KWAZULU-NATAL PROVINCE

EDUCATION
REPUBLIC OF SOUTH AFRICA

CURRICULUM GRADE 10 -12 DIRECTORATE

NCS (CAPS)

LEARNER SUPPORT DOCUMENT

GRADE 11

PHYSICAL SCIENCES

JUST IN TIME

REVISION DOCUMENT

2024

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:

ATOMIC COMBINATIONS

MOLECULAR STRUCTURE

- The structure mainly depends on the type of chemical bond (force) that exists between the atoms that the molecule consists of.

RULES FOR BOND FORMATION

Different atoms:

- each with an unpaired valence electron, can share these electrons to form a chemical bond
  example: two H atoms form a H_2 molecule by sharing an electron pair
- with paired valence electrons, called lone pairs, cannot share these 4 electrons and cannot form a chemical bond
  example: no bond forms between 2 He atoms
- with unpaired valence electrons, can share these electrons and form a chemical bond for each electron pair shared (multiple bonds can be formed)
  example: two O atoms form an O_2 molecule.

Atoms with an empty valence shell can share a lone pair of electrons from another atom to form a coordinate bond or a dative covalent.

- example: in NH_4^+ the lone pair of nitrogen from NH_3 is shared with H^+

CHEMICAL BONDS

A chemical bond is the net electrostatic force that two atoms sharing electrons exert on each other.

- Bonding occurs when valence electrons are shared between two atoms or transferred from one atom to another.
- Valence electrons correspond to the group number of an element in the Periodic table
- Valence electrons: Valence electrons or outer electrons are the electrons in the highest energy level of an atom in which there are electrons.
- The type of bond that forms is dependent on the electronegativity difference (ΔEN) between the atoms.
- Electronegativity is a measure of the tendency of an atom in a molecule to attract bonding electrons. If one atom has a greater electronegativity than another, the electrons will be pulled more towards one atom than another. Such a shift of electrons creates negative and positive charge distributions inside the molecule.
  - ΔEN = 0: Non-polar (pure) covalent
  - ΔEN < 1: Weakly polar covalent
  - ΔEN >1: polar covalent
  - ΔEN > 2,1: Ionic (transfer of electrons)
  - ΔEN > 3: purely ionic

Types of bonds and molecules

- Non-polar bond: a bond in which the electron density is shared equally between the two atoms
  Example: H – H
- EN (H) = EN (H): Bonding electrons are evenly shared. Charge is evenly distributed, and no dipole formed.
  ΔEN = 2,1 – 2,1 = 0
- Polar bond: a bond in which the electron density is shared unequally between the two atoms.
- Example: H – C*l*
- EN (C*l*) > EN (H): Electrons shift towards chlorine. Chlorine is slightly negative (δ−) and hydrogen is slightly positive (δ+).
  ΔEN = 3,0 – 2,1 = 0,9
- Polar molecule: A molecule over which charge is distributed unevenly.
  Example: H_2O
- Non-polar molecule: A molecule over which the harge is evenly distributed.
-

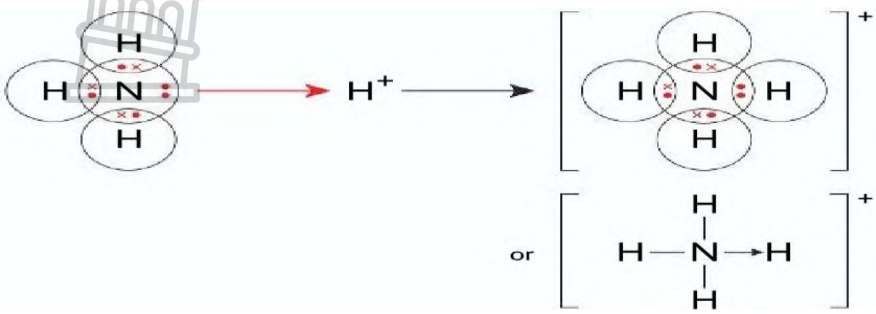
Covalent Bonding (Between non-metals)

- Covalent bonding involves the sharing of electrons between two atoms to form a molecule.
- The covalent bond may be non-polar, weakly polar or polar.
- A non-polar (pure) covalent bond is a bond in which the electron density is shared equally between the two atoms.
  example:
  Two chlorine atoms are joined by a non-polar covalent bond (C*l* – C*l*)
  EN for chlorine atom is 3,0.
  ΔEN = 3,0 – 3,0 = 0
- In a weakly polar covalent bond there is an unequal sharing of electrons
  example:
  A hydrogen atom and a bromine atom are joined by a weakly polar bond
  (H – Br)
  EN for hydrogen is 2,1 and EN for Br is 2,8.
  ΔEN = 2,8 – 2,1 = 0,7
- A polar covalent bond has an unequal sharing of electrons leading to a dipole forming
- example:

A hydrogen atom and an oxygen atom are joined by a polar covalent bond (H_2O)
EN for oxygen atom is 3,5.
$\Delta EN = 3,5 - 2,1 = 1,4$

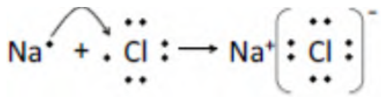
- bonds between them. If two pairs of electrons are shared, a double bond is formed, e.g. between two O atoms to form H_2O.
- Atoms with an empty valence shell can share a lone pair of electrons from another atom to form a coordinate covalent or dative covalent bond, e.g. in NH_4^+ the lone pair of nitrogen is shared with H^+ and in H_3O^+ the lone pair of oxygen is shared with H^+.

Example (NH_3)



Ionic Bonding (between metals and non-metals)
Show how the ionic bond is formed between the sodium and the chlorine atoms.

1. $Na - 1e^- \rightarrow Na^+$ (Na atom loses one electron and becomes a positive ion called a cation)
2. $Cl + 1e^- \rightarrow Cl^-$ (Cl atom gains one electron and becomes a negative ion an anion)
3. $Na^+ + Cl^- \rightarrow NaCl$ (electrostatic attraction between the two ions lead to a formation of giant crystal lattice)

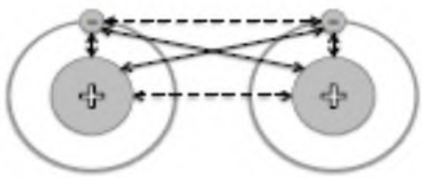


Metallic Bonding (between metals)

- Metallic bonding forms between the positive metal kernels and the sea of delocalized electrons.
- The metal atoms release their valence electrons to surround them.
- There is a strong but flexible bond between the positive metal kernels and a sea of delocalised electrons

BOND ENERGY

- Bond energy is required to break one mole of its molecules into separate atoms.



- There are various attractive and repulsive forces at play between the two atoms during bonding.
- Attractive forces between the protons of one atom and the electrons of another.
- Attractive forces between the protons and electrons from the same atom.
- A repulsive force between the protons from each atom.
- A repulsive force between the electrons from each atom.
- The net electrostatic forces will determine bond strength, which can be quantified as the bond energy. This is the energy required to break the bond, or it is the energy released when bonds are formed.

FACTORS INFLUENCING BOND STRENGTH

- Bond length
  The shorter the length of the bond, the stronger the bond.

- Atom size

The smaller the atoms, the stronger the bond.

- Bond order
  The more bonds (double, triple bonds etc.) between the atoms, the stronger the bond.

BOND LENGTH
Bond length: The average distance between the nuclei of two bonded atoms.
As the atoms get closer, the attractive forces get stronger until the minimum possible potential energy is reached (bond energy). The distance between the nuclei of the atoms at the minimum potential energy

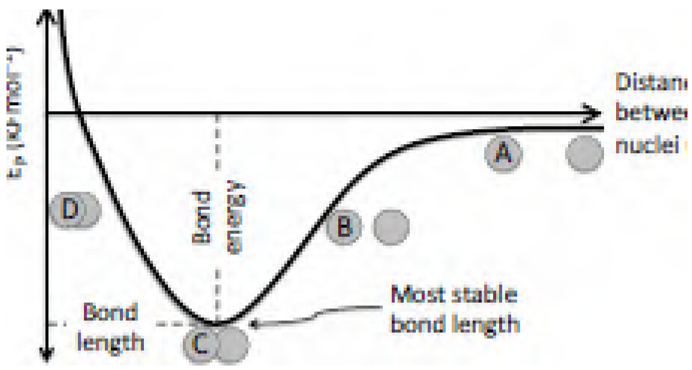
is the bond length. If the two atoms get closer than the bonding length, they will be forced apart by the repulsive forces, increasing the potential energy.

FACTORS INFLUENCING BOND LENGTH

- Atom size
  The smaller the atoms, the shorter the bond.
- Bond order
  The more bonds (double, triple bonds etc.) between the atoms, the shorter the bond.
- Difference in electronegativity (ΔEN). The greater the ΔEN, the shorter the bond.

Process of bond formation

- Atoms are infinitely separated; potential energy is nearly zero.
- As the atoms move closer, the forces of attraction and repulsion increase until the forces of attraction dominate.
- The lowest, most stable energy state reached, chemical bond forms.
- Atoms move too close, forces of repulsion increase, potential energy increases



Worked example 1

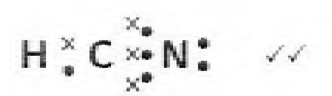
Hydrogen cyanide (HCN) is a very poisonous compound used in the manufacturing of plastics, mining of gold and as a poison.

1.1	Define the term chemical bond.		(2)
1.2	Draw Lewis structures for:		
	1.2.1	HCN	(2)
	1.2.2	H_2O	(2)
1.3	What is the shape of the HCN molecule?		(1)
1.4	Calculate the electronegativity difference for the CN bond.		(2)
1.5	What is polarity of the HCN molecule? Write only POLAR or NON-POLAR.		(1)
			[10]

SOLUTION

1.1 Chemical bond is mutual attraction between two atoms resulting from the simultaneous attraction between their nuclei and (outer) electrons ✓✓ (2)

1.2 1.2.1



(2)

1.2.2 (2)

```
        ●●
    H ×● O●●      ✓✓
        ×●
        H
```

1.3 Linear ✓ (1)

1.4 =2.4 3 – 2,5 ✓ (2)

= 0,5 ✓

1.5 Polar ✓ (1)

Worked example 2

2.1 Draw the Lewis diagram of a methane molecule. (2)

2.2 What is the name of the special kind of bond found inside the methane molecule? (1)

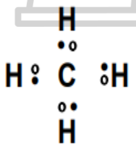
2.3 Answer the following questions about magnesium chloride:

2.3.1 Make use of Lewis diagrams to indicate the transfer of electrons between magnesium and chlorine. (4)

2.3.2 Magnesium chloride is an ionic substance. Prove this statement with an appropriate calculation. (3)

SOLUTION (2)

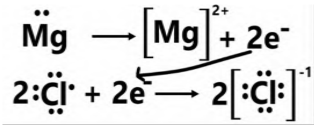
2.1



✓✓

2.2 covalent bond ✓ (1)

2.3 (4)



✓✓✓✓

2.4 (2)

EN=3,0-1,2✓
=1,8 ✓ (Cl = 3,0 Mg = 1,2)

ACTIVITIES
QUESTION 1

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number.

1.1 The type of bond formed between a H^+ ion and H_2O is called a/an … (hydrogen ion with molecule of central atom with lone pair electrons)

A hydrogen bond.
B dative covalent bond
C ionic bond.
D covalent bond (2)

1.2 The bond energy of a C–Cℓ bond is 338 $kJ.mol^{-1}$ whereas the bond energy of a C–I bond is 238 $kJ.mol^{-1}$. The difference in bond energy exists because …... (relationship between bond length and bond energy)

A the bond length of the C–Cℓ bond is greater than that of the C–I bond.
B chlorine is more electronegative than iodine.
C the bond length of the C–I bond is greater than that of the C–Cℓ bond.
D the chlorine atom is bigger than the iodine atom. (2)

1.3 If the total bond enthalpy for methane (CH_4) is 1652 kJ mol^{-1} and ethane (C_2H_6) is 2826 kJ mol^{-1}, what is the strength of a C–C bond? (Calculating of bond energies)

A 1,71 $kJ.mol^{-1}$
B 348 $kJ.mol^{-1}$
C 1 174 $kJ.mol^{-1}$
D 4 478 $kJ.mol^{-1}$ (2)

1.4 Which one of the following statements concerning the length of carbon-carbon single, double and triple covalent bond is true? (Relationship between number of bonds and bond length)

A The carbon-carbon single bond is shorter than either the carbon-carbon double or triple bond.
B The carbon-carbon double bond is shorter than either the carbon-carbon single or triple bond.

C The carbon-carbon triple bond is shorter than either the carbon-carbon single or double bond.

D The carbon-carbon single, double, and triple bonds all have the same (2)

1.5 The electron configuration of an element is $1s^2$, $2s^2$, $2p^4$. The valency of this element is:

A 1
B 2
C 3
D 4 (2)

QUESTION 2

Electronegativity of atoms may be used to explain the polarity of bonds.

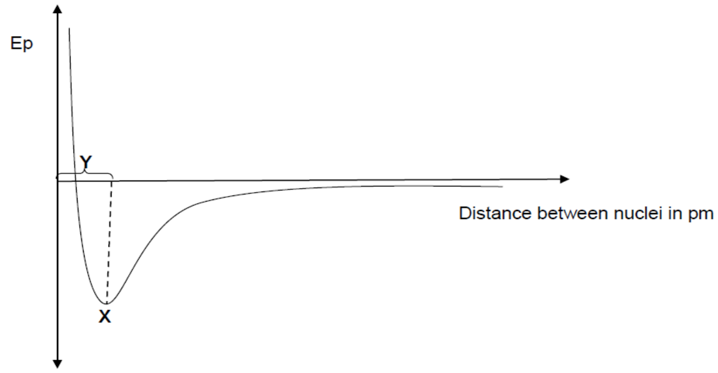
2.1 Define the term electronegativity. (2)

2.2 Draw the Lewis diagram of an oxygen difluoride molecule. (3)

2.3 Calculate the electronegativity difference between O and F in oxygen difluoride and predict the polarity of the bond.
Refer to this guideline:

- ΔEN = 0: non-polar (pure) covalent
- ΔEN < 1: Weakly polar covalent
- ΔEN >1: polar covalent
- ΔEN > 2,1: Ionic (transfer of electrons)
- ΔEN > 3: purely ionic (3)

2.4 Study the diagram below and answer questions that will follows



2.4.1 What do X and Y represent? (2)

2.4.2 Define the concept represented by X. (2)

2.4.3 Explain the relationship between bond order, bond length and bond energy. (3)

QUESTION 3

Molecules such as CO_2 and H_2O are formed through covalent bonding.

3.1 Define the term *covalent bonding*. (2)

3.2 ONE of the above molecules has lone pairs of electrons on the central atom.

3.2.1 Draw the Lewis diagram for this molecule. (2)

3.2.2 Draw the Lewis diagram for the H_3O^+ ion (2)

3.2.3 State TWO conditions for the formation of such a bond. (2)

3.3 The polarity of molecules depends on the DIFFERENCE IN ELECTRONEGATIVITY and the MOLECULAR SHAPE

3.3.1 Define the term *non-polar covalent bond*. (2)

3.3.2 Calculate the difference in electronegativity between:

a) C and O in CO_2 (2)

b) H and O in H_2O (2)

3.4 Explain the difference in polarity between CO_2 and H_2O by referring to the polarity of the bonds. (6)

QUESTION 4

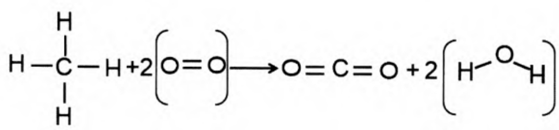
A group of learners decide to investigate the relationship between bond energy and bond length. The data is collected theoretically as shown in the table below:

BOND	BOND LENGTH (pm)	BOND ENERGY ($kJ.mol^{-1}$)
C≡C	120	839
C=O	123	804
O=O	121	498
C–C	154	348
H–O	96	463
H–C	109	413

4.1 Write down investigative question for this investigation (2)

4.2 Apart from bond length, name TWO other factors that influence bond energy (2)

4.3 In a combustion reaction, methane burns oxygen to form carbon dioxide and water. The balanced reaction showing bonds is given below:



Using the table above, determine whether there is a net release or a net absorption of energy in this reaction. (6)

4.4 Which ONE of the following bond energies is correct for the C=C bond? Choose from **880 $kJ.mol^{-1}$, 540 $kJ.mol^{-1}$ or 320 $kJ.mol^{-1}$**. Explain the choice. (4)

QUESTION 5

Consider the following molecules and answer the questions that follow:

A	B	C	D	E
SO_2	HCl	H_2	HOCl	H_2O

5.1 5.1 Consider molecule A (1)

5.1.1 Draw the Lewis Dot structure. (2)

5.1.2 Name the type of bonding between the atoms of molecule A. Give a reason for the answer. (2)

5.2 Write down the NAME or FORMULA of a non-polar molecule from the list above. (1)

5.3 Is the bond in molecule B POLAR or NON-POLAR? (3)
Explain your answer with the aid of a relevant calculation.

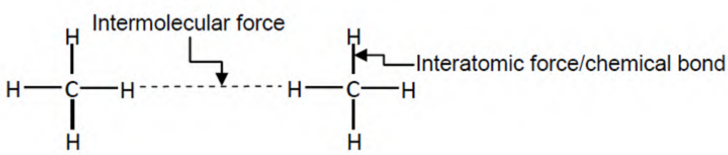
5.4 5.4.1 bonding electron pairs (1)

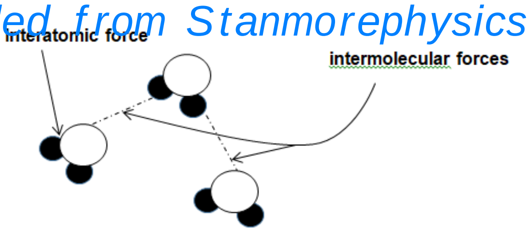
5.4.2 lone pairs (1)

INTERMOLECULAR FORCES

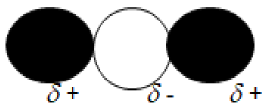
- Intermolecular forces are forces of attraction between molecules in a substance.
- Intermolecular forces are weak forces of attraction between molecules or between atoms of noble gases
- Intermolecular forces are not the same as intramolecular bonds.
- Intramolecular (interatomic) bonds exist between atoms in a molecule.
- The intermolecular forces are **weaker** than interatomic forces.

Examples of intermolecular forces and intramolecular (interatomic)forces



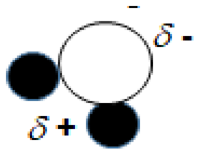


- Molecules can be **polar** or **non-polar**.
- The polarity of a molecule is determined by two factors:
  - The difference in electronegativity between the bonding atoms.
  - The geometry (shape) of a molecule
- **Non-polar molecules** have no dipoles (positive and negative ends) e.g., CO_2



Polar molecule

- In polar molecule there are ∂+ and ∂- ends e.g., H_2O and the geometry of the water molecule is angular (bent).



- H_2O molecule has H-end being ∂+ and O-end being ∂-, it has **dipoles.** The molecule is polar

- **Non-polar bonds:**
  - H_2 is non-polar because the two atoms are identical, there is even or symmetrical distribution of charge, this makes H_2 a non-polar molecule.

TYPES OF INTERMOLECULAR FORCES

- Different intermolecular forces (Van der Waals forces) ARE:
  - Mutually induced dipole forces or London forces: Forces between non-polar Molecules
  - Dipole-dipole forces: Forces between two polar molecules
  - Dipole-induced dipole forces: Forces between polar and non-polar molecules
  - Hydrogen bonding: Forces between molecules in which hydrogen is covalently bonded to nitrogen, oxygen, or fluorine – a special case of dipole-dipole forces
  - Ion-dipole forces: Forces between ions and polar molecules

Factors(Physical properties) affecting the strength of intermolecular forces

Boiling point and melting point

- Intermolecular forces dictate several properties, such as melting points, boiling points, solubilities of substances, vapour pressure, viscosity etc.
- **Boiling point** is the temperature at which the vapour pressure of a substance equals atmospheric pressure. The stronger the intermolecular forces, the higher the boiling point.
- **Melting point** is the temperature at which the solid and liquid phases of a substance are at equilibrium. The stronger the intermolecular forces, the higher the melting point.
- A liquid with high boiling point, like water (H_2O, b.p. 100 °C), exhibits stronger intermolecular forces compared to a liquid with low boiling-point, like hexane (C_6H_{14}, b.p. 68.73 °C).

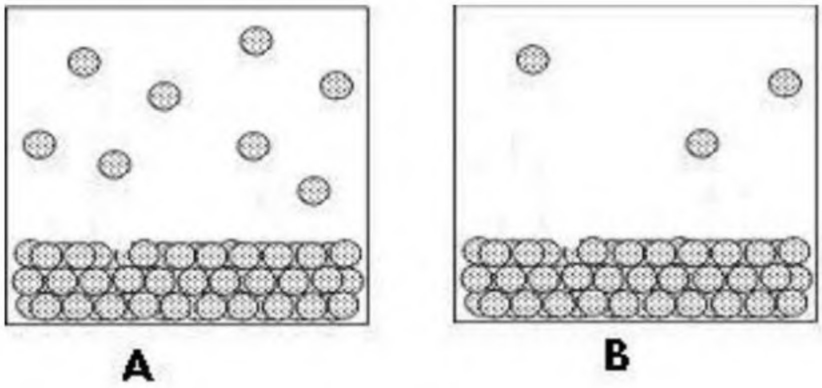
Solubility

- **Solubility** is the property of a solid, liquid, or gaseous chemical substance (solute) to dissolve in a solid, liquid, or gaseous solvent to form a homogeneous solution.
- Miscible liquids have similar polarities.
- For example, methanol and water are miscible and are both polar and capable of hydrogen bonding.
- When methanol and water are mixed, they interact through intermolecular hydrogen bonds of comparable strength to the methanol–methanol, and water–water interactions; thus, they are miscible.
- Likewise, nonpolar liquids like hexane and bromine are miscible with each other through dispersion forces.
- The chemical axiom “like dissolves like” is useful to predict the miscibility of compounds.

- For example, non-polar hexane is immiscible in polar water. Relatively weak attractive forces between the hexane and water do not adequately overcome the stronger hydrogen bonding forces between water molecules

Vapour Pressure

- **Vapour pressure** is the pressure exerted by a vapour at equilibrium with its liquid in a closed system. The stronger the intermolecular forces, the lower the vapour pressure.
- At the surface, some molecules of a liquid have enough kinetic energy to break their attractive forces with neighbouring molecules.
- These molecules escape from the liquid phase and form a gas above the surface of the liquid. If there is a lid, pressure develops.



- In the picture above, A has more gas, meaning gas molecules are breaking away from the liquid state easier than molecules in B.
- The intermolecular forces must be weaker in A than in B.
- Molecules in A are less attracted to each other than molecules in B.
- Intermolecular forces in A are weaker than those in B.

WORKED EXAMPLE: INTERMOLECULAR FORCES
QUESTION 1
Which intermolecular forces are found in?

1.1 hydrogen fluoride (HF) (1)
1.2 methane (CH_4) (1)
1.3 potassium chloride in ammonia (KCl in NH_3) (1)
1.4 krypton (Kr) (1)
[4]

SOLUTIONS

1.1 Dipole-dipole✓ (1)
1.2 London Forces✓ (1)
1.3 Ion dipole forces✓ (1)
1.4 London forces✓ (1)
[4]

MULTIPLE CHOICE QUESTIONS
QUESTION 1

1.1 Hydrogen bonds and London forces (induced dipole forces) have a common characteristic in that they …

A. are both stronger than chemical bonds.
B. both occur between non-polar molecules.
C. both occur between polar molecules.
D. are both intermolecular forces.

(2)

1.2 Which ONE of the following has the strongest forces between its molecules?

A. F_2
B. $C\ell_2$
C. Br_2
D. I_2

(2)

1.3 Solid iodine sublimes easily. The intermolecular forces present in iodine are …

A. London forces.
B. hydrogen bonding.
C. ion-dipole forces.
D. dipole-dipole forces.

 (2)

1.4 The intermolecular forces in dry ice (CO_2) are …

A. ion-induced dipole forces.
B. hydrogen bonding.
C. ion-dipole forces.
D. London forces. (2)

1.5 The table below shows the melting points of water (H_2O) and hydrogen bromide (HBr).

Compounds	Melting point (K)
H_2O	273
HBr	159

Which combination below CORRECTLY lists the strongest intermolecular forces in H_2O and HBr that explain the relatively high melting points of these compounds?

	In H_2O there are:	In HBr there are:
A	Hydrogen bonds	London forces
B	Hydrogen bonds	Dipole-dipole forces
C	Dipole-dipole forces	Hydrogen bonds
D	London forces	Hydrogen bonds

ACTIVITIES: LONG QUESTIONS
QUESTION 2

The reaction below is used in the Haber process to manufacture ammonia.
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

The boiling points of the substances in the reaction are as follows:

SUBSTANCE	BOILING POINT(ºC)
H_2	-252,9
N_2	-195,8
NH_3	-33,3

(3)

2.1 Refer to the intermolecular forces and explain the difference in boiling point between NH_3 and N_2.
2.2 Write down the FORMULA of the substance in the table that will have the lowest melting point. (1)
2.3 Explain why H_2 will evaporate faster than N_2. Refer to the type and relative strength of the intermolecular forces. (3)
2.4 Write down the FORMULA of the substance in the table that will have the highest vapour pressure. Explain your answer. (3)

QUESTION 3

3.1 The boiling points of compounds A to E are given in the table below

COMPOUND	FORMULA	BOILING POINT (°C)
A	CH_4	–164
B	C_2H_6	–89
C	C_5H_{12}	36
D	C_6H_{14}	69
E	$C_{20}H_{42}$	343

3.1.1 Define the term boiling point. (2)
3.1.2 Calculate the molecular mass of compound D. (1)
3.1.3 In what phase is compound B at 25 °C? (1)
3.1.4 Name the type of intermolecular force present in compound A. (1)
3.1.5 Explain why the boiling point increases from compound A to E. (3)

3.1.6 How does the vapour pressure of compound B compare to the vapour pressure of compound C? Write down only HIGHER THAN, LOWER THAN or EQUAL TO. (1)

3.2 Consider the boiling points of the compounds in the table below.

SUBSTANCE	BOILING POINT (°C)
H_2S	–60
NH_3	–33
H_2O	100

3.2.1 Which ONE of the substances in the table above has the weakest forces between its molecules? (1)

3.2.2 Name the type of intermolecular force found between NH3 molecules. (1)

3.2.3 Explain the following statement:

Although the shape of the molecules of H_2S and H_2O is similar, there is a remarkable difference in their boiling points. (4)

QUESTION 4

The following table gives the melting points of various hydrides:

Hydride	Melting point (℃)
HI	-34
NH_3	-33
H_2S	-60
CH_4	-164

4.1 In which of these hydrides does hydrogen bonding occur?

A HI only

B NH_3 only

C HI and NH_3 only

D HI, NH_3 and H_2S (2)

4.2 Draw a graph to show the melting points of the hydrides. (4)

4.3 Explain the shape of the graph (2)

4.4 The respective boiling points for four chemical substances are given below:

Hydrogen sulphide	−60 ℃
Ammonia	−33 ℃
Hydrogen fluoride	20 ℃
Water	100 ℃

4.4.1 Which substance has the lowest vapour pressure? (1)

4.4.2 Which one of the substances exhibit the strongest forces of attraction between its molecules in the liquid state? (1)

4.4.3 Give the name of the force responsible for the relatively high boiling points of hydrogen fluoride and water and explain how this force originates. (3)

4.4.4 The shapes of the molecules of hydrogen sulphide and water are similar, yet their boiling points differ. Explain. (3)

4.5 Simphiwe states that van der Waals forces include ion-dipole forces, ion-induced dipole forces and induced dipole forces.

