KWAZULU-NATAL PROVINCE

EDUCATION
REPUBLIC OF SOUTH AFRICA

CURRICULUM GRADE 10 -12 DIRECTORATE

NCS (CAPS)

LEARNER SUPPORT DOCUMENT

GRADE 10

PHYSICAL SCIENCES STEP AHEAD

BOOK 2

2022

This document has been compiled by the KZN FET Physical Sciences Subject Advisors.

PREFACE

This support document serves to assist Physical Sciences Learner on how to deal with curriculum gaps and learning losses because of the impact of COVID-19 since 2020. It also captures the challenging topics in the Grade 10 – 12 work. Activities should serve as a guide on how to assess topics dealt with in this document. It will cover the following:

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GRADE 10

MATTER AND MATERIALS

MATTER AND ITS CLASSIFICATION

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.
- Compounds are pure substances made up of atoms of elements that are chemically combined in fixed ratios. 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
Properties are unique	Properties differ from those of constituent elements	Properties are the same as those of the constituent substances
Constituents cannot be separated by chemical or physical methods	Constituents can be separated by chemical methods	Constituents can be separated by physical methods

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.

The following table gives examples of elements with their symbols:

Element	**Symbol**	**Metal/non-metal/ metalloid**
Hydrogen	H	Non-metal
Sodium	Na	Metal
Boron	B	Metalloid
Iron	Fe	Metal

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 decreasing conductivity with increasing 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: 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.

STATES OF MATTER AND THE 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.
- Diffusion is the movement of atoms or molecules from an area of higher concentration to an area of lower concentration.
- The properties of the states are summarised in the following table:

Solids	Liquids	Gases
Particles are bonded in fixed positions	Particles can move over one another	Particles are far apart
Strong forces between the particles	Forces between particles are weaker than in solids	Virtually no forces between particles
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
Particles vibrate in their fixed positions	Particles move about more vigorously	Particles move about at high speed.
Not easily compressible	Not easily compressible	Compressible
Keep a fixed volume and shape	Take the shape of the container	Fill the whole container

- 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.
- When one or more electrons are added to an atom, it becomes negatively charged.
- Determine the charge on an ion after removing electrons from or adding electrons to an atom.

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.

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 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): $1s^2\ 2s^2\ 2p^6\ 3s^1$

THE PERIODIC TABLE OF ELEMENTS

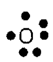
The positions of the elements in the periodic table related to their electronic arrangements

- 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.

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.
- 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:

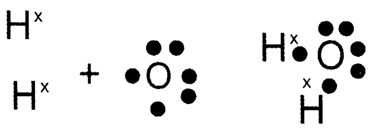
Oxygen : 

Hydrogen: $H^{\times}$

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.

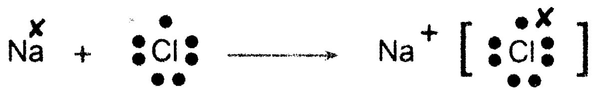
- The formation of a covalent bond between two hydrogen atoms and one oxygen atom can be represented by means of Lewis structures as follows:



- 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.

ACTIVITIES (MATTER & MATERIALS)

MULTIPLE-CHOICE QUESTIONS

QUESTION 1

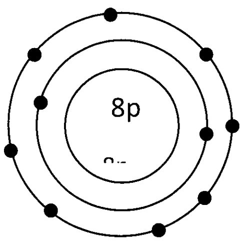
1.1 The electron configuration of a neutral atom of an element X is $1s^2\ 2s^2\ 2p^3$. Which one of the following would be the electron configuration of X^{3-} ?

A $1s^2\ 2s^2$
B $1s^2\ 2s^2\ 2p^6$
C $1s^2\ 2s^2\ 2p^3$
D $1s^2\ 2s^2\ 2p^0$ (2)

1.2 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)

1.3 Which of the following does the Bohr model below represent?

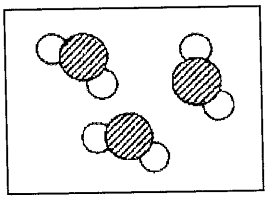
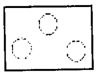
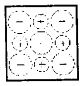


A An atom of neon
B An ion of oxygen
C A molecule of oxygen
D A neutral atom of oxygen (2)

1.4 Covalent bonding involves the ____________ of electrons, while ionic bonding involves the ____________ of electrons.

A sharing; splitting
B exchanging; sharing
C sharing; transferring
D transferring; sharing (2)

1.5 Which diagram represents the structure of an ionic compound?

A.  B.  C.  D. 

(2)

1.6 A neutral atom of an element has an electron configuration of $1s^22s^22p^5$.
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)

1.7 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)

1.8 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 increases (2)

1.9 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)

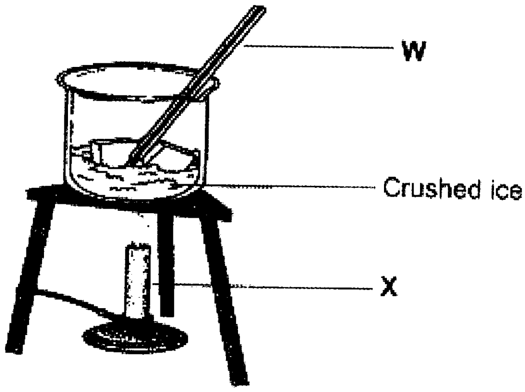
1.10 What is the percent by mass of oxygen in H_2SO_4?

A 16%
B 33%
C 65%
D 98%
(2)
[20]

STRUCTURED QUESTIONS

QUESTION 2

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.

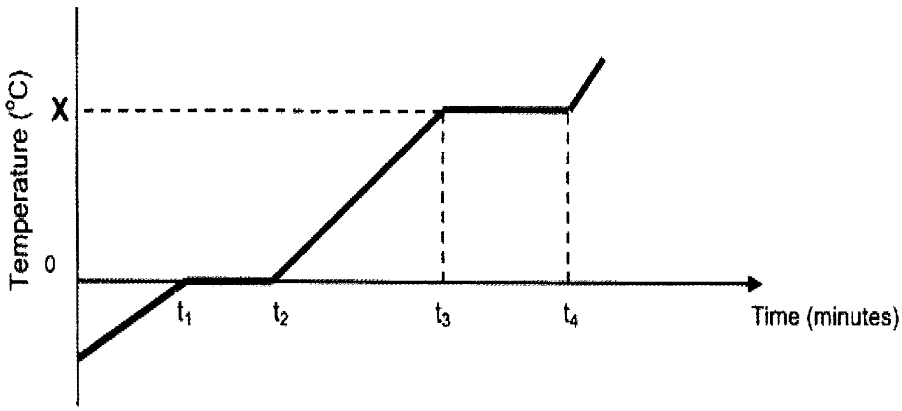


2.1 Define the boiling point. (2)

2.2 Write down the name of an instrument labelled W (1)

2.3 Explain why crushed ice was used instead of ice cubes? (2)

2.4 The graph below, not drawn into scale, shows the results obtained.



2.4.1 Write down the value represented by **X**. (1)

2.4.2 Name the predominantly phase of this substance between t_2 and t_3. (1)

2.4.3 Write down the process taking place between t_3 and t_4. (1)

2.4.4 Explain increase in temperature between t_2 and t_3. (2)

2.4.5 How will the above graph be affected if a larger quantity of crushed ice was used? (2)
[12]

QUESTION 3

Consider Magnesium and Chlorine:

3.1 How many valence electrons does each atom have? (2)

3.2 Using Lewis Diagrams, show the formation of the cation and the anion when magnesium and chlorine bond chemically. (3)

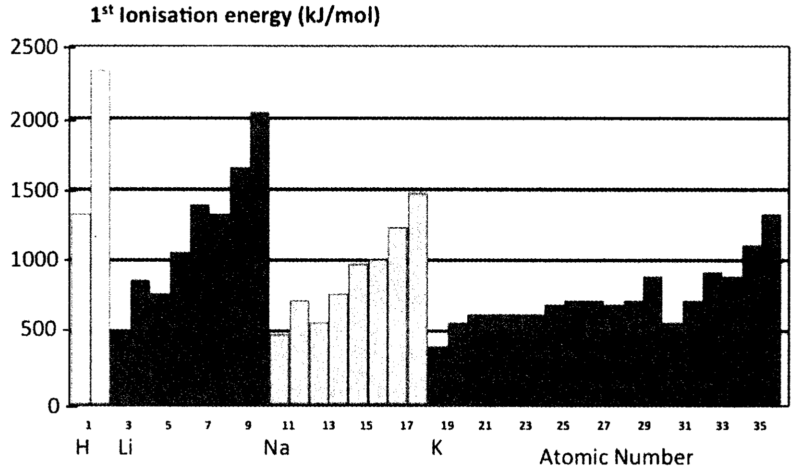
3.3 What force keeps the ions together in the crystal lattice? (1)

3.4 In which ratio are the cations and anions found in the crystal lattice? (2)

3.5 Name this compound. (1)
[9]

QUESTION 4

Refer to the graph below and answer the questions that follow:



4.1	Explain what is meant by first ionisation energy.	(2)
4.2	In which group do the elements in each period with the highest energy appear?	(1)
4.3	Why does the group in QUESTION 4.2 have such high ionisation energies?	(2)
4.4	Describe the general trend of ionisation energy across period 2.	(2)
4.5	In which energy level are the valence electrons of Li and Be found in?	(2)
4.6	Explain why Beryllium has a greater ionisation energy than Lithium.	(2)
4.7	Explain why Boron's ionisation energy is lower than Beryllium.	(2)
4.8	Why is Neon's ionisation energy higher than Argon's ionisation energy?	(2)
		[15]

QUESTION 5

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

5.2 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)

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

5.4 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)

[16]

