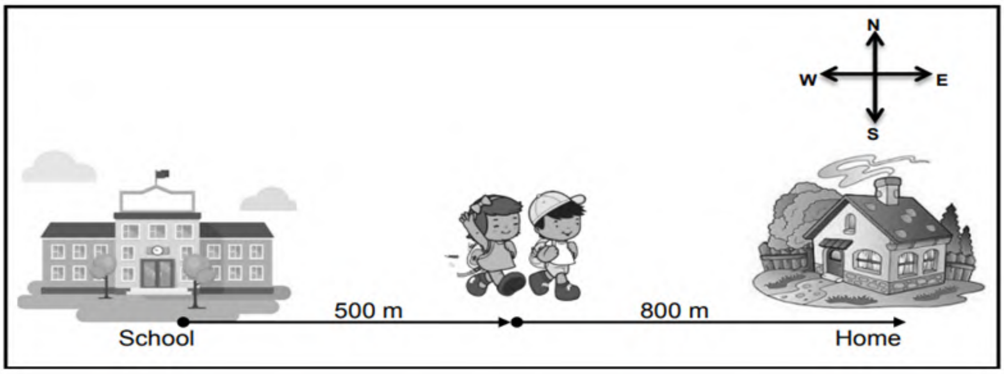
EXAMPLE 2 [9 marks]			
A girl walks from her home at point A to a shop located at point B. On her return she stops at a friend's house at point C. The girl walks on a flat horizontal surface past houses with yards that are squares of 20 m length each, as shown in the diagram.			
She completes the motion from point A to point C in 300 s.  Point B and C are both east of point A.			
2.1	Define the term distance		(2)
2.2.	For the motion of the girl from point A to C, calculate the:		
	2.2.1	Total distance covered	(2)
	2.2.2	Girl's average speed	(3)
	2.2.3	Total displacement	(2)
SOLUTIONS [9 marks]			
2.1	The total path length travelled ✓✓		(2)
2.2.1	Total distance = 160 m ✓✓		(2)
2.2.2	$Average\ speed = \frac{distance\ travelled}{time\ taken}$ ✓ $= \frac{160}{300}$ ✓ $= 0.53\ m \cdot s^{-1}$ ✓		(3)
2.2.3	Displacement = 4 x 20 ✓ = 80 m ✓		(2)
<u>ACTIVITIES [MOTION IN ONE DIMENSION]</u>			
QUESTION 1 [6 MARKS]			
1.1	A cricket ball is thrown vertically upwards and reaches a height of 18 m above the ground. On the way down it gets stuck in a tree 10 m above the ground. What is the resultant displacement of the ball?		
	A	10 m downwards	
	B	10 m upwards	
	C	8 m downwards	
	D	8 m upwards	(2)

1.2	A car sets out from town X and travels 40 km along a straight road to town Y. The driver turns around and immediately drives back to town X. The whole trip takes 2 hours. The magnitude of the average velocity for the whole journey, in kilometres per hour, will be …		
	A	0	
	B	20	
	C	40	
	D	80	(2)
1.3	A trolley runs down a slope, pulling a ticker tape behind it through a ticker timer. A portion of the tape is shown below and represents the distances moved during equal time intervals.  The ticker tape represents an acceleration that is …		
	A	Zero	
	B	Uniform	
	C	Increasing	
	D	Decreasing	(2)
Question 2 [13 marks]			
Two friends, Tom and James are training for athletics meeting on a sport field of length 200m. Both friends start from the middle of the field at point A  			
Tom runs using two cones. The first cone is places 50 m east of the starting point (point A, while the second cone is placed 40 m east of cone 1. Tom runs along the following route: • From the starting point (point A) due east to Cone 1, and then turns around and return to the starting point running due east. • From point A due to east to Cone 2. He then turns around and runs due west ending at Cone 2			
2.1	Write down the final position of Tom, relative to the starting point.		(2)
2.2	The complete route described above took Tom 30 seconds to complete. Determine his average speed in $m.s^{-1}$.		(4)
2.3	James runs from the starting point (point A), due east to Cone 2. He immediately turns around and runs in a westerly direction until he reaches		

	Point B. Point B lies on the boundary of the field, due west from the starting point.		
	2.3.1	Determine the total time taken by James if his average speed is 1 m.s-1 SLOWER THAN that of Tom's.	(3)
	2.3.2	Calculate the average velocity of James for the entire motion.	(4)

QUESTION 3 [12 MARKS]

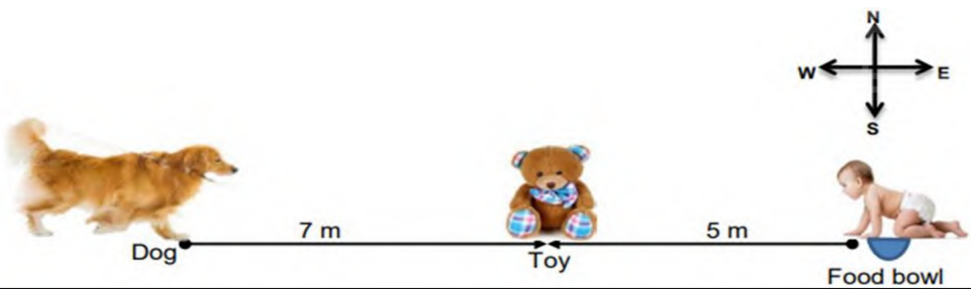
A brother and sister walk home from school. After walking 500 m eastwards, the brother realises that he has left a book at school and he returns to school. His sister continues walking another 800 m to their home. She arrives home 30 minutes after leaving school.