Thembile states that van der Waals forces include dipole-induced dipole forces, dipole-dipole forces and induced dipole forces.

4.5 Who is correct? and why? (3)

QUESTION 5

Jason and Bongani are arguing about which molecules have which intermolecular forces. They have drawn up the following table:

Compound	Compound
Potassium iodide in water KI (aq)	Potassium iodide in water KI (aq)
Hydrogen sulphide (H_2S)	Hydrogen sulphide (H_2S)
Helium (He)	Helium (He)
Methane (CH4)	Methane (CH_4)

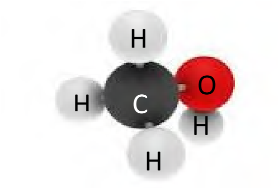
5.1 Jason says that hydrogen sulphide (H_2S) is non-polar and so has induced dipole forces. Bongani says hydrogen sulphide is polar and has dipole-dipole forces. Who is correct and why? (3)

5.2 Bongani says that helium (He) is an ion and so has ion-induced dipole forces. Jason says helium is non-polar and has induced dipole forces. Who is correct and why? (3)

5.3 They both agree on the rest of the table. However, they have not got the correct force for potassium iodide in water (KI (aq)). What type of force exists in this compound? (2)

QUESTION 6

Consider the following three compounds below:



Substance: *Methanol*
Formula: CH_3OH
Phase at room temperature: liquid
Molar mass: 32,04 $g.mol^{-1}$
Boiling point: 64,07°C

Substance: *Methane*
Formula: CH_4
Phase at room temperature: gas
Molar mass: 16,04 $g.mol^{-1}$
Boiling point: -164°C

Substance: *Tetrachloromethane*
Formula: CCl_4
Phase at room temperature: liquid
Molar mass: 153,82 $g.mol^{-1}$
Boiling point: 76,72°C

6.1 Identify the inter-molecular forces found in methane gas. (1)

6.2 Explain how these forces are formed. (2)

6.3 By identifying and comparing the intermolecular forces, provide a detailed explanation for:

6.3.1 the difference in boiling points of methane and tetrachloromethane (3)

6.3.2 the fact that methanol is miscible (dissolves) in water, but Tetrachloromethane is not. (4)

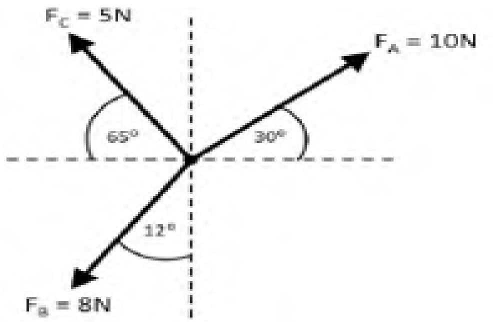
VECTORS IN 2 DIMENSIONS

- **Vector**- A physical quantity with magnitude and direction.

  (Example: force, displacement, velocity, acceleration, electric field, etc.)
- **Scalar**- A physical quantity with magnitude only.

  (Example: time, temperature, charge, work, Energy, distance, speed etc.)
- A **resultant** – is the single vector having the same effect as two or more vectors together.
- An **equilibrant** – is the force that brings equilibrium to a system of forces. It is equal in magnitude but acts in opposite direction to the resultant.
- The direction of a vector that is not horizontal or vertical (acting at an angle) can be described using different methods.

X and Y axes



F_A: 10 N at 30° above the positive x- axis (horizontal axis)

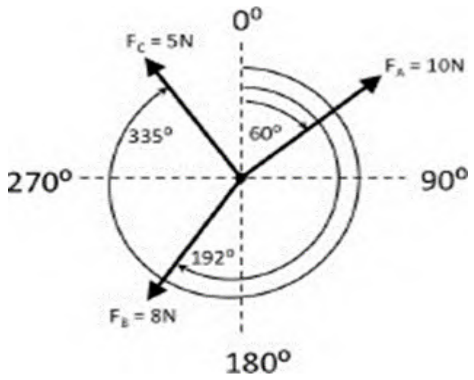
F_B: 8 N at 12° left of the negative y- axis (vertical axis)

F_C: 5 N at 65° above the negative x- axis (horizontal axis)

Bearing

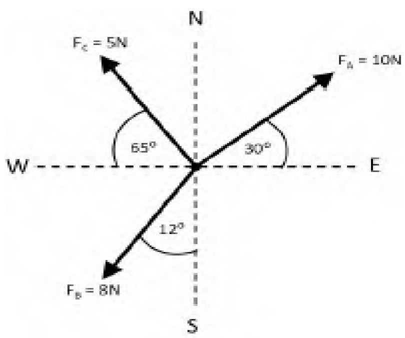
Only for vectors in the horizontal plane i.e. parallel to the surface of the Earth.

Use North as 0° and always measure **clockwise**.



F_A : 10 N on a bearing of 60° F_B : 8 N on a bearing of 192° F_C : 5 N on a bearing of 335°

Compass (Cardinal points or directions)



NB: The 30° N of E means you start from east and move 30° towards the North

F_A : 10 N at 30° North of East

F_B : 8 N at 12° West of South

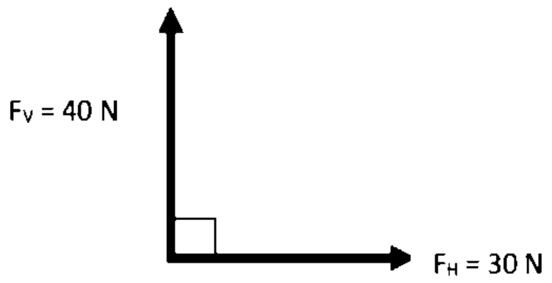
F_C : 5 N at 65° North of West

RESULTANT OF VECTORS

Resultant of perpendicular vectors

- Perpendicular vectors are at right angles to each other
- A horizontal force of 30 N and a vertical force of 40 N that act on an object are an example of two forces that are perpendicular to each other.

Diagram



Adding co-linear vectors

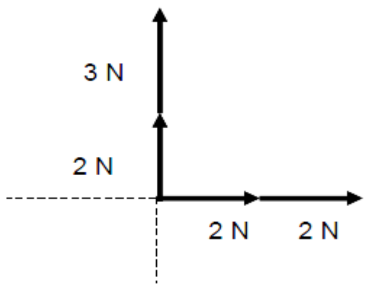
- Co-linear vectors are simply vectors that lie in the same straight line.
- The net x-component (Rx) is the sum of the vectors parallel with the

  x-direction: $R_x = R_{x1} + R_{x2}$
- The net y-component (Ry) is the sum of the vectors perpendicular to the x-direction: $R_y = R_{y1} + R_{y2}$

Worked Example 1

Two forces of 3 N and 2 N apply an upward force to an object. At the same time, two forces each of 2 N act horizontally to the right. Find the resultant force acting on the object.

Draw a diagram and calculate the net vertical and net horizontal forces



$R_y = R_{y1} + R_{y2}$ = 2 + 3 = 5N upwards

$R_x = R_{x1} + R_{x2}$ = 2 + 2 = 4N right

Graphical representation of Rx and Ry

- Pythagoras theorem is used to calculate the magnitude of the resultant.

$$R^2 = R_x^2 + R_y^2$$

$$R^2 = 4^2 + 5^2$$

$$R = \sqrt{4^2 + 5^2}$$

$$= 6.40\ N$$

- Use trigonometry to find the direction of the resultant as follows:

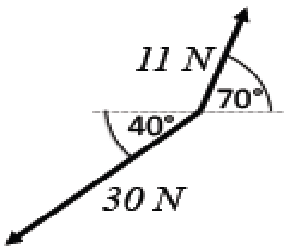
$$tan\theta = \frac{R_y}{R_x} = \frac{5}{4}$$

$\theta = 51.24°$ above the positive x-axis

Worked Example 2

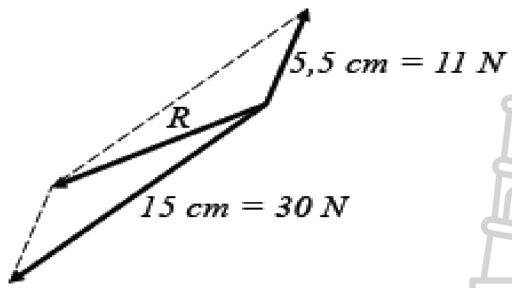
Two forces are applied on an object as shown in the diagram below. Determine the resultant force by accurate construction and by calculations.

By construction



Draw the forces using a specified scale and accurate angle measurements.

Scale: 1cm = 2N



Measurement:

Resultant = 10,6cm = 21, 20 N at an angle of 25° below the negative x-axis.

(The equilibrant will be 21,20 N at an angle of 25° above the positive x-axis)

By calculations

- Determine the x- and y-components of each force.

11N force:

$F_x = F \cos \theta = 11 \cos 70^o = 3,76$ N right

$F_y = F \sin \theta = 11 \sin 70° = 10{,}34$ N up

30N force:

$F_x = F \cos \theta = 30 \cos 40° = 22{,}98$ N left

$F_y = F \sin \theta = 30 \sin 40° = 19{,}28$ N down

- Determine the x- and y-resultants of components.

Take left as positive Take down as positive

$Fx = -3{,}76 + 22{,}98 = 19.\ 22$ N left

$Fy = -10{,}34 + 19{,}28 = 8,\ 94$N down

- Find the resultant using Pythagoras theorem.

$R^2 = x^2 + y^2$

$R^2 = 19,\ 22^2 + 8,\ 94^2$

$R = 21,\ 20$ N

- Find angle (trigonometry)

$\tan \theta = \frac{8{,}94}{19{,}22}$

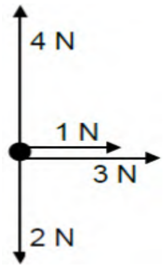
$\theta = 24{,}95°$

ACTIVITIES

QUESTION 1

MULTIPLE CHOICE

1.1 Four forces act on a point, as indicated in the diagram.



The magnitudes of the components of the resultant (net) force in the horizontal (F_X) and vertical (F_Y) directions are …

A $F_X = 3$ N and $F_Y = 6$ N.

B $F_X = 1$ N and $F_Y = 4$ N.

C $F_X = 2$ N and $F_Y = 2$ N.

D $F_X = 4$ N and $F_Y = 2$ N. (2)

1.2 Two forces, F_1 and F_2, act on a point. If F_1 and F_2 act in the same direction the maximum resultant has a magnitude of 13 N. If forces F_1 and F_2 act in opposite directions the magnitude of the minimum resultant is 3 N. The magnitude of the two forces, in newton, is …

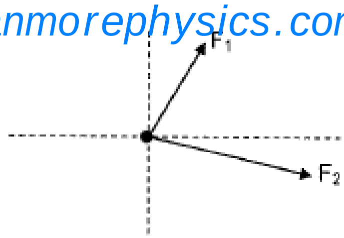
A 8 and 5.

B 16 and 10.

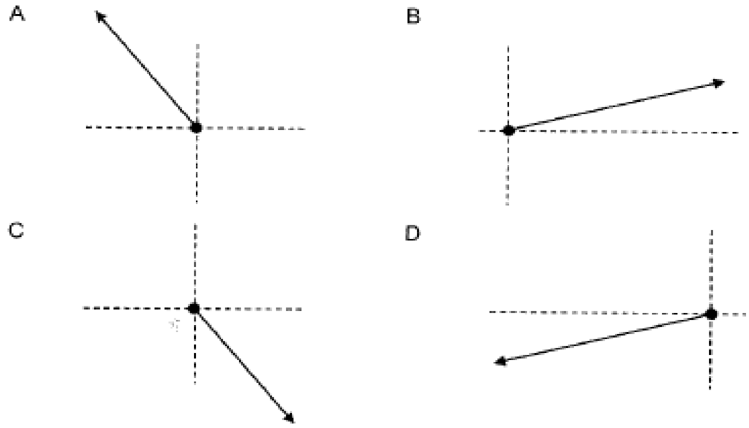
C 3 and 10.

D 10 and 7. (2)

1.3 Two forces, F_1 and F_2, act simultaneously at a point in the directions as shown in the sketch below.



Which ONE of the following represents the resultant of the two forces?



(2)

1.4 Two forces 5 N and 7 N respectively act simultaneously on an object. Which of the following CANNOT be the magnitude of the resultant for these forces?

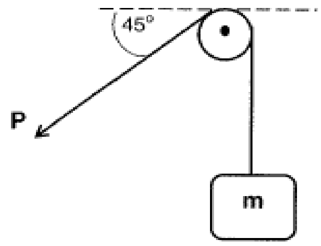
A 12 N

B 2 N

C 13 N

D 9 N (2)

1.5 In the diagram below, an object of mass **m** is held at rest by a string passing over a frictionless pulley. The mass of the string is negligible



The magnitude of force **P** in the strings is….

A Mg

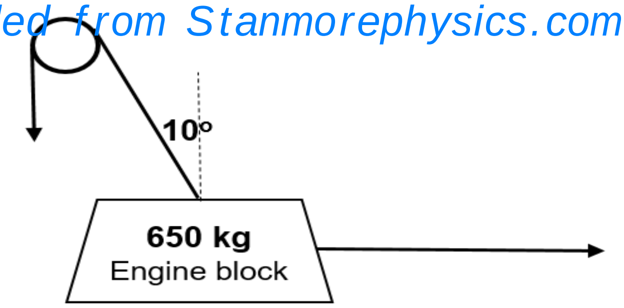
B mg sin 45°

C ½ mg

D Mg tan 45° (2)

QUESTION 2

An engine block with a total mass of 650 kg, is suspended by a cable over a frictionless pulley. A learner pulls a rope, attached to the engine block, horizontally to the right so that the cable forms an angle an angle of 10° with vertical. It is then kept in this position.



2.1 Explain the concept of Forces in Equilibrium (2)

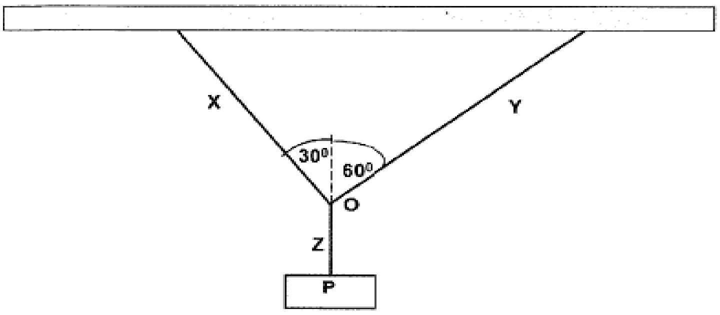
2.2 Draw a labelled, free-body vector diagram showing ALL the forces acting on the engine block. (3)

2.3 Calculate the magnitude of the tension in the cable. (3)

2.4 The cable can withstand a maximum tension of 7 000 N. The engine block is now pulled further to the right so that the angle of the cable with the vertical is 32°. Determine if the cable will snap. (4)

QUESTION 3

The diagram below shows an object P suspended from a ceiling with the aid of three light strings X, Y and Z connected at point O.



3.1 Define the term resultant vector (2)

3.2 Draw a closed vector diagram to show all the forces acting at point O. Indicate two angles in your diagram (4)

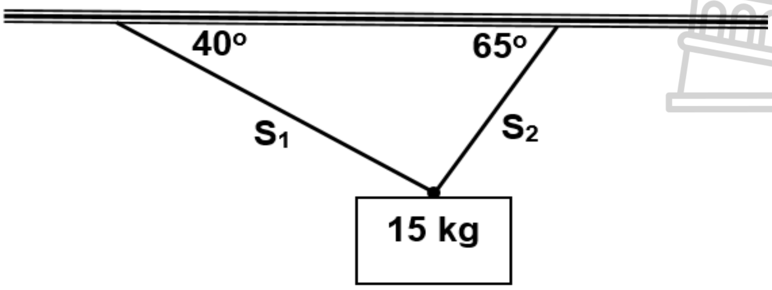
3.3 Using the vector diagram in QUESTION 3.2, identify which string, exerts the largest force on point O. Give a reason for the answer. (2)

The tension in string Y is 1, 225 N

3.4 Calculate the mass of object P. (4)

QUESTION 4

A billboard, mass 15 kg, is suspended from a roof by means of two light inextensible strings, S_1 and S_2, as shown in the diagram below.



4.1 Draw a labelled vector diagram of ALL the forces acting on the billboard. (3)

4.2 Draw a closed vector diagram (triangle) showing the forces acting on the billboard. Indicate at least two angles. (4)

4.3 Calculate the tension in the string S_1. (4)

SOLUTIONS: VECTORS IN 2D

QUESTION 1

1.1 D

1.2 A

1.3 B

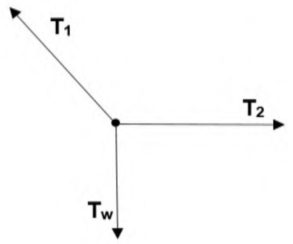
1.4 C

1.5 A

QUESTION 2

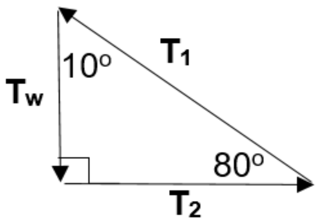
2.1 Forces are at equilibrium when their resultant is zero. (2)

2.2



(3)

2.3



Tw = mg = 650 x 9, 8 = 6370 N

Sin 80° = $\frac{T_W}{T_1}$

T1= = $\frac{6370}{sin\ 80^o}$

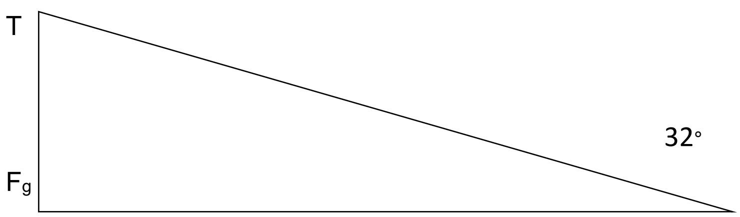
T1 = 6468, 27 N

2.4 $\cos\theta = \frac{\text{Fg}}{T}$ (4)

$\cos 32° = \frac{650 \text{ X } 9{,}8}{T}$

T = 7511,37 N

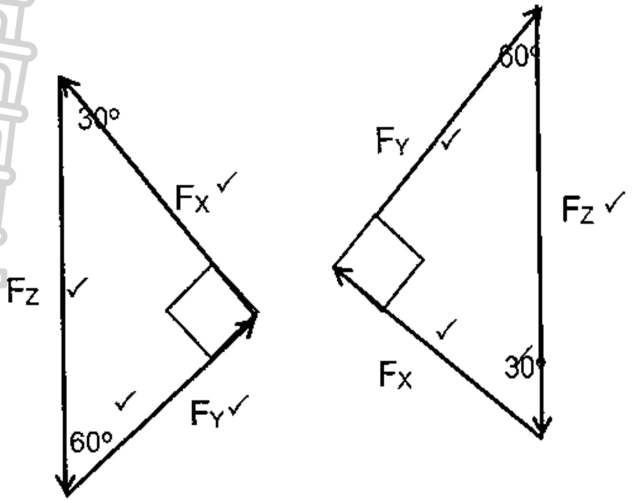
Yes, the cable will snap



QUESTION 3

3.1 It is a single vector having the same effect as two or more vectors together. (2)

3.2 (4)



F_X = Force in string X

F_Y = Force in string Y

F_Z = Force in string Z / Weight

3.3 Z, The lengths of the sides of the triangle represent the magnitudes of the forces. F_Z is the largest force (opposite the largest angle). (2)

3.4 FZ = W = mg = 9,8 m (4)

$Sin\ 30° = \frac{FY}{Fz}$

$Sin\ 30° = \frac{1,225}{9,8m}$

$m = \frac{1,225}{0,5\ X\ 9,8}$

$m\ = 0,25kg$

OR

$Cos\ 60° = \frac{FY}{Fz}$

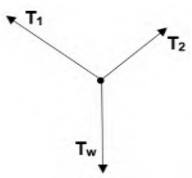
$Cos\ 60° = \frac{1,225}{9,8m}$

$m = \frac{1,225}{0,5\ X\ 9,8}$

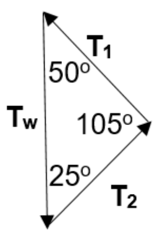
$m\ = 0,25kg$

QUESTION 4

4.1 (3)



4.2 (4)



4.3 w = mg = 15 x 9, 8 = 147 N (4)

$\frac{T_1}{Sin\ 25^o} = \frac{T_W}{Sin\ 105^o}$

$\frac{T_1}{Sin\ 25^o} = \frac{147}{Sin\ 105^o}$

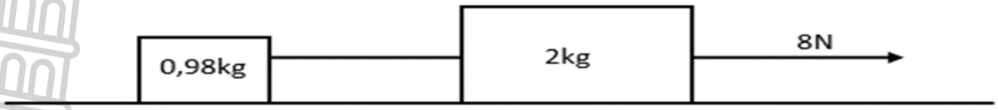
T1 = 64, 32 N

NEWTON'S LAWS

ACTIVITIES- NEWTONS LAWS

QUESTION 1

An 8 N force pulls horizontally on a block of mass 2 kg. The block slides on a smooth horizontal surface. The first block is connected by a horizontal weightless inelastic string to a second block of mass 0.98 kg on the same surface.



1.1 Draw a free-body diagram for each block (7)

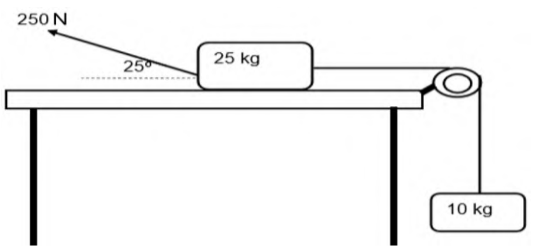
1.2 Determine the acceleration of the blocks. (7)

1.3 Determine the tension in the string. (3)

1.4 The mass of the first block is increased. State whether the tension in the string will INCREASE, DECREASE OR STAY THE SAME. (1)

QUESTION 2

A 250 N force is applied on a block of mass 25 kg. The 25 kg block is connected to a 10 kg block by a light inextensible string through a frictionless pulley as shown on the diagram below. The 250 N force acts at an angle of 25° to the horizontal so that the system of blocks accelerates to the left. The coefficient of kinetic frictional force between the 25 kg block and the surface is 0,15.



2.1 Define the term kinetic frictional force (2)

2.2 Draw a labelled free-body diagram of all forces acting on the 25 kg block (5)

2.3 Calculate the:

2.3.1 Normal force exerted by the surface on the 25 kg block (3)

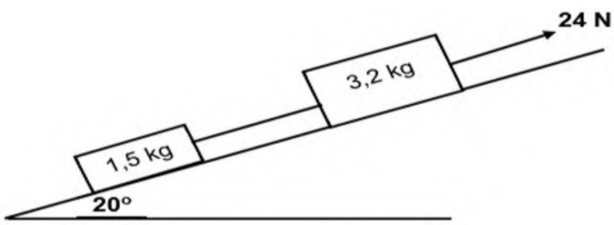
2.3.2 Acceleration of the system of blocks (7)

QUESTION 3

Two blocks of masses 1, 5 kg and 3, 2 kg are connected by a light inextensible string.

A 24 N force is applied on a system of blocks to move them up an inclined surface which is 25° to the horizontal at a CONSTANT VELOCITY as shown on the diagram below.

The 1, 5 kg box experiences a constant frictional force of 2 N as it moves up the incline.



3.1 State Newton's Second Law of Motion in words. (2)

3.2 Draw a labelled free-body diagram of all forces acting on the 1,5kg block. (4)

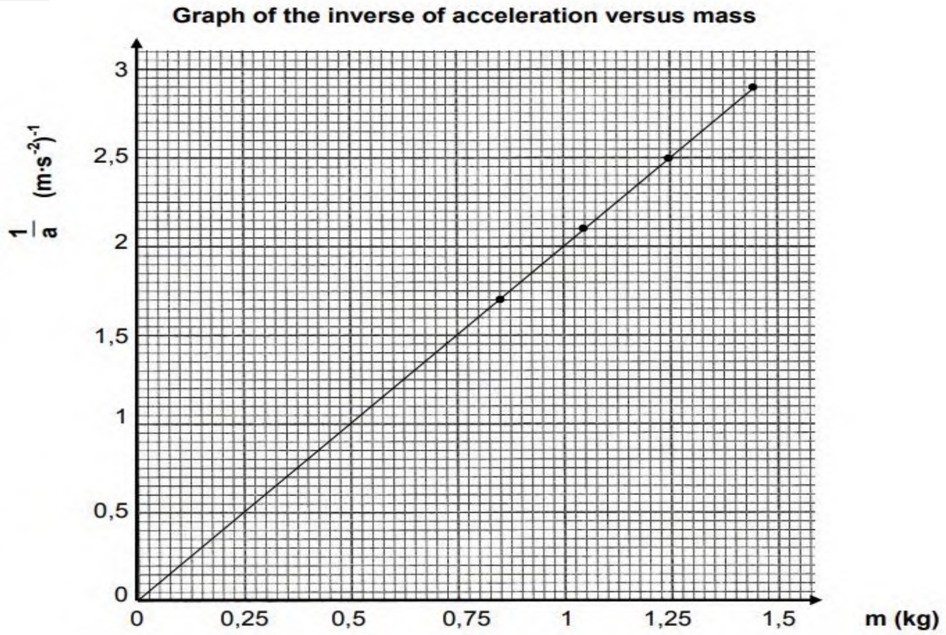
3.3 Calculate the:

3.3.1 Tension in the string connecting the blocks (5)

3.3.2 Coefficient of kinetic frictional force between the 3,2kg block and the surface (6)

QUESTION 4

4.1 Learners investigate the relationship between the mass of an object and the acceleration it experiences when a constant net force is applied on the object. They use their results to draw the graph below.