QUESTION 6

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

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

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

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

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

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

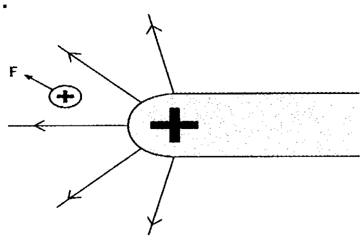
6.6 Write down the symbol for the anion formed when oxygen accepts two electrons into its valence shell. (1)

[11]

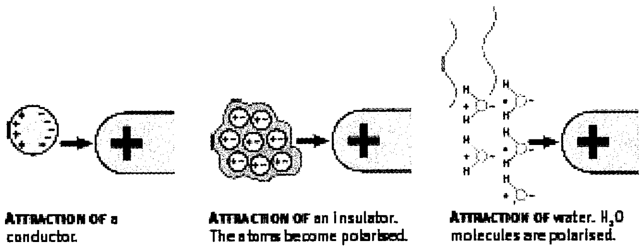
ELECTROSTATICS

Two Kinds of Charge

- The property of particles in atoms that enables them to attract and repel is called charge. There are only two types of charge i.e. a positive and a negative charge.
- Like charges repel, unlike charges attract.
- Charges are called positive and negative because when the two types come together
- they cancel out to produce a zero charge.
- Atoms are made up of a central nucleus comprised of positively charged protons and neutral neutrons. The nucleus is surrounded by a number of negatively charged electrons that are much smaller than protons.
- Objects become charged when electrons are either removed from them or added to them. This can be done by rubbing two materials together, called tribo-electric charging.
- An object that has an equal number of positive and negative charges is neutral.
- Conductors allow a flow of charge through them. Conductors contain charges that are free to move.
- Insulators do not allow a flow of charge through them. They do not contain charged particles that are free to move.



- An electric field is a region in space in which an electric charge will experience a force. All charged objects are surrounded by electric fields.
- An electric field line is a line drawn with an arrow to show the direction in which a positive charge will experience a force if placed in the field.



- An uncharged conductor can be attracted by a charged object. In the process, the conductor becomes polarised. Free electrons in the conductor move under the action of the electric field, making one side of the conductor negative and the other positive.

- An uncharged insulator (for instance, dust or paper) can be attracted by a charged object. Here each atom becomes polarised. Electrons in each atom move under the action of the electric field, making one side of the atom negative and the other positive.
- Water is made up of polarised molecules. The oxygen end is slightly negatively charged, and the hydrogen end slightly positively charged. A thin stream of water is attracted by a charge rod. The molecules rotate under the action of the electric field so that one side of the stream is negative and the other positive.

Conservation and Quantisation

- Charge is measured in coulombs, where one coulomb is the charge carried by $6{,}25 \times 10^{18}$ electrons.
- The principle of conservation of charge states that the net charge of an isolated system remains constant during any physical process.
- When two identical conductors that are charged are brought into contact, electrons will flow from the more negative object to the other until both have the same charge. To calculate the charge on each, simply add together the original charges and divide by two. $Q = \frac{Q_1 + Q_2}{2}$
- The charge on one electron (q_e) is called the elementary charge ($q_e = 1{,}6 \times 10^{-19}$ C).
- The principle of quantisation of charge states that every charge in the universe must be a multiple of the charge on one electron.
  $Q = nq_e$ where $q_e = 1{,}6 \times 10^{-19}$ C.

ACTIVITIES

1 A plastic rod and a dry cloth are uncharged. The plastic rod is rubbed with the dry cloth and they both become charged. The rod becomes negatively charged because some particles move from the cloth to the rod.
What is the charge on the cloth and which particles moved in the charging process?

	CHARGE ON ROD	PARTICLES THAT MOVED
A	Positive	Protons
B	Positive	Electrons
C	Negative	Protons
D	Negative	Electrons

(2)

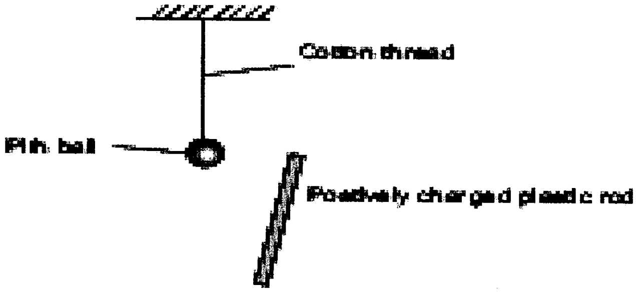
2 A positively charged plastic rod attracts small pieces of paper because …….

A the paper pieces are negatively charged.
B. the paper pieces are neutral.
C. the paper pieces are very small.
D. the paper pieces become polarised.

LONG QUESTIONS

3 A pith ball is a polystyrene sphere coated with metal paint.

A plastic rod is charged by rubbing it with a cloth. It is held next to an uncharged pith ball that is suspended on light cotton thread.



3.1 Describe how the plastic rod becomes positively charged when it is rubbed with a cloth. (2)

3.2 Describe what happens in the metal paint on the pith ball when the positively charged plastic rod is brought near to it. (2)

3.3 The ball is attracted to the rod. Explain why this happens, given that the pith ball is uncharged. (2)

3.4 Predict what you would see if the pith ball touches the positively charged rod. (2)

3.5 Explain your prediction in QUESTION 3.4. (2)

4 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.

4.1 State the principle of quantization of charge. (2)

4.2 Calculate the number of extra electrons added to pith ball B. (4)

4.3 Describe the type of force that pith ball B exerts on pith ball A. The pith balls are brought up together, and then they are separated again to hang at the same original distance apart. (1)

4.4 State the law of conservation of charge. (2)

4.5 Use the law of conservation of charge to calculate the charge on pith ball B after it has touched pith ball A and is separated, and hangs back at its original position. (4)

4.6 How many electrons were transferred from pith ball B to pith ball A when the pith balls touched each other? (4)

5 Draw a diagram to show why it is dangerous to take shelter under a lone tree in openveld during a thunderstorm. Write a brief description to explain your reasoning. (6)

6 Explain each of the following phenomena using your knowledge of electrostatics

6.1 When the air is very dry, your hand feels a small sharp electric shock when you touch a metal door knob after walking along the carpet to the door. (3)

6.2 When a charged plastic ruler is brought close to small pieces of paper the paper pieces are attracted to the ruler. (3)

MULTIPLE CHOICE QUESTIONS

1 A positively charged rod is brought near to the following objects.

I Small uncharged pieces of paper
II A thin stream of water
III A positively charged balloon
IV A negatively charged cloth

Which of these objects will not be attracted to the rod?

A i) ii) and iii)
B i) iii)
C ii) iii)
D iii)

2 When a charged object becomes polarised, it …

A gains electrons
B loses electrons
C gains a north and a south pole
D experiences a shift in charge

3 A neutral object has…

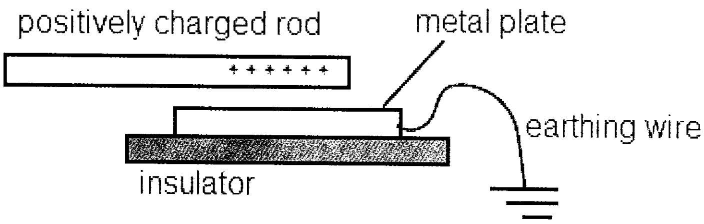
A no charges
B no magnetic field
C more neutrons than protons and electrons
D no imbalance in charge

4 Two identical positively charged pith balls are brought up to touch one another, and then moved apart to their original distance. Initially the fi rst pith ball A carried twice as much charge as the second pith ball B. When they have separated both pith balls each carry a charge of +6 nC. What was the original charge on the pith balls?

A	12	0
B	8	4
C	6	6
D	4	2

STRUCTURED QUESTIONS

5 A positively charged plastic rod is placed above a thick metal plate. The metal plate is connected to the Earth by a wire. The metal plate rests on an insulator.



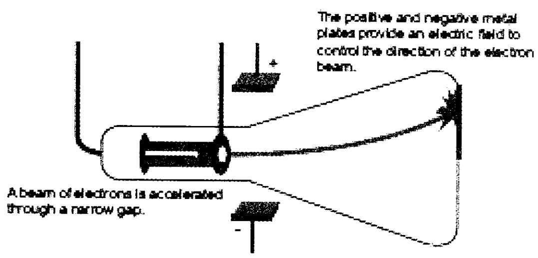
A learner disconnects the earthing wire and then removes the positively charged rod.
The experiment is repeated. On the second attempt, the learner removes the positive rod, and then disconnects the earthing wire.

5.1 Initially the metal plate is earthed. Explain what happens when the positively charged rod is placed above the metal plate while the earthing wire remains attached to it. (4)

5.2 When the earthing wire is disconnected and then the positively charge rod is removed, what charge (if any) remains on the metal plate? Explain your answer. (4)

5.3 On the second attempt, the positive rod is removed first, and then the earthing wire is disconnected. What is the charge (if any) on the metal plate now? Explain your answer. (4)

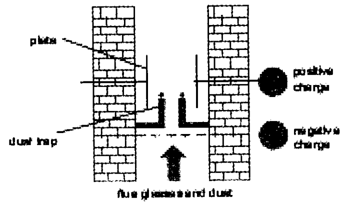
6 Inside a cathode ray tube such as those that were used in the "old fashioned TV sets"the direction of a beam of electrons is controlled by oppositely charged plates. Study the simplified diagram shown below.



6.1 Explain how the direction of the beam of electrons is controlled by the positive and negative plates. (4)

6.2 These types of TV sets collect dust particles on their screens. Explain why dust particles tend to stick to the screens of these types of TV sets. (4)

7 An electrostatic smoke precipitator collects smoke (carbon) particles and dust from a coal-fired furnace. The diagram below shows how the particles are collected. The flue gases and dust enter through a grid which is negatively charged. They then pass through positively charged plates, and fall into the dust trap. The dust trap is cleaned frequently so that the precipitator does not become clogged up.



