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

2023

PREFACE

This support document serves to assist Physical Sciences learners on how to deal with curriculum gaps and learning losses because of the impact of COVID-19 in 2021. It also addresses the challenging topics in the Grade 11 curriculum in Term 1, 2,3 and Term 4.

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

ATOMIC COMBINATIONS

DEFINITIONS

- Chemical bond – a mutual attraction between two atoms resulting from the simultaneous attraction between their nuclei and the outer electrons.
- Intramolecular bond – bond which occurs between atoms within molecules
- Lewis dot diagram – a structural formula in which valence electrons are represented by dots or crosses.
- Valence electrons – the electrons in the highest energy level of an atom in which there are electrons.
- Covalent bond – the sharing of electrons between two atoms to form a molecule.
- Ionic bond – a transfer of electrons and subsequent electrostatic attraction
- Metallic bond – metallic bonding as the bond between positive ions and delocalized valence electrons in a metal
- Molecule – a group of two or more atoms covalently bonded and that function as a unit.
- Bonding pair – a pair of electrons that is shared between two atoms in a covalent bond.
- Lone pair – a pair of electrons in the valence shell of an atom that is not shared with another atom.
- Electronegativity – a measure of the tendency of an atom in a molecule to attract bonding electrons.
- Non-polar covalent bond – a bond in which the electron density is shared equally between the two atoms.
- Polar covalent bond – a bond in which the electron density is shared unequally between the two atoms.
- Bond energy of a compound – the energy needed to break one mole of its molecules into separate atoms.
- Bond length – the average distance between the nuclei of two bonded atoms

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. o ΔEN = 0: Non-polar (pure) covalent o ΔEN < 1: Weakly polar covalent o ΔEN >1: polar covalent o ΔEN > 2,1: Ionic (transfer of electrons) o 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 charge 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 ($Cl – Cl$)
  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

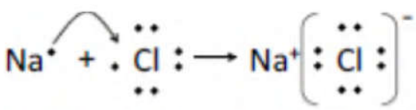
- A polar covalent bond has an unequal sharing of electrons leading to a dipole forming
- example:
  A hydrogen atom and an oxygen atom are joined by a polar covalent bond
  (H_2O)
  EN for oxygen atom is 3,5.
  ΔEN = 3,5 – 2,1 = 1,4

Ionic Bonding (between metals and non-metals)

- involves a complete transfer of electrons
- metal atom gives electron or electrons to non-metal atom
- metal forms a positive ion
- positive ion is called a cation
- non-metal atom accepts electron or electrons
- non-metal forms a negative ion
- negative ion is called an anion
- electrostatic attraction of ions leads to formation of giant crystal lattice

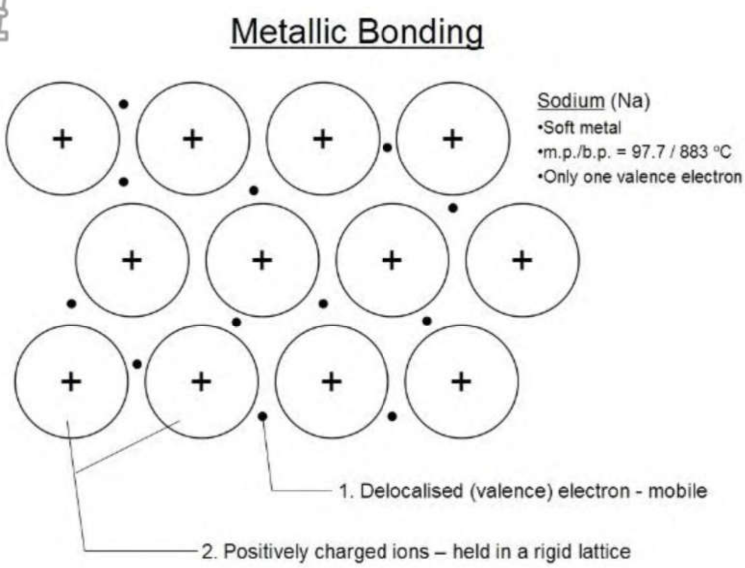
example:
Show how the ionic bond is formed between the sodium and the chlorine atoms.