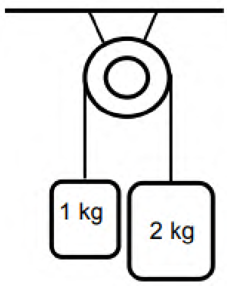
4.1.1 State Newton's Second Law of Motion in words. (2)

4.1.2 Calculate the gradient of the graph. (3)

4.1.3 Hence, determine the net force applied on the object during the experiment. (2)

4.1.4 Write down a conclusion for this experiment. (2)

4.2 In the diagram below, a 1 kg mass and a 2 kg mass are connected by an inextensible string of negligible mass. The string is passed over a light frictionless pulley so that the masses hang down as shown. Initially the system is held stationary.



4.2.1 Draw a labelled free-body diagram showing ALL the forces acting on each block. (4)

4.2.2 Calculate the acceleration of the blocks. (5)

QUESTION 5

Two satellites orbiting the Earth are situated on opposite sides of the Earth.

Satellite A has a mass of 3 800 kg and Satellite B has a mass of 4 500 kg. Satellite A is at a height of 25 000 km above the surface of the Earth.

5.1 State Newton's Universal Gravitational Law in words. (2)

5.2 Explain the term weightlessness (2)

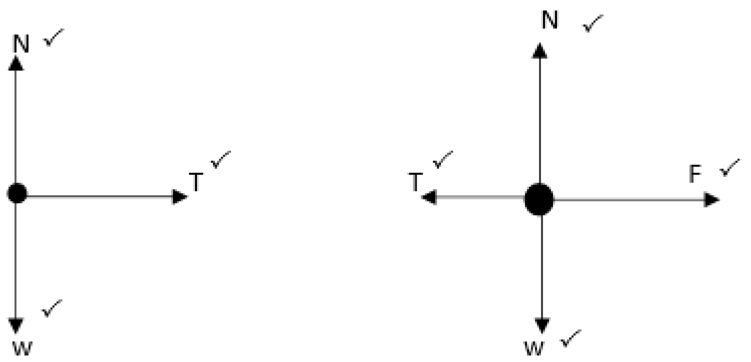
5.3 Calculate the force between the Earth and Satellite A. (4)

5.4 What distance above the surface of the Earth should Satellite B be to experience the same force towards the Earth as Satellite A? (4)

<u>Newton's laws solutions</u>

Question 1

1.1



(7)

1.2

F_{net} = ma ✓

For 0.98kg block

T = ma

T = (0.98)a ✓……….(1)

For 2kg block

F - T = ma

8 - T = (2)a ✓……….(2)

Subst. (1) into (2)

8-0.98a ✓= 2a ✓

a = 2.68 m.s^{-2} ✓✓

(7)

1.3 m = 0.98kg block

T = ma

T = (0.98)(2.68) √

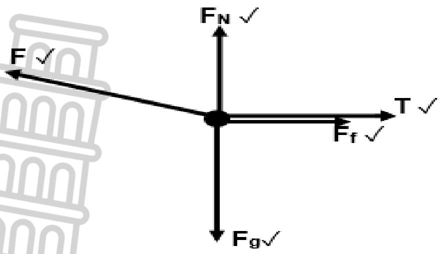
T = 2.63N √ (2)

1.4 Stays the same √ (1)

QUESTION 2

2.1 The force that opposes the motion of a moving object relative to the surface √√ (2)

2.2



(5)

2.3

2.3.1

$$N = Fg - F\,sin\theta$$

$$N = 25x\ 9{,}8\surd - 250\ sin\ 25°\ \surd$$

$$N = 139{,}35\ N\surd$$ (3)

2.3.2 $Fnet = ma$ √

$$Fnet = Fcos\theta - T - f$$

$$250\ cos\ 25°\surd - T - (0{,}15\ x\ 139{,}35)\ \surd = 25a\ \surd$$

$$25a = 205{,}6744468 - T \ldots (1)$$

$$Fnet = T - Fg$$

$$T - 98\ \surd = 10a\ \surd \ldots\quad (2)$$

$$Adding\ the\ two\ equations$$

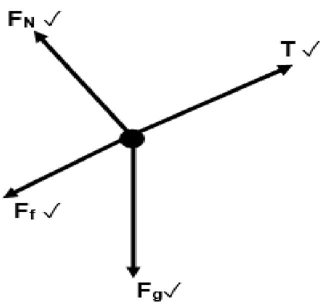
$$35a = 107{,}6744468$$

$$a = 3{,}08\ m.s^{-2}\ \surd$$ (7)

QUESTION 3

3.1 When a resultant force acts on an object, the object will accelerate in the direction of the force. The acceleration is directly proportional to the resultant force and inversely proportional to the mass of the object. √√ (2)

3.



(4)

3.3

3.3.1

$$Fnet = ma\ \surd$$

$Fnet = T - Fg_{//} - f$

$T - Fg_{//} - f = ma$

$T - Fg_{//} - f = 0$

$T - (1{,}5 \times 9{,}8\, sin20°)\surd - 2\surd = 0\surd$

$T = 7{,}03\ N\ \surd$ (5)

3.3.2 $Fnet = ma\ \surd$

$$Fnet = F - T - Fg_{//} - f$$

$$F - T - Fg_{//} - f = ma$$

$$F - T - Fg_{//} - f = 0$$

$$[24 - 7{,}03 - (3{,}2 \times 9{,}8\, sin20°)\surd - fk] = 0\surd$$

$$fk = 6{,}22425\ N$$

$$fk = \mu_k N$$

$$[6{,}22425\ \surd = \mu_k \times 3{,}2\, x 9{,}8\, cos\ 20°\surd]$$

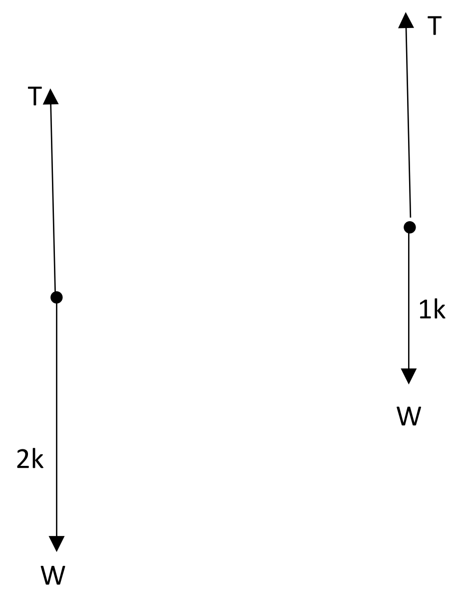
$$\mu_k = 0{,}21\surd$$ (6)

QUESTION 4

4. When a resultant/net force acts on an object, the object will accelerate in the direction of the force. The acceleration is directly proportional to the net force and inversely proportional to the mass of the object. √√ (2)

4.2

4.2.1 (4)



4.2.2 $Fnet = ma$

For the 1 kg block

$T - (1)(9,8) = (1)a$

$T - 9,8 = a \ldots\ldots\ldots(1)$

For the 2 kg block

$(2)(9,8) - T = 2a$

$19,6 - T = 2a \ldots\ldots\ldots (2)$

$9,8 = 3a$

$a = 3,27\ m \cdot s - 2$

QUESTION 5

5.1 Every body in the universe attracts every other body with a force that is directly proportional to the product of their masse and inversely proportional to the square of the distance between their centres.

5.2 Weightlessness is the sensation experienced when all contact forces are removed.

5.3 $F = \frac{Gm_1m_2}{r^2}$

$F = \frac{(6{,}67\ X\ 10^{-11})(5{,}98\ X 10^{24})(3800)}{(6.38\ X\ 10^6 + 25\ X\ 10^6)^2}$

$F = 1\,539{,}23\ N$

5.4 $F = \frac{Gm_1m_2}{r^2}$

$1539{,}23 = \frac{(6{,}67\ X\ 10^{-11})(5{,}98\ X\ 10^{24})(4500)}{r^2}$

$r = 3{,}41\ X\ 10^7 m$

ELECTROSTATICS

Principle of charge conservation

- The SI unit for electric charge is the coulomb (C).
- **Principle of conservation of charge**: The net charge of an isolated system remains constant during any physical process e.g., two charges making contact and then separating.
- Final charge after separation: $Q_{new} = \frac{Q_1 + Q_2}{2}$
- Amount of charge transferred: $\Delta Q = Q_f - Q_i$
- **Note:** This also applies to three physical identically sized spheres

$$Q_{new} = \frac{Q_1 + Q_2 + Q_3}{3}$$

Principle of charge quantization

- **The principle of charge quantization:** All charges in the universe consist of an integer multiple of the charge on one electron, i.e. 1,6 x 10^{-19} C.
- Apply the principle of charge quantization $n = \frac{Q}{q_e}$
- where q_e= 1,6 x 10^{-19} C and n is an integer (whole number)

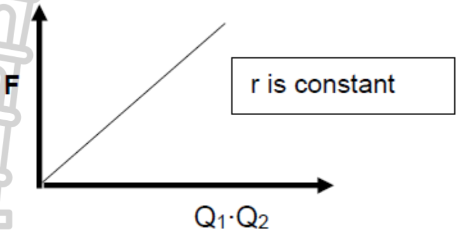
COULOMB'S LAW

The magnitude of the electrostatic force exerted by two-point charges (Q_1 and Q_2) on each other is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them.

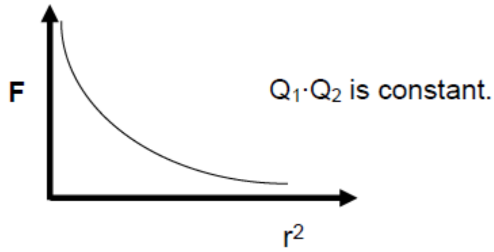
$$F = k\frac{Q_1Q_2}{r^2}$$

Graphical representation of Coulombs law:

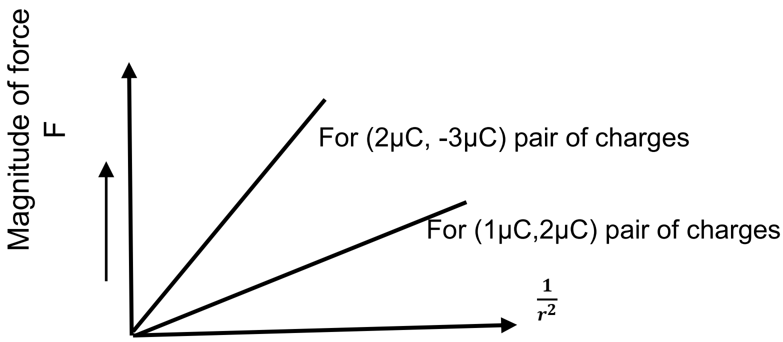
- The electrostatic force is directly proportional to the product of the charges ($F \alpha Q_1 \cdot Q_2$)



- The electrostatic force is inversely proportional to the square of the distance ($F\alpha\frac{1}{r^2}$)

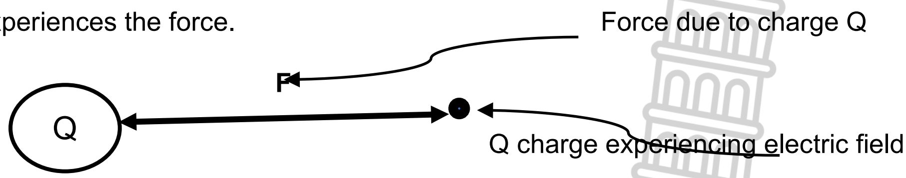


- Electrostatic force is directly proportional to the inverse of a square of a distance.

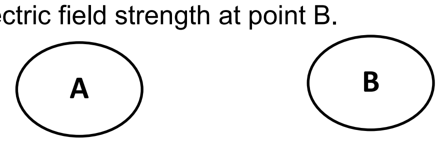


ELECTRIC FIELDS

- **An electric field** is described as a region in space in which an electric charge experiences a force.
- The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point.
- **q** is the charge that experiences the force.



- **Example:** Charge B experiences a force of 2 N due to charge A.
  Determine the electric field strength at point B.



+2 μC-5 μC

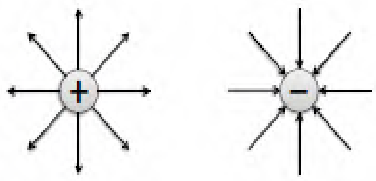
E = $\frac{F}{q}$

E = $\frac{2}{5 \times 10^{-6}}$

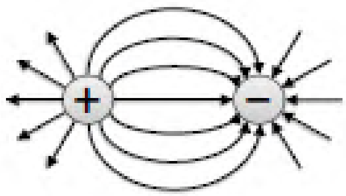
E = 4×10^{5} NC^{-1} to the right

ELECTRIC FIELD PATTERN

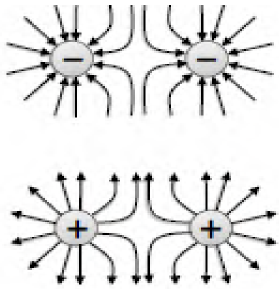
- Field lines around the single point charge



- Field lines between two unlike charges



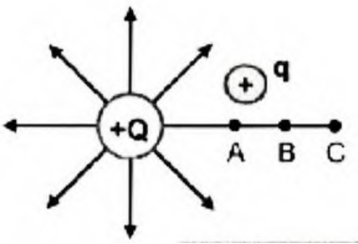
- Electric Field Lines between the two like charges



ELECTRIC FIELD

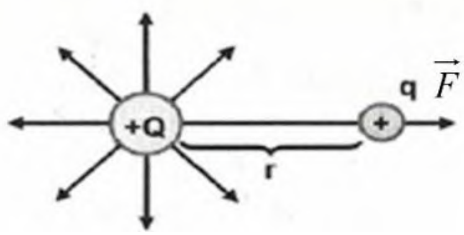
- **The electric field at a point** is the electrostatic force experienced per unit positive charge placed at that point.
- The test charge placed at a point in electric field will experience a force; the magnitude of the force experienced will depend on the distance of the test charge(q) away from the charge(Q) setting the field`

$$\mathbf{E} = \frac{\mathbf{F}}{\mathbf{q}}$$



+q experiences a greater force at A than at C. Therefore, E is stronger at A than at C

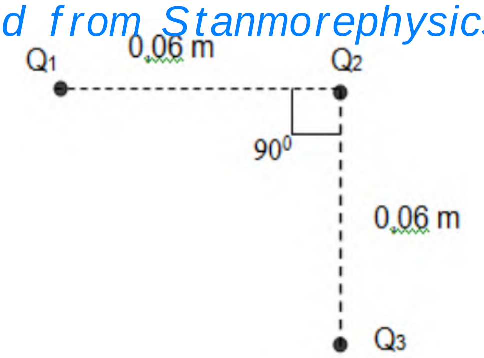
- **Electric field at distance r from point charge Q**
- If a test charge q is placed at a distance r from a charge Q, the magnitude of the electrostatic force F that Q and q are exerting on each other is:



- Therefore, $\mathrm{E} = \frac{\mathrm{kQ}}{\mathrm{r}^2}$

WORKED EXAMPLE 1

Three point charges Q_1, Q_2 and Q_3 are placed in vacuum as shown in the diagram below. Charge Q_1 has a charge of $+6 \times 10^{-6}$ C, Q_2 has a charge of $+3 \times 10^{-6}$ C, and Q_3 has a charge of $+6 \times 10^{-6}$ C.



1.1 State Coulomb's Law in words. (2)

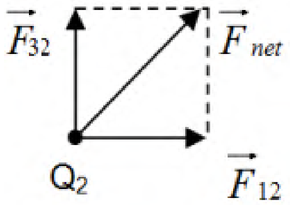
1.2 Draw a free body diagram to show the forces acting on the point charge Q_2 and find the resultant force that acts on Q_2 graphically. Ignore gravitational force. (3)

1.3 Calculate the magnitude of the resultant force that acts on point charge Q_2. (6)

SOLUTION 1

1.1 Coulomb's law states that the magnitude of the electrostatic force between two point charges is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them.

1.2



1.3

$$F_{net} = \sqrt{(F_{12})^2 + (F_{32})^2}$$

$$F_{net} = \sqrt{\left(\frac{kq_1q_2}{(r_{12})^2}\right)^2 + \left(\frac{kq_3q_2}{(r_{32})^2}\right)^2}$$

$$F_{net} = \sqrt{\left(\frac{9\times10^9 \times 6\times10^{-6} \times 3\times10^{-6}}{(0.06)^2}\right)^2 + \left(\frac{9\times10^9 \times 6\times10^{-6} \times 3\times10^{-6}}{(0.06)^2}\right)^2}$$

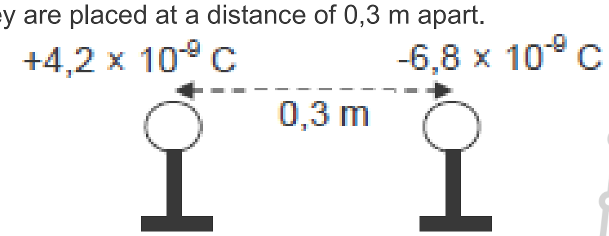
$$F_{net} = \sqrt{\left(\frac{162\times10^{-3}}{3{,}6\times10^{-3}}\right)^2 + \left(\frac{162\times10^{-3}}{3{,}6\times10^{-3}}\right)^2}$$

$$F_{net} = \sqrt{(45)^2 + (45)^2}$$

$$F_{net} = 63{,}64 N$$

WORKED EXAMPLE 2

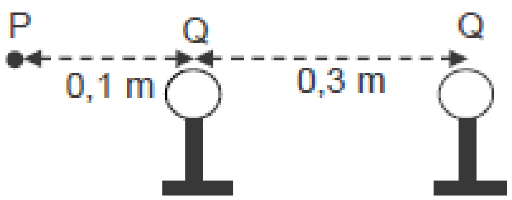
Two small identical metal spheres on insulated stands carry charges of $+4{,}2 \times 10^{-9}$ C and $-6{,}8 \times 10^{-9}$ C respectively. They are placed at a distance of 0,3 m apart.



2.1 State *Coulomb's law* in words. (2)

2.2 Calculate the magnitude of the electrostatic force that the one charge exerts on the other. (3)

The two spheres are allowed to touch and are then returned to their original positions.



2.3 Calculate the number of electrons that were transferred. (3)

2.4 Define electric field at a point. (2)
2.5 Draw the electric field pattern between the two charged spheres. (2)
2.6 Calculate the magnitude of the net electric field at point **P** situated at 0,1 m to the left of the spheres, as shown in the diagram above. (5)

SOLUTION 2

2.1 The magnitude of the electrostatic force exerted by two-point charges (Q_1 and Q_2) on each other is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them (2)

2.2 $F = \frac{KQ_1Q_1}{r^2}$ ✓

$= \frac{(9\times10^9)(4,2\times10^{-9})(6,8\times10^{-9})}{(0,3)^2}$ ✓

$= 2,856 \times 10^{-4}$ N ✓ (3)

2.3 $Q_{new} = \frac{Q_1 + Q_2}{2}$

$= \frac{4,2\times10^{-9}+(-6,8\times10^{-9})}{2}$ ✓

$= -5,5 \times 10^{-9}$C

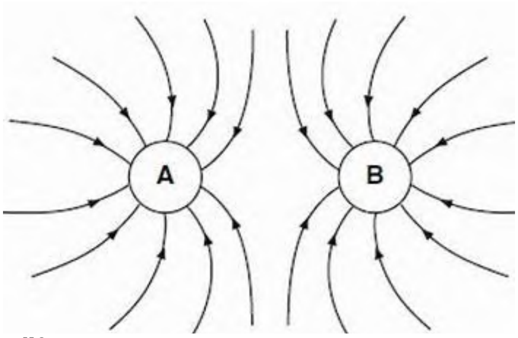
$n = \frac{\Delta Q}{e}$

$n = \frac{-5,5\times10^{-9}-4,2\times10^{-9}}{-1,6\times10^{-19}}$ ✓

$n = 6,0625 \times 10^{10}$ electrons ✓ (3)

2.4 It is the electrostatic force experienced per unit positive charge placed at that point. (2)

2.5



2.6 $E_{net} = \frac{KQ_1}{r^2} + \frac{KQ_2}{r^2}$ ✓

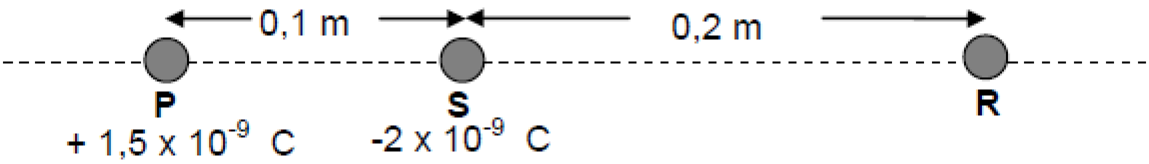
$E_{net} = \frac{(9\times10^9)(5,5\times10^{-9})}{(0.4)^2}$ ✓ $- \frac{(9\times10^9)(5,5\times10^{-9})}{(0.3)^2}$ ✓

$E_{net} = -2,41 \times 10^2$

$E_{net} = 2,41$ N·C^{-1} ✓ *left* ✓ (5)

WORKED EXAMPLE 3

Two point charges, P and S, are placed a distance 0,1 m apart. The charge on P is +1,5 x 10^{-9} C and that on S is -2 x 10^{-9} C. A third point charge, R, with an unknown positive charge, is placed 0,2 m to the right of point charge S, as shown in the diagram below.

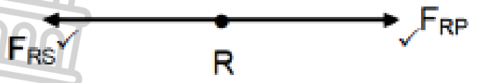


3.1 State Coulomb's law in words. (2)
3.2 Draw a labelled force diagram showing the electrostatic forces acting on **R** due to **P** and **S**. (2)
3.3 Calculate the magnitude of the charge on **R**, if it experiences a net electrostatic force of 1,27 x 10^{-6} N to the left. Take forces directed to the right as positive (7)

SOLUTION 3

3.1 The magnitude of the electrostatic force exerted by two-point charges (Q_1 and Q_2) on each other is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them (2)

3.2 (2)



3.3 To the right as positive✓ (1)

(6)

$$F = k\frac{Q_1Q_2}{r^2} \checkmark$$

$$F_{netR} = F_{PR} + F_{SR}$$

$$F_{net} = \frac{kQ_1Q_2}{r^2} + \frac{kQ_1Q_2}{r^2}$$

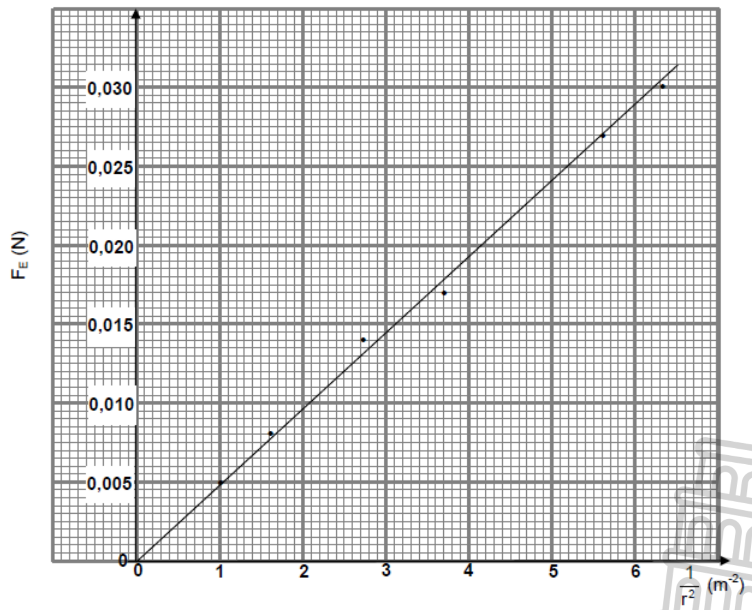
$$\overset{\checkmark}{-1{,}27 \times 10^{-6}} = \left\{\overset{\checkmark}{\frac{(9\times10^9)(1{,}5\times10^{-9})(Q)}{(0{,}3)^2}} - \overset{\checkmark}{\frac{(9\times10^9)(2\times10^{-9})(Q)}{(0{,}2)^2}}\right\}$$

$-1{,}27 \times 10^{-6} = 150Q - 450Q$ ✓ ∴ $4{,}23 \times 10^{-9}$ C ✓

WORKED EXAMPLE 4

In an experiment to verify the relationship between the electrostatic force, F_E, and distance, r, between two **identical**, positively charged spheres, the graph below was obtained.

Graph of F_E versus $\frac{1}{r^2}$



4.1 Write down the dependent variable of the experiment. (1)

4.2 What relationship between the electrostatic force F_E and the square of the distance, r^2, between the charged spheres can be deduced from the graph? (1)

4.3 Use the information in the graph to calculate the charge on each sphere. (6)

SOLUTION 4

4.1 F_E/Electrostatic force (1)

4.2 The electrostatic force is inversely proportional to the square of the distance between the charges. (1)

4.3 (6)

$$\text{Slope} = \frac{\Delta F_E}{\Delta \frac{1}{r^2}} \checkmark = \frac{0{,}027 - 0}{5{,}6 - 0} \checkmark = 4{,}82 \times 10^{-3}\ N{\cdot}m^2$$

Slope = $F_E r^2 = kQ_1Q_2 = kQ^2$ ✓ ∴ $4{,}82 \times 10^{-3}$ ✓ = $\underline{9 \times 10^9\ Q^2}$ ✓ ∴ Q = $7{,}32 \times 10^{-7}$C ✓

[16]

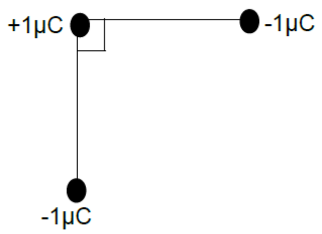
ACTIVITIES

QUESTION 1 (MULTIPLE CHOICE)

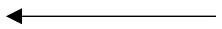
1.1 Two identical small metal spheres on insulated stands carry equal charges and are a distance *d* apart. Each sphere experiences an electrostatic force of magnitude F. The spheres are now placed a distance *d* apart. The magnitude of the electrostatic force each sphere now experiences is:

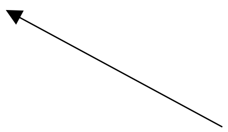
A. 1/2F
B F
C 2F
D 4F (2)

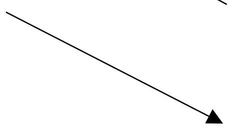
1.2 Three point-charges of magnitude +1 μC, -1 μC and -1 μC are placed in a vacuum to form a right-angle as shown in the diagram below.