Explain how the precipitator works in terms of electrostatic principles. (6)

ELECTRIC CIRCUITS

Potential difference

- An electric current is a flow of charge, positive or negative.
- A battery supplies electrons to a circuit at its negative terminal and draws them in at the positive terminal by means of a chemical reaction in the battery. So, there is a conversion of chemical potential energy in the battery to electrical potential energy of the electrons.
- The voltage measured across the terminals of a battery when it is not providing current to a circuit is called the emf of the battery.
- The voltage measured across the terminals of a battery when it is providing current to a circuit is called the potential difference across the circuit. This is always smaller than the emf, due to the fact that the battery has some resistance.
- Emf and potential difference are measured in volts with a voltmeter, which has a very high resistance and is always connected in parallel across the circuit or resistor.

Current

- Current (I) is the rate of flow of charge.
- $I = Q/\Delta t$
- While an electric current can be a flow of negative or positive charge, current direction is shown as the direction in which positive charge would move in the circuit – from positive to negative. This is referred to as 'conventional current'.
- Current is measured in amperes (A). 1 ampere = 1 coulomb per second
- Definition of an ampere: The current in a conductor is one ampere when one coulomb of charge passes through the conductor per second.
- Current is measured with an ammeter, which has a very low resistance and is always connected in series.

Resistance

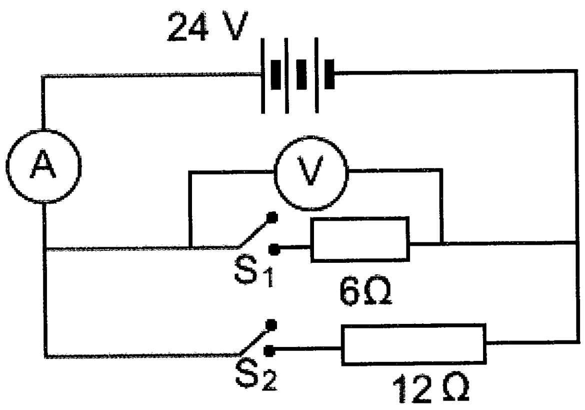
- Resistance (R) is the extent to which a resistor limits the flow of charge in it. When connected to the same potential difference, the higher the resistance of the resistor, the smaller the current.
- Resistance is measured in ohms (Ω).

- 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.
- Factors affecting resistance: Resistance depends on the type of metal, length, thickness and temperature.
- A metal will have a higher resistance if its outer electrons are held more tightly by the nucleus of the atom. So, for instance, nichrome (an alloy of nickel and chromium) has a much higher resistance than copper.
- Current in metals is a flow of loosely bound electrons in the metal. The battery sets up an electric field in the circuit. The loosely bound electrons move under the action of this field. There is a conversion of electrical potential energy into kinetic energy of the moving electrons. The electrons collide with the atoms of the metal, causing them to vibrate faster. So, there is a conversion of kinetic energy of the electrons to vibrational kinetic energy of the atoms in the metal. The faster the atoms vibrate, the hotter they are. If very hot, they could give out light.
- Energy conversions:
  Chemical potential energy in battery to electrical potential energy of electrons to kinetic energy of electrons to vibrational kinetic energy of atoms of metal to heat energy and possibly light energy.
- Resistance increases as the length of the resistor increases
- Resistance decreases as the thickness of the resistor increases.
- Resistance increases as the temperature of the resistor is increased.
- When a resistor is added in series to an identical one, the total resistance is doubled.
- When a resistor is added in parallel to an identical one, the total resistance is halved.
- To calculate the total resistance (equivalent resistance) R_s of a number of resistors connected in series, simply add them together:
  $Rs = R_1 + R_2 + R_3 \ldots\ldots$
- Current is the same at all points in a series circuit.
- Resistors in series divide the potential difference in proportion to the resistance. They are voltage dividers. Add the potential differences across each resistor together to get the potential difference across the whole circuit.
- Resistors in parallel divide the current – they are current dividers. Add the currents together to get the mainstream current.
- The voltage across each resistor in a parallel connection is the same.
- To calculate the total resistance (equivalent resistance) Rp of a number of resistors in parallel, apply the formula:
  $$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots +$$
  After calculating the right-hand side of the equation, remember to invert both sides.
- For two resistors in parallel, the equation can be written as:
  $$R_P = \frac{R_1 \times R_2}{R_1 + R_2}$$
- Remember that the above equation can only be used for two resistors in parallel.

ACTIVITIES

1 A 12 V battery supplies a maximum of 120 J of energy when charge passes through it. Calculate the amount of charge passing through the battery. (4)

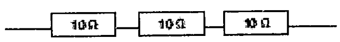
2 When three cells are connected in series, the total emf of the battery is 24 V. Two resistors are connected in parallel with switches S_1 and S_2 as shown in the diagram below, and connected to the battery. An ammeter (A) reads the current passing through the battery and voltmeter (V) reads the potential difference across the 6 Ω resistor. The cells and ammeter have negligible resistance. The voltmeter has a very high resistance.



2.1 Explain what it means when we say: 'The emf of the battery is 24 V.' (2)
2.2 What is the reading on the voltmeter when switch S_1 is open? (1)
2.3 What is the reading on the voltmeter when S_1 is closed? (1)
2.4 What is the reading on the voltmeter when S_1 and S_2 are closed? (1)
2.5 Calculate the equivalent resistance of the two resistors in parallel. (4)

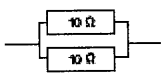
3 All the resistors in the following diagrams are identical. Each resistor has a resistance of 10 Ω. Calculate the effective resistance of each combination of resistors.

3.1



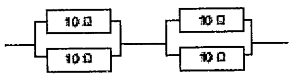
(2)

3.2



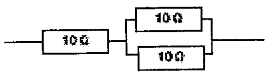
(3)

3.3



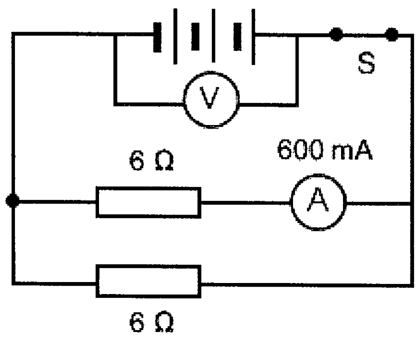
(3)

3.4



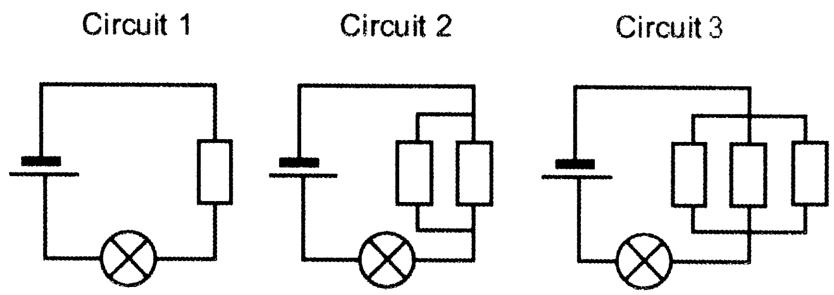
(3)

4 Three identical cells are connected in series to make a battery. The battery is connected to two identical 6 Ω resistors which are in parallel. When the switch S is closed the ammeter reads the current in one of the parallel branches as 600 mA.



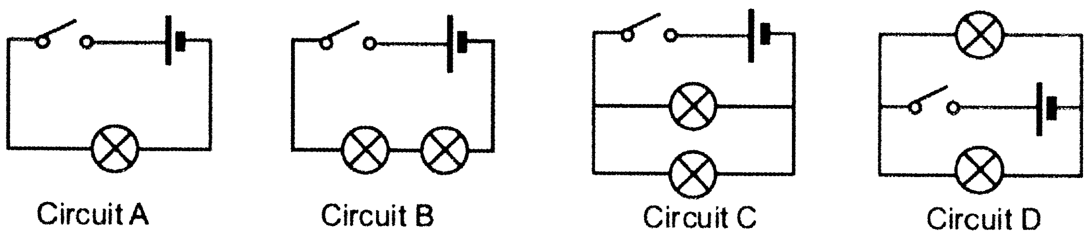
4.1 Determine the current through the other parallel branch. (2)
4.2 Calculate the current passing through the battery. (2)

5 Study the three circuit diagrams shown below.
The cells, light bulbs and resistors are identical in each circuit.



In which circuit will the light bulb glow the brightest? Show your reasoning. (4)

6 Four circuit diagram are shown below. Each circuit uses an identical cell, and identical light bulbs.



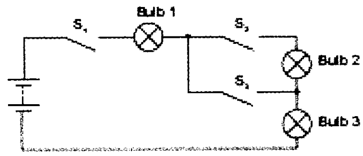
The switch in each of the four circuits is closed.

6.1 In which circuit(s) are the light bulbs brightest? (A, B, C and/or D). Explain briefly. (4)
6.2 Compare the brightness of the bulb in Circuit A with the brightness of the bulbs in Circuit B. (4)
6.3 Compare Circuit C with Circuit D. (4)

7.1 Explain what is meant by "the current is 2 A". (4)
7.2 Calculate the charge that passes through a resistor when a steady current of 2 A is maintained for 2 minutes. (4)
7.3 Explain what is meant by "the potential difference across the resistor is 4 V". (4)
7.4 Calculate the energy transferred when a potential difference of 4 V is connected across a resistor, and a steady current of 2 A passes through it for 2 minutes. (4)
7.5 Explain what is meant by resistance in an electric circuit. (1)

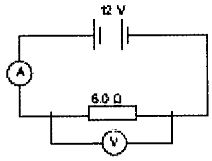
MULTIPLE CHOICE QUESTIONS

1 The diagram shows a circuit containing three bulbs and three switches.



Bulb 1 and Bulb 3 are lit, but Bulb 2 is not lit.
Which switch (or switches) is (are) closed?
A S_1 only
B S_2 only
C S_1 and S_3
D S_2 and S_3

Refer to the circuit shown below to answer both Question 2 and 3.