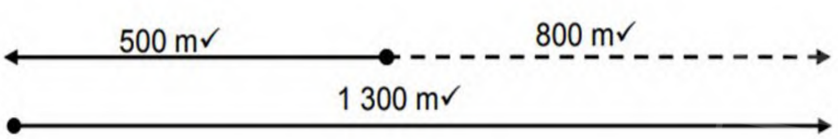
3.1	Define the term average speed.	(2)
3.2	Calculate the average speed of the girl from the school to her home.	(4)
3.3	Use a vector scale diagram and represent the displacement of the boy from the time he realised he left his book at school until he reached home. Include ALL relevant information in the diagram. Use scale 1 cm = 100 m for the diagram.	(3)
3.4	If the average speed of the boy is the same as that of the girl, calculate how long it would take the boy to reach home from the time they both left the school together.	(3)

QUESTION 4 [16]

A baby leaves a bowl of food on the floor and crawls westwards to fetch a toy placed 5 m away. At the same time a dog walks eastwards towards the baby. It takes the baby 30 s to reach the toy. The dog walks past the toy to eat the baby's food in the bowl.



4.1	Define the term displacement in words	(2)
4.2	Determine the position of the dog relative to the baby before they both moved.	(2)

4.3	Calculate the average velocity of the baby	(4)
4.4	If the average speed of the dog is TWICE that of the baby, calculate how long it would take the dog to reach the food bowl from the moment the dog started moving.	(4)
4.5	Another dog's average velocity changes from 3 m.s^{-1} to 5 m.s^{-1} in 0, 8 seconds. Calculate the dog's acceleration.	(4)
SOLUTIONS		
QUESTION 1 [6 MARKS]		
1.1	B✓✓	(2)
1.2	A✓✓	(2)
1.3	B✓✓	(2)
QUESTION 2 [12 marks]		
2.1	50 m east ✓✓	(2)
2.2	Distance = 50+50+90+40 = 230 m ✓ speed= $\frac{distance}{time}$ ✓ = $\frac{230}{30}$ ✓ = 7,67 m.s^{-1} ✓	(4)
2.3.1	speed= $\frac{distance}{time}$ ✓ 6.67 = $\frac{90+90+100}{time}$ ✓ time = 41,98 m.s^{-1} ✓	(3)
2.3.2	v=$\frac{\Delta x}{\Delta t}$ ✓ v=$\frac{100}{41,98}$ ✓ v= 2.38 m.s^{-1} west ✓	(3)
QUESTION 2 [12 marks]		
3.1	The total distance travelled per total time.	(2)
3.2	Average speed= $\frac{distance\ travelled}{time\ taken}$ = $\frac{(500+800)}{(30\times60)}$ =0,72 m.s^{-1}	(4)
3.3		(3)
3.4	Average speed= $\frac{distance\ travelled}{time\ taken}$ 0.72 = $\frac{(500+500+1300)}{time\ taken}$ t= 3194,44s	(4)
QUESTION 4 [16]		
4.1	The difference in position in space. ✓✓	(2)
4.2	12 m ✓west ✓ or -12 m ✓✓	(2)

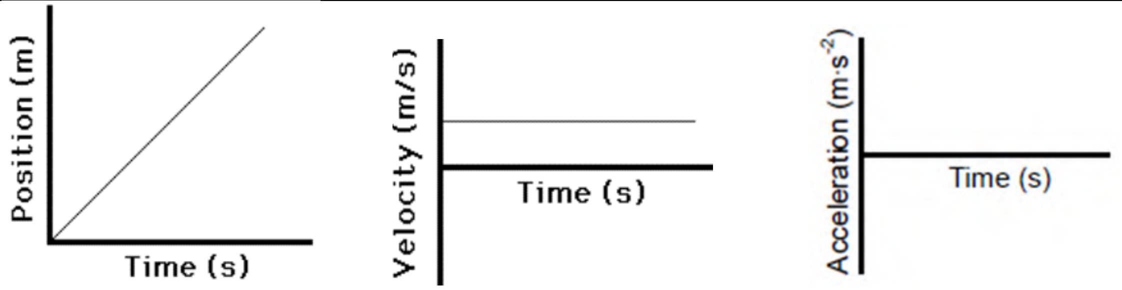
4.3	$$v = \frac{\Delta x}{\Delta t}$$ $= \frac{5}{30}$ ✓✓ $= 0{,}17\ m \cdot s^{-1}$ ✓ west ✓	(4)
4.4	$speed = \frac{distance}{time}$ ✓ $(0{,}17)(2)$ ✓$= \frac{12}{t}$ ✓ $0{,}34 = \frac{12}{t}$ $t = 35{,}29\ s$ ✓	(4)
4.5	$a = \frac{\Delta v}{\Delta t}$ ✓ $$= \frac{v_f - v_i}{t_f - t_i}$$ $= \frac{5-3}{0{,}8-0}$ ✓ $a = 2{,}5$ ms^{-2} ✓ east ✓	(4)

INSTANTANEOUS VELOCITY AND INSTANTANEOUS SPEED

Instantaneous velocity:	The rate of change in position, i.e. the displacement divided by a very small time interval or the velocity at a particular time. Know that instantaneous velocity is a vector
Instantaneous speed	The magnitude of the instantaneous velocity. Know that instantaneous speed is a scalar

DESCRIPTION OF MOTION IN WORDS, DIAGRAMS AND GRAPHS

Uniform velocity	Motion at constant velocity, i.e. no acceleration



Characteristics for velocity-time graph	1. gradient = acceleration 2. Area under the graph = position (distance / displacement)
Characteristic of position-time graph	1. Gradient = velocity
Characteristic of acceleration-time graph	1. Area under the graph = velocity

WORKED EXAMPLE 1 [16 marks]

The engineers at a company conduct varies tests on their cars. During one of the test they measure the change in position during equal time intervals. The results obtained are recorded in the table below.