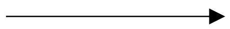


The net force acting on the + 1 μC can by represented by …

A 

B 

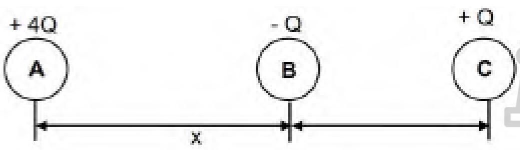
C 

D  (2)

1.3 The magnitude of the electric field at a point P from a positive point charge *q* is *x* $N \cdot C^{-1}$. Which ONE of the statements below regarding this electric field is CORRECT?

A A + 1 C charge placed at P will experience a force of magnitude *x* N directed away from *q*.
B The force on a + 2 C charge placed at P will have a magnitude ¼ *x* N directed away from *q*.
C A + 1 C charge placed at P will experience a force of magnitude *x* N directed towards *q*.
D The force on a + 2 C charge placed at P will have a magnitude ¼ *x* N directed towards *q*. (2)

1.4 Three small identical spheres **A**, **B** and **C** carry charges as shown in the diagram below. The distance between spheres **A** and **B** is **x**

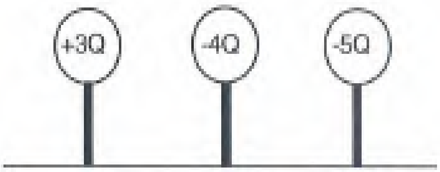


For sphere **B** to experience a ZERO net electrostatic force, what must the distance between spheres **B** and **C** be?

A $\frac{1}{2}x$
B $\frac{1}{4}x$
C 2x
D 4x

(2)

1.5 Three spheres with charges of +3Q, -4Q and -5Q respectively are placed on isolated stands as shown in the diagram below.

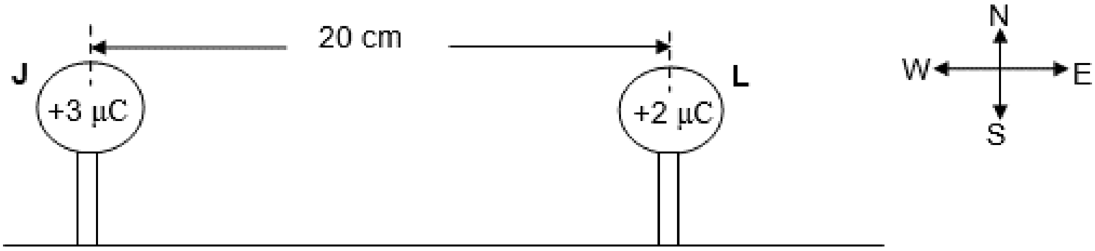


The spheres are simultaneously brought into contact with each other and returned to their original positions.
The charge on each sphere after contact is….

A Q
B -2Q
C -3Q
D 6Q

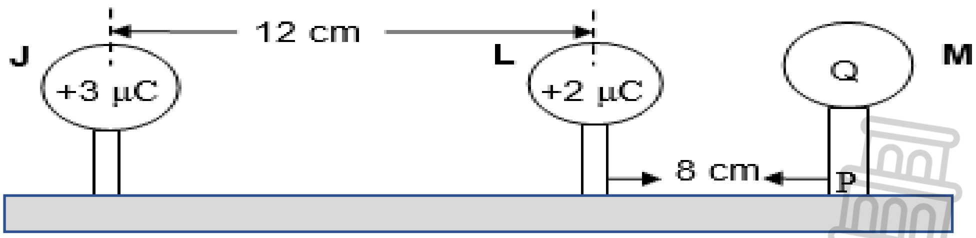
QUESTION 2

Two metal spheres, **J** and **L** placed on wooden stands, carry charges +3 μC and +2 μC respectively. The diagram is not drawn according to scale.



2.1 State Coulomb's Law in words. (2)
2.2 Calculate the electrostatic force experienced by sphere **L** as a result of sphere **J**. (4)

2.3 Sphere **L** is now placed 12 cm away from sphere **J**. Another sphere **M** with a charge of -8 μC is brought into contact with sphere **L**. **After contact**, sphere **M** is placed on a wooden stand **P**, 8 cm from sphere **L**, as shown in the diagram.

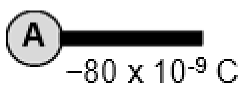


2.3.1 What is the charge (Q) of sphere **M** after contact with sphere **L**? (1)
2.3.2 Calculate the number of electrons transferred between sphere L and sphere **M** after contact. (3)
2.3.3 Draw the electric field pattern due to the charge of sphere **J** and sphere **L** after contact. (3)

2.4 Calculate the net electric field strength on sphere L **due** to sphere J **and** sphere **M** after contact. (6)

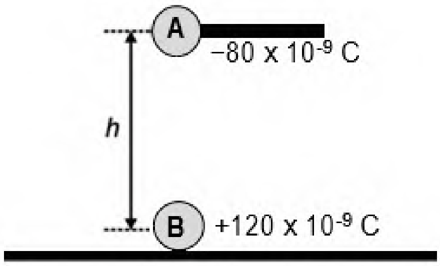
QUESTION 3

In the diagram below a small metal sphere **A** on an insulating rod has a charge of -80×10^{-9} C.



3.1 Describe the term *electric field* in words. (2)
3.2 Calculate the number of electrons sphere **A** has in excess. (3)

Sphere **A** is now kept vertically above another sphere **B** of mass 0,01 kg lying on a horizontal insulated surface. The charge on sphere **B** is +120 x 10^{-9} C. Sphere **A** is slowly brought closer to sphere **B** in order to pick it up. Ignore the effects of air resistance.



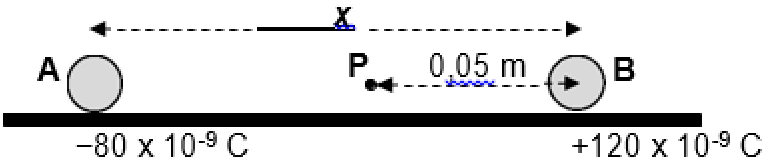
3.3 Draw a diagram that shows the electric field pattern between spheres **A** and **B**. (3)

At a certain height **h** Sphere **B** is just lifted off the surface due to its attraction to sphere **A**.

3.4 Draw a free body diagram showing all the forces acting on sphere **B** at this instant. (2)

3.5 Calculate the height **h** in the diagram at this instant. (4)

Sphere **A** is now placed on the horizontal insulated surface, a distance ***x*** from sphere **B** as shown in the diagram below. **P** is a point between **A** and **B,** 0,05 m from **B**. The magnitude of the **net** electric field intensity at point **P** as a result of the presence of spheres **A** and **B** is 54,45 x 10^{4} N·C^{-1}.

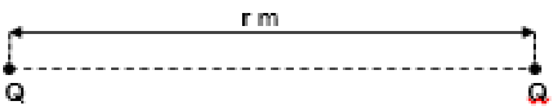


3.6 Draw a labelled vector diagram indicating the directions of the electric field at point **P** as a result of spheres **A** and **B** respectively. (2)

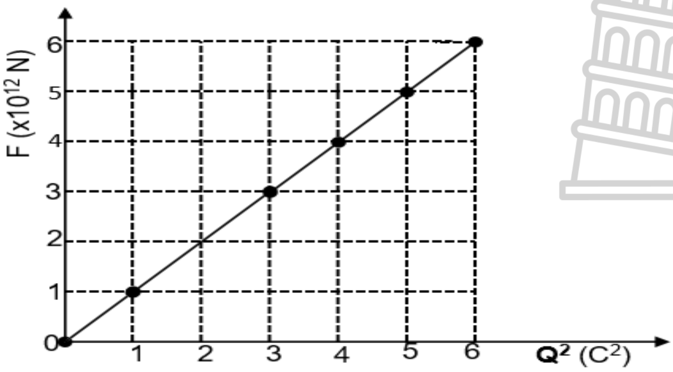
3.7 Calculate the distance ***x*** between spheres **A** and **B** (6)

QUESTION 4

4.1 An investigation is conducted with pairs of IDENTICAL point charges, all placed a distance **r** meters from each other, as shown in the diagram below.



The graph below shows the relationship between the electrostatic FORCE **F**, exerted by one point charge on the other, and the PRODUCT of the two charges, **Q².**



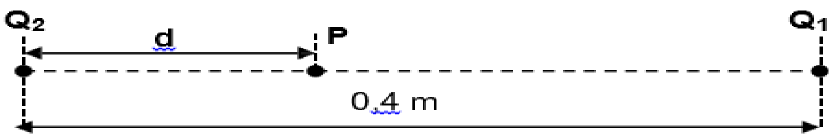
4.1.1 For this investigation, write down the controlled variable. (1)

4.1.2 Write down the relationship between the electrostatic force **F** and the product of the two-point charges, **Q²**. (1)

4.1.3 **Using the graph**, calculate the value of the gradient of the graph. (3)

4.1.4 Using the mathematical expression of Coulomb's law and the answer to **QUESTION 4.1.3**, calculate the distance **r** between the charges. (4)

4.2 Two-point charges, $\mathbf{Q_1}$ = +8 μC and $\mathbf{Q_2}$ = +2 μC, are separated by a distance of 0,4 m, as shown in the diagram below.



4.2.1 Define *electric field at a point* in words. (2)

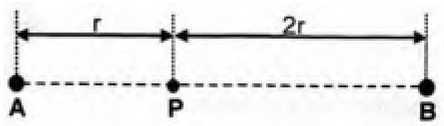
The two-point charges are allowed to touch and returned to their original positions.

4.2.2 Calculate the distance **d** between point **P** and point charge $\mathbf{Q_2}$, as shown in the diagram above. (4)

4.2.3 Calculate the number of electrons transferred from one charge to the other when they come into contact. (4)

QUESTION 5

Two-point charges, A and B, each with a charge of +3 × 10^{-9} C, are stationary on a horizontal surface. Point P is r metres from charge A and 2r metres from charge B, as shown in the diagram below.



5.1 Describe an electric field (2)

5.2 Draw the resultant electric field pattern due to charges A and B (3)

The magnitude of the net electric field at Point P is 27 N.C^{-1}

5.3 Calculate the value of r. (5)

5.4 Calculate the magnitude of the net electrostatic force that an electron would experience if place at point P (3)

ELECTROSTATICS SOLUTIONS

QUESTION 1 (MULTIPLE CHOICE QUESTIONS)

1.1 B✓✓ (2)

1.2 C✓✓ (2)

1.3 A✓✓ (2)

1.4 B✓✓ (2)

1.5 B✓✓ (2)

QUESTION 2

2.1 The magnitude of the electrostatic force exerted by one point charge (Q_1) on another point charge (Q_2) is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them ✓✓ (2)

2.2 $F_J = \frac{kQ_JQ_L}{r^2}$✓

$$F_J = \frac{(9 \times 10^9)(3 \times 10^{-6})(2 \times 10^{-6})\ ✓}{(0,2)^2 ✓}$$

F_J = 1,35 N right ✓

(4)

2.3.1 Q_L = -3 × 10^{-6} C✓

(1)

2.3.2 **OPTION 1**

$n_e = \frac{Q_f - Q_i}{q_e}$ ✓

$n_e = \frac{-3\times10^{-6} - 2\times10^{-6}}{1.6\times10^{-19}}$ ✓

$n_e = 3.125 \times 10^{13}$ ✓

OPTION 2

$n_e = \frac{Q_f - Q_i}{q_e}$ ✓

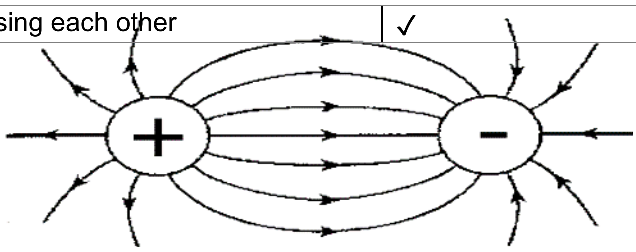
$n_e = \frac{-3 \times 10^{-6} + 8 \times 10^{-6}}{1,6 \times 10^{-19}}$ ✓

$n_e = 3,125 \times 10^{13}$ ✓

(3)

2.3.3

Field lines not crossing each other	✓



CRITERIA	Marks
Correct shape	✓
Correct direction	✓

(3)

2.4

OPTION 1

$E_J = \frac{kQ_J}{r^2}$ ✓ $= \frac{9\times10^9 \times 3\times10^{-6}}{(0,12)^2}$ ✓= 1 875 000 N•C^{-1} (West/Left)

$E_M = \frac{kQ_M}{r^2} = \frac{9\times10^9 \times 3\times10^{-6}}{(0,08)^2}$ ✓ = 4 218 750 N•C^{-1} (West/Left)

$E_{net} = E_J + E_M$ ✓

E_{net} = (+1 875 000) + (+4 218 750) ✓(both substitutions)

E_{net} = 6 093 750 N•C^{-1} West/Left ✓

(6)

QUESTION 3

3.1 An Electric field as a region of space in which an electric charge experiences a force. ✓✓ (2)

3.2

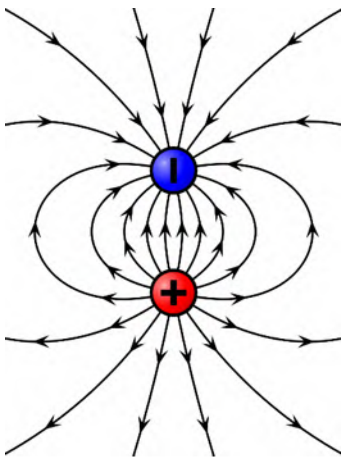
$Q = nq_e$ ✓

$n = \frac{(-80\times10^{-9})}{(-1.6\times10^{-19})}$ ✓

$n = 5 \times 10^{11}$ electrons ✓

(3)

3.3



✓	shape between charges
✓	shape outside charges
✓	direction

(3)

3.4

(2)

3.5 $F_g = F_E$

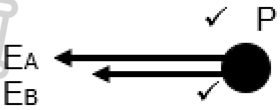
$mg = \frac{kQ_AQ_B}{r^2}$ ✓ any formula

$(0,01)(9,8)$ ✓ $= \frac{(9\times10^9)(80\times10^{-9})(120\times10^{-9})}{r^2}$ ✓

$r = 0,0296$ m ✓ ACCEPT: r = 0,03 m

(4)

3.6



(2)

3.7

(a) $E_A = kQ/r^2$ ✓

$= (9\times10^9)(80\times10^{-9}) / (x - 0,05)^2$ ✓

(b) $E_B = kQ/r^2$

$= (9\times10^9)(120\times10^{-9}) / (0,05)^2$ ✓

$= 432\ 000\ N{\cdot}C^{-1}$

(c) $E_{NET} = E_A + E_B$

$54,45\times10^4$ ✓ $= 720/(x - 0,05)^2 +$ ✓ $432\ 000$

$x = 0,13$ m ✓

(6)

QUESTION 4

4.1.1 Distance (between the point charges)/medium/air ✓ (1)

4.1.2 The electrostatic force is directly proportional to the product of charges. ✓ (1)

4.1.3

$\text{gradient} = \frac{\Delta F}{\Delta Q^2}$

$= \frac{(4-3)\times10^{12}}{\Delta Q^2}$ ✓ **NOTE:** accept any value from the graph

$= \frac{1\times10^{12}}{1}$ ✓

$= 1\times10^{12}\ N\cdot C^{-2}$ ✓ (3)

4.1.4

$F = \frac{KQ_1Q_2}{r^2}$ ✓

$\frac{F}{Q^2} = \frac{K}{r^2}$

1×10^{12} ✓ $= \frac{9\times10^9}{r^2}$ ✓

$r^2 = 9\times10^{-3}$

$r = 0,09487$ m (0,095 m) ✓

NOTE: If $F = \frac{KQ^2}{r^2}$ is used, then maximum: $^3/_4$ (4)

4.2.1 A region in space in which an electric charge experiences a force. ✓✓ (2)

4.2.2

$E = \frac{KQ}{r^2}$ ✓

$E_{net}, P = 0$

$\frac{KQ_1}{r^2}$ ✓ $= \frac{KQ_2}{r^2}$

$\frac{(9\times10^9)(8\times10^{-6})}{(0,4-d)^2} = \frac{(9\times10^9)(2\times10^{-6})}{d^2}$ ✓

ACCEPT: If 10^{-6} is omitted since it appears on both sides.

$\frac{d^2}{(0,4-d)^2} = \frac{(2\times10^{-6})}{(8\times10^{-6})}$

$= 0,25$

$\frac{d}{(0,4-d)} = 0,5$

$d = 0,1333$ m ∴ the distance is 0,1333 m ✓ (4)

4.2.3

OPTION 1

$Q_{new} = \frac{Q_1 + Q_2}{2}$

$= \frac{8\times10^{-6}+2\times10^{-6}}{2}$ ✓

$= 5 \times 10^{-6}C$

$n = \frac{Q}{e}$✓

$n = \frac{5\times10^{-6}-8\times10^{-6}}{-1{,}6\times10^{-19}}$✓

$n = 1{,}875 \times 10^{13}$electrons✓

OPTION 2

$Q_{new} = \frac{Q_1 + Q_2}{2}$

$= \frac{8\times10^{-6}+2\times10^{-6}}{2}$✓

$= 5 \times 10^{-6}C$

$n = \frac{Q}{e}$✓

$n = \frac{5\times10^{-6}-2\times10^{-6}}{1{,}6\times10^{-19}}$ ✓

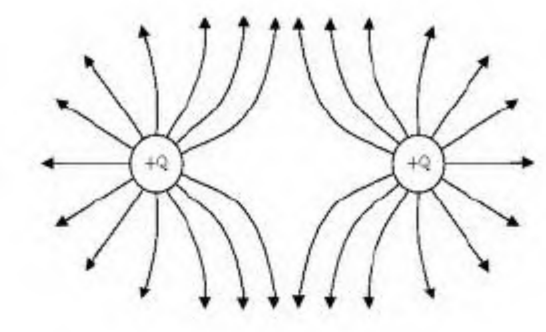
$n = 1{,}875 \times 10^{13}$electrons✓

QUESTION 5

5.1 Electric field is a region in space in which an electric charge experiences a electric force. ✓ ✓

5.2

✓ Correct direction of field lines
✓ Correct shape of the electric field lines
✓ No field lines crossing each other



5.3

$E = k\frac{Q}{r^2}$

Enet = E_A + E_B

Enet = E_A + ($-E_B$)

√anyone

$E_{net} = \frac{kQ_R}{r^2} - \frac{kQ_S}{r^2}$

27 √ $= \frac{(9\times10^{9})(3\times10^{-9})\surd}{(r)^2} - \frac{(9\times10^{9})(3\times10^{-9})\surd}{(2r)^2}$

r = 0.87 m√

5.5 F = Eq√

= 27 × $(1.6 \times 10^{-19}$√

= 4.32×10^{-18} N √

ELECTRIC CIRCUITS

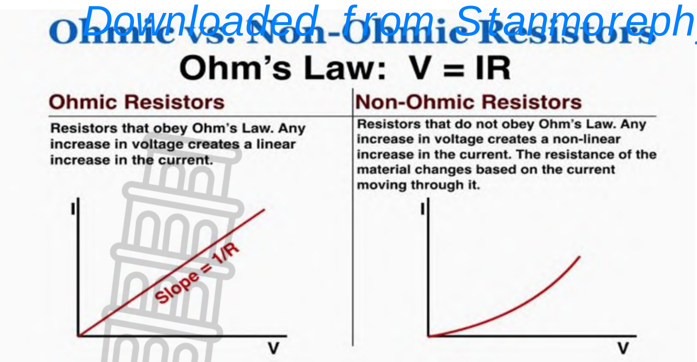
Grade 11 concepts

Ohm's law

The potential difference across a conductor is directly proportional to the current in the conductor at constant temperature.

I= V/R

Graphical representation of Ohm's law



Power Is the rate at which work is done (or energy is transferred)
P= W/Δt
P: Power in Watt (w)
W: Energy in Joules (J)
Δt: time (s)

The following formulae can be used to calculate Power.
P = VI
P = I2R
P=V^2/R

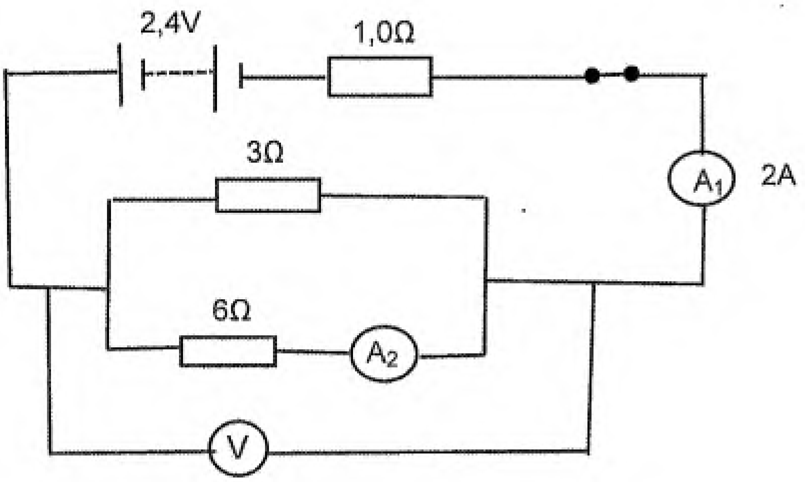
Energy is the ability to do work
Energy can be calculated as
W = P Δt

Knowing that
W: energy in Joules (J)
P: Power in Watts (w)
Δt: Time in seconds (s)
Other formulae to consider:
W = VIΔt
W = I2RΔt
W=V^2/R Δt

Cost of electricity
To calculate the cost of electricity, the energy has to be expressed in Kilowatt – hour.
W = P. Δt
P: Power in Kilowatt
Δt: time in Hours
W: Energy in Kilowatt – hour (kWh)
The kilowatt-hour (kWh) refers to the use of 1 kilowatt of electricity for 1 hour.
1 kWh is an amount of electrical energy, also known as one unit of electricity.
Cost = Energy x Cost per unit

Main aspects addressed in each sub-question:
Connection of ammeter and voltmeter.
Types of connection (series/parallel) and the current (brightness) of light bulb
The total resistance in both parallel and series connections
The influence of resistance on power.

WORKED EXAMPLE
The battery of EMF 2,4V and negligible internal resistance is connected in a circuit as shown below. A current of 2A registers on ammeter A_1



1.1 State the Ohms law in words. (2)

1.2 Calculate the effective resistance of the circuit. (3)

1.3 Calculate the reading on :

1.3.1 The voltmeter (3)

1.3.2 The ammeter A_2 (3)

1.4 Calculate the amount of energy (KWh) that is transferred to the circuit in 48 hours. (5)

1.5 The 3Ω resistor is now replaced by a 6Ω resistor.
How will this affect each of the following (choose from INCREASES, DECREASES, OR REMAIN THE SAME).

1.5.1 The reading on A_1
Explain the answer (3)

1.5.2 The reading on A_2 (1)

SOLUTIONS

1.1 The current in a metal is directly proportional to the potential difference across the ends of the conductor, provided the temperature remains constant. (2)

1.2 (3)

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_p} = \frac{1}{6} + \frac{1}{3}✓$$

$R_p = 2Ω$

Effective Resistance = $R_P + R_s = 2 + 1 = 3Ω$

1.3 1.3.1 $V = IR_{//} = 0,8 \times 2 = 1,6V$ (3)

1.3.2 $R = \frac{V}{I}$

$6 = \frac{1,6}{I}$

$I = 0,27$ A (3)

1.4 $P = VI$

$= 2,4 \times 0,8$

$= 1,92W = 0,00192$ KW

$W = Pt$

$= 0,00192 \times 48$

$= 0,09216$ KWh (5)

1.5.1 Decrease
Resistance of circuit increases, from Ohms Law, R is inversely proportional to the current. (3)

1.5.2 Increases (1)

2 Learners conduct an investigation to verify Ohm's Law. They measure the current through a resistor for different potential differences across its ends, ie the potential difference was chosen as the independent variable. The results obtained are tabulated below:

Potential Difference (V)	Current Strength (A)
21,4	0.80
35,8	1,20
56,0	1,90
72,04	2,30
98,04	3,20
124,04	4,13

2.1 State Ohm's law in words (2)

2.2 The dependant variable in this was the current

2.2.1 Name one quantity that was controlled in this investigation. (1)

2.2.2 State how the quantity in Q 9.2.1 was kept constant (1)

2.3 Using the information in the table and the graph sheet provided, draw a graph of current versus potential difference. (5)

2.4 Calculate the gradient of the graph. (4)

2.5 What quantity does the gradient of the graph represent? (1)

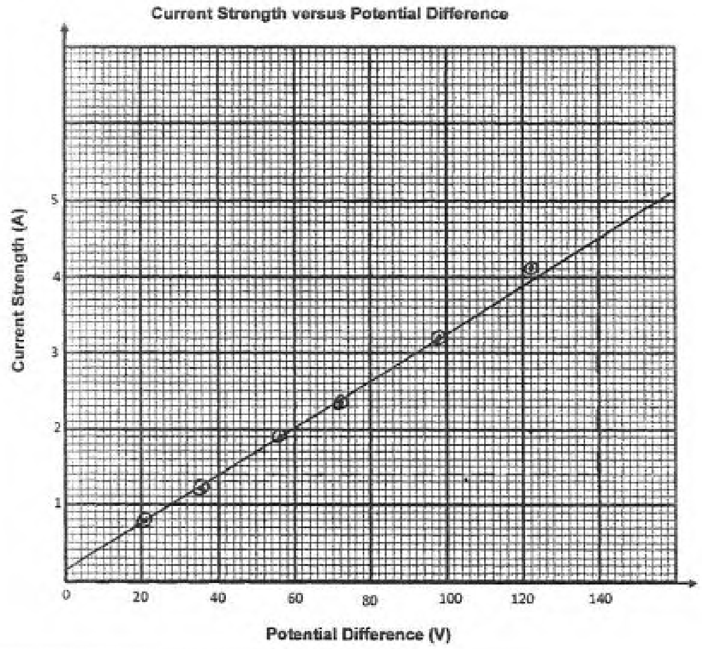
2.6 Hence determine the resistance of the resistor. (2)

SOLUTIONS

2.1 The potential difference across the conductor is directly proportional to the current in the conductor at constant temperature. (2)

2.2.1 Resistance / Temperature of the resistor (1)

2.2.2 Do not keep the circuit on for long periods of time. (1)



2.3

Marking rubric

suitable scale used on X and Y axes	1 mark
X and Y axes correctly labelled	1 mark
correct plotting of points	2 marks
best fit curve drawn joining points	1 mark

(5)

2.4 Gradiant (1/R) = $\frac{\Delta I}{\Delta V}$√

$= \frac{4.5-1.4}{140-40}$√√

=0.031Ω/V (4)

2.5 Inverse of resistance/ $\frac{1}{R}$ (1)

2.6 $\frac{1}{R}$= 0,031 (2)

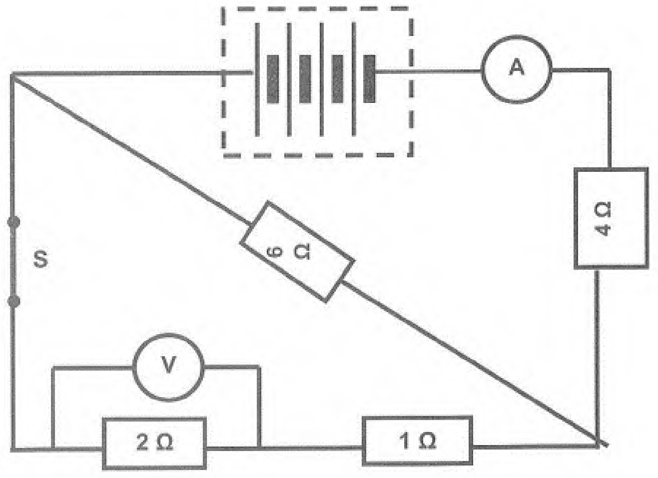
R =32,26 Ω

3.1 You are given four identical resistors, each of magniyude "R" and battery of Emf "v" volts.

3.1.1 Sketch an appropriate circuit diagram, use all the above components, toshow how you would connect them to obtain a total resistance of R in the circuit. (2)

3.1.2 Use the relevant calculations to show that the total resistance in your circuit in 3.1.1 is equal to R. (2)

3.2 The circuit diagram below shows a battery of known Emf with neglible internal resistance, connected as shown below.



The reading on voltmeter is 4V.