1. $Na – 1e^- \rightarrow Na^+$ (Na atom loses one electron)
2. $Cl + 1e^- \rightarrow Cl^-$ (Clatom gains one electron)
3. $Na^+ + Cl^- \rightarrow NaCl$ (electrostatic attraction between the two ions)



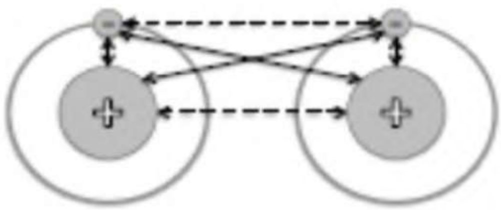
Metallic Bonding (between metals)

- 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

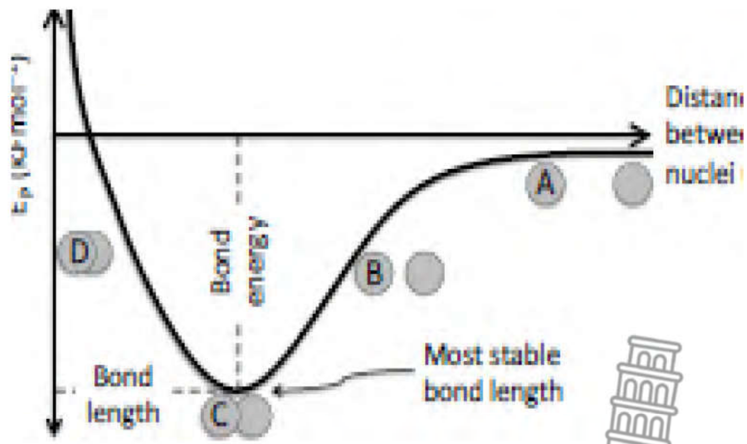
Bond length: The average distance between the nuclei of two bonded atoms.
As the atoms get closer, the attractive forces get stronger until the minimum possible potential energy is reached (bond energy). The distance between the nuclei of the atoms at the minimum potential energy is the bond length.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

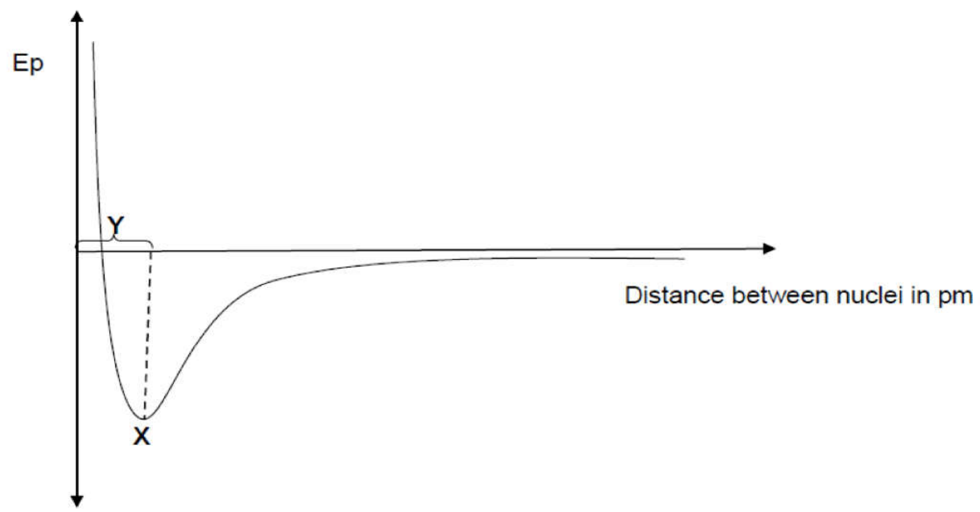
- Atom size
  The smaller the atoms, the shorter the bond.
- Bond order
  The more bonds (double, triple bonds etc.) between the atoms, the shorter the bond.
- Difference in electronegativity (ΔEN). The greater the ΔEN, the shorter the bond.