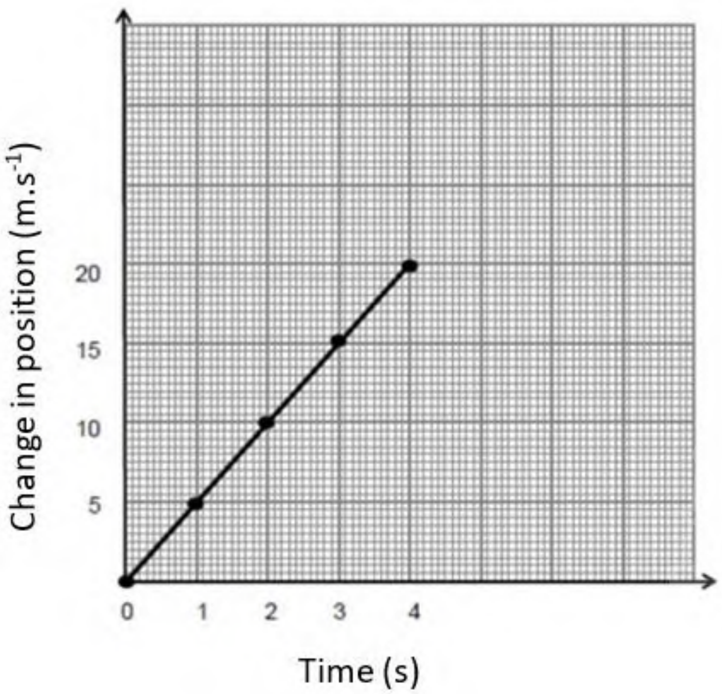
TIME (s)	POSITION (m)
0	0
1	5
2	10
3	15
4	20

1.1	Give the correct term for the *change of position per unit time*		(1)
1.2	For this test, write down the:		
	1.2.1	Independent variable	(1)
	1.2.2	Dependent variable	(1)
	Use the information in the table and draw an accurate position-time graph on the graph paper.		(5)
1.4	Calculate the gradient of the graph		(4)
1.5	Draw (NOT to scale) a corresponding velocity-time graph for the motion of the car. Label the axes.		(2)
1.6	Hence, deduce the magnitude of the acceleration of the car.		(2)

WORKED EXAMPLE 1 (SOLUTIONS)

1.1	(average) velocity ✓	(1)
1.2.1	Time ✓	(1)
1.2.2	Position ✓	(1)

1.3



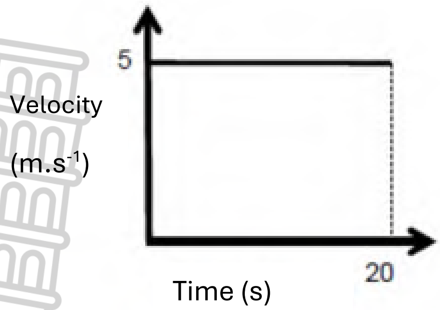
✓✓✓✓✓ (5)

1.4

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

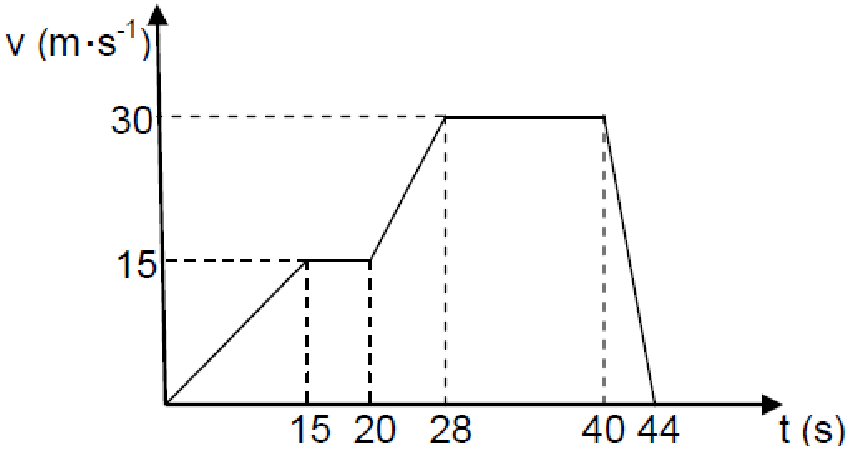
$$= \frac{20-5}{4-1} ✓✓$$

(3)

	$= 5\ m.s^{-1}$ ✓	
1.5	 ✓✓	(2)
1.6	The car has zero acceleration as its velocity is constant ✓✓	(2)

WORKED EXAMPLE 2 [13 marks]

The following graph represents the motion of a train.

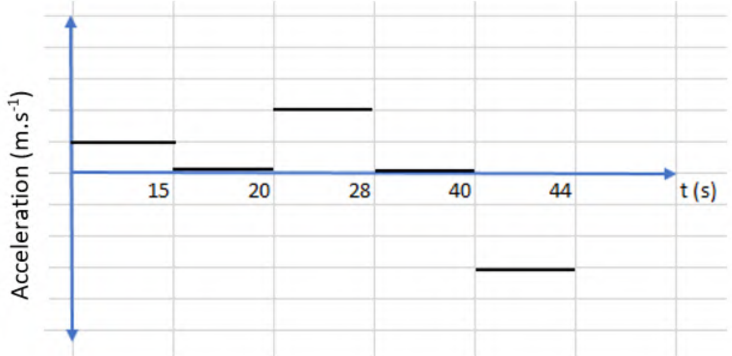


2.1	Calculate the acceleration of the train between 20 and 28 s.	(3)
2.2	Calculate the distance travelled in the 44 s.	(5)
2.3	Draw an acceleration time graph from this velocity time graph.	(5)

WORKED EXAMPLE 2 (SOLUTIONS)

2.1	$acceleration = \frac{\Delta y}{\Delta x}$ $= \frac{30-15}{28-20}$ ✓✓ $= 1.875\ m.s^{-2}$ ✓	(3)
2.2	Displacement $= \frac{1}{2}(15)(15) + (13 \times 15) + \frac{1}{2}(8)(15) + (12 \times 30) + \frac{1}{2}(4)(30)$ ✓✓✓✓ $= 787.50\ m$ ✓	(5)