Calculate :

3.2.1 The effective resistance in the circuit. (3)

3.2.2 The current flowing through the 1Ω resistor. (3)

3.2.3 The reading on the ammeter. (4)

3.2.4 The Emf of the battery (3)

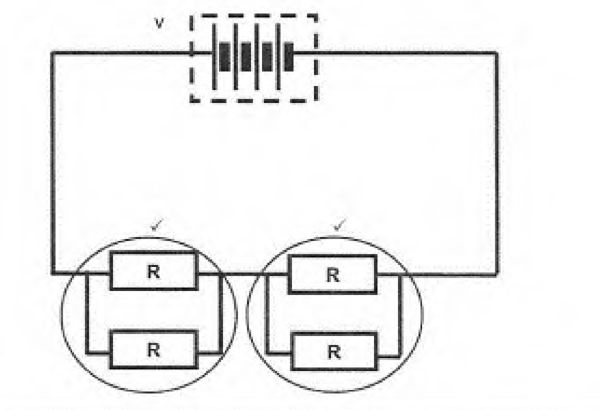
3.3 The switch is now opened

3.3.1 How will the energy dissipated by the 4Ω resistor change if the time is in operation remains constant ? State whether it will increase , decrease or remain the same. (1)

3.3.2 Briefly explain your answers using relevant formulae. (2)

ANSWERS

3.1.1



3.1.2

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

$\frac{1}{R_P} = \frac{1}{R} + \frac{1}{R}$ ✓

$R_P = ½ R$

$R_{TOTAL} = ½ R + ½ R$ ✓
$= R$

3.2.1

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

$\frac{1}{6} + \frac{1}{3}$ ✓

$R_P = 2\ \Omega$ ✓

$R_{TOTAL} = R_P + R_S$
$= 2 + 4$
$= 6\ \Omega$ ✓ (3)

3.2.2

$I_{1\Omega} = I_{2\Omega}$
$= \frac{V}{R}$ ✓
$= \frac{4}{2}$ ✓
$= 2\ A$ ✓ (3)

3.2.3

OPTION 1

$V_{6\Omega} = (2+1)2 = 6\ V$ ✓

$I_{6\Omega} = \frac{V}{R}$
$= \frac{6}{6}$ ✓
$= 1\ A$

$I_{TOTAL} = I_{3\Omega} + I_{6\Omega}$
$= 2 + 1$ ✓
$= 3\ A$ ✓ (4)

⊕

OPTION 2

$I_{6\Omega} : I_{2\Omega} = 3 : 6$

$I_{6\Omega} = \frac{3}{6} \cdot I_2$ ✓
$= \frac{3}{6} \cdot \frac{2}{1}$ ✓
$= 1\ A$

Positive marking from 3.2.2

3.2.4 Positive marking from 3.2.3

$V = I \times R$ OR $Emf = V_P + V_{4\Omega}$
$= 3 \times 6$ $= 6 + (3)(4)$
$= 18\ V$ $= 18\ V$ (3)

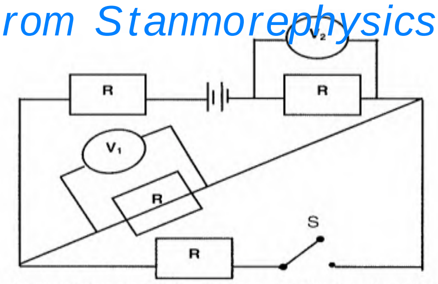
3.3.1 Decreases (1)

3.3.2 When switch S is opened, the total resistance in the circuit increases and the current strength decreases.
$W = I^2 R\Delta t$
Since R and Δt remains constant,
$W \propto I$, whereby I decreases
∴ W decreases
Hence the energy dissipated by the 4Ω resistor decreases. (2)

Multiple choice questions

1.1 In the circuit diagram below, the battery has negligible resistance. The resistance of the ammeter and the wires may also be ignored.

1.1

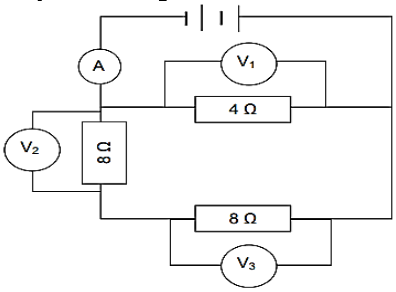


When the switch S is closed, the readings on voltmeters V_1 and V_2 will CHANGE as follows:

	Reading on V_1	Reading on V_2
A	Decreases	Increases
B	Increases	Increases
C	Stays the same	Decreases
D	Increases	Decreases

(2)

1.2 In the circuit diagram below, the battery has negligible internal resistance. The resistance of the ammeter and wires may also be ignored.



The reading on voltmeter V_3 will be equal to …

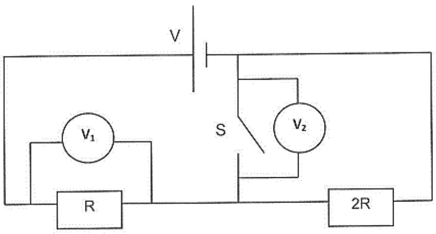
A V_1

B $\frac{1}{2} V_1$

C $V_1 + V_2$

D $V_2 - V_1$ (2)

1.3



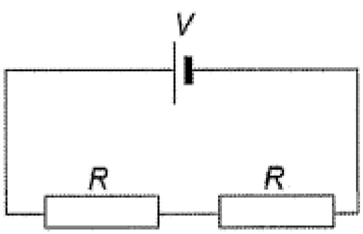
When switch S is closed, the readings on V_1 and V_2 (respectively) will change as follows:

	V_1	V_2
A	decreases	increases
B	increases	decreases
C	decreases	decreases
D	increases	remains the same

(2)

Consider the circuit diagram below:

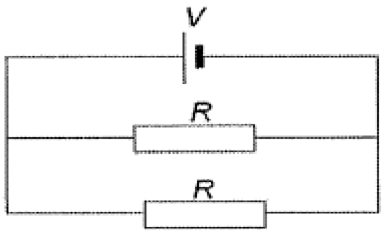
1.4 The two resistors in circuit 1 below are identical. They are connected in series to a cell of Emf V and negligible internal resistance. The power dissipated by each resistor is P.



Circuit 1

The two resistors are now connected in parallel, as shown in circuit 2 below.

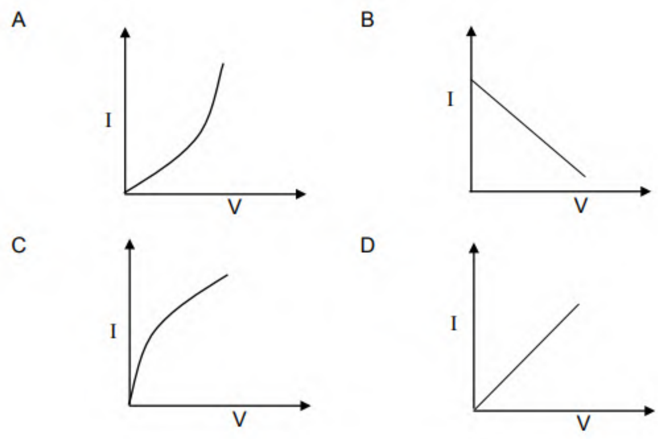
Circuit 2



The power dissipated by each resistor in the circuit is

A. 2P
B. 4P
C. 8P
D. P

1.5 Which ONE of the following graphs best represents the relationship between the current and potential difference for a conductor which obeys Ohms'



Law.

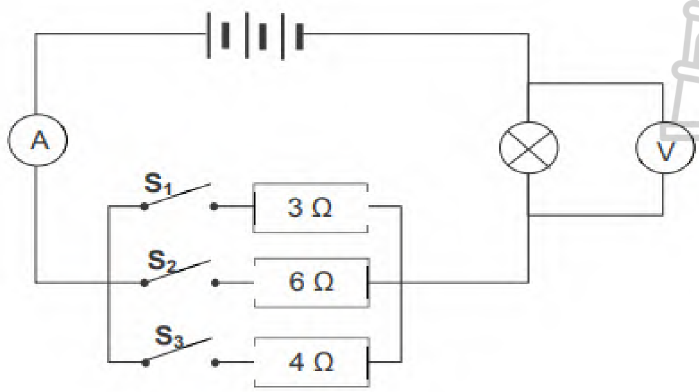
SOLUTIONS

1.1 A √√
1.2 B √√
1.3 B √√
1.4 B √√
1.5 D √√ (10)

LONG QUESTIONS

QUESTION 1

Three resistors , of 3Ω, 4Ω and 6Ω, and a bulb are connected in a circuit, as shown below. Initially all the switchesz , S_1 , S_2,and S_3 are open. The internal resistance of the battery and the resistance of the connecting



wires may be ignored.

1.1 State the Ohms' law in words. (2)

Switch S_1 is now closed and the voltmeter and ammeter readings are recorded. The voltmeter and ammeter readings, when both switch S_1 and switch S_2 are closed, are then recorded, as well as the readings when all three switches, S_1 ,S_2 , and S_3 , are closed.
The results are shown in the table below.

SWITCHES CLOSED	VOLTMETER READING (V)	AMMETER READING (A)
S_1	4,8	2,4
S_1 and S_2	6	3
S_1, S_2 and S_3	7,2	3,6

1.2 Explain the increase in the ammeter reading as more switches are closed. (2)

1.3 Calculate the :

1.3.1 Resistance of the bulb. (3)

1.3.2 Potential difference of the battery (4)

1.4 Define the term power. (2)

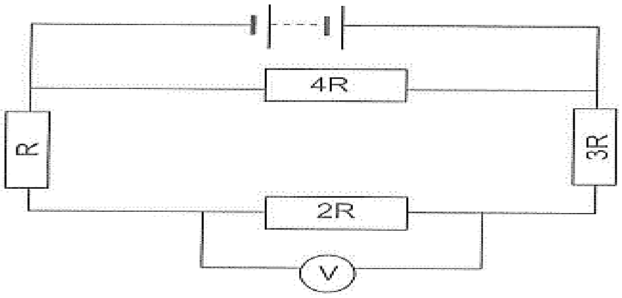
1.5 Calculate the power dissipatedin the 6Ω resistor when ONLY SWITCHES S_1 and S_2 are closed. (4)

1.6 How will the BRIGHTNESS of the bulb be affected as more switches in the circuit are closed? Write only INCREASES, DECREASES or REMAINS THE SAME. (1)

1.7 Explain the answer to question 1.6. (2)

QUESTION 2

Consider the circuit diagram below. The internal resistance of the battery and any resistance in the wires can be ignored.



2.1 Calculate the value of resistor R if the total resistance of the circuit is 4,8Ω (3)

2.2 Calculate the reading on the voltmeter if the current through the 4R resistor is 1,8A. (5)

2.3 Calculate the energy converted in resistor 4R in 2 minutes. (3)

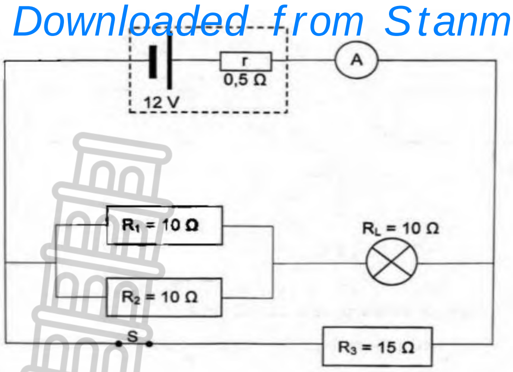
The 4R resistor is replaced with an ammeter

2.4 How will the reading on the voltmeter be influenced? Write only INREASES, DECREASES or STAYS THE SAME. (1)

2.5 Explain the answer to 2.4 (2)

QUESTION 3

The circuit diagram below shows abattery with an emf of 12V and an internal resistance of 0,5Ω connected to three resistors, a light bulb, a switch, an ammeter and connecting wires. The ammeter and connecting wires have negligible resistance.



3.1 State the Ohms' law in words. (2)

Switch S is initially CLOSED,

3.2 Calculate the :

3.2.1 Total external resistance of the circuit. (5)

3.2.2 Reading on the ammeter. (3)

3.2.3 Power dissipated by resistor R_3. (4)

3.3 Switch S is now OPENED.

3.3.1 If the resistance of the light bulb remains constant, how will the brightness of the light bulb be affected ? Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

3.3.2 Explain the answer to QUESTION 3.3.1 (3)

SOLUTIONS

QUESTION 1

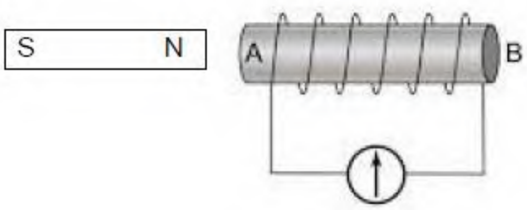
1.1 The potential difference across a conductor is directly proportional to the current in the conductor at constant temperature. √√ (2)

1.2 More resistors connected in parallel. √
Therefore the effective resistance of the circuit decreases.√ (2)

1.3.1 $R = \frac{V}{I}$√
$= \frac{4.8}{2.4}$ √ (3)
= 2 Ω√

ELECTROMAGNETISM
WORKED EXAMPLES

1.1 In the diagram below, the north pole of a bar magnet approaches end A of a solenoid.

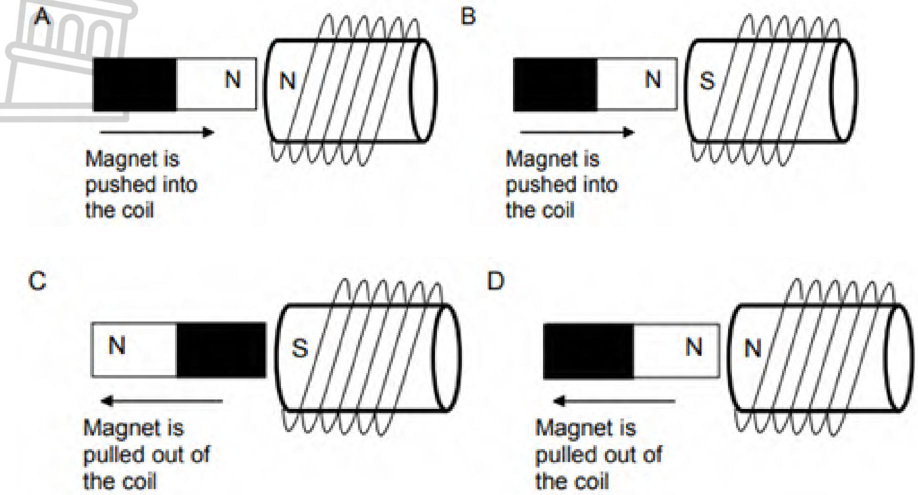


Which ONE of the following statements about the polarity of A and the direction of the magnetic field INSIDE the solenoid is CORRECT as the NORTH POLE approaches A?

(2)

	POLARITY OF A	DIRECTION OF FIELD IN SOLENOID
A	South pole	A to B
B	North pole	B to A
C	North pole	A to B
D	South pole	B to A

1.2 In which ONE of the sketches below is the induced polarity of the coil CORRECTLY indicated?

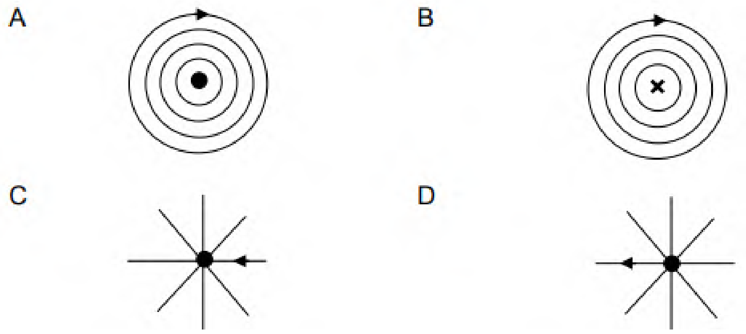


(2)

1.3 A circular coil is placed inside a magnetic field and rotated clockwise to induce an emf. Which ONE of the following changes will increase the induced emf?

A Rotating the coil slower
B Decreasing the number of turns/windings of the coil
C Increasing the speed of rotation of the coil
D Changing the polarity of the magnets (2)

1.4 Which ONE of the sketches below represents the CORRECT magnetic field pattern around a straight current-carrying conductor? (2)

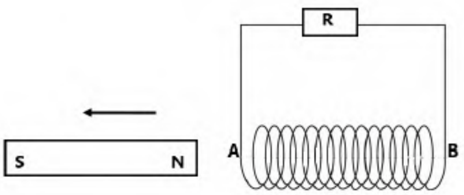


1.5 When a current, passes through a straight conductor a field is generated around the conductor. Which ONE of the following combinations is correct for the **nature of the field** and the **orientation of the field**?

	NATURE OF THE FIELD	ORIENTATION OF THE FIELD
A	Magnetic	Perpendicular to the conductor
B	Electric	Perpendicular to the conductor
C	Magnetic	Parallel to the conductor
D	Electric	Parallel to the conductor

(2)

1.6 The diagram below shows a magnet that is being moved away from a solenoid



Which of the following statements is CORRECT?

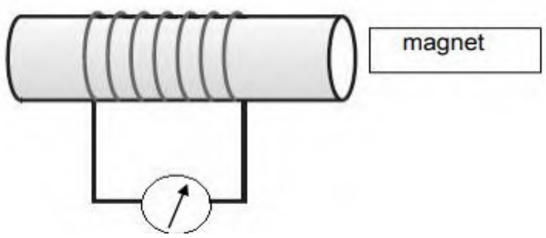
A The induced current will flow from A to B as it moves through the resistor.
B The induced current will flow from B to A as it moves through the resistor
C No current will flow through the resistor
D Alternating current will flow through the resistor. (2)

SOLUTIONS FOR WORKED EXAMPLES

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

QUESTION 2

2.1 The arrangement of apparatus to demonstrate Faraday's law of electromagnetic induction is shown below.



2.1.1 State Faraday's law of electromagnetic induction in words. (2)

2.2.2 State TWO ways in which the deflection on the galvanometer can be increased.
(Factors affecting the induced emf) (2)

2.2 A coil with area 0,6 m^2 is held with its axis coinciding with the direction of a magnetic field of strength 0,4 T.

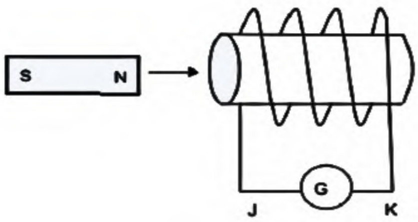
2.2.1 Calculate the magnetic flux linkage.
(Calculating magnetic flux and identifying the value of angle ɵ) (3)

In order to produce an emf of 9 V, the area of the coil, with its axis coinciding with the direction of a magnetic field, is halved from 0, 6 m^2 to 0, 3 m^2 in 2 minutes.

2.2.2 Calculate the number of turns in the coil.
(Application of Faraday's law equation) (4)

QUESTION 3

3.1 The setup of the apparatus below was used to demonstrate the Faraday's Law of electromagnetic induction.



3.1.1 State the Faraday's Law of electromagnetic induction in words. (2)

3.1.2 What will be observed on the Galvanometer when the bar magnet is held stationary inside the solenoid? Give a reason for the answer. (2)

3.1.3 What is the direction of the induced current through the Galvanometer? Choose from **J** to **K** or from **K** to **J** (1)

3.2 A magnetic field with a field strength of 0,5 T passes through a conducting loop of area 10 cm^2 in such a way that the field lines are at 70^0 to the plane of the loop.

3.2.1 Calculate the magnetic flux linkage (3)

3.2.2 Calculate the average emf that will be induced across the ends of the coil if it is removed from the field in 0,2 s (3)

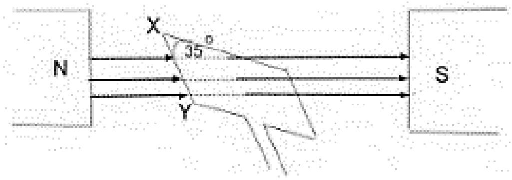
3.3 A circular coil is placed inside the magnetic field and rotated clockwise to induce an emf. How will the following changes influence the magnitude of the induced emf?
Choose from INCREASES, DECREASES or REMAINS THE SAME

3.3.1 Changing the polarity of the magnet (1)

3.3.2 Increases the speed of rotation of the coil (1)

QUESTION 4

A coil makes an angle of 35^0 with the horizontal plane. The coil has an area of 0,04 m^2 and magnetic field of 0,3 T is directed which passes through the coil as shown in the diagram below.



4.1 If the coil is rotated clockwise, in which direction does the induced current flow? Write down only **X** to **Y** or **Y** to **X** (1)

4.2 Which Physics law or principle is used to arrive to the answer in QUESTION 4.1? (1)

SOLUTIONS FOR WORKED EXAMPLES

2.1.1 The magnitude of the induced emf (in a conductor) is equal to the rate of change of magnetic flux linkage. ✓✓ (2)

2.1.2 Move the magnet quickly inside the coil. ✓
Use a stronger magnet ✓ (2)

2.3.1 $\Phi = BA\cos\theta$ ✓
$\Phi = (0,4)(0,6)\cos 0^0$ ✓
$\Phi = 0.24$ Wb ✓ (3)

2.3.2 $\Phi = BA\cos 0^0$
$\Phi_{1/2} = (0,4)(0,3)\cos 0^0$✓
$\Phi = 0,12$ Wb
$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$✓
$9 = -N\frac{(0,12-0,24)}{120}$✓
N = 9000 turns✓ (4)

QUESTION 3

3.1.1 The magnitude of the induced emf across the ends of a conductor is directly proportional to rate of change in the magnetic flux linkage with the conductor. ✓✓ (2)

3.1.2 No deflection / zero reading ✓
No change in the magnetic flux linkage. ✓ (2)

3.1.3 K to J✓ (1)

3.2.1 $\Phi = BA\cos\theta$ ✓
$\Phi = (0,5)(0,001)\cos 20^0$ ✓
$\Phi = 4,70 \times 10^{-4}$ Wb ✓ (3)

3.2.2 $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$✓
$= \frac{-1(04,70 \times 10^{-4})}{0,2}$✓
$= 2,35 \times 10^{-3}$ V ✓ (3)

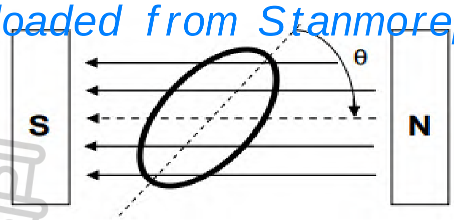
3.3.1 REMAIN THE SAME✓ (1)
3.3.2 INCREASES✓ (1)

QUESTION 4

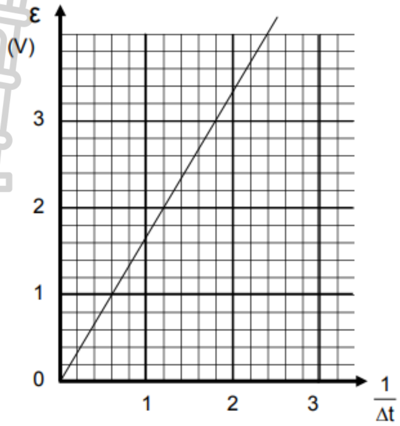
4.1 X to Y✓ (1)
4.2 Faraday's law OR Electromagnetic induction✓ (1)

ELECTRODYNAMICS
PRACTICE ACTIVITIES
QUESTION 1

An induction coil of area 48, 6 cm^2 and 200 windings is rotated clockwise in a constant magnetic field of magnitude 2, 4 T. Refer to the diagram below.



The graph below shows how the induced emf varies with the inverse of time.



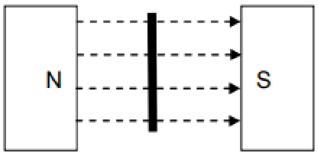
1.1 State Faraday's law in words (2)

1.2 Use the information in the graph to calculate the change in magnetic flux when the emf is 3 V **(Interpretation of graph)** (4)

1.3 The coil rotates through an angle θ to a position where the magnetic flux becomes zero. Calculate angle θ. **(Calculating the change in magnetic flux)** (5)

QUESTION 2

A SQUARE induction coil with a side length 3 cm and 400 windings, is placed perpendicularly in a uniform magnetic field and then rotated through an angle of 45º in 0,08 s



An emf of 7 V is induced in the coil.