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



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)
			[10]
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			
	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)
			[15]
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)

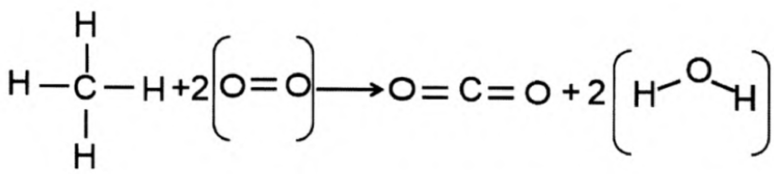
	3.2.2	Draw the Lewis diagram for the H_3O^+ ion	(2)
	3.2.3	State TWO conditions for the formation of such a bond.	(2)
3.3	The polarity of molecules depends on the DIFFERENCE IN ELECTRONEGATIVITY and the MOLECULAR SHAPE		
	3.3.1	Define the term *non-polar covalent bond*.	(2)
	3.3.2	Calculate the difference 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)
			[20]

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

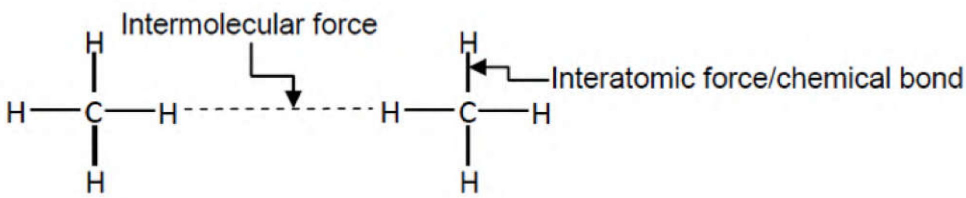
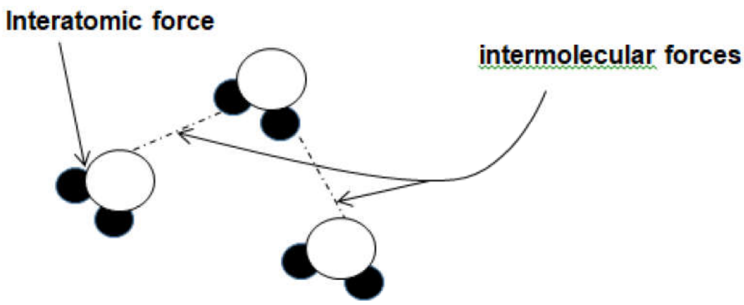
4.1	Write down investigative question for this investigation	(2)
4.2	Apart from bond length, name TWO other factors that influence bond energy	(2)
4.3	In a combustion reaction, methane burns oxygen to form carbon dioxide and water. The balanced reaction showing bonds is given below:	



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)
		[14]

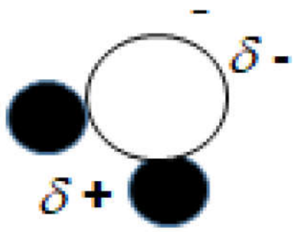
QUESTION 5			
5.1	Draw the Lewis diagram of a methane molecule.		(2)
5.2	What is the name of the special kind of bond found inside the methane molecule?		(1)
5.3	Answer the following questions about magnesium chloride:		
	5.3.1	Make use of Lewis diagrams to indicate the transfer of electrons between magnesium and chlorine.	(4)
	5.3.2	Magnesium chloride is an ionic substance. Prove this statement with an appropriate calculation.	(3)
			[10]

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

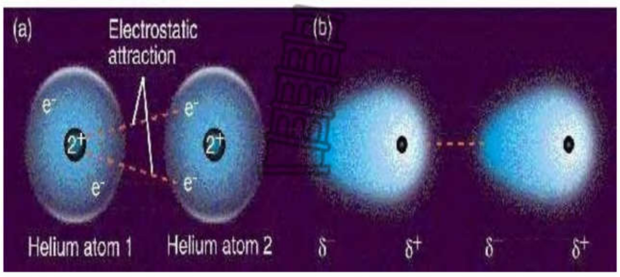
- Different intermolecular forces (Van der Waals forces) ARE
  - Mutually induced dipole forces or London forces: Forces between non-polar Molecules
  - Dipole-dipole forces: Forces between two polar molecules
  - Dipole-induced dipole forces: Forces between polar and non-polar molecules
  - Hydrogen 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