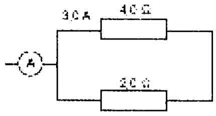


The ammeter reads 2,0 A and the voltmeter reads 12 V.

2 How much charge passes through the resistor in 10 seconds?
A 2,0 C
B 20 C
C 12 C
D 120 C

3 How much energy is transferred by the resistor in 10 seconds?
A 2,4 J
B 14,4 J
C 240 J
D 144O J (2)

4 The diagram below shows part of an electrical circuit.



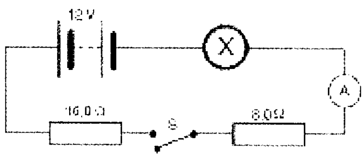
(2)

The current in the 4,0 Ω resistor is 3,0 A.
What is the current through the ammeter?

A 4,5 A
B 6,0 A
C 9,0 A
D 12,0 A

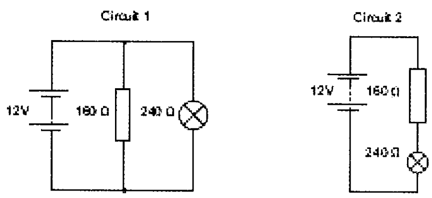
LONG QUESTIONS

5 The electric circuit shown below contains a battery, two resistors, a switch and another component.



5.1 Name component X (1)
5.2 Which quantity does this instrument measure? (1)
5.3 The switch is closed so that current passes through the circuit. What flows in the circuit to create the current? Choose one of the following quantities: (1)
charge, potential difference, energy or resistance
5.4 Calculate the equivalent resistance of the two resistors when the switch is closed. (3)
5.5 When the switch is opened, what is the potential difference across the 16 Ω resistor? (2)
5.6 If these two resistors are connected in parallel with one another, what would be their equivalent resistance? Show your working. (4)

6 Circuit 1 and Circuit 2 consist of a 12 V battery connected to a 160 Ω resistor and a light bulb with a resistance of 240 Ω.



6.1 Describe the arrangement of the resistor and light bulb in Circuit 1 (1)
6.2 Calculate the equivalent resistance of Circuit 1. (4)
6.3 In Circuit 1, the current through the battery 125 mA. How much current passes through the light bulb? (4)
6.4 Calculate the equivalent resistance of Circuit 2. (2)
6.5 In Circuit 2 the current through the battery is 30 mA. How much current passes through the light bulb? (3)
6.6 Calculate the potential difference across the light bulb in Circuit 2. (3)
6.7 In which circuit (1 or 2) does the light bulb shine the brightest? Justify your answer. (3)

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.

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).

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?
1.1.2 when it gets right into the net?
1.1.3 when it lands on the ground after the goal is scored?

Solutions

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

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 mv2
= ½ .0,15.960
= 69 120 J

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

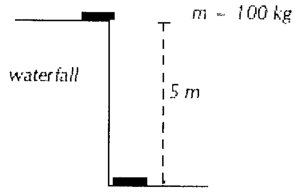
Conservation of Mechanical Energy

NB: Always start calculation with:

$$E_{k1} + E_{p1} = E_{k2} + E_{p2}$$

Examples

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.
1.2 the kinetic energy of the tree trunk at the bottom of the waterfall.
1.3 the magnitude of the velocity of the tree trunk at the bottom of the waterfall.

Solutions

1.1 Ep = mgh
= 100.9,8.5
= 4 900 J

1.2 Total mechanical energy must be conserved, so:

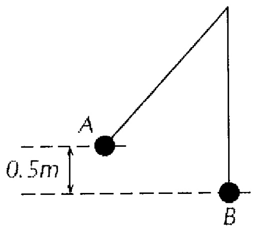
$$E_{k1} + E_{p1} = E_{k2} + E_{p2}$$

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

1.3 Since
$E_k = \frac{1}{2} mv^2$
$4\,900 = \frac{1}{2} .100.v^2$
$v^2 = 98$
$v = 9{,}90 \text{ m.s}^{-1}$

2. A 2 kg metal ball is suspended from a rope as a pendulum. If it is released from point A and swings down to the point B (the bottom of its arc):

Pendulum



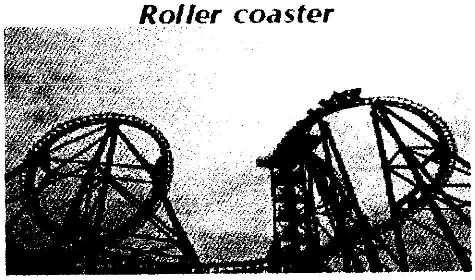
Calculate the velocity of the ball at point B.

Solution
Since there is no friction, mechanical energy is conserved.

$E_{k1} + E_{p1} = E_{k2} + E_{p2}$
$mgh_1 + \frac{1}{2} mv_1^2 = mgh_2 + \frac{1}{2} mv_2^2$
$mgh_1 + 0 = 0 + \frac{1}{2} mv_2^2$
$2.9{,}8.0{,}5 = \frac{1}{2} .2.v^2$
$v = 3{,}13 \text{ m.s}^{-1}$

3. A roller coaster ride at an amusement park starts from rest at a height of 50 m above the ground and rapidly drops down along its track. At some point, the track does a full 360 degree loop which has a height of 20 m, before finishing off at ground level. The roller coaster train itself with a full load of people on it has a mass of 850 kg.

Roller coaster



If the roller coaster and its track are frictionless, calculate:

3.1 the velocity of the roller coaster when it reaches the top of the loop

3.2 the velocity of the roller coaster at the bottom of the loop (i.e. ground level)

Solutions

3.1 $E_{M1} = E_{M2}$

$E_{p1} + E_{k1} = E_{p2} + E_{k2}$

$mgh_1 + \frac{1}{2} mv_1^2 = mgh_2 + \frac{1}{2} mv_2^2$

$mgh_1 + 0 = mgh_2 + \frac{1}{2} mv_2^2$

$850.9{,}8.50 + 0 = 850.9{,}8.20 + \frac{1}{2} .850.v^2$

$v^2 = 588$

$v = 24{,}25 \text{ m.s}^{-1}$

3.2 $E_{M1} = E_{M3}$

$E_{p1} + E_{k1} = E_{p3} + E_{k3}$

$mgh_1 + \frac{1}{2} mv_1^2 = mgh_3 + \frac{1}{2} mv_3^2$

$mgh_1 + 0 = 0 + \frac{1}{2} mv_3^2$

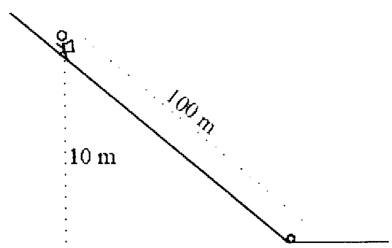
$850.9{,}8.50 = \frac{1}{2} .850.v_3^2$

$v_3^2 = 980$

$v_3 = 31{,}30 \text{ m.s}^{-1}$

4. A mountain climber who is climbing a mountain in the Drakensberg during winter, by mistake drops her water bottle which then slides 100 m down the side of a steep icy slope to a point which is 10 m lower than the climber's position. The mass of the climber is 60 kg and her water bottle has a mass of 500 g.

Inclined Plane



4.1 If the bottle starts from rest, how fast is it travelling by the time it reaches the bottom of the slope? (Neglect friction.)

4.2 What is the total change in the climber's potential energy as she climbs down the mountain to fetch her fallen water bottle? i.e., what is the difference between her potential energy at the top of the slope and the bottom of the slope?

Solutions

4.1 $E_{M1} = E_{M2}$

$E_{p1} + E_{k1} = E_{p2} + E_{k2}$

$mgh_1 + ½ mv_1^2 = mgh_2 + ½ mv_2^2$

$mgh_1 + 0 = 0 + ½ mv_2^2$

$0,5.9,8.10 = ½ .0,5.v_2^2$

$v_2^2 = 196$

$v_2 = 14$ m.s^{-1}

4.2 At the top of the slope, her potential energy is:

$E_{p1} = mgh_1$
$= 60.9,8.10$
$= 5880$ J

At the bottom of the slope, her potential energy is:

$E_{p2} = mgh_2$
$= 60.9,8.0$
$= 0$ J

Therefore, the difference in her potential energy when moving from the top of the slope to the bottom is:

$E_{p1} – E_{p2} = 5880 - 0$
$= 5880$ J

ACTIVITIES

MULTIPLE CHOICE QUESTIONS

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·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

1.2 The SI unit for gravitational potential energy is …

A kg·m·s^{-1}
B kg·m·s^{-2}
C kg·m^{2}·s^{-2}
D kg·m^{-1}·s^{-1}

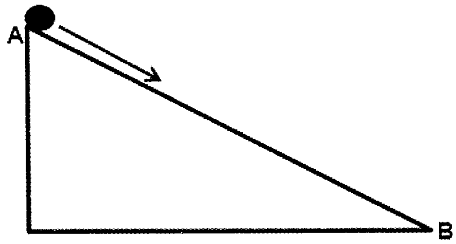
1.3 A motorbike moving at a speed v, has a kinetic energy E. If the speed of the motorbike increases to 3v, the kinetic energy will be …

A 3E
B ⅓E
C 6E
D 9E

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

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 $(E_p + E_k)_A = - (E_p + E_k)_B$

STRUCTURED QUESTIONS

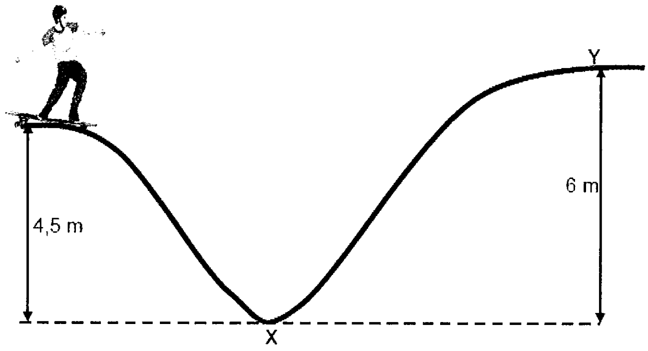
2. A lift takes a man to a sky bridge, which is 100 m above the ground, as shown below. He makes a bungee jump from the sky bridge. Ignore the effects of air resistance.