2.3

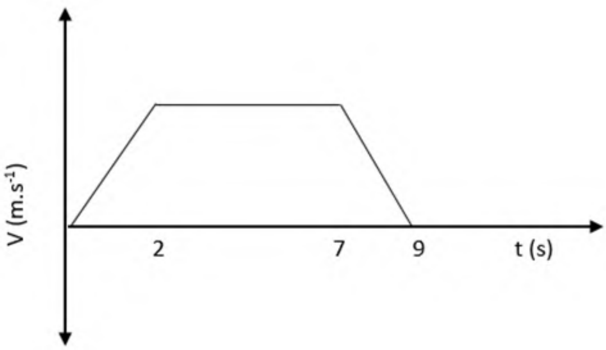


✓ ✓✓✓✓ (5)

WORKED EXAMPLE 3

Draw the velocity time graph for the motion described below:
A lift accelerates from rest for 2 s and then moves at a constant velocity for 5 s before it slows down and comes to a standstill in 2 s.

SOLUTION:

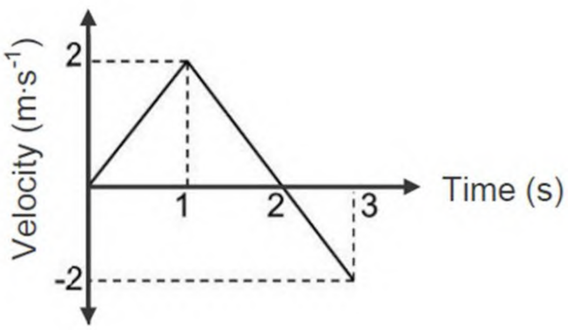


✓✓✓ (3)

ACTIVITIES (INSTANTANEOUS VELOCITY AND INSTANTANEOUS SPEED)

QUESTION 1

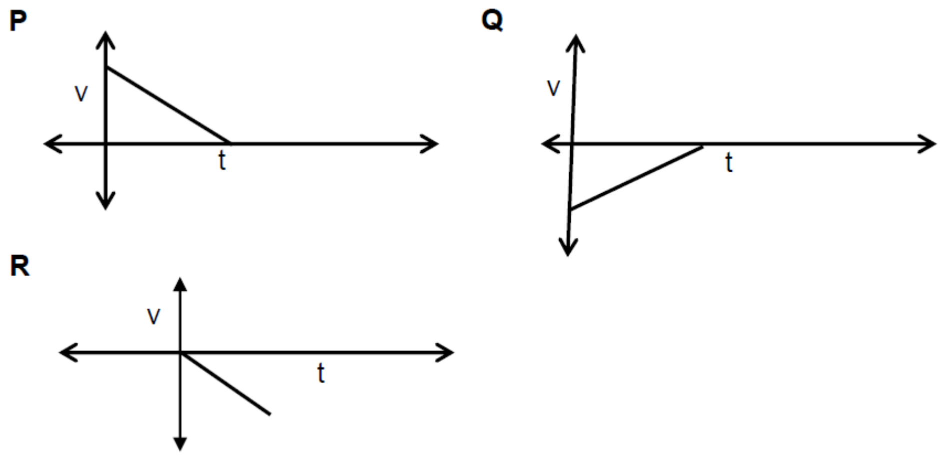
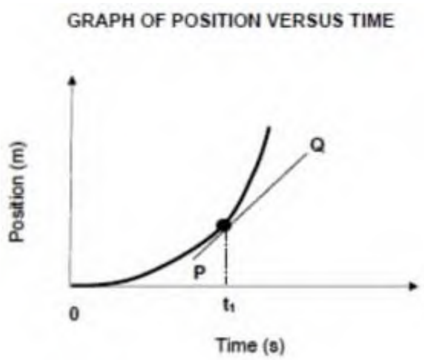
1.1 The velocity-time graph for the motion of an object is shown below.



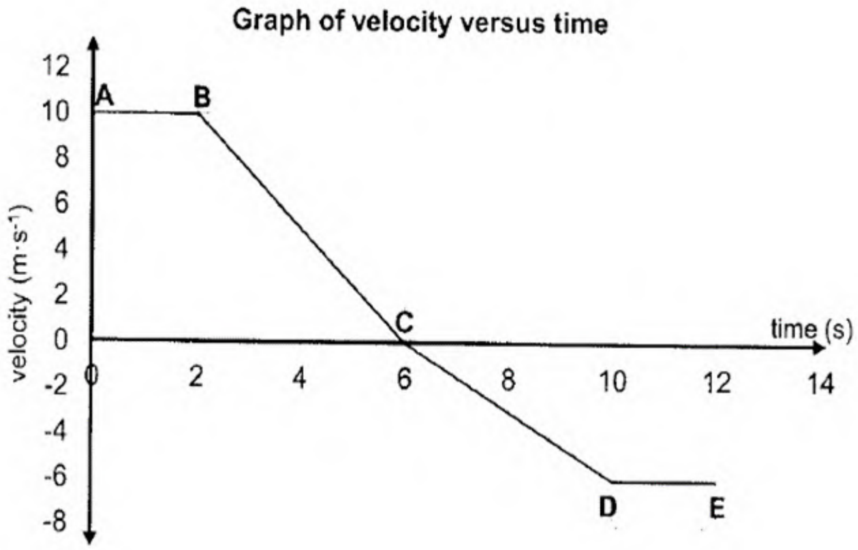
The object changes direction at …

A	0,5 s	
B	1 s	
C	2 s	
D	3 s	(2)