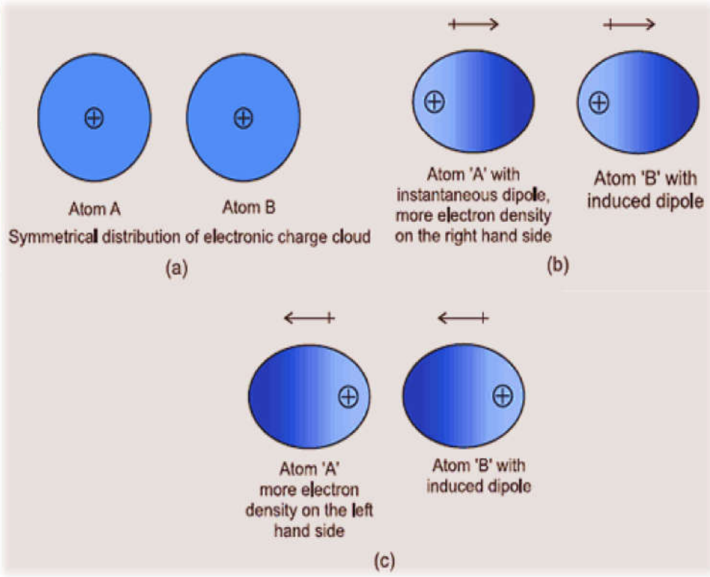
LONDON FORCES (DISPERSION FORCES)

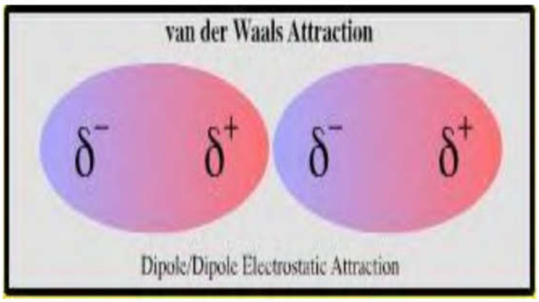
London forces arise from temporary variations in electron density in atoms and molecules.

At any instant, the electron distribution may be unsymmetrical and hence produce an instantaneous dipole.

This can cause an induced transient dipole in the neighboring molecule and cause the molecules to be attracted.



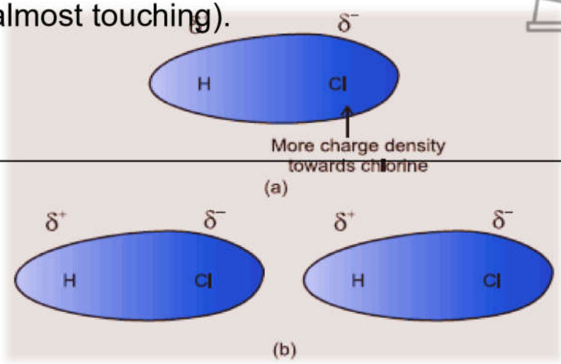




- The London dispersion force is the weakest intermolecular force.
- The London dispersion force is a temporary attractive force that results when the electrons in two adjacent atoms occupy positions that make the atoms form temporary dipoles.
- This force is sometimes called an **induced dipole induced dipole** attraction.
- London forces are the attractive forces that cause non-polar substances to condense to liquids and to freeze into solids when the temperature is lowered sufficiently.

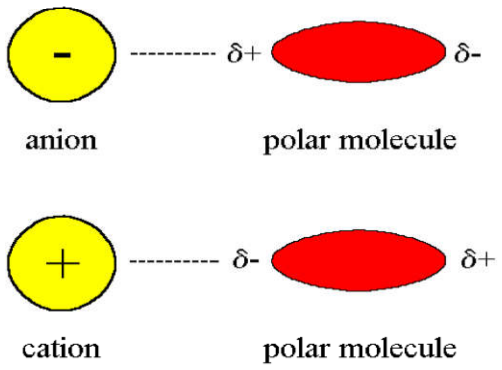
DIPOLE - DIPOLE FORCES

- Dipole-dipole forces are attractive forces between the positive end of one polar molecule and the negative end of another polar molecule.
- Dipole-dipole forces are much weaker than ionic or covalent bonds
- Dipole-dipole forces have a significant effect only when the molecules involved are close together (touching or almost touching).