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 1.3 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)

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 State the *principle of conservation of mechanical energy* in words. (2)
3.4 Use the principle stated in QUESTION 5.3 to calculate the magnitude of the velocity of the skateboarder when he reaches the ground at point **X**. (4)
3.5 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)

4. A truck of mass 180kg is parked at the top of a hill, 80 m high. The truck driver releases the break and the truck free-wheels down the hill.
4.1 What is the maximum velocity that the truck can achieve at the bottom of the hill? (4)
4.2 In reality, will the truck achieve this velocity? Why?/Why not? (3)

5. An 800 g pendulum is swung from a height of 13 cm with a downward velocity of 3 $m.s^{-1}$.
5.1 Determine the potential energy of the pendulum at the top of its movement. (3)
5.2 Calculate the maximum velocity that the pendulum will reach. (4)
5.3 Determine the maximum height of the swinging pendulum (3)
An object of 300 g is placed in the path of the pendulum at the bottom of its swing. The pendulum makes contact with the object, and continues to swing up to a height of 11cm. Determine:
5.4 The amount of energy transferred to the object. (5)
5.5 The magnitude of the velocity with which the object moves off after contact. (3)
Assume the energy losses due to air resistance are negligible, if no dissipative forces were experienced.

VECTORS AND SCALARS

Scalar quantities have magnitude only.
examples: mass, charge, energy, time, distance, speed
Vector quantities have both magnitude and direction.
examples: force, weight, displacement, velocity, acceleration
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.

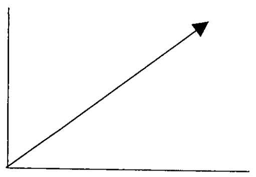
Negative vectors act in opposite direction to chosen positive direction.

Vectors can be added and subtracted and their magnitudes can be multiplied.
A **resultant vector** is the single vector that has the same effect as two or more vectors acting together.
Resultant vectors can be determined:

- graphically, using the tail-to-head and tail-to-tail methods
- by calculation.

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 ($m.s^{-2}$)

Graphical representation of a vector

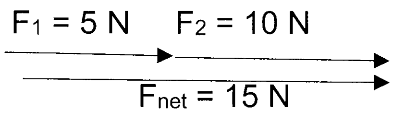


+ and – are used to indicate direction of vector
eg. right is +: ⟶ +5 N
left is -: ⟵ -3 N

NET OR RESULTANT VECTOR
Single vector that has the same effect as two or more vectors acting together.
Net vector is greatest when vectors are in the same direction.
Net vector is smallest when vectors are in opposite directions.

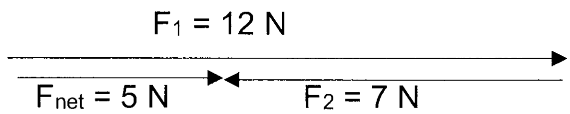
Vectors in same direction

Determine the net force when a 5 N force acts to the right and a 10 N force also acts to the right.



Vectors in opposite directions

Determine the net force when a 12 N force acts to the right and a 7 N force acts to the left.



Let to the right be positive
$F_{net} = F_1 + F_2$
$= 5 + 10$
$= 15$ N right

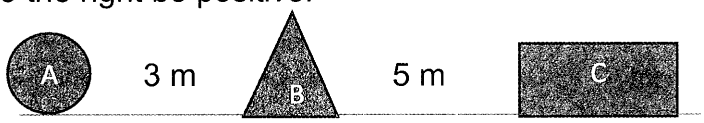
Let to the right be positive
$F_{net} = F_1 + F_2$
$= 12 + (-7)$
$= 5$ N right

MOTION IN ONE DIMENSION

A frame of reference is a reference point combined with a set of directions.
A frame of reference must have an origin.
One dimensional motion is straight line motion in the forward or backward direction.
Position is a measurement of a location, with reference to an origin.
Position is always stated relative to a reference point, and may be positive or negative.
x is used for horizontal motion, y is used for vertical motion.

Examples:

Let to the right be positive:



1. Describe the position of objects A and C using object B as a reference point as in the diagram.
2. Describe the position of objects B and C using object A as a reference point as in the diagram

Solutions:

1. Object A is -3 m from B (3 m to the left)
   Object C is +5 m from B (5 m to the right)
2. Object B is 3 m to the right of A.
   Object C is 8 m to the right of A.

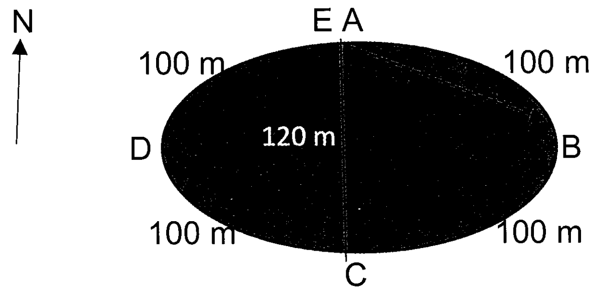
Displacement (Δx or Δy) is change in an object's position.
Displacement is represented as follows: $\Delta x = x_f - x_i$
Distance is the length of the actual path taken between a starting position and a new position

DISTANCE AND DISPLACEMENT

Distance	**Displacement**
Total path length travelled	Difference in position in space. Measured from start to final position
Scalar quantity	Vector quantity
Symbol: D	Symbol: Δx (or Δy)
Unit: metre (m)	Unit: metre (m)

Example:

A boy runs from position A to E in a clockwise motion as shown in the diagram. Describe his distance and displacement at position B,C and E using A as the starting (reference) point.



PLEASE INSERT 25^{O} BETWEEN AB AND AC, TA!

Solutions:

B: distance is 100 m, displacement is 80 m at 25^{O} East of South

C: distance is 200 m, displacement is 120 m South

E: distance is 400 m, displacement is 0 m

INSTANTANEOUS SPEED / VELOCITY AND THE EQUATIONS OF MOTION

DEFINITIONS

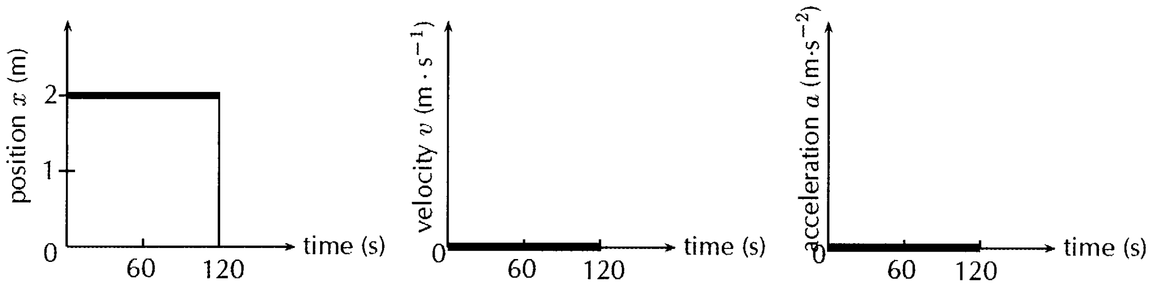
- Instantaneous velocity is the rate of change of displacement, i.e. the displacement divided by a very small-time interval or velocity at a particular time.
- Instantaneous velocity is a vector quantity.
- Instantaneous speed is the magnitude of instantaneous velocity.
- Instantaneous speed is a scalar quantity.

STATIONARY OBJECT

- A stationary object does not move and so its position does not change.
- Velocity is zero.
- Acceleration is zero.

EXAMPLE

Vusi is waiting for a taxi. She is standing 2 m from the stop street at t = 0s. After one minute, at t =60s, she is still 2m from the stop street and after 2 minutes from the stop street and after 2 minutes, at t = 120s, also2m from the stop street, His position has not changed. His displacement is zero, because his position is the same, his velocity is zero and his acceleration is zero, because his velocity is not changing. Graphs of position vs. time, velocity vs. time and acceleration vs. time



MOTION WITH UNIFORM VELOCITY

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

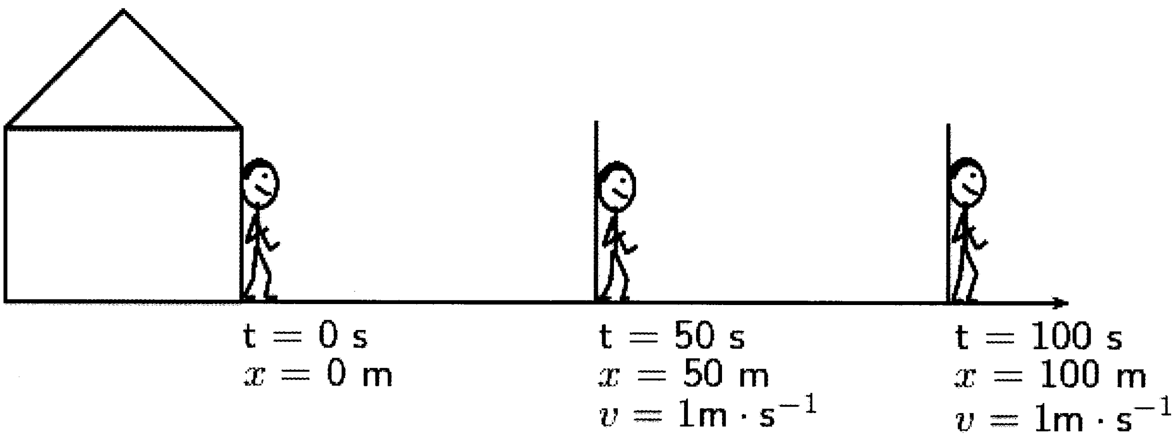
EXAMPLE
Assume that Vusi takes 100 s to walk the 100 m to the taxi-stop every morning. If we assume that Vusi's house is the origin and the direction to the taxi is positive, then assume that Vivian's house is the origin and the direction to the taxi is positive, then