2.1 State Faraday's law of electromagnetic induction in words. (2)

2.2 Calculate the change in the magnetic flux. (3)

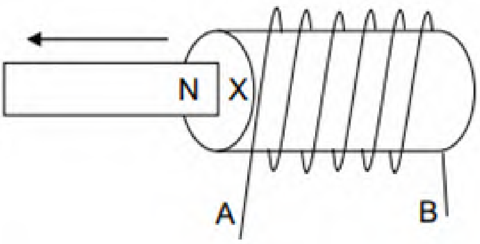
2.3 Calculate the magnitude of the magnetic field. (4)

The coil is now rotated through an angle of 45º in 0,05 s

2.4 How will the induced emf be affected? Write only INCREASE, DECREASE or STAY THE SAME. (1)

2.5 Explain the answer to QUESTION 2.4 (1)

The north pole of a bar magnet is moved away from a solenoid, as shown in the sketch below

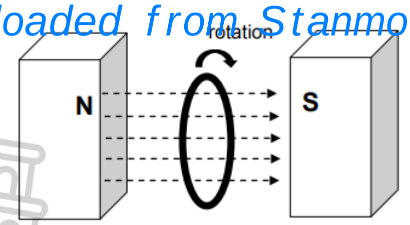


2.6 Which pole will be induced at point **X**? Write only NORTH or SOUTH. (1)

2.7 In which direction will the induced current flow? Write only FROM **A** TO **B** or FROM **B** TO **A**. (1)

QUESTION 3

A circular coil with 250 windings (turns) and a radius of 0,04 m, is rotated clockwise inside a magnetic field with a field strength of 3, 2 T.



3.1 Calculate the magnetic flux through the coil at the position indicated on the diagram, where the coil is perpendicular to the field.
(Make use of formula to calculate magnetic flux) (3)

3.2 If the coil rotates clockwise through 25°, and the potential difference induced is 2, 8 V, calculate the time in which this rotation took place.
(Effect of changing the angle on the induced emf) (4)

3.3 Which law can be used to explain the phenomenon described in QUESTION 3.2? Name and state the Law. **(Recall)** (3)

3.4 3.4.1 If the circular coil is replaced with a square coil with a side length of 0,04 m, and the same movement is made in the same amount of time, will the induced emf be the same as, larger than or smaller than the circular coil? Write down only THE SAME AS, LARGER THAN or SMALLER THAN.
(Effect of change in area on the electromagnetic flux) (1)

3.4.2 Explain the answer to QUESTION 3.4.1 (2)

QUESTION 4

A flat rectangular coil consisting of 150 turns has the dimensions 25 cm by 30 cm. it is in a uniform 1,20 T magnetic field with plane of the coil parallel to the field. In 0,2 s it is rotated so that the plane of the coil is perpendicular to the field.

4.1 State Faraday's Law of electromagnetic induction in words. (2)

4.2 Calculate the:

4.2.1 Change in magnetic flux through the coil during this rotation (5)

4.2.2 emf induced in the coil during this rotation. (3)

4.2.3 Current induced in the coil during this rotation if the coil is connected to a resistor of 50 Ω. (3)

QUESTION 5

Consider a solenoid of 9 turns with an unknown radius *r*. The solenoid is subjected to a magnetic field of 0,12 T. The face of the solenoid is perpendicular to the magnetic field. When the field is uniformly switched to 12 T over a period of 2 minutes an emf with a magnitude of –0,3 V is induced.

5.1 State the Faraday's law of electromagnetic induction in words. (2)

5.2 Calculate the:

5.2.1 The change in magnetic flux. (4)

5.2.2 The radius of the solenoid. (4)

ELECTRODYNAMICS
SOLUTION FOR ACTIVITIES
QUESTION 1

1.1 The magnitude of the induced emf across the ends of the conductor is directly proportional to the rate of chenge in magnetic flux linkage with the conductor✓✓ (2)

1.2 Accept any correct combination of co-ordinate from tye graph.

OPTION 1	**OPTION 2**
$\mathcal{E} = \frac{-N\Delta\phi}{\Delta t}$ ✓ 3✓ = (–200) ✓ (Δϕ)(1,8) ✓ Δϕ = –0,0083 Wb✓	$\mathcal{E} = \frac{-N\Delta\phi}{\Delta t}$ ✓ 3✓ = (–200)✓(Δϕ) $\frac{(1)}{0,56}$ ✓ Δϕ = –0,0083 Wb✓

(5)

1.3 $\Delta\phi = \phi_f - \phi_i$ ✓
–0,0083✓ = $\underline{(4,86 \times 10^{-3})(2,4\ \text{Cos}90^0 - (4,86 \times 10^{-3})(2,4)\text{Cos}\theta}$✓
Θ = $44,64^0$✓ (4)

QUESTION 2

2.1 The magnitude of the induced emf across the ends of the conductor is directly proportional to the rate of chenge in magnetic flux linkage with the conductor✓✓
(2)

2.2 $\mathcal{E} = \frac{-N\Delta\phi}{\Delta t}$ ✓

$7 = \frac{-400\ \Delta\phi}{0{,}08}$ ✓ (3)

$\Delta\phi = -1{,}4 \times 10^{-3}$ Wb ✓

2.3 $\Delta\Phi = BA(\cos\theta_f - \cos\theta_i)$ ✓

$-0{,}0014$ ✓ $= (0{,}03)^2 B (\cos 45^0 - \cos 0^0)$ ✓

B = 5,31 T ✓ (4)

2.4 Increase ✓ (1)

2.5 emf is inversely proportional to time. ✓ (1)

2.6 North ✓ (1)

2.7 From A to B ✓ (1)

[13]

QUESTION 3

3.1 $\Phi = BA\cos\theta$ ✓

$= (3{,}2)\pi(0{,}04)^2\cos 0^0$ ✓

$= 0{,}016$ Wb ✓ (3)

3.2 $\mathcal{E} = \frac{-N\Delta\phi}{\Delta t}$ ✓

$2{,}8$ ✓ $= -\frac{250\ (0{,}016\cos 25^0 - 0{,}016)}{\Delta t}$ ✓

$\Delta t = 0{,}13$ s ✓ (4)

3.3 Faraday's law. ✓ The magnitude of the induced emf across the ends of the conductor is directly proportional to the rate of chenge in magnetic flux linkage with the conductor ✓ ✓ (3)

3.4.1 Smaller than ✓ (1)

3.4.2 The area of a square is smaller than the area a circle with the radius equals to the side length of the square. ✓✓

OR

$\mathcal{E}$ directly proportional to **A** ✓✓ (2)

[13]

QUESTION 4

4.1 The magnitude of the induced emf across the ends of the conductor is directly proportional to the rate of chenge in magnetic flux linkage with the conductor ✓✓ (2)

4.2.1 $\Phi_i = BA\cos\theta$ ✓

$= 1{,}20\ (0{,}25)(0{,}30)\cos 90^0$ ✓

$= 0$ Wb

$\Phi_f = BA\cos\theta$

$= (1{,}20)(0{,}25)0{,}30)\cos 0^0$ ✓

$= 0{,}09$ Wb

$\Delta\phi = \Phi_f - \Phi_i$ (5)

$= 0{,}09 - 0$ ✓

$= 0{,}09$ Wb ✓

4.2.2 $\mathcal{E} = \frac{-N\Delta\phi}{\Delta t}$ ✓

$= -150\ \frac{0{,}09}{0{,}2}$ ✓

$= -67{,}50$ V ✓ (3)

4.2.3 $R = \frac{\mathcal{E}}{I}$ ✓

$50 = \frac{67{,}50}{I}$ ✓

I = 1,35 A ✓ (3)

[13]

QUESTION 5

5.1 The magnitude of the induced emf across the ends of the conductor is directly proportional to the rate of chenge in magnetic flux linkage with the conductor ✓✓ (2)

5.2.1 $\varepsilon = \frac{-N\Delta\phi}{\Delta t}$ ✓

$0,3$✓ $= \frac{-9\Delta\phi}{2 \times 60}$ ✓

$\Delta \phi = 4$ Wb✓ (4)

5.2.2 $\Phi_i = BA\cos\theta$ ✓

$= 0,12\ \pi r^2 \cos 0^0$✓

$= 0,12\ \pi r^2$

$\Phi_f = BA\cos\theta$

$= 12\ \pi r^2 \cos 0^0$

$= 12\ \pi r^2$

$\Delta\phi = 12\ \pi r^2 - 0,12\ \pi r^2$✓

$4 = 11,88\pi r^2$

$r = 0,33$ m ✓ (4)

QUANTITATIVE ASPECT OF CHEMICAL CHANGE

- The mole is the SI unit for the amount of substance (describe as mole)
- The Mole is a name for a specific number. The Mole is the SI unit for quantity of substance
- One mole is the amount of a substance having the same number of particles as there are atoms in 12 g carbon-12. (define a mole)

  Abbreviation of units – the official SI abbreviation of the unit mole is mol.

  The mole - mass relationship is summarised if the formula:

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

Where: n – number of moles of substance in mol.
m – mass of sample of substance in g.
M – molar mass of substance in $g.mol^{-1}$.

Worked Example 1

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

solution

$$n = \frac{m}{M} = \frac{100}{16+(2\times1)} = 5{,}56\ mol$$

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)

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

The mole and Avogadro constant

- The mole is defined as the number of particles or atoms in 12,0 g of Carbon -12.
- A mole of particle is an amount of $6,\ 02 \times 10^{23}$ particles.
- $6,\ 02 \times 10^{23}$ is known as Avogadro's number (N_A).

Worked Example 3

. Calculate the number of moles in:

(i) 2,5g of NH_3

(ii) 213 of Cl_2

Solutions

(i) Molar mass of NH_3

$M_{NH_3}= 14 + 3(1) = 17 g.mol^{-1}$

$n = \frac{m}{M} = \frac{2.5}{17}$ = 0.15 mol

(ii) Molar mass of Cl_2

$M(Cl_2)= 35,5(2) = 71 g.mol^{-1}$

$n = \frac{m}{M} = \frac{213}{71}$ = 3 mol

Practice exercise

1. Calculate the number of moles in:

(i) 213g of Cl_2 (ii) 128g of SO_2

(iii) 39,5g $KMnO_4$ (iv) 20,5g of $Ba(OH)_2$

2. Calculate the mass of:

(i) 0,2mol of NH_3 (ii) 0.7 mol of O_2

(iii) 2,5mol of $Mg(OH)_2$ (iv) 3,5mol of Fe

3. Calculate the molar mass for each of the following:

(i) Ca (ii) $MgCl_2$

(iii) CO_2 (iv) $CaCO_3$

Relationship derived from Balanced Chemical Equation

4Fe(s)	+	$3O_2(g)$	→	$2Fe_2O_3(s)$
Iron	+	oxygen	→	iron(iii)oxide
4 atoms Fe	+	3 molecules O_2	→	2 formula units of Fe_2O_3
4 mol Fe	+	3 mol O_2	→	2 mol of Fe_2O_3
223,4 g Fe	+	96 g O_2	→	319 g of Fe_2O_3
319,4 g reactants			→	319,4 g products

The Mole and the Gases

AVOGADRO'S LAW:

- Avogadro also determine that: One mole of any gas occupies the same volume at the same temperature and pressure.

<u>1 mole of ANY gas at STP is occupies a volume of 22,4 dm^3</u>

For the reactions at STP gas volumes will be according to their molar ratio.

N_2 + $2O_2$ → $2NO_2$

1mol + 2mol → 2mol

1(22,4dm^3) + 2(22,4dm^3) → 2(22,4dm^3)

- The Molar volume of ANY gas at STP is given the symbol V_m **(V_m = 22,4dm^{3}mol^{-1})**

NOTE:STP stands for Standard Temperature and Pressure is 273K(0^{0}C) and 1,01×10^{5}Pa

- For any gas at STP **n** = $\frac{v}{v_m}$
- Where : n - number of moles of gas
  V – Volume of gas sample
  V_m – molar Volume of gas (22, 4 dm^{-3}.mol^{-1})
- The Volume of the gas sample (V) must always be measured in
  dm^3(1 dm^3 = 0,001 m^3 = 1000 cm^3 = dm^3 100ml = 1 litre)

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

- **The mole and Concentrations of solution.**
  - Solutions are homogeneous (uniform) mixture of solute and Solvent
  - Solute and Solvent can be a Gas, liquid or solid.
  - The most common solvent is liquid water, this is called aqueous solution.
  - **Concentration** – Amount of solute per litre of solution.
  - **c** = $\frac{n}{v}$ concentration can also be calculated with c = $\frac{m}{MV}$
    Where: C – concentration (mol.dm^{-3})
    n – number of moles (mol)
    V – Volume (dm^3)
    m – mass in (g)
    M – Molar mass (g.mol^{-1})

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

Solutions

1. $c = \frac{m}{MV} = \frac{5.55}{(111)(0.75)} = 0.067\ mol.dm^{-3}$
2. $c = \frac{m}{MV}$

   $0.4 = \frac{m}{(159.5)(0.2)}$ = 12,76 g

- **The mole and Percentage Composition of Substances**
  - The subscripts in a chemical formula give the mole ratio in which the elements combine.
  - The mole ratio enables one to calculate the percentage composition, of the elements in the compound.
- **The Mole and Empirical formula of compounds.**
  - The empirical formula of a compound gives the simplest mole ratio in which the element of the compound combines.
  - Empirical formula simply tells us the ratio of the different elements in a compound, not number of atoms of each element in molecule.

Steps to find the empirical formula:

Step 1:
Find the mass
Convert the % mass into grams by assuming 100g of a given sample

↓

Step 2:
Calculate the moles of each element by using the formula $n = \frac{m}{M}$

↓

Step 3:
Determine the empirical formula by diving each number of moles by the smallest number of moles to get the simplest whole number ratio

Worked Example 5
E.g. In a combustion reaction 0.48 g of Mg ribbons is burnt. The amount of MgO produced is 0.8g. Calculate the empirical formula for MgO

Steps	Magnesium	Oxygen
Step 1 : mass(grams)	0.48 g	0.80- 0.48= 0.32 g
Step 2: Mol ($n = \frac{m}{M}$)	$n = \frac{m}{M} = \frac{0.48}{24}$ = 0.02 mol	$n = \frac{m}{M} = \frac{0.32}{16}$ = 0.02 mol
Step 3:Atom ratio (divide by smallest number in ratio)	$\frac{0.02}{0.02}$ = 1	$\frac{0.02}{0.02}$ = 1

Therefore the empirical formula is MgO

Worked example 6
The action of bacteria on meat and fish produces a stinking compound called CADAVERINE. The compound has a composition of 58, 77% C; 13,81% H and 27, 42% N by mass.
Determine the empirical formula of CADAVERINE.

Solutions

In 100 g of compound we have 58,77 g C; 13,81 g H; and 27,40 g N

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

n(C) = $\frac{58,77}{12}$ ✓ = 4,8975 mol C

n(H) = $\frac{13,81}{1}$ ✓ = 13,81 mol H

n(N) = $\frac{27,40}{14}$ ✓ = 1,9571 mol N

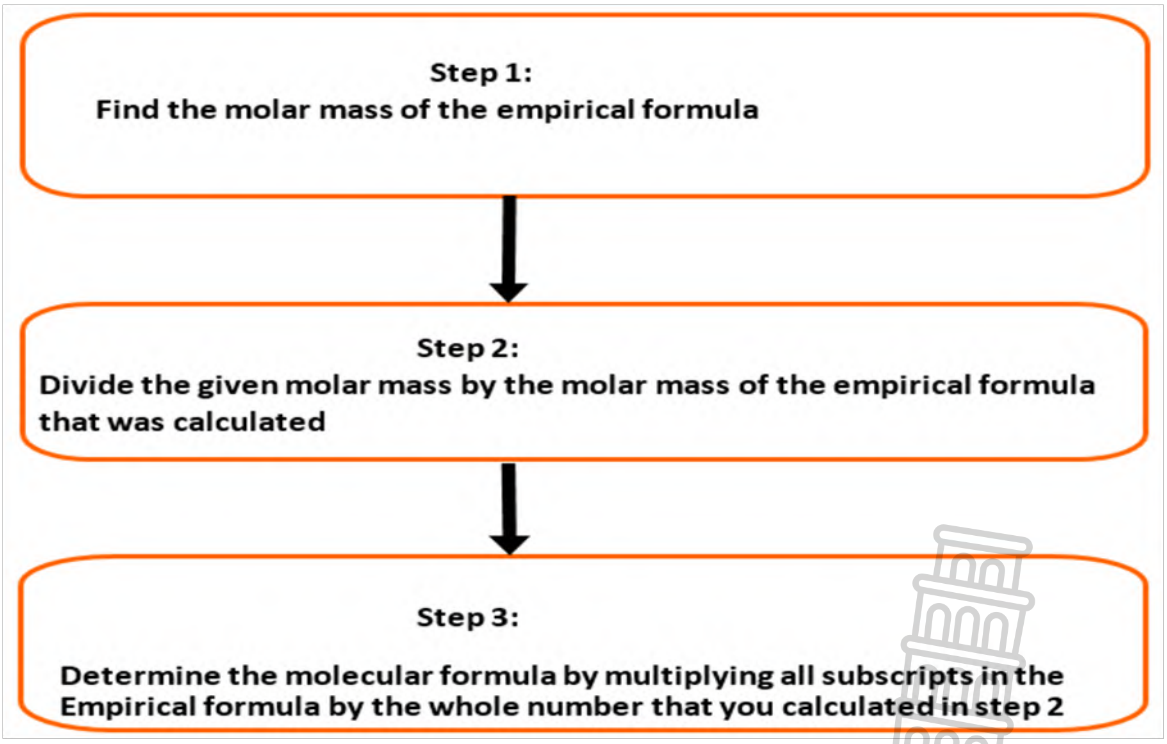
Mole ratios = C: H : N

= 2,50 : 7,06 : 1,00✓ x 2

Nearest whole number ratios = 5 : 14 : 2✓

∴empirical formula is $C_5H_{14}N_2$✓

- **Empirical formula to Molecular formula**
  - Molecular formula is the actual ratio of an atom in a molecular mass.
  - The molecular formula can be calculated from the empirical formula and the relative molecular mass.



Worked example 7

Butene has the empirical formula CH_2.The molecular mass of butene is 56 g.mol^{-1} determine the molecular formula of butene.

Step 1 Empirical formula given CH_2.
Step 2 M (CH_2)= 12+2(1) = 14 g.mol^{-1}

Step 3 ratio number = $\frac{molecular\ formula\ mass}{empirical\ formula\ mass} = \frac{56}{14} = 4$
Step 4 $CH_2 \times 4 = \boldsymbol{C_4H_8}$

Molecular formula: C_4H_8

- **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.
  - 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 8

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

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

1.1. Balance the equation.
1.2. Determine:
1.2.1. Which reactant is a limiting reactant?
1.2.2. The mass of ammonia that can be produced.

Solutions

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

1.2.1. 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

- **Percentage purity**
- Sometimes chemicals are not pure and one needs to calculate the percentage purity.
- Only the pure component of the substance will react.
- For impure sample of a substance :

Percentage purity = $\frac{\textbf{Mass of pure substance}}{\textbf{Mass of impure substance}} \times \mathbf{100}\ \%$

Steps to determine the percentage purity

- ✓ Determine moles of a product.
- ✓ Balance the equation.
- ✓ Determine the ratio between reactants and products.
- ✓ Using the ratio, determine the number of moles of reactants.
- ✓ Determine the mass of pure substance.

✓ Calculate the percentage purity of the sample.

- **Percentage Yield**
- The percentage yield shows how much product is obtained compare to the maximum possible mass.
- Some of the product may be lost due to evaporation into the surrounding air, or to a little being left in solution. This results in the amount of produced being less than maximum theoretical amount you would expect.
- We can express this by the percentage yield :

Percentage yield = $\frac{\textbf{Actual yield}}{\textbf{Theoritical yield}} \times \mathbf{100}\%$

- Percentage yield is usually determined using mass, but can also be determined with mol and volume.

STEPS TO DETERMINE THE PERCENTAGE YIELD

✓ Determine the moles of reactant
✓ Balance the equation.
✓ Using the ratio from the balance equation, determine the numbers of moles of product.
✓ Determine the theoretical mass of product.
✓ Calculate the percentage yield.

Worked example 9

Emphasis that for percentage yield the focus on actual yield and theoretical yield

An excess of $Pb(NO_3)_2$ reacts with 0.75g of KI according to the reaction:

$$Pb(NO_3) + KI \rightarrow PbI_2 + KNO_3$$

After titration and drying, a mass of 0.583g of PbI_2 is measured.

1. Determine the percentage yield of PbI_2

Solutions

1.

Step 1 : (balance chemical equation)
$Pb(NO_3) + 2KI \rightarrow PbI_2 + 2KNO_3$
Step 2 : (convert all given information to mole)

$$n(KI) = \frac{m}{M} = \frac{0.75}{166} = 4.52\text{x}10^{-3}mol$$

Step 3 : (use stoichiometric ratio)
From the balance equation
(n)KI **:** (n)PbI_2
2 **:** 1
$4.52X10^{-3}$:?
(n)PbI_2= $\frac{1}{2}(4.52\text{x}10^{-3}) = 2.26\text{x}10^{-3}\ mol$
Step 4 : (convert the number of moles to mass)

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

$$2.26\text{x}10^{-3} = \frac{m}{461}$$

$$m = 1.04g$$

Step 5 : (percentage yield)

$$Percentage\ yield = \frac{actual\ yield\ mass}{theoretical\ yeild\ mass}X100$$

$$Percentage\ yield = \frac{0.583}{1.04}\text{x}100$$

$$Percentage\ yield = 56.1\%$$

Worked example 10

A sample of $NaNO_3(s)$ of mass 4,25 g was heated and 500 cm^3 of $O_2(g)$ was collected at STP. The chemical reaction that takes place is:

$2NaNO_3(s) \rightarrow 2NaNO_2(g) + O_2(g)$

Calculate:

1. The theoretical volume of $O_2(g)$ that was formed.
2. The percentage purity of the $NaNO_3(s)$.

Solution

1. $M_{NaNO3} = 23 + 14 + (16 \times 3) = 85 g.mol^{-1}$

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

$n = \frac{4.25}{85}$

$= 0.05\ mol\ NaNO_3$

$n_{NaNO3} = n_{O2}$

$2 = 1$

$0.05 = n_{O2}$

$0.05 \times 1 = 2n_{O2}$

$n_{O2} = \frac{0.05}{2}$

$n_{O2} = 0.025\ mol$

Volume of oxygen produced

$V_{O2} = nV_m$

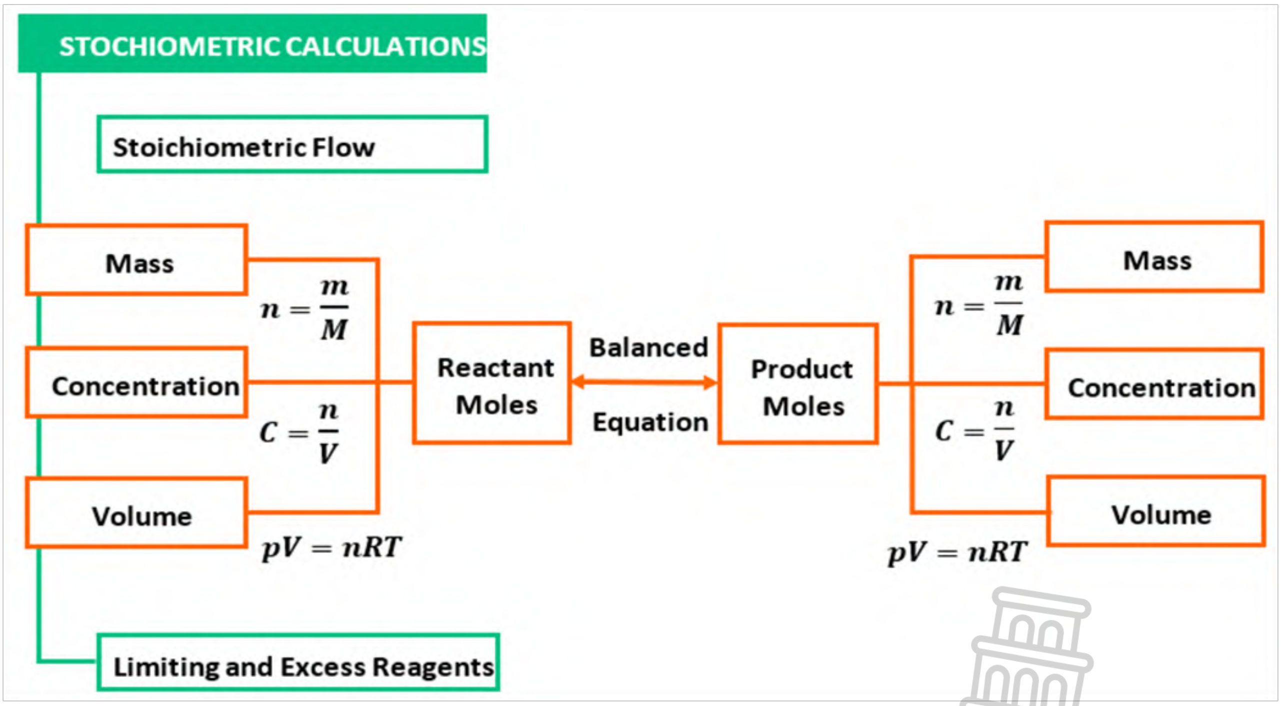
$V_{O2} = 0.025 \times 22.5$

$= 0.560\ dm^3$

2. $Percentage\ purity = \frac{Actual\ Volume}{Theoretical\ Volume} \times 100\%$

$= \frac{0.500}{0.560} \times 100$

$= 89.29\%$



Multiple choice questions

1. Choose the correct answer

1.1 ….of a gas is the volume of one mole of a substance at STP.

A. Molar mass
B. Molar volume
C. Atomic weight
D. Molar weight

1.2 Equal volumes of all gases at the same temperature and pressure contain the same number of…

A. protons
B. neutrons
C. electrons
D. molecules

1.3 How many moles of chloride ions are present in 111 g of calcium chloride?

A. 0,5
B. 2
C. 1
D. 1,47

1.4 What amount of oxygen gas (in moles) contains $1,8 \times 10^{22}$ molecules?

A. 0,03
B. 33,34
C $1,2 \times 10^{24}$
D $1,08 \times 0^{46}$

Question 1 - CONCENTRATION

1.1 Learners prepare a solution of sodium hydroxide (NaOH) in water by placing 8 g of sodium hydroxide (NaOH) in a volumetric flask and adding water to produce 250 cm^3 of solution after stirring.

1.1.1 Define concentration in words. (2)

1.1.2 Calculate the concentration of sodium hydroxide (NaOH) in solution. (4)

Sodium azide (Na_3N) is used in car airbags. For the airbag to inflate the following reaction must take place:

$$\mathbf{2\,Na_3N\,(s) \longrightarrow 6Na\,(s) + N_2\,(g)}$$

1.2 Calculate the volume of nitrogen gas (N_2) that would be produced at STP if 55 g of sodium azide reacts completely. (5)

Question 2 – EMPIRICAL FORMULA

2.1 Methyl propanoate is an organic compound with the following percentage composition:

54,55% C ; 9,09% H ; 36,36% O

The molar mass of the compound is 88 $g.mol^{-1}$

2.1.1 Define the term empirical formulae. (2)

2.1.2 Determine, by calculation , the empirical formula. (6)

2.1.3 Determine the molecular formula. (2)

2.2 In order to determine the empirical and molecular formula of a compound, C_xH_y, a certain mass of compound is burnt completely in excess oxygen to produce 47,1 g CO_2 and 19,35 g H_2O as the only products.