1.2 An object accelerates uniformly when the … of the object changes with the

	same amount in equal time intervals.		
	A	velocity	
	B	displacement	
	C	speed	
	D	mechanical energy	(2)
1.3	Consider the three velocity-time graphs P, Q and R shown below. 		
	Which ONE(S) of the following velocity-time graphs represent the motion of an object whose velocity is decreasing uniformly?		
	A	R only	
	B	Q only	
	C	P and Q	
	D	P and R	(2)
1.4	A position-time graph for an object travelling along a straight horizontal surface is shown below: 		
	Line PQ is a tangent to the curve at t_1 Which one of the following is equal to the gradient of PQ?		
	A	Average velocity over the period 0 to t_1	
	B	Instantaneous velocity at t_1	
	C	Average acceleration over the period 0 to t_1	
	D	Instantaneous acceleration at t_1	(2)
QUESTION 2 [16 marks]			
The Velocity-time graph below represents the motion of a car over a time period of			

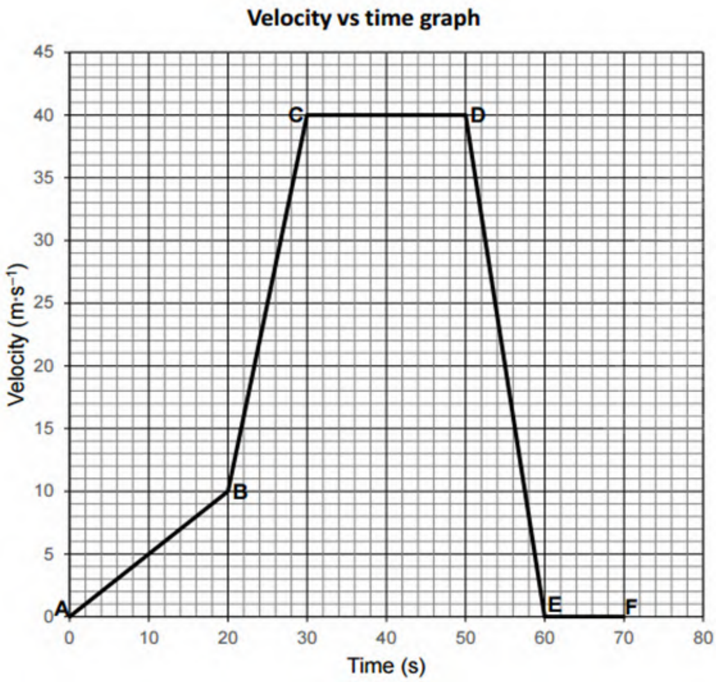
12 seconds. The car initially moves NORTH.



2.1	Define the term instantaneous velocity.		(2)
2.2	Describe the motion of the car from C to E.		(3)
2.3	WITHOUT USING EQUATIONS OF MOTION, calculate the:		
	2.3.1	Distance that the car travels from A to C.	(4)
	2.3.2	Acceleration of the between B and C.	(4)
2.4	How does the magnitude of the acceleration of the car between B and C Compare to the magnitude of its acceleration between C and D? Choose from GREATER THAN, SMALLER THAN or EQUAL TO.		(1)
2.5	Refer to the graph and gives a reason for the answer to QUESTION 2.4.		(1)
2.6	Write down the direction of the resultant displacement of the car.		(1)

QUESTION 3 [10]

Study the velocity versus time graph below for the motion of a car travelling east



3.1	Define the term instantaneous speed		(2)
3.2	Use the graph to describe the motion of the car in the following sections:		
	3.2.1	AB	(2)
	3.2.2	CD	(2)
	3.2.3	EF	(2)
3.4	In which section, AB or BC, is the acceleration of the car greatest? Give a reason for your answer.		(2)

SOLUTIONS (INSTANTANEOUS VELOCITY AND INSTANTANEOUS SPEED)

QUESTION 1 [8 marks]

1.1	C ✓✓	
1.2	A ✓✓	
1.3	C ✓✓	
1.4	B ✓✓	

QUESTION 2 [16 marks]

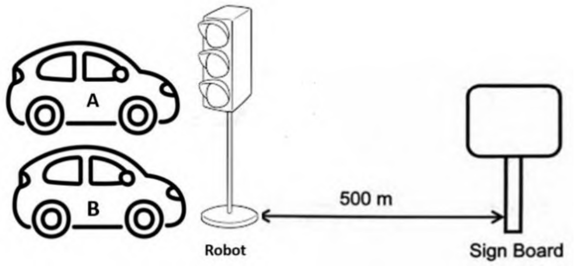
2.1	Is displacement (change in position) divided by very small time interval. ✓✓	(2)
2.2	From C to D: The car turns around/moves south/moves in opposite direction/moves with velocity that increases from 0 m·s^{-1} to 6 m·s^{-1}. ✓ at an increased velocity/constant acceleration. ✓ From point D to E: The car travels at a constant velocity south. ✓	(3)
2.3.1	$A = L \times B$ $= 20 \times 2$✓ $= 20m$ $A = \frac{1}{2} b \times h$ $= \frac{1}{2}(4)(40)$ ✓ $= 20m$ Total distance =20m + 20m ✓ = <u>40m</u> ✓	(4)
2.3.2	$m = \frac{\Delta v}{\Delta t}$ $= \frac{0-10}{6-2}$✓✓ $= -2.5$ <u>$a = 2.5 m.s^{-2}$ south</u> ✓✓	(4)
2.4	Smaller than ✓	(1)
2.5	Slope of the graph at B – C is steeper than C – D ✓	(1)
2.6	North ✓	(1)