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

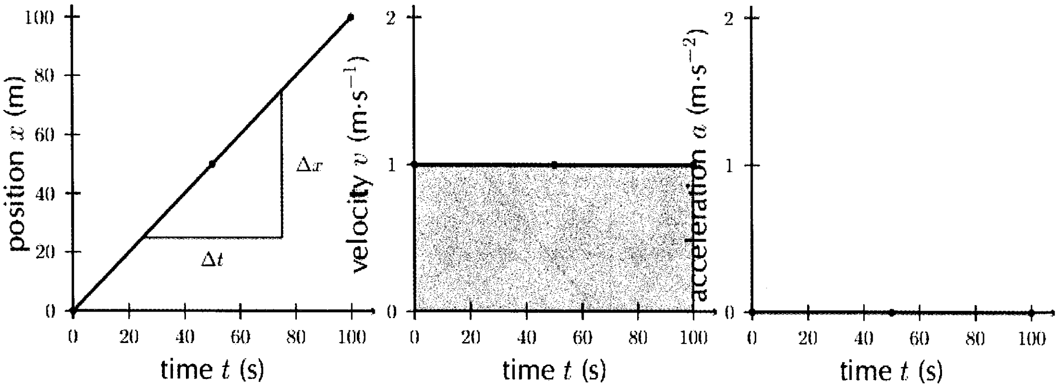
$$v = \frac{100 - 0}{100 - 0}$$

v = 1s

Vusi's velocity is 1 m· s^{-1}. This means that she walked 1 m in the 1st second, another metre in the 2nd second, and another in the 3rd second, and so on. For example, after 50 s she will be 50 m from home. Her position increases by 1 m every 1 s. A diagram of Vusi's position is shown below:



Graphs of position vs. time, velocity vs. time and acceleration vs. time



We can use the velocity vs. time graph to calculate the displacement by finding the area under the graph.

Δx = Area under graph

$\Delta x = \ell \times b$

$\Delta x = 100 \times 1$

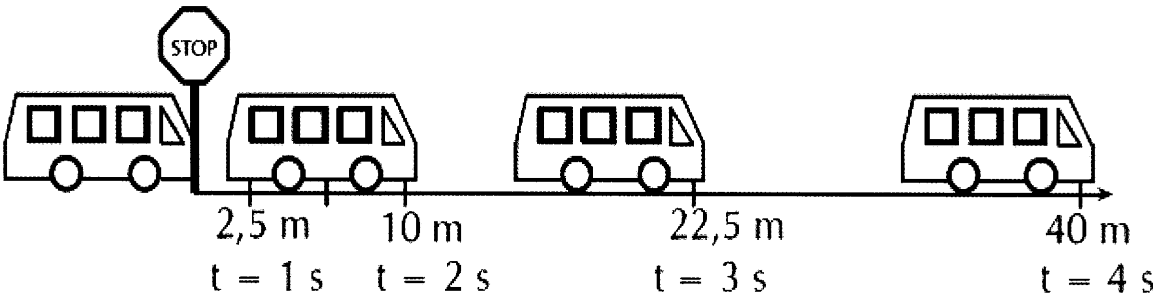
$\Delta x = 100$ m

UNIFORMLY ACCELERATED MOTION

- Velocity of an object changes with the same amount during time interval.
- Acceleration is the rate of change of velocity.
- Uniform acceleration means that the velocity changes at a constant rate.

EXAMPLE

Vusi is waiting at taxi stop again. A taxi arrived and Vusi got it. The taxi stopped at the stop street and accelerated in the opposite direction. After 1second the taxi covered a distance of 2, 5m, after 2 s it covered 10m, after 3s it covered 2,5 m and



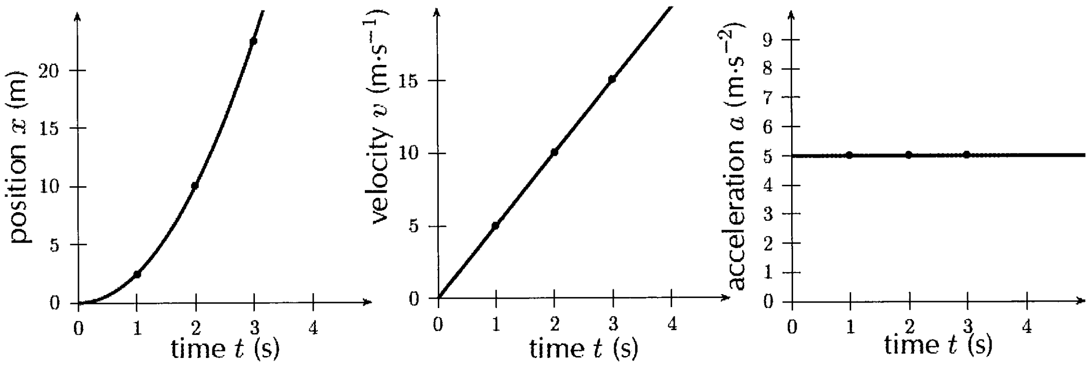
after 4 s I covered 40 m. The taxi is covering a larger distance every second. This means that the taxi is accelerating.

To calculate the velocity of the taxi, you need to calculate the gradient of the line at each second.

Velocity after 1s	Velocity after 2s	Velocity after 3s	Acceleration
$v = \frac{\Delta x}{\Delta t}$	$v = \frac{\Delta x}{\Delta t}$	$v = \frac{\Delta x}{\Delta t}$	$a = \frac{\Delta v}{\Delta t}$
$v = \frac{5-0}{1{,}5-0{,}5}$	$v = \frac{15-5}{2{,}5-1{,}5}$	$v = \frac{30-15}{3{,}5-2{,}5}$	$a = \frac{15-5}{3{,}5-0{,}5}$
v = 5 m·s^{-1}	v = 10 m·s^{-1}	v = 15 m·s^{-1}	a = 15 m·s^{-2}

The acceleration does not change, the gradient stays uniform. This is the motion of uniform acceleration.

Graphs of position vs. time, velocity vs. time and acceleration vs. time



We can use the acceleration vs. time graph to calculate the velocity by finding the area under the acceleration vs. time graph.
The velocity at 2s is:

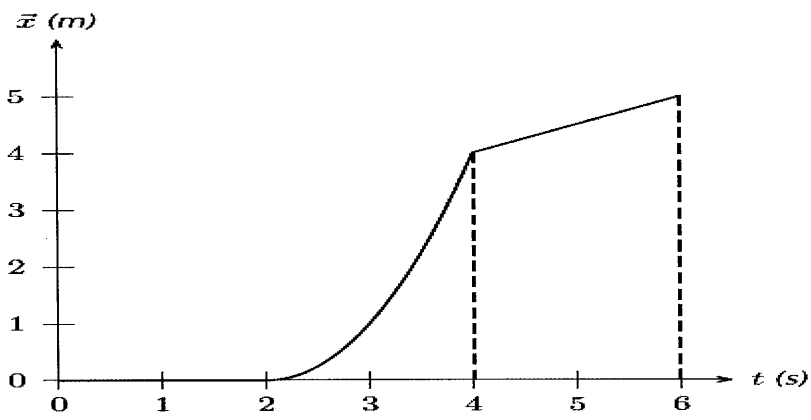
v = Area under graph
v = ℓ × b
v = 5 x 2
v = 10 m·s^{-1}

DESCRIBING THE MOTION OF AN OBJECT, DRAWING AND CAULCULATING THE DISTANCE, DISPLACEMENT, VELOCITY AND ACCELERATION

- We describe the motion of an object in terms of velocity and acceleration
- It is important to distinguish between motion at uniform motion and motion at uniform acceleration.
- For motion at uniform velocity, acceleration is zero.
- For motion at uniform acceleration, velocity is increasing or decreasing.
- We always state if displacement, velocity and acceleration are positive or negative.
- In an acceleration vs. time, the horizontal line with a positive value indicates positive acceleration.
- The horizontal line with a negative value indicates slowing down in a positive direction or speeding up in a negative direction.

EXAMPLE 1

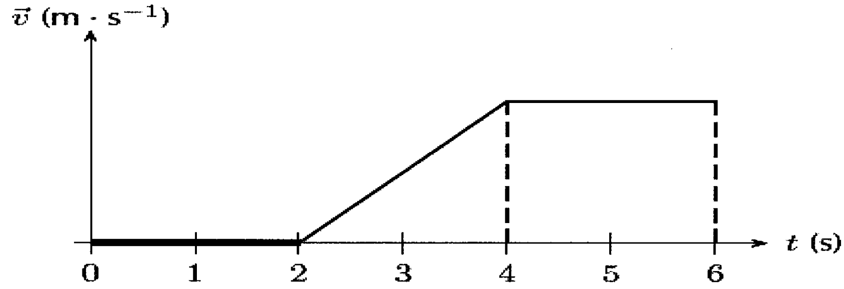
The position vs. time graph for the motion of a car is given below.



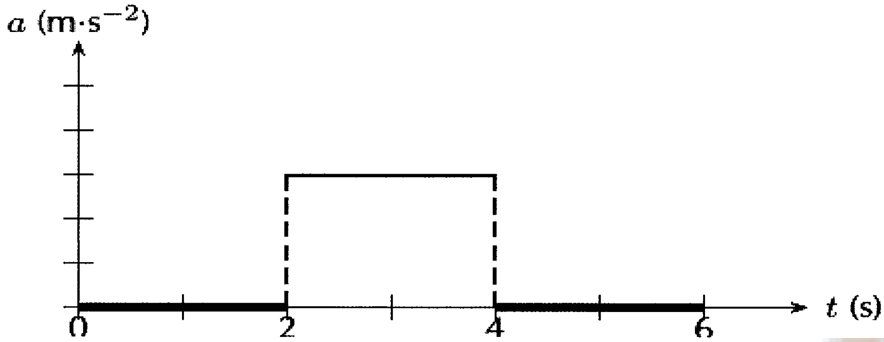
Describe the motion of the car.