2.2.1 Use relevant calculations to determine the empirical formula of the compound. (8)

2.2.2 The molar mass of the compound is 28 $g.mol^{-1}$. Determine by using calculations the values of x and y. (2)

Question 3 – COMPLEX STOICHIOMETRIC CALCULATIONS

3.1 A sample of IMPURE calcium carbonate (limestone) of unknown mass required a continuous supply of strong heat to decompose according to the following equation:

$$\mathbf{CaCO3(s) \rightarrow CaO(s) + CO_2(g)}$$

After the completion of reaction, 11,76 g CaO was produced.
The percentage purity of calcium carbonate is found to be 80%
Calculate the mass of impure calcium carbonate. (6)

3.2 During a chemical reaction, 7,62 g potassium was added to a test tube containing 4,34 g molten sulphur. The potassium and the sulphur reacted to form a potassium sulphide according to the following balanced equation:

$$2K_{(S)} + S_{(s)} \rightarrow K_2S_{(S)}$$

3.2.1 Calculate the number of moles of potassium. (3)

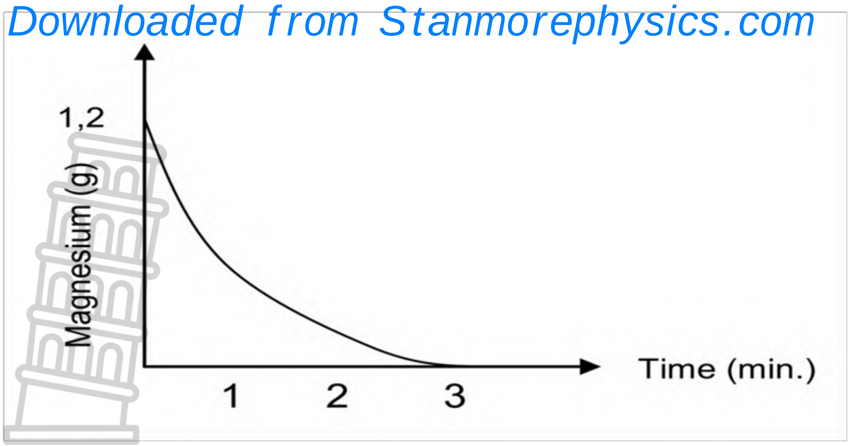
3.2.2 Determine the limiting reagent. (5)

3.2.3 Calculate the mass of K_2S produced (3)

3.3 During the reaction In an experiment, a learner adds $\mathbf{500}\boldsymbol{cm}^3$of hydrochloric acid (HCℓ) along with a concentration of $\mathbf{0.36}\boldsymbol{mol.\,dm}^{-3}$to 1, 2 g of magnesium in a test tube.
She records the change in the mass of magnesium as the reaction proceeds at regular intervals. The balanced chemical equation for the reaction is:

$$\mathbf{Mg(\boldsymbol{s}) + 2\boldsymbol{HC\ell}_{(\boldsymbol{aq})} \rightarrow MgCl_{2(aq)} + H_{2(\,g\,)}}$$

The mass change of magnesium graph is shown on the graph below.



Use the graph given above to answer following questions.

3.3.1 Identify the limiting agent in the reaction. Give a reason for your answer. (2)

3.3.2 Calculate the number of moles of reacted hydrochloric acid in three minutes. (5)

[7]

3.4 An excess of $Pb(NO_3)_2$ reacts with 0.75g of KI according to the reaction:

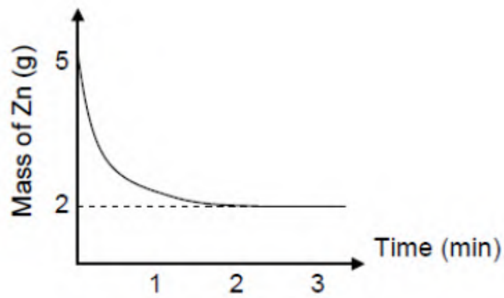
$$Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$$

After titration and drying, a mass of 0.583g of PbI_2 is measured.
Determine the percentage yield of PbI_2 [6]

3.5 Zinc reacts with sulphuric acid according to the reaction below.

$$\mathbf{Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)}$$

The mass of zinc is recorded during the experiment and is shown on the graph below. The reaction stops after 2 minutes



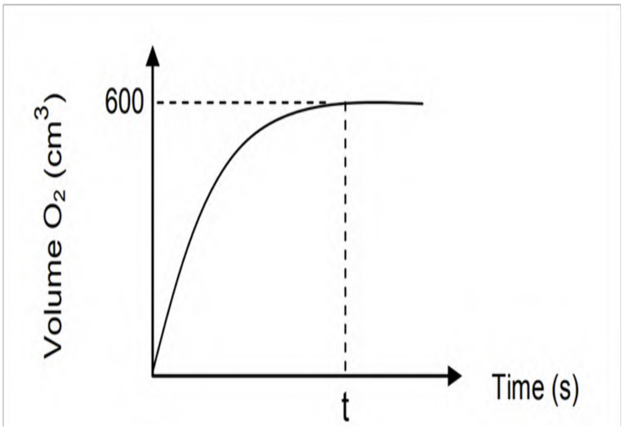
3.5.1 Name the substance that is the limiting reagent. Give a reason for your answer. (2)

3.5.2 Calculate the initial concentration of the sulphuric acid if 50 cm^3 of the acid was used. (5)

3.6 Decomposing hydrogen peroxide in the presence of a catalyst at a specific pressure and room temperature is given by the unbalanced chemical equation below:

$$H_2O_2 \rightarrow H_2O + O_2$$

Oxygen gas is collected and the volume is recorded over time(T). The results are then graphed below.



Take the molar gas volume (V_m) to be 24,45 dm^3 at room temperature and standard pressure.

3.6.1 Balance the equation given above. (2)

3.6.2 Using the information from the graph, calculate the mass of hydrogen peroxide that decomposed. (5)

QUESTION 4

4 15g of impure $Mg(OH)_2$ was reacted with excess phosphoric acid to produce 16g of $Mg_3(PO_4)_2$ according to the following balanced equation:

$$3Mg(OH)_2\ (s) + 2H_3PO_4\ (aq) \rightarrow Mg_3(PO_4)_2\ (s) + 6H_2O\ (l)$$

4.1 Calculate the percentage purity of the $Mg(OH)_2$ (5)

4.2 If 20g of the same impure $Mg(OH)_2$ was used in the above reaction, how will each of the following be affected?
Choose from INCREASES, DECREASES, or REMAINS THE SAME
4.2.1 The mass of $Mg_3(PO_4)_2$ produced (1)
4.2.2 The percentage purity of the Mg(OH)2. (1)
4.2.3 Explain the answer to question 4.2.2 (2)

QUESTION 5- EMPIRICAL FORMULA and PERCENTAGE YIELD

5.1 Aspirin is known by the chemical formula acetylsalic acid. It is made up of C, H and O only. A sample of asprin has the following percentage compositions:

C	H	O
58,065%	7,527%	X

5.1.1 Define the term empirical formula. (2)
5.1.2 What is the percentage of oxygen(X) in aspirin? (1)
5.1.3 Determine the empirical formula of aspirin. (5)
5.1.4 If the molecular mass of aspirin is $186g.mol^{-1}$, determine its molecular formula. (2)

5.2 The chemical reaction for the production of the drug, aspirin, from two compounds, X and Y, is represented by the balanced equation below.

$$\underset{X}{2C_7H_6O_3} + \underset{Y}{C_4H_6O_3} \rightarrow \underset{\text{aspirin}}{2C_9H_8O_4} + H_2O$$

A chemist reacts 14g of compound X with 10g of compound Y.
5.2.1 Define the term limiting reagent in a chemical reaction. (2)
5.2.2 Perform the necessary calculations to determine which one of the compound X or compound Y is the limiting reagent. (5)
5.2.3 During the production of aspirin it is found that the actual mass obtained is 11.5 g. Calculate the percentage yield of aspirin (5)

QUESTION 6
The fizz produced when an antacid dissolves in water is caused by the reaction between sodium hydrogen carbonate ($NaHCO_3$) and citric acid ($H_3C_6H_5O_7$). The balanced equation for the reaction is:

$$3NaHCO_3(aq) + H_3C_6H_5O_7(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3CO_2(g) + 3H_2O\ (l)$$

6.1 Write down the formula of the substance that causes the fizz when the antacid dissolves in water. (1)

6.2 A certain antacid contains 1.8 g of $H_3C_6H_5O_7$ and 3.36 g of $NaHCO_3$. The antacid is dissolved in $100cm^3$ distilled water in a beaker.

6.2.1 Define 1 mole of a substance. (2)
6.2.2 Calculate the number of moles of $NaHCO_3$ in the antacid. (3)
6.2.3 Determine, using calculations, which substance is the limiting reagent. (4)
6.2.4 Calculate the mass of the reactant in excess. (3)
6.2.5 Calculate the mass decrease of the beaker contents on completion of the reaction. (3)

QUANTITATIVE ASPECT OF CHEMICAL CHANGE
SOLUTIONS
Multiple choice questions
1.1 B✓✓ (2)
1.2 D✓✓ (2)
1.3 B ✓✓ (2)
1.4 A✓✓ (2)
QUESTION 1 [8]
1.1.1 Concentration is the amount of solute per litre of solution ✓✓ (2)
1.1.2 Option 1

$M_r = 23 + 16 + 1$
$= 40g.mol^{-1}$
$n = \frac{m}{M}$

Option 2

$c = \frac{m}{MV}$ ✓
$c = \frac{8}{40\times250\times10^{-3}}$ ✓✓

$n = \frac{8}{40}$ ✓ $\qquad n = 0.8\ mol.dm^{-3}$ ✓

$= 0.2\ mol\ NaOH$

$c = \frac{n}{V}$ ✓

$c = \frac{0.2}{250\times10^{-3}}$ ✓

$= 0.8\ mol.dm^{-3} NaOH$ ✓ (4)

1.2 $2\ Na_3N\ (s) \rightarrow 6Na\ (s) + N_2\ (g)$

Moles of Na_3N:

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

$n = \frac{55}{(23\times3)+14}$ ✓

$n = \frac{55}{83}$

$= 0.66\ mol$

Ratio

$n_{Na3N} : n_{N2}$

$2 : 1$ ✓

$\therefore n_{N2} = 0.33\ mol$

Volume of Nitrogen produced:

$n = \frac{V}{V_m}$ ✓

$0.33 = \frac{V}{22.4}$ ✓

$V = 7.392\ dm^3$ ✓ (5)

[11]

QUESTION 2

2.1.1 The empirical formula of a compound gives the simplest mole ratio in which the element of the compound combines ✓✓ (2)

2.1.2 Assume that there is 100g of sample

Elements	C	H	O	
Mass (g)	54.55	9.09	36.36	✓
Molar mass ($g.mol^{-1}$)	12	1	16	✓
Number of moles (mol)	$n = \frac{m}{M}$ $n = \frac{54.55}{12}$ $= 4.546$	$n = \frac{m}{M}$ $n = \frac{9.09}{1}$ $= 9.09$	$n = \frac{m}{M}$ $n = \frac{36.36}{16}$ $= 2.275$	✓
Ratio	$n = \frac{2.275}{40}$ $= 2$	$n = \frac{9.09}{2.275}$ $= 4$	$n = \frac{9.09}{2.275}$ $= 1$	✓

Empirical formula: C_2H_4O ✓ (5)

2.1.3 $M_{Empirical\ Formula} = 2 \times 2 + (4 \times 1) + 16$

$= 44 g.mol^{-1}$

$nM_{(Empirical\ formula)} : M_{(Molecular\ formula)}$

$n \times 44 = 88$

$n = 2$ ✓

Therefore: the molecular formula is: $C_{2\times2}\ H_{4\times2} O_{1\times2}$

$= C_4H_8O_2$ ✓ (2)

2.2.1 $n_{(H2O)} = \frac{m}{M}$ ✓

$n = \frac{19.35}{18}$ ✓

$= 1.075\ mol$

$n_{H2} : n_{H2O}$

$2 : 1$ ✓

$n_{H2} :\ 2 \times 1.075$ ✓

$n_{H2} = 2.15\ mol$

$n_{CO2} = \frac{m}{M}$

$n = \frac{47.1}{44}$✓

$= 1.07\ mol$

$mol_C : mol_H$

$1.07 : 2.15$✓

$1 : 2$✓

Therefore: the Empirical formula is: CH_2✓ (8)

2.2.2 $M_{(CH2)} = 12 + (2 \times 1)$

$= 14 g.mol^{-1}$

$nM_{(Empirical\ formula)} : M_{(Molecular\ formula)}$

$n \times 14 = 28$✓

$n = 2$

Therefore the molecular formula is: $C_{1\times2} : H_{2\times2}$

$= C_2H_4$✓ (2)

QUESTION 3

3.1 Number of moles of CaO $M_{CaO} = 40 + 16$

$= 56\ \mathrm{g.mol}$

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

$n = \frac{11.76}{56}$✓

$= 0.21 mol$

$n_{CaCO3} : n_{CaO}$

$1 : 1$✓

$n_{CaCO3} = 1 \times 0.21$

$n_{CaCO3} = 0.21\ mol$

$n_{CaCO3} = \frac{m}{M}$

$0.21 = \frac{m}{100}$✓

$= 21 g$

$Percentage\ purity = \frac{Mass\ of\ pure\ sample}{Mass\ of\ Impure\ Sample} \times 100\%$✓

$80 = \frac{21}{Mimpure} \times 100\%$✓

$= 26.25 g$✓ (6)

3.2.1 Moles of potassium

$n = \frac{m}{M}$✓

$= \frac{7.62}{39}$✓

$= 0.195 mol$✓ (3)

3.2.2 No. of mol potassium

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

$= \frac{7.62}{39}$✓

$= 0.195 mol$

No. of moles of sulphur

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

$= \frac{4.34}{32}$✓

$= 0.135\ mol$✓

Ratio Potassium

$n = \frac{0.195}{2}$

$= 0.0975 mol$

Sulphur

$n = \frac{0.135}{1}$ ✓

$= 0.135\ mol$

$n_K < n_S$

Therefore: Potassium is a limiting reagent ✓ (5)

3.2.3 $n_{K2S} = n_K$

$1 : 2$✓

$n_{K2S} : 0.195$

$n_{K2S} = \frac{0.195}{2}$

$n_{K_2S} : 0.0975\ mol$

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

$0.0975 = \frac{m}{110}$✓

$= 10.72 g\ K_2S$✓ (3)

[11]

3.3.1 Magnesium. Mass of magnesium was zero at the end of the reaction✓✓ (2)

3.3.2 No. of mol HCl

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

$n = cV$✓

$= 0.36 \times 0.5$ ✓

$= 0.18\ mol$

No. of moles of magnesium

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

$= \frac{1.2}{24}$✓

$= 0.05\ mol$✓

Mol HCl reacted:

$n_{HCl} = n_{Mg}$

$2\ : 1$✓

$n_{HCl} : 0.05$

$n_{HCl} = 0.1\ mol$

$n_{excess} = n_{initial} - n_{reacted}$

$n_{excess} = 0.18 - 0.1$ ✓

$n_{excess} = 0.08\ mol\ HCl$ ✓ (5)

[7]

3.4

$n = \frac{m}{M}$ ✓

$= \frac{0.75}{166}$ ✓

= 4.5×10^{-3} mol

KI : PbI_2

2: 1 ✓

n(PbI_2)=2.26X10-3 mol

$2.26 \times 10^{-3} = \frac{m}{461}$ ✓

m(PbI_2)=1.04186 g

$$percentage\ yield = \frac{\text{actual mass}}{\text{theoretical mass}} x100$$

$$= \frac{0,583}{1,04186} x100 \quad ✓$$

$$= 55,96\ \% \quad ✓$$

[6]

3.5

3.5.1 Sulfuric acid✓ , used up completely after 2 minutes✓ (2)

3.5.2 Marking criteria

- formula ; $n = \frac{m}{M}$
- Subt.Into n=n/M
- Ratio 1:1
- Substitution of moles and volume in dm^3
- Answer with units

$n = \frac{m}{M}$ ✓

$= \frac{3}{65}$ ✓

=0.0462 mol

Ratio Zn: H_2SO_4

1:1 ✓

N(H2SO4)=0.0462 mol

$C = \frac{n}{v}$✓

$= \frac{0.0462}{0.05}$ ✓

$= 0.92$ $mol.dm^{-3}$✓ (6)

[8]

3.6

3.6.1 $2H_2O_{2(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$ ✓✓ (2)

3.6.2 $n = \frac{V}{Vm}$ ✓

$= \frac{0.6}{24.45}$ ✓

$= 0.0245$ mol O_2 produced

H_2O_2: O_2

2:1 ✓

n=0.049 mole H_2O_2 reacted

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

$0.049 = \frac{m}{34}$ ✓

$= 1{,}67g$ ✓ (5)

4.1 Mg_3PO_4 Produced:

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

$= \frac{16}{262}$ ✓

$= 0.061mol$

Mol of pure $Mg(OH)_2$ used

Ratio

$n_{Mg(OH)2} = n_{Mg3(PO4)2}$

3 : 1

$n_{Mg(OH)2}$: 0.061

$n_{Mg(OH)2} = 0.061 \times 3$ ✓

$n_{Mg(OH)2}$: $0.183\ mol$

Mass of pure $Mg(OH)_2$ used:

$M_r = 24 + 2(16 + 1)$

$= 58g.mol$

$m = nM$

$m = 0.183 \times 58$ ✓

$= 10.614g$

$$Percentage\ purity = \frac{Mass\ of\ pure\ sample}{Mass\ of\ Impure\ sample} \times 100\%$$

$\%\ purity = \frac{10.614}{15} \times 100$ ✓

$= 70.76\%$ ✓ (5)

4.2.1 Increases ✓ (1)

4.2.2 Remains the same ✓ (1)

4.2.3 The ratio of the mass of pure $Mg(OH)_2$ in a given sample to the total mass of the sample remains constant ✓✓ (2)

5.1

5.1.1 Simplest whole number of atoms in a compound ✓✓ (2)

5.1.2 (X)Percentage O =100- (58,065+7,527)

=34,408% ✓ (1)

5.1.3

	C	H	O
Mass(grams)	58,065	7,527	34,408
n=m/M	$\frac{58{,}065}{12}$ =4,83875	$\frac{7{,}527}{1}$ =7,527	$\frac{34{,}408}{16}$ =2,1505
Divide by smallest mol	$\frac{4{,}83875}{2{,}1505}$ =2.25	$\frac{7{,}527}{2{,}1505}$ =3,5	$\frac{2{,}1505}{2{,}1505}$ =1
Ratio	2,25x4 =9	3,5x4 =14	1x4 =4
Empirical formula	$C_9H_{14}O_4$		

Marking criteria

- Mass in grams for all compounds(C=58,065g;H=7,527g;O=34,408g)
- Subst. into n=m/M
- Dividing by smallest ratio
- Multiplying by 4 to find simplest whole number ratio
- Empirical formula (5)

5.1.4 M($C_9H_{14}O_4$) = 9(12)+14(1)+4(16)

=186 g.mol^{-1}✓

molecular formula is $C_9H_{14}O$ ✓ (2)

5.2.1 Liming reagent is the substance that is totally used up in chemical reaction.✓✓ (2)

5.2.2 Marking criteria

- Formula n=m/M
- Subst. into n=m/M
- Mole ratio
- Compare required and available mole
- Correct identification of limiting reagent

OPTION 1

n($C_7H_6O_3$) =m/M ✓

=14/138 ✓

=0.1014 mol

n($C_4H_6O_3$) =m/M

=10/102✓

=0.098 mol

2n($C_7H_6O_3$): n($C_4H_6O_3$)

2:1 ✓

From the balanced equation: 2n($C_7H_6O_3$) reacts with n($C_4H_6O_3$)

0.1014mol of $C_7H_6O_3$(x) needs 0.0507 mol of $C_4H_6O_3$(Y)

Therefore, $C_4H_6O_3$(X) is the limiting reagent. ✓

OPTION 2

n($C_7H_6O_3$) =m/M ✓

=14/138 ✓

=0.1014 mol

n($C_4H_6O_3$) =m/M✓

=10/102 ✓

=0.098 mol

2n($C_7H_6O_3$): n($C_4H_6O_3$)

2:1 ✓

Mole ratio (x) = 0.1014/2

= 0.0507

Mole ratio(Y) = 0.098/1

=0.098

Ratio(X) < Ratio (Y)

Therefore, $C_4H_6O_3$(X) is the limiting reagent. ✓ (5)

5.2.3 $C_9H_60_3$: $C_9H_80_4$

1 : 2✓

0.098: x

n($C_9H_60_3$) =0.196 mol

m=nM✓

m=0.196x180 ✓

m=35,28g

$$percentage\ yield(\%) = \frac{\text{actual yield}}{\text{theoretical yield}}x100$$

$$= \frac{11{,}5}{35{,}28}x100 ✓ \qquad =32{,}60\ \%\ ✓$$ (5)

QUESTION 6

6.1 CO_2✓ (1)

6.2

6.2.1 The amount of substance having the same number of particles as there are atoms in exactly 12 grams of carbon-12. ✓✓ (2)

6.2.2 Moles of NaH(CO)$_3$

$n = \frac{m}{M}$✓

$n = \frac{3.36}{84}$✓

$= 0.04\ mol$✓ (3)

6.2.3 Mole of $H_3C_6H_5O_7$:

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

$n = \frac{1.8}{192}$✓

$= 9.38 \times 10^{-3} mol$

Ratio

$n_{NaHCO3} : n_{H3C6H5O7}$

$3 : 1$

n_{NaHCO3} : 9.38×10^{-3}

n_{NaHCO3} : $9.38 \times 10^{-3} \times 3$✓

$= 2.81 \times 10^{-2} mol$✓

$n_{NaHCO3} > n_{H3C6H5O7}$

Therefore: $H_3C_6H_5O_7$ is a limiting reagent✓ (4)

6.2.4

$n_{(NaHCO3)excess} = n_{initial} - n_{reacted}$

$n_{(NaHCO3)} = 0.04 - 2.81 \times 10^{-2}$ ✓

$= 1.19 \times 10^{-2} mol$

Mass of $NaHCO_3$ in excess:

$m = nM$

$m = 1.19 \times 10^{-2} \times 84$✓

$= 0.998 g$✓ (3)

6.2.5

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

$2.81 \times 10^{-2} = \frac{m}{44}$✓✓

$= 1.24\ g$✓ (3)

IDEAL GASES & THERMAL PROPERTIES

TERM	DEFINITION
Boyle's Law	The pressure of an enclosed gas is inversely proportional to the volume it occupies at constant temperature.
The Ideal gas law	The amount of a gas is determined by its pressure, volume and temperature. In symbols, PV = nRT.
Ideal gas	A gas which fulfils a number of assumptions and obeys the equation: PV = nRT.
Real gas	A gas that occurs in nature and will not obey PV = nRT, especially at high pressure and low temperatures.
Kelvin temperature	0 K is absolute zero, and 273 K = 0°C. T(K)= T(°C) + 273
Pressure	Pressure arises from the collisions of the particles with the walls of the container. It depends on the frequency of the collisions per unit area
Temperature	A measure of the average kinetic energy of the particles. A measure of hotness or coldness, usually measured with a thermometer.
Volume	The space occupied by the gas in the container.

KINETIC MOLECULAR THEORY (Grade 10 Revision)

- All matter is made up of particles which are atoms, molecules, and ions.
- The particles move continually and move in straight lines except when they collide with each other or the walls of a container.
- There are empty spaces between the particles.
- The molecules in a gas are so small that they occupy zero volume.
- Forces of attraction exist between the particles of a gas when they are relatively close to each other.
- Forces of repulsion occur when particles come too close to each other.
- If heat is transferred to the substance, the average kinetic energy of particles of a substance increase (i.e. the temperature of particles increase).
- Phase change occurs when temperature is absorbed or released.

Properties of an ideal gas
The particles of the ideal gas:
- Occupy no volume.
- Are identical in all ways.
- Exert no forces on each other except during a collision. All collisions between gas molecules are completely elastic. No energy is lost or gained during a collision.

When will a real gas show an ideal behaviour?
- A real gas such as nitrogen, hydrogen, oxygen, carbon dioxide etc., will display an ideal gas behavior at high temperature and low pressure.

At high temperature:
- The gas molecule has a higher average kinetic energy.
- The gas molecules move faster and further apart so that the attractive forces between the gas molecules decreases.
- The volume of the gas increases.

At low pressure:
- The gas molecules move far away from each other.
- The forces of attraction between gas molecules are negligible.
- The gas molecules do not contribute to the volume of the gas.

When will a real gas exhibit non-ideal behaviour?
At low temperature:
- Average kinetic energy of the gas molecules is lower.
- Particles move much slower and near to each other so that the forces of attraction between the gas molecules increase.
- The volume is smaller than what the gas laws predict.
- At very low temperatures molecules of the gas move so close together that the gas liquefies.

At high Pressure:
- The gas molecules move closer together.
- The intermolecular forces are greater.
- The measured volume of the gas is greater than expected.
- The gas molecules contribute to the volume of the gas.

TYPES OF REACTIONS

1. ACIDS AND BASES

Define acids and bases according to Arrhenius and Lowry-Brønsted:

Arrhenius theory:

An acid is a substance that produces hydrogen ions (H^+)/hydronium ions (H_3O^+) when it dissolves in water.

A base is a substance that produces hydroxide ions (OH^-) when it dissolves in water.

Lowry-Brønsted theory:

An acid is a proton/H^+ ion donor.

A base is a proton/H^+ ion acceptor.

Common acids: hydrochloric acid, nitric acid, sulphuric acid and ethanoic acid (acetic acid).

Common bases: ammonia, sodium carbonate (washing soda), sodium hydrogen carbonate, sodium hydroxide (caustic soda) and potassium hydroxide.

1.1. Strength of acid and base

STRONG ACIDS	STRONG BASES
($HC\ell$)Hydrochloric acid (monoprotic) (HNO_3)Nitric acid(monoprotic) (H_2SO_4)Sulphuric acid (diprotic) (H_3PO_4)Phosphoric acid (triprotic)	($NaOH$) Sodium hydroxide (KOH)Potassiumhydroxide ($LiOH$) Lithium hydroxide $Ba(OH)_2$ Barium hydroxide
WEAK ACIDS	WEAK BASES
(CH_3COOH)Aceticacid $(COOH)_2$ Oxalic acid	NH_3 - Ammonia $Zn(OH)_2$ – Zinc hydroxide Na_2CO_3 – Sodium carbonates

Strong acids ionise completely in water to form a high concentration of H_3O^+ ions. Weak acids ionise incompletely in water to form a low concentration of H_3O^+ ions.
Strong bases dissociate completely in water to form a high concentration of OH^- ions.Weak bases dissociate/ionise incompletely in water to form a low concentration of OH^- ions.