QUESTION 3 [10 marks]		
3.1	Magnitude of instantaneous velocity or the velocity at a specific moment ✓✓	(2)
3.2.1	The car start from rest and velocity increases to 10 m.s^{-1} in 20 seconds Constant positive acceleration or uniformly accelerated motion ✓✓	(2)
3.2.2	Velocity is constant (uniformly) ✓ Acceleration is zero ✓	(2)
3.2.3	Car has stopped. Acceleration is zero ✓✓	(2)
<u>EQUATIONS OF MOTION</u> $v_f = v_i + a\Delta t$ $\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$ $v_f^2 = v_i^2 + 2a\Delta x$ $\Delta x = \left(\frac{v_i + v_f}{2}\right)\Delta t$		
Worked example 1 [8 marks]		
A space-rocket is launched and accelerates uniformly from rest to 576 km.h^{-1} in 4.5 s.		
1.1	What is the final speed of the rocket in m.s^{-1}?	(2)
1.2	Calculate the acceleration of the rocket	(3)
1.3	How far does the rocket travel during the first 4.5 s?	(3)
SOLUTION		
1.1	576 km.h^{-1} ×1000/3600 = 160 m.s^{-1} ✓✓	(2)
1.2	vf =vi + aΔt ✓ 160 = 0 + a(4,5) ✓ a= 35,56 m.s^{-2} ✓	(3)
1.3	Δx = viΔt + ½ aΔt^2 ✓ = 0×4,5 + ½(35,56)(4,5)^2 ✓ = 360,05 m ✓	(3)
Worked example 2 [6 marks]		
A car is travelling along a straight road at 75 km.h^{-1}. In an attempt to avoid an accident, the motorist has to brake to a sudden stop.		
2.1	If the reaction time of the motorist is 0.25 s, what distance does the car travel while the driver is reacting to apply the brakes?	(3)
2.3	What total distance does the car travel from when the driver notices the danger to when the car comes to a stop	(3)
Solution [6 marks]		
2.1	$\Delta x = v_i\Delta t + ½ a\Delta t^2$ ✓ = (20,83)(0,25)+½(0)(0,25)^2 ✓ = 5,21 m ✓	(3)
2.2	v_f^2 = vi2 + 2aΔx ✓	(3)

	$(0)^2 = (20{,}83)^2 + 2(-6)\Delta x$ ✓ $\Delta x = 36{,}16$ m ✓	

QUESTION 1 [10 marks]

In the diagram below, a robot (traffic light) and a sign board are 500 m apart. Two cars, Car A and Car B, both passes a robot at the same time. Car A takes off from rest at the robot and accelerate at 1,2 $m.s^{-2}$. Car B travels at constant 27,78 $m.s^{-1}$. Both cars are travelling in an easterly direction.



1.1	Use suitable calculations to determine which, Car A or Car B, will reach the sign board first.	(6)
1.2	Determine the velocity of Car A when it reaches sign board.	(4)

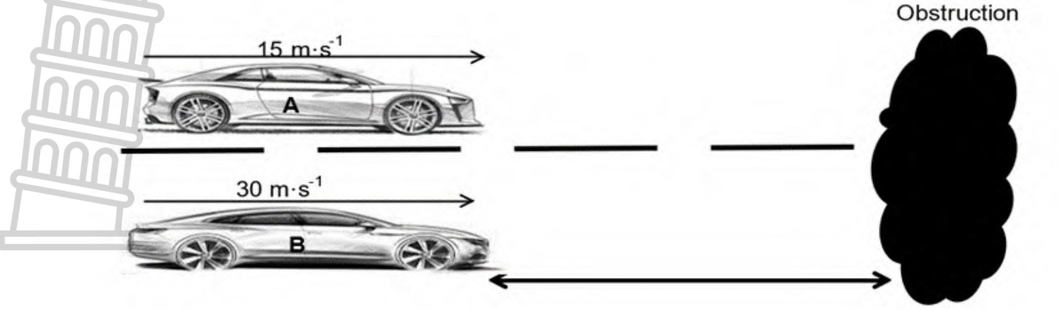
QUESTION 2 [8 MARKS]

A car C and a van V are both travelling at a constant velocity of 25 m.s-1 east, on different lanes along the same horizontal road. The driver of the car follows the van, keeping a distance of 5 metres between them. Seeing a box on his lane, the driver of the van brakes and slows down uniformly to stop in 5 seconds.

2.1	Calculate the acceleration of the van whilst slowing down.	(3)
2.2	If the car continued at its original motion, how far ahead of the van will the car be when the van stops?	(5)

QUESTION 3 [14]

Two cars, A and B, are moving at speeds of 15 m•s-1 and 30 m•s-1 in the same direction. They are side by side when both drivers observe an obstruction ahead of them, as shown in the diagram below.



Both drivers apply their brakes and accelerate at –4,5 $m\cdot s^{-2}$ until both cars come to rest. Ignore the reaction time of the drivers.

3.1	Define the term acceleration in words.		(2)
3.2	Calculate the:		
	3.2.1	Time it takes car **A** to come to rest	(3)
	3.2.2	Stopping distance of car **A**	(3)
3.3	Which car (**A** or **B**) has the longer stopping distance? Support the answer with a calculation.		(4)
3.4	What conclusion can be made about the relationship between speed and stopping distance?		(2)

SOLUTIONS

QUESTION 1 [10]

1.1	Car A $\Delta x = v_i\Delta t + ½ a\Delta t^2$ ✓ $500 = 0\Delta t + ½(1,2)\Delta t^2$ ✓ $\Delta t = 28,87$ s ✓	Car B $\Delta x = v_i\Delta t + ½ a\Delta t^2$ $500 = 27,78\Delta t + ½(0)\Delta t^2$ ✓ $\Delta t = 18$ s ✓ Car B will reach the robot 2 first ✓	(6)
1.2	$v_f = v_i + a\Delta t$ ✓ $v_f = 0 + 1,2(28,87)$ ✓ $v_f = 34,64\ m.s^{-1}$ East ✓✓		(4)

QUESTION 2 [8 MARKS]

2.1	$v_f = v_i + a\Delta t$ ✓ $0 = 25 + a(5)$ ✓ $a = -5$ $a = 5\ m.s^{-2}$ west ✓		(3)
2.2	**VAN** $\Delta x = v_i\Delta t + ½ a\Delta t^2$ ✓ $\Delta x = 25(5) + ½(-5)(5)^2$ ✓ $\Delta x = 62,50$ m	**CAR** $\Delta x = v_i\Delta t + ½ a\Delta t^2$ $\Delta x = 25(5) + ½(0)(5)^2$ ✓ $\Delta x = 125$ m 125 – 62.50 – 5 ✓ = 57.5m ✓	(5)