- For the first 2 seconds, we see that the position (displacement) remains uniform, so the car is not moving, thus it has zero velocity during this time. The graph has a gradient of zero. The velocity during this time is zero, acceleration is also zero and the car is stationary.
- For the next 2 - 4 seconds, we see that the displacement is increasing with time, so the car is moving. The gradient is not uniform. The gradient of the graph is increasing as time increases. The gradient of position vs. time graph is the velocity, as the time increases the velocity also increases. The car acceleration is uniform.
- For the final 2 seconds, we see that the displacement is still increasing with time, but the gradient is uniform. The car is travelling at uniform velocity, acceleration is zero. The car is not accelerating.

The velocity time graph

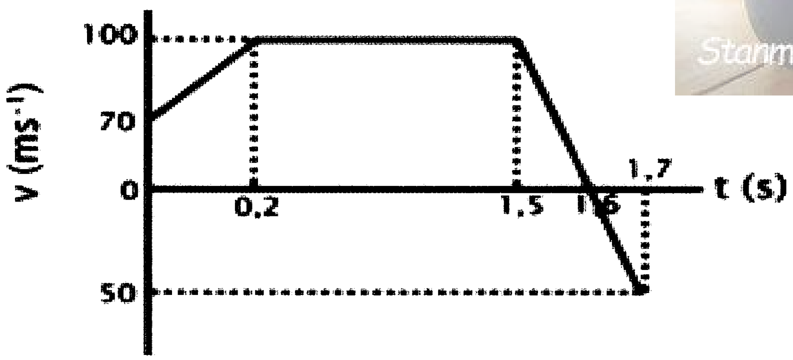


The acceleration vs. time graph



EXAMPLE 2

Consider the following velocity vs. time graph for the motion of Barry, as he chases after the bus headed west.



2.1. Describe Barry's motion for the 1,7s shown.

- For 0 – 0,2 second, Barry's acceleration is uniform.
- For 2,2 – 1,5 seconds, Barry's velocity is uniform, acceleration is zero.
- For 1,5 – 1,6 seconds, Barry's acceleration is uniform in the negative direction, velocity decreasing until he stops.
- For 1,6 – 1,7 seconds, Barry's acceleration is uniform from rest in the negative direction.

2.2. Calculate Barry's acceleration during the first 0,2s.

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

$$a = \frac{100 - 70}{0,2 - 0}$$

a = 150 m·s^{-2}

2.3. What is the total distance he covered in 1,6s.

Distance = Area

$= \frac{1}{2}$ (b x h) + (l x b) + (l x b) + $\frac{1}{2}$ (b x h)

$= \frac{1}{2}$ (0,2) (100 - 70) + (0,2) (70) + (1,5 - 0,2) (100) + $\frac{1}{2}$ (1,6 – 1,5)

= 152m

Distance = 152m

2.4. What is Barry's displacement after 1,7s.

Displacement = Area above – Area below

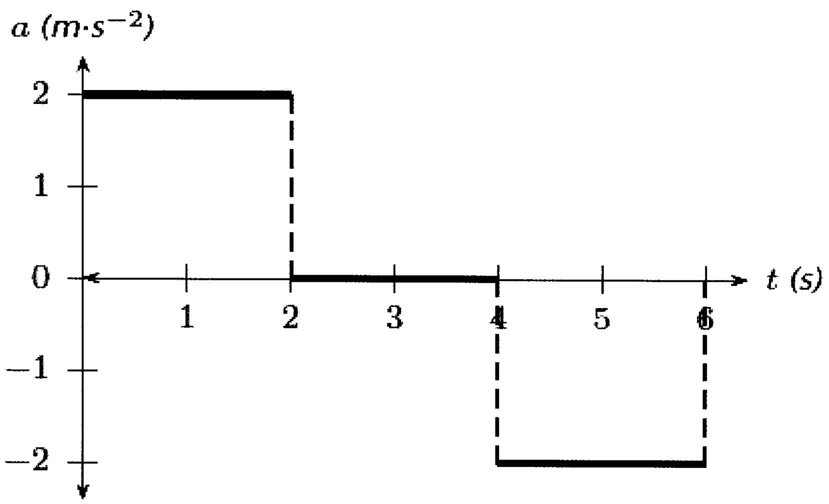
Displacement = 152 – $\frac{1}{2}$(1,7 – 1,6) (50)

Displacement = 152 – 2,5

Displacement = 149,50 m, west.

EXAMPLE 3

The acceleration vs. time graph for a car starting from rest, is given below.

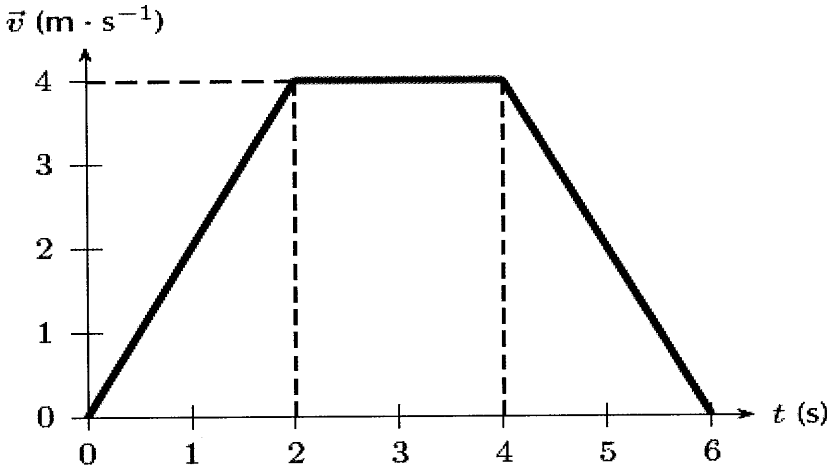


Calculate the velocity of the car and hence draw the velocity vs. time graph.

The velocity is equal to the area of the square under the graph

For 0 – 2s	For 2 – 4s	For 4 – 6s
Area = (l x b) Area = 2 x2 Area = 4m·s^{-1} The velocity of the car is 4m·s^{-1}	Area = (l x b) Area = 2 x 0 Area =0 m·s^{-1} The velocity of the car is 0 m·s^{-1}	Area = (l x b) Area =2 x -2 Area = -4 m·s^{-1} The velocity of the car is -4m·s^{-1} , negative means that the velocity is decreasing.

Velocity vs. time graph



USING THE EQUATIONS OF MOTION TO SOLVE PROBLEMS INVOLVING MOTION IN ONE DIMENSION IN HORIZONTAL PLANE ONLY

- Equations of motion are set of equations that enables us to calculate the quantities involved when the object is moving with constant acceleration.
- The following are the variables that will be used in the equations of motion

v_i - initial velocity
v_f - final velocity
a - acceleration
Δx - displacement
Δt - time taken

When the motion start form rest, the initial velocity is zero.

EQUATIONS OF MOTION

EXAMPLE 1

$v_f = v_i + a\Delta t$	$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$
$v_f^2 = v_i^2 + 2a\Delta x$	$\Delta x = \left(\frac{v_f + v_i}{2}\right)\Delta t$

An aircraft accelerates from rest at 10 m·s^{-2} down a runway. Calculate how fast it will be travelling after 45 s.

$v_f = v_i + a\Delta t$
$v_f = 0 + (10)(45)$
$v_f = 450$ m·s^{-1}, in the direction of the motion

EXAMPLE 2

Vusi starts his bicycle from rest at a speed of 6 m·s^{-1} for some time. If he covers a distance of 12min this time, what is his acceleration?

$v_f^2 = v_i^2 + 2a\Delta x$
$(6)^2 = (0)^2 + (2)(a)(12)$
$a = 1,5$ m·s^{-2}, in the direction of the motion

EXAMPLE 3

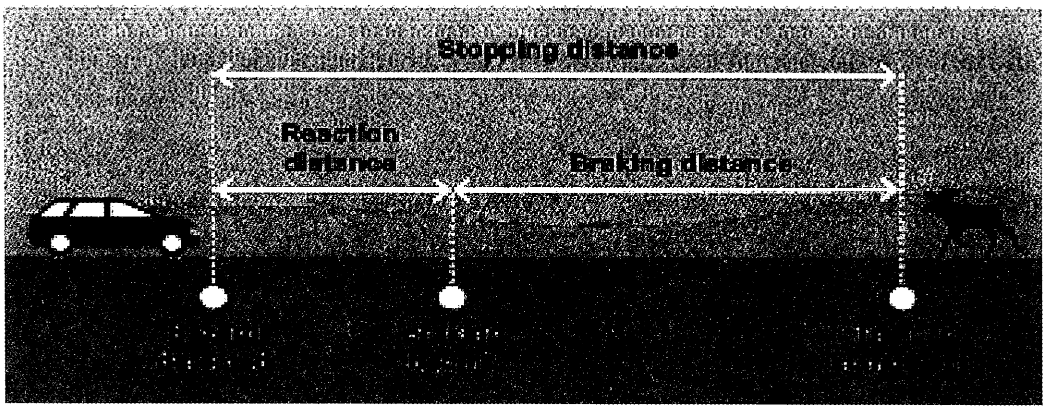
A car travelling along the road at 14 $m \cdot s^{-1}$. It accelerates at 2 $m \cdot s^{-2}$ for 6s. Calculate the displacement while accelerating.

$$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$$

$$\Delta x = (14)(6) + \frac{1}{2}(2)(6)^2$$

$\Delta x = 120\ m \cdot s^{-1}$, in the direction of the motion.