1.2. Concentrated and dilute acids/bases.

Concentrated acids/bases contain a large amount (number of moles) of acid/base in proportion to volume of water. Dilute acids/bases contain a small amount (number of moles) of acid/base in proportion to volume of water.

Dilutions : $C_1V_1 = C_2V_2$ **$V_2 = V_1 + V_{water}$ (Note: to calculate V_2)**

Example:
Calculate how much water must be added to 30cm^3 of a 0.2 mol.dm^{-3} HCl solution to change the concentration to 0.03 mol.dm^{-3}.

Solution
$C_1V_1 = C_2V_2$
$0.2 \times 0.03 = 0.03V_2$
$V_2 = \frac{0.006}{0.03}$
$V_2 = 0.2dm^{-3}$ therefore the volume of water to be added is:$V_2 = V_1 + V_{H_2O}$
$V_{H_2O} = V_2 - V_1$
$V_{H_2O} = 0.17dm^3$

1.3. Reaction equations of aqueous solutions of acids and bases.

Examples:
Ionisation equations.
$HC\ell(g) + H_2O(\ell) \rightarrow H_3O^+(aq) + C\ell^-(aq)$ ($HC\ell$ is a monoprotic acid.)
$NH_3(g) + H_2O(\ell) \rightarrow NH_3\ (aq) + OH^-(aq)$
$H_2SO_4(aq) + 2H_2O(\ell) \rightarrow 2H_3O^+(aq) + HSO_4^-\ (aq)$ (H_2SO_4 is a diprotic acid.)

Dissociation equations
$NaOH_{(aq)}\ H_2O \rightarrow\ Na^+_{(aq)} + OH^-_{(aq)}$
$KOH_{(aq)}\ H_2O \rightarrow\ K^+_{(aq)} + OH^-_{(aq)}$
$Mg(OH)_{2(aq)}\ H_2O \rightarrow\ Mg^{2+}_{(aq)} + 2OH^-_{(aq)}$

1.4. Identifying conjugate acid-base pairs.

When the acid, HA, loses a proton, its conjugate base, A^-, is formed. When the base, A^-, accepts a proton, its conjugate acid, HA, is formed. These two are a conjugate acid-base pair.

Example

I. $HC\ell(g) + H_2O(\ell) \rightarrow H_3O^+(aq) + C\ell^-(aq)$
Acid 1 Base 2 Acid 2 Base 1

II. $NH_3(g) + H_2O(\ell) \rightarrow NH_4^+\ (aq) + OH^-(aq)$
Base 2 Acid 1 Acid 2 Base 1

III. HSO_4^- aq) + $H_2O(\ell) \rightarrow H_3O^+(aq) + SO_4^{2-}\ (aq)$
Acid 1 Base 2 Acid 2 Base 1

IV. $H_2S0_4\ (aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + HSO_4^-\ (aq)$
Acid 1 Base 2 Acid 2 Base 1

1.5. Ampholytes

- Substance that can act as either acid or base.
- Water is a good example of an ampholyte substance in reaction (I) water act as a base receiving a proton but in reaction (II) water act as an acid donating a proton when reacting with ammonia.
- HSO_4^- is also an ampholyte because in reaction (III) it act as an acid but in reaction (IV) it act as an base and accepts a proton.

1.6. Neutralisation reactions of common laboratory acids and bases.

General equations

When an acid reacts with a metal hydroxide a salt and water are formed. The salt is made up of a cation from the base and an anion from the acid.

Acid + metal hydroxide (base) → salt + water

Eg. $H_2SO_4\ (aq) + Mg(OH)_2\ (aq) \rightarrow MgSO_4\ (aq) + 2H_2O\ (\ell)$

When an acid reacts with a metal oxide a salt and water are formed. An example is the reaction between magnesium oxide (MgO) and hydrochloric acid (HCl).

Acid + metal oxide → salt + water

E.g. $2HC\ell\ (aq) + MgO(s) \rightleftharpoons MgCl_2\ (aq) + 2H_2O\ (\ell)$

When an acid reacts with a metal carbonate a salt, water and carbon dioxide are formed. An example is the reaction between calcium carbonate ($CaCO_3$) and $HC\ell$

Acid + metal carbonate → salt + water + carbon dioxide

E.g. $2HC\ell\ (aq) + CaCO_3\ (s) \rightleftharpoons CaC\ell_2(aq) + H_2O\ (\ell) + CO_2(g)$

1.7. Indicators

An indicator is a compound that changes colour according to the pH of the substance. During titrations, the indicator needs to be selected according to the acidity/alkalinity of the salt that will be produced (see hydrolysis).

INDICATOR	COLOUR IN ACID	COLOUR IN BASE	COLOUR AT EQUIVALENCE POINT	pH RANGE OF EQUIVALENCE
Litmus	Red	Blue		4,5 - 8,3
Methyl orange	Red	Yellow	Orange	3,1 - 4,4
Bromothymol blue	Yellow	Blue	Green	6,0 - 7,6
Phenolphthalein	Colourless	Pink	Pale Pink	8,3 - 10,0

pH calculation

To calculate the pH of a solution the concentration of H_3O^+ must be known or be determined. The reaction of water with itself produces H_3O^+ and OH^- ions, it is called the auto-ionisation of water. The equation is given below:

$H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$

neutral solution $[H_3O^+] = [OH^-] = 1\times10^{-7}\ mol\cdot dm^{-3}$

acidic solution $[H_3O^+] > 1\times10^{-7}\ mol\cdot dm^{-3}$ and $[H_3O^+] > [OH^-]$

basic solution $[H_3O^+] < 1\times10^{-7}$ and $[H_3O^+] < [OH^-]$

Calculate pH values of strong acids and strong bases using $pH = -\log[H_3O^+]$.

Steps to calculate pH of acids

1. Write down a balanced equation for the ionisation reaction of the acid (reaction with water)
2. Use ratios to determine the concentration of $[H3O^+]$
3. Substitute the concentration of $[H3O^+]$ in the formula $pH = -\log[H3O^+]$

Example 1

A few drops of bromothymol blue indicator are added to a potassium hydroxide solution in a beaker. A dilute sulphuric acid solution is now gradually added to this solution until the colour of the indicator changes.

Write down the:

1. Colour change of the indicator

Solution: green

Activity 1

1. Identify the conjugate acid base pair for the reactions below

1.1. $H_2CO_3 + H_2O \rightarrow H_3O^+ + HCO_3^-$ (2)

1.2. $H_2O + HCO_3^- \rightarrow H_3O^+ + CO_3^{2-}$ (2)

1.3. $H_2SO_4 + 2H_2O \rightarrow 2H_3O^+ + SO_4^{2-}$ (2)

Solutions 1

1.

1.1. H_2CO_3 is the conjugate acid of HCO_3^- (base) (2)
OH^- is the conjugate base of H_2O (acid)

1.2. HCO_3^- is a conjugate acid of CO_3^{2-} base (2)
H_3O^+ is a conjugate acid of H_2O base.

1.3. SO_4^{2-} is a conjugate base for H_2SO_4 acid (2)

H_3O^+ is a conjugate acid for H_2O base

Activity 2

2.

2.1. Calculate the pH of a 0,25 mol·dm^{-3} H_2SO_4 solution (4)

Solutions

2 2.1. $H_2SO_4(aq) + H_2O(\ell) \rightleftharpoons 2H_3O^+(aq) + SO_4^{2-}(aq)$ (4)

0,25 mol·dm^{-3} 2(0,25) mol·dm^{-3} (**1:2 ratio**) (diprotic acid)

$[H_3O^+] = 0,5$ mol·dm^{-3}

pH = -log $[H_3O^+]$

= -log (0,5)

= 0,301

QUESTION 1: **Multiple choice questions**

1.1 Consider the equilibrium $H_2SO_4 + HSO_3^- \rightleftharpoons HSO_4^- + H_2SO_3$.

The two Lowry-Brønsted bases are: (*conjugates*)

A HSO_4^- and H_2SO_4

B HSO_3^- and HSO_4^-

C HSO_3^- and H_2SO_3

D HSO_4^- and H_2SO_3 (2)

1.2 Water can act as either an acid or a base. Which equation represents water reacting as an acid? (*donating proton*)

A $H_2O(\ell) + NH_3(g) \rightleftharpoons OH^-(aq) + NH_4^+(aq)$

B $H_2O(\ell) + HC\ell(aq) \rightleftharpoons H_3O^+(aq) + C\ell^-(aq)$

C $H_2O(\ell) \rightleftharpoons H_2(g) + ½O_2(g)$

D $H_2O(\ell) + C(s) \rightleftharpoons CO(g) + H_2(g)$ (2)

1.3 Consider the following equilibrium: $HC_2O^-_4 + HCO_3^- \rightleftharpoons H_2CO_3 + C_2O_4^{2-}$

Which ONE of the following CORRECTLY identifies the order of Lowry-Brønsted acids and bases in the above reaction? (*conjugates*)

A Base, acid, acid, base

B Acid, base, base, acid

C Acid, base, acid, base

D Base, acid, base, acid (2)

1.4 Which ONE of the reactions below will produce the salt sodium ethanoate (sodium acetate)? (*acid and base salts formation*)

A $HC\ell(s) + CH_3COOH(aq) \rightarrow$

B $CH_3COOH(aq) + H_2O(\ell) \rightarrow$

C $CH_3COOH(aq) + NaOH(aq) \rightarrow$

D $H_2CO_3(aq) + NaOH(aq) \rightarrow$ (2)

1.5 If base P is titrated against acid Q, the pH of the solution at the end point is 9.

Which ONE of the following combinations CORRECTLY represents base P and acid Q? (2)

	BASE P	ACID Q
A	KOH	HNO_3
B	$NaHCO_3$	HCl
C	NH_3	H_2SO_4
D	NAOH	CH_3COOH

[10]

QUESTION 2 (*conjugates and ampholytes*)

NH_4^+ ions are mixed with HCO_3^- ions.

2.1 Write a balanced equation for the reaction that takes place (3)

2.2 Define the term conjugate acid−base pair (2)

2.3 Identify the two bases in the above reaction (2)

2.4 The hydrogen sulphate ion can <u>act as both an acid and a base</u>. It reacts with water according to the following balanced equation.

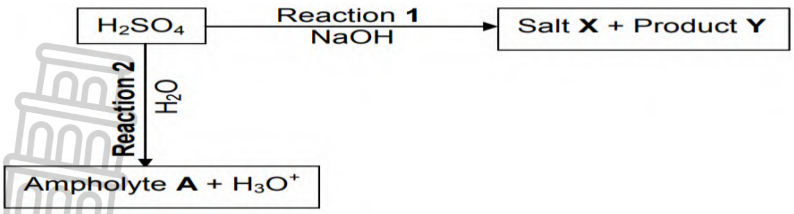
$HSO_4^- + H_2O \rightarrow H_2SO_4 + OH^-$

2.4.1 Write down ONE word for the underlined sentence (1)

2.4.2 Show with the aid of equations that HSO_4^- can act as a base or acid (4)

QUESTION 3 (*Interpretation and stoichiometry calculations*)

3.1 Two reactions of sulphuric acid are shown in the diagram below.



3.1.1 Define a Lowry-Brønsted base. (2)
3.1.2 Write down a balanced equation for Reaction 1 (3)
3.1.3 Write down the NAME of the salt represented by X (2)
3.1.4 Write down the FORMULA of ampholyte A (2)
3.1.5 Write down the formulae of the TWO conjugate acid-base pairs in Reaction 2. (4)

3.2 A solution of sodium hydroxide (NaOH) is prepared by dissolving 6 g solid NaOH in 500 cm^3 water.

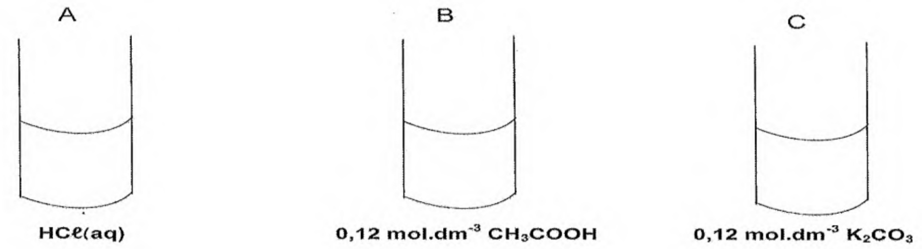
This solution reacts completely with 10 g impure ammonium chloride (NH4Cℓ) according to the equation below.

$NaOH(aq) + NH_4C\ell(s) \rightarrow NaC\ell(aq) + H_2O(\ell) + NH_3(aq)$

3.2.1 Calculate the concentration of the NaOH solution. (4)
3.2.2 Calculate the percentage impurities in the NH4Cℓ (6)

QUESTION 4 (*Strength and titration stochiometry*)

Three test-tubes A ,B and C contain three solutions :HCl(aq), 0.12 $mol.dm^{-3}$ CH_3COOH and 0.12 $mol.dm^{-3}$ K_2CO_3 respectively as indicated below



4.1 Which of these solutions
4.1.1 Is a strong acid (1)
4.1.2 Is an organic acid (1)
4.1.3 Will turn red litmus paper blue (1)

4.2 Solution A is formed when hydrogen chloride gas is added in water
4.2.1 Write down the balance equation for the reaction taking place here (3)

4.3 You are required to prepare 200cm^3 of solution C. Calculate the mass of solute that must be used. (4)

4.4 In a titration ,25.10 cm^3 of solution B is neutralised by unknown volume of solution C in the presence of an indicator.

The following reaction takes place.

$2CH_3COOH\ (aq) + KOH\ (aq) \rightarrow 2CH_3COOK\ (aq) + H_2O(\ell) + CO_2(g)$

4.4.1 What is an indicator (1)
4.4.2 Calculate the volume of solution C that was neutralised (4)

4.5 Write down the balance equation for each of the following reactions using appropriate chemical formulae
4.5.1 Magnesium + solution A (4)
4.5.2 $MgO + H_2O \rightarrow$ (2)

4.6 You are required to prepare some sodium sulphate in the laboratory using acid and a base.
4.6.1 Name the acid and base that you would use. (2)
4.6.2 Write down the balanced equation for the reaction that will take place (3)

QUESTION 5

5.1 Define an acid in terms of the Lowry-Brønsted theory. (2)

5.2 Carbonated water is an aqueous solution of carbonic acid, H_2CO_3. H_2CO_3 (aq) ionises in two steps when it dissolves in water.
5.2.1 Write down the FORMULA of the conjugate base of $H_2CO_3(aq)$. (1)
5.2.2 Write down a balanced equation for the first step in the ionisation of carbonic acid. (3)
5.2.3 The pH of a carbonic acid solution at 25 °C is 3,4. Calculate the concentration of hydronium ion in the solution. (3)

REDOX REACTIONS
Summary of notes

OIL: Oxidation is loss	LEO: Loss of electrons is oxidation
RIG: Reduction is gain	GER: Gain of electrons is reduction

In order to keep track of the electrons during a chemical reaction oxidation numbers are assigned to each element in the reaction. The oxidation number is similar to the valency of the element.

Rules for assigning oxidation numbers.

1. Pure elements and diatomic elements (eg. O_2) = 0.
2. Hydrogen = +1 (except when bonded to a metal, then −1).
3. Oxygen = -2 (except peroxides, eg. H_2O_2, = −1). (When bonded to fluorine, = +2).
4. Metals = group number, i.e. group 1=+1; group 2 =+2; group 3=+3
5. The oxidation number of monoatomic ions is the same as its charge. eg. $Zn^{2+:}$ Zn = +2
6. Group 17 elements = −1.
7. The oxidation number of transition metals is indicated by stock notation. eg. iron (**III**): Fe = +3
8. In a neutral compound, the sum of the oxidation numbers is 0.
9. In a polyatomic ion the sum of the oxidation numbers is equal to the charge of the ion.

REPRESENTING REDOX REACTIONS

Redox reactions can be shown in two half-reactions showing the transfer of electrons. Oxidation half-reaction: X → X^{2+} + $2e^-$ (electrons are shown as products)

Reduction half-reaction: Y^{2+} + $2e^-$→ Y (electrons are shown as reactants)

Nett ionic reaction: X + Y^{2+} → X^{2+} + Y (no electrons are shown in the reaction)

NOTE: The number of e^- must balance

Redox reactions may be balanced by using half reactions from the table of Standard reduction potentials(Table 4B)

QUESTION 6

6.1 A laboratory technician prepares the following two dilute nitric acid solutions:
0,20 mol.dm^{-3} HNO_3 solution ……………………...(I)
0,30 mol.dm^{-3} HNO_3 solution ……………………...(II)

6.1.1 Distinguish between a *concentrated acid* and a *dilute acid*. (2)
6.1.2 Give a reason why nitric acid is classified as a strong acid. (2)
6.1.3 Determine the pH of solution (**I**) at 25 °C . (3)

Worked Examples

1. Give the oxidation number of both elements in ammonia (NH_3) (3)
2. Determine the oxidation number of : (2)
   2.1 Sulphur in sulphate (SO_4^{2-}) ion. (2)
   2.2 Chromium in $Cr_2O_7^{2-}$. (2)
   2.3 Oxygen in H_2O_2 (2)
   2.4 Oxygen in O_2 (1)
3. Consider the following UNBALANCED equation below:
   Fe^{2+} (aq) + Cl_2 (g) ⟶ Fe^{3+} (aq) + Cl^- (aq)
   3.1 Define the term *reducing agent* with reference to electron transfer. (2)
   From the above reaction, write down the:
   3.2.1 FORMULA of the reducing agent. (1)

3.2.2 FORMULA of the oxidizing agent. (1)
3.2.3 Reduction half-reaction. (2)
3.2.4 Oxidation half-reaction. (2)
3.2.5 Balanced net redox reaction. (2)

Solutions (Worked examples)

1. $x+3(1)=0$✓
$x+3=0$
$x=-3$✓
∴ The oxidation number of Nitrogen is -3 and the oxidation number for hydrogen is +1✓ from the rules. (3)

2.1 $x + (-8)=-2$✓
$x=-2+8$ (2)
$x = +6$✓
∴ The oxidation number of Sulphur in sulphate (SO_4^{2-}) ion is +6

2.2 $2(x) + 7(-2) = -2$✓ (2)
$x = +6$
Oxidation number of Cr in $Cr_2O_7^{2-}$ = + 6 ✓

2.3 $2(1) + 2(x) = 0$✓ (2)
$2x = -2$
$x = -1$
∴ The oxidation number of oxygen in H_2O_2 is −1) ✓

2.4 O_2 is a pure element. Therefore, the oxidation number of oxygen in O_2 is 0✓ (1)

3.1 A reducing agent loses electrons. ✓✓ (2)

3.2 3.2.1 Fe^{2+} (aq) ✓ (1)
3.2.2 Cl_2 (g) ✓ (1)
3.2.3 Cl_2 (g) + $2e^-$ ⟶ $2Cl^-$ (aq) ✓✓ (2)
3.2.4 Fe^{2+} (aq) ⟶ Fe^{3+} (aq) + e^- ✓✓ (2)
3.2.5 $2Fe^{2+}$ (aq) + Cl_2 (g) ⟶ $2Fe^{3+}$ (aq) + $2Cl^-$ (aq) ✓✓ (2)

ACTIVITIES
Multiple choice questions
QUESTION 1

1.1 Oxidation takes place when the …
A reducing agent loses electrons.
B oxidising agent loses electrons.
C reducing agent gains electrons.
D oxidising agent gains electrons. (2)

1.2 Consider the reaction below.
$$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$$
Which substance is the oxidising agent?
A Zn
B Cu^{2+}
C Zn^{2+}
D Cu (2)

1.3 The oxidation number of phosphorus in H_3PO_4 is …
A +3
B -2
C 2
D 5 (2)

1.4 The oxidation number of sulphur in HSO_4^- is ….
A +2
B +6
C +1
D +4 (2)

1.5 Consider the following redox reaction:
Zn (s) + Cu^{2+}(aq) → Zn^{2+}(aq) + Cu (s)
Electrons are transferred from …
A Zn (s) to Zn^{2+} (aq).
B Cu^{2+} (aq) to Cu (s).
C Zn(s) to Cu^{2+} (aq).
D Zn^{2+} (aq) to Cu (s). (2)

Long Questions

QUESTION 2

A silver Christmas tree can be made by placing copper wire, shaped in the form of a tree, into a silver nitrate solution. The unbalanced equation for the reaction is:

$Cu(s) + AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + Ag(s)$

2.1 Define the term *oxidation* in terms of oxidation number. (2)

2.2 Write down the following for the reaction above:

2.2.1 Formula of the reducing agent (2)

2.2.2 Name of the oxidising agent (2)

2.2.3 Oxidation half-reaction (2)

2.2.4 Balanced net ionic equation using the ion-electron method (3)

2.3 Use oxidation numbers to explain your choice of oxidising agent in QUESTION 2.2.2. (2)

QUESTION 3

The reaction between permanganate ions (MnO^-_4) and hydrogen sulphide (H_2S) is given below.

$MnO^-_4(aq) + H^+(aq) + H_2S(g) \rightarrow Mn^{2+}(aq) + S(s) + H_2O(\ell)$

3.1 Define reduction in terms of oxidation numbers. (2)

3.2 Determine the oxidation number of manganese in the permanganate ion. (1)

3.3 Write down the FORMULA of the substance that undergoes oxidation. (1)

3.4 Explain the answer to QUESTION 3.3 in terms of oxidation numbers. (2)

3.5 Write down the FORMULA for the oxidising agent. (1)

3.6 Write down the oxidation half-reaction. (2)

3.7 Use the ion-electron method and write down the balanced net ionic equation. (3)

QUESTION 4

The reaction between dichromate ions ($Cr_2O_7^{-2}$) and iron(II) ions (Fe^{2+}) in an acidic medium is given below.

$Cr_2O_7^{-2}(aq) + Fe^{2+}(aq) + H^+(aq) \rightarrow Cr^{3+}(aq) + Fe^{3+}(aq) + H_2O(\ell)$

4.1 Determine the oxidation number of CHROMIUM in $Cr_2O_7^{-2}(aq)$. (2)

4.2 Define *reduction* in terms of electron transfer. (2)

4.3 Write down the FORMULA of the substance that undergoes oxidation. Explain the answer in terms of oxidation numbers. (2)

4.4 Write down the FORMULA of the oxidising agent. (2)

4.5 Write down the reduction half-reaction. (2)

4.6 Write down the net balanced ionic equation for the reaction, using the ion-electron method. (3)

QUESTION 5

The unbalanced equations for two redox reactions, in which SO_2 is involved, are shown below.

Reaction 1: $SO_2(g) + H_2S(g) \rightarrow S(s) + H_2O(\ell)$

Reaction 2: $SO_2(g) + KMnO_4(s) + H_2O(\ell) \rightarrow MnSO_4(aq) + K_2SO_4(aq) + H_2SO_4(aq)$

5.1 Explain what is meant by the term *redox reaction*. (2)

5.2 Write down the oxidation number of Mn in:

5.2.1 $KMnO_4$ (1)

5.2.2 $MnSO_4$ (1)

5.3 Is MnO_4^- in **Reaction 2** OXIDISED or REDUCED? Give a reason for the answer. (2)

5.4 In which reaction, **Reaction 1** or **Reaction 2**, does SO_2 act as an oxidising agent? Give a reason for the answer. (2)

5.5 Write down the oxidation half-reaction in **Reaction 1** (2)

5.6 Use the Table of Standard Reduction Potentials and write down the balanced net ionic equation for **Reaction 1**. Show the half-reactions and how you arrived at the final equation. (4)

SOLUTIONS: REDOX REACTIONS

QUESTION 1

1.1 A✓✓ (2)

1.2 B✓✓ (2)

1.3 D✓✓ (2)

1.4 B✓✓ (2)

1.5 C✓✓ (2)

QUESTION 2

2.1 An increase in oxidation number.✓✓ (2)

2.2 2.2.1 Cu ✓✓ (2)

2.2.2 Silver nitrate or silver ion✓✓ (2)

2.2.3 $Cu \rightarrow Cu^{2+} + 2e^-$ ✓✓ (2)
2.2.4 $Cu + 2Ag^+$ ✓ $\rightarrow Cu^{2+} + 2Ag$ ✓ ✓for Balancing (3)
2.3 The oxidation number of silver decreases from +1 to 0✓✓ (2)

QUESTION 3
3.1 A decrease in oxidation number✓✓ (2)
3.2 +7✓ (1)
3.3 H_2S or S^{-2} ✓ (1)
3.4 Oxidation number increases from -2 to 0✓✓ (2)
3.5 MnO_4^- ✓ (1)
3.6 $H_2S \rightarrow S + 2H^+ + 2e^-$ ✓✓ (2)
3.7 $5H_2S + 2MnO_4^- + 6H^+$ ✓ $\rightarrow 5S + 2Mn^{2+} + 8H_2O$ ✓ ✓ Balancing (3)

QUESTION 4

4.1 +6✓✓ (2)
4.2 Gain of electrons✓✓ (2)
4.3 Fe^{+2}✓, the oxidation number increases from +2 to +3. ✓ (2)
4.4 $Cr_2O_7^{-2}$ ✓✓ (2)
4.5 $Cr_2O_7^{-2} + 14H^+ + 6e^- \rightarrow 2Cr^{+3} + 7H_2O$ (1)
4.6 $Cr_2O_7^{-2} + 14H^+ + 6Fe^{+2}$ ✓ $\rightarrow 2Cr^{+3} + 7H_2O + 6Fe^{+3}$ ✓ ✓Balancing (3)

QUESTION 5
5.1 Reaction involving electron transfer✓✓ (2)
5.2 5.2.1 +7✓ (1)
5.2.2 +2 ✓ (1)
5.3 Reduced✓ , the oxidation number of Mn decreases from +7 to +2✓ (2)
5.4 Reaction 1✓ (2)
The oxidation number decreases from +4 to 0✓
5.5 $H_2S \rightarrow S + 2H^+ + 2e^-$ ✓✓ (2)
5.6 Oxidation half-reaction: $H_2S \rightarrow S + 2H^+ + 2e^-$ ✓
Reduction half-reaction: $SO_2 + 4H^+ + 4e^- \rightarrow S + 2H_2O$ ✓ (4)
Net ionic reaction: $2H_2S + SO_2$ ✓ $\rightarrow 3S + 2H_2O$ ✓