QUESTION 3 [14]		
31.	The rate of change of velocity ✓✓	(2)
3.2.1	$v_f = v_i + a\Delta t$ ✓ $0 = 15 + (-4,5)\ \Delta t$ ✓ $\Delta t = 3,33s$ ✓	(3)
3.2.2	$v_f^2 = v_i^2 + 2a\Delta x$ ✓ $(0)^2 = (15)^2 + 2(-4,5)\ \Delta x$ ✓ $\Delta x = 25$ m ✓	(3)
3.3	$v_f^2 = v_i^2 + 2a\Delta x$ ✓ $(0)^2 = (30)^2 + 2(-4,5)\ \Delta x$ ✓ $\Delta x = 100$ m ✓ Car B has a larger stopping distance (100 m > 25 m) ✓	(4)
3.4	The greater/larger the speed, the larger the stopping distance if acceleration is constant. ✓✓	(2)

ENERGY

In Grade 10 Mechanics we consider 3 forms of energy: gravitational potential energy, kinetic energy and mechanical energy.

Gravitational potential energy – energy an object has because of its position in the gravitational field relative to some reference point

- When the object moves up or down from the reference position its gravitational potential energy changes.
- Potential energy is calculated using the formula: Ep = mgh

Kinetic energy – energy an object possesses because of its motion

- Any object which moves, possesses kinetic energy.

A stationary object has no kinetic energy.

- Kinetic energy is calculated using the formula: Ek = ½ mv2

Mechanical energy – the sum of gravitational potential energy and kinetic energy.

Equation: $\mathbf{E_M = E_k + E_p}$

The Law of Conservation of Energy: The total energy of an isolated system remains constant.
The Principle of Conservation of Mechanical Energy: The total mechanical energy in an isolated system remains constant. $\mathbf{(E_{k1} + E_{p1} = E_{k2} + E_{p2})}$
Isolated system – a system that does not interact with its surroundings (there is no transfer of energy or mass between the system and the surroundings).

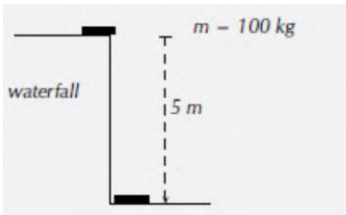
Worked example 1 (Gravitational Potential Energy)

1.1	A netball player, who is 1,7 m tall, holds a 0,5 kg netball 0,5 m above her head and shoots for the goal net which is 2,5 m above the ground. What is the gravitational potential energy of the ball:		
	1.1.1	when she is about to shoot it into the net?	(3)
	1.1.2	when it gets right into the net?	(3)
	1.1.3	when it lands on the ground after the goal is scored?	(3)

SOLUTION			
1.1.1	h = (1,7 + 0,5) = 2,2 m (height of the ball above the ground) Ep = mgh ✓ = (0,5) (9,8) (2,2) ✓ = 10,78 J ✓	1.1.2 Ep = mgh ✓ = (0,5) (9,8) (2,5) ✓ = 12,25 J ✓ 1.1.3 Ep = mgh ✓ = (0,5) (9,8) (0) ✓ = 0 J ✓	(9)

Worked example 2 (Kinetic energy)	
2.1	A bullet, having a mass of 150 g, is shot with a muzzle velocity of 960 $m.s^{-1}$. Calculate its kinetic energy.
Solution	
	Ek = ½ mv^2 ✓ = ½ (0,15)(960) ✓ = 69 120 J ✓

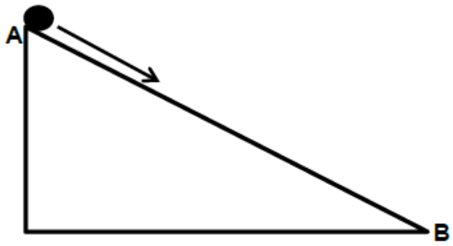
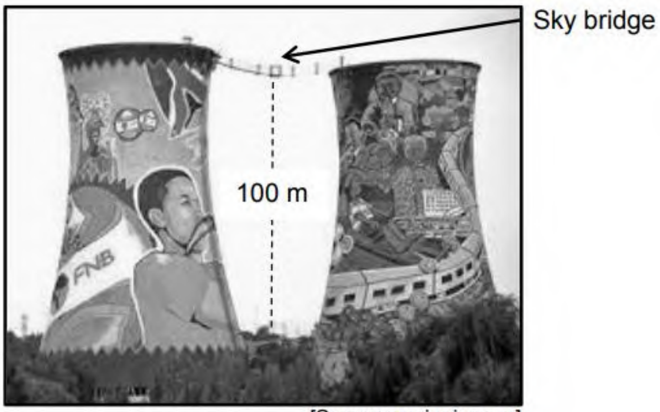
Worked example 3 Mechanical energy		
3.1	Calculate the total mechanical energy for a ball of mass 0,15 kg which has a kinetic energy of 20 J and is 2 m above the ground.	
SOLUTION		
	$E_M = E_p + E_k$ ✓ = mgh + E_k = (0,15) (9,8) (2) + 20 ✓ = 22,94 J ✓	(3)

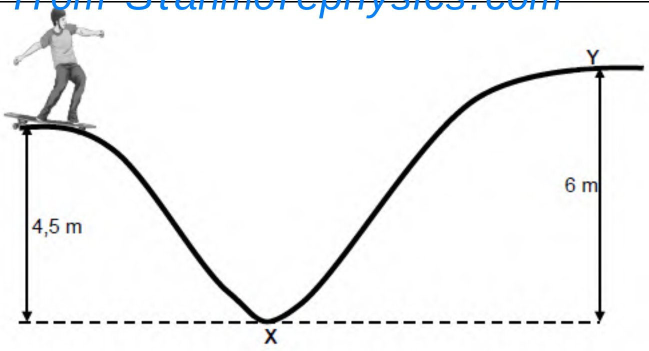
Worked example 4 (Conservation of Mechanical Energy)			
1.	**Object moving vertically downward**  During a flood a tree trunk of mass 100 kg falls down a waterfall. The waterfall is 5 m high. If air resistance is ignored, calculate:		
	1.1	the potential energy of the tree trunk at the top of the waterfall.	(3)
	1.2	the kinetic energy of the tree trunk at the bottom of the waterfall.	(3)
	1.3	the magnitude of the velocity of the tree trunk at the bottom of the waterfall.	(3)
SOLUTION			
1.1	Ep = mgh ✓ = (100) (9,8) (5) ✓ = 4 900 J ✓		(3)