SOLVING PROBLEMS FOR THE MOTION OF A VEHICLE INCLUDING SAFETY ISSUES SUCH AS THE RELATIONSHIP BETWEEN SPEED AND STOPING DISTANCE



- **Braking distance** refers to the distance a vehicle will travel from the point when its brakes are fully applied to when it comes to a complete stop.
- **Stopping distance** is the distance covered between the time when the body decides to stop a moving vehicle and the time when the vehicle stops entirely.
- **Thinking distance** is the distance a vehicle travels in the time it takes for the driver to apply the brakes after realising they need to stop.
- **Reaction distance** is the distance you travel from the point of detecting a hazard until you begin braking or swerving.
- The reaction distance is affected by
- The car's speed (proportional increase):
  - 2 x higher speed = 2 x longer reaction distance.
  - 5 x higher speed = 5 x longer reaction distance.
- Your reaction times.
  - Normally 0.5–2 seconds, 45–54-year-olds have the best reaction time in traffic,18–24 year- olds and those over 60 have the same reaction time in traffic. Young people have sharper senses but older people have more experience.

- The reaction distance can be decreased by anticipation of hazards and preparedness.
- The reaction distance can be increased by the necessity of decision making (e.g. between braking or steering out of the way), alcohol, drugs, medication and tiredness.

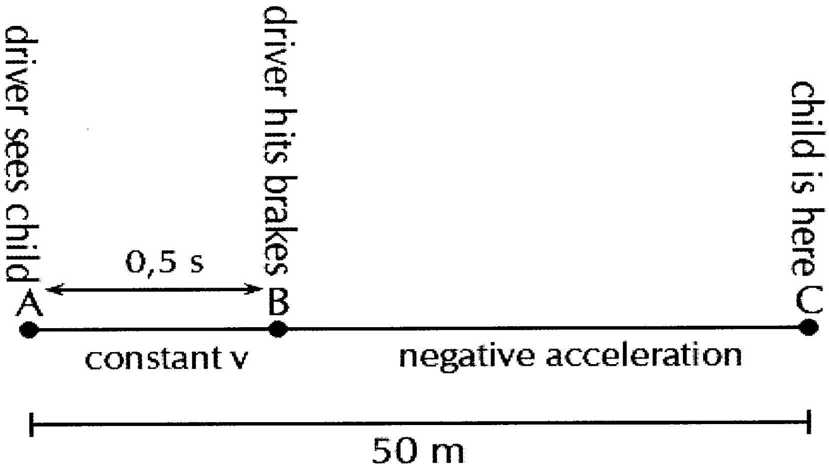
It is important to note that the thinking distance is proportional to the starting speed. This means that it increases proportionally as speed increases – i.e. if speed doubles, thinking distance also doubles. However, the braking distance increases by a factor of four each time the starting speed doubles.

The formula to calculate the stopping distance is

Stopping distance = thinking/reaction distance + braking distance

EXAMPLE

A truck is travelling at s constant velocity of 10 $m \cdot s^{-1}$ when the driver sees a child 50 m in front of him in the road. He hits the brake to stop the truck. The truck accelerates at a rate of -1,25 $m \cdot s^{-2}$. His reaction time to hit the brakes is 0,5 s. Will the truck hit the child?
It is important to draw a time-line like the following diagram.



1. What distance the driver covers before hitting the brakes, Calculate the distance AB (Reaction distance)

$$v = D$$
$$10 = \frac{D}{0,5}$$
$$D = 5m$$

2. How long it takes the truck to stop after hitting the brakes.

   Calculate the time taken to BC.

$$v_f = v_i + a\Delta t$$
$$0 = 10 + (-1,25)\,\Delta t$$
$$\Delta t = 8s$$

Calculate the distance BC

$$\Delta x = \left(\frac{v_f + v_i}{2}\right)\Delta t$$

$$\Delta x = \frac{(10+0)}{2}(8)$$
$$\Delta x = 40m$$

3. What total distance the truck cover to stop?
   Write the final answer.
   Total distance = $d_{AB} + d_{BC}$
   Total distance = 5 + 40
   Total distance = 45m

   OR

   Stopping distance = reaction distance + braking distance
   Stopping distance = 5 + 40
   Stopping distance = 45m

   The child is 50m ahead. The truck will not hit the child.

ACTIVITIES

VECTORS AND SCALARS

QUESTION 1

Consider the physical quantities mass, weight, distance, displacement, speed, velocity, acceleration and energy.

1.1 Give the name and abbreviation of the unit(s) in which each is measured. (8)

1.2 List those that are vector quantities and those that are scalar quantities. (8)

1.3 Using a scale of 10 mm to represent 10 m, draw vectors to represent:

1.3.1 a displacement of 50 m north (2)

1.3.2 a displacement of 80 m east (2)

1.4 Find the resultant of two forces F_1 = 50 N and F_2 = 80 N graphically:

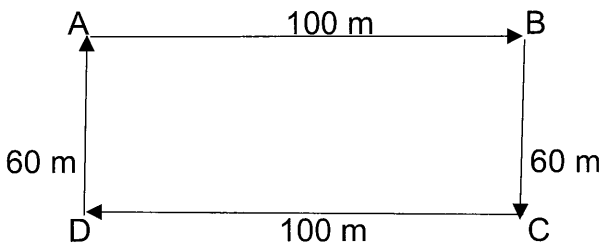
1.4.1 if they both act to the right (5)

1.4.2 if the 50 m vector acts to the right and the 80 m vector acts to the left (5)

1 1.4.3 if the 50 m vector acts to the left and the 80 m vector acts to the right (6)

QUESTION 2

2. Bongumusa Mthembu is training for the 2022 Comrades Marathon by running along a rectangular field as shown in the figure below. He runs 100 m from point A to B in 10 s, then 60 m to point C. He rests for 5 s and then sprints another 100 m along the width of the field to point D. He finally walks the last 60 m from D to A.



2.1 Determine his total distance covered when he reaches:

2.1.1 point B

2.1.2 point C

2.1.3 point D

2.1.4 point A

2.2 Determine his total displacement covered when he reaches:

2.2.1 point B

2.2.2 the end of his run

INSTANTANEOUS SPEED, VELOCITY AND EQUATIONS OF MOTION

Equations of Motion

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

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

$v_f = v_i + a\Delta t$

$v_f^2 = v_i^2 + 2a\Delta x$

$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$

QUESTION 3

3. Define the following terms

3.1. Instantaneous velocity (2)

3.2 Instantaneous speed (2)

3.3. Reaction distance (2)

3.4. Stopping distance (2)

QUESTION 4

4. Thoko is driving her bicycle. Assume that the direction of her initial velocity is positive.

4.1. If Thoko increases the speed while moving in the positive direction, what is the direction of her acceleration? (1)

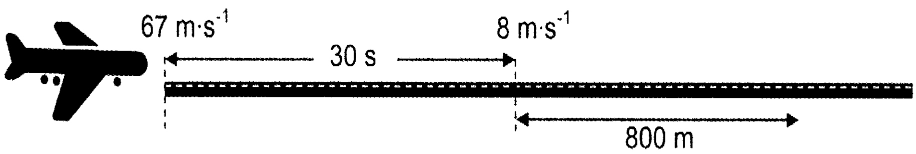
4.2. If Thoko decreases the speed while moving in the positive direction, what is the direction of her acceleration? (1)

4.3. If Thoko increases the speed while moving in the negative direction, what is the direction of her acceleration? (1)

4.4. If Thoko decreases the speed while moving in the negative direction, what is the direction of her acceleration? (1)

QUESTION 5

An aeroplane touches down on a runway at a velocity of 67 $m \cdot s^{-1}$, as illustrated below. After 30 seconds the velocity of the aeroplane is 8 $m \cdot s^{-1}$. The aeroplane then continues at a CONSTANT VELOCITY for a further 800 m before leaving the runway. The length of the runway is 2 000 m.



5. Calculate the:

5.1. Acceleration of the aeroplane during the first 30 seconds (4)

5.2. Distance travelled by the aeroplane during the first 30 seconds (4)

5.3. Time taken by the aeroplane to travel the 800 m (3)

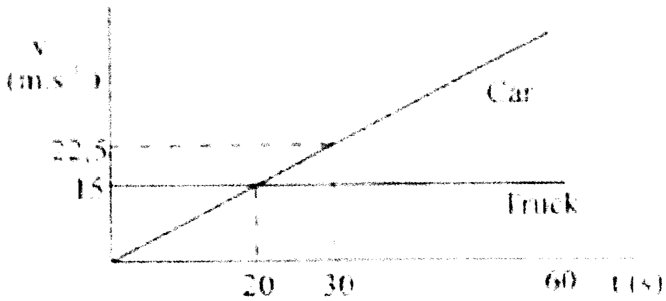
5.4. Length of the runway NOT USED when the aeroplane leaves the Runway

5.5 How should a pilot adapt the landing speed if the surface of the runway is wet? Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

5.6 Explain the answer to QUESTION 3.5. by referring to the stopping distance in relation to the landing speed. (2)

QUESTION 6

6. A car stops at a traffic light. When the light turns green, the car pulls of and accelerate uniformly. At the moment when the car starts to move, a truck passes it at a constant speed of 15m·s^{-1}. The graph below represents the speeds of the two vehicles for the first 60s. use the to answer the following question.



6.1. At what time will the car and the truck will have the same speed? (1)

6.2. What is the distance between the car and the truck after the first 30 seconds? (5)

6.3. Calculate the acceleration of the car. (3)

QUESTION 7

7. A bus on a straight road starts from rest at a bus stop and accelerates at 2 m·s^{-2} until it reaches a speed of 20 m·s^{-1}. Then the bus travels for 20 s at a constant speed until the driver sees the next bus stop in the distance. The driver applies the brakes, stopping the bus in a uniform manner in 5 s.

7.1. How long does the bus take to travel from the first bus stop to the second bus stop? (4)

7.2. Determine the average velocity of the bus during the trip. (7)