1.2	Total mechanical energy must be conserved, so: $\mathbf{E_{k1} + E_{p1} = E_{k2} + E_{p2}}$ Since the trunk's velocity is zero at the top of the waterfall, E_{k1} = 0 J At the bottom of the waterfall, h = 0 m, so E_{p2} = 0 J Therefore $E_{k1} = E_{p2}$, and so the kinetic energy of the tree trunk at the bottom of the waterfall equals the potential energy at the top of the waterfall. And so, Ek = 4 900J	(3)
1.3	Since $E_k = \frac{1}{2} mv^2$ ✓ $4\ 900 = \frac{1}{2} .100.v^2$ ✓ $v^2 = 98$ $v = 9{,}90\ m.s^{-1}$ ✓	(3)
ACTIVITIES [10 marks]		
QUESTION 1		
1.1	A girl weighing 500 N takes 50 seconds to climb a flight of stairs 18 meters high. If her speed at the top of the stairs is 2 $m{\cdot}s^{-1}$, her potential energy at the top of the stairs is ____________J.	
	A 9 000	
	B 8 820	
	C 102,04	
	D 9 102,4	(2)
1.2	The SI unit for gravitational potential energy is …	
	A $kg{\cdot}m{\cdot}s^{-1}$	
	B $kg{\cdot}m{\cdot}s^{-2}$	
	C $kg{\cdot}m^2{\cdot}s^{-2}$	
	D $kg{\cdot}m^{-1}{\cdot}s^{-1}$	(2)
1.3	A motorbike moving at a speed v, has a kinetic energy E. If the speed of the motorbike increases to 3v, the kinetic energy will be …	
	A 3E	
	B ⅓E	
	C 6E	
	D 9E	(2)
1.4	Ntsako rides an escalator that moves her downward at constant speed. Select the option that best describes the change in her gravitational potential energy and kinetic energy.	

	Gravitational Potential Energy	Kinetic Energy
A.	Decreases	Decreases
B.	Decreases	Remains the same
C.	Increases	Decreases
D.	Increases	Remains the same

(2)

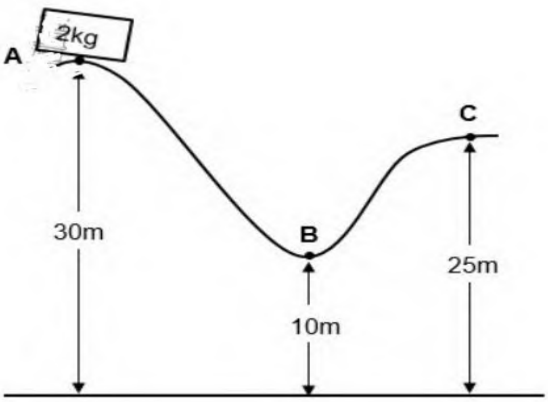
1.5	An object is released from the top of a frictionless inclined plane, AB, as shown below. 		
	Which ONE of the following statements regarding the total mechanical energy of the object is CORRECT?		
	A	$(E_p + E_k)_A > (E_p + E_k)_B$	
	B	$(E_p + E_k)_A < (E_p + E_k)_B$	
	C	$(E_p + E_k)_A = (E_p + E_k)_B$	
	D	$(E_p + E_k)_A = - (E_p + E_k)_B$	(2)
QUESTION 2			
A lift takes a man to a sky bridge, which is 100 m above the ground, as shown below. He makes a bungee jump from the sky bridge. Ignore the effects of air resistance.			
[Source: myjozi.co.za]			
2.1	Define the term kinetic energy.		(2)
2.2	The man and his gear have a mass of 72 kg. Calculate the gravitational potential energy of the man just before he jumps from the sky bridge.		(3)
2.3	State the law of conservation of mechanical energy.		(2)
2.4	Use the law in QUESTION 2.3 to calculate the velocity of the man at a height of 50 m above the ground.		(5)
2.5	Draw a graph of E_p versus E_k for the motion of the man from the instant he jumps until he reaches the ground		(3)
QUESTION 3			
A skateboarder, starting from the top of a ramp 4,5 m above the ground, skates down the ramp, as shown in the diagram below. The mass of the skateboarder and his board is 65 kg. Ignore the effects of friction.			



3.1	Define the term gravitational potential energy in words.	(2)
3.2	Calculate the gravitational potential energy of the skater just before he skates down the ramp.	(3)
3.3	Use the principle stated in QUESTION 3.3 to calculate the magnitude of the velocity of the skateboarder when he reaches the ground at point **X**.	(4)
3.4	Will the skateboarder be able to reach point **Y** if he were to remain on his skateboard? Write YES or NO and support the answer with a relevant calculation.	(6)

QUESTION 4

A rollercoaster cart of mass 2 kg is released from rest at point A, 30 metres above the ground. The cart moves along a frictionless surface ABC as shown below.



4.1	Define the term mechanical energy.	(2)
4.2	Prove with calculations that the mechanical energy of the cart at point A is 588 J.	(3)
4.3	Calculate the velocity of the cart when it is at point B.(	(3)
4.4	How will the mechanical energy of the cart at point C compare with the mechanical energy of the cart at point B? Write only GREATER THAN, LESS THAN or EQUAL TO. Give a reason for your answer.	(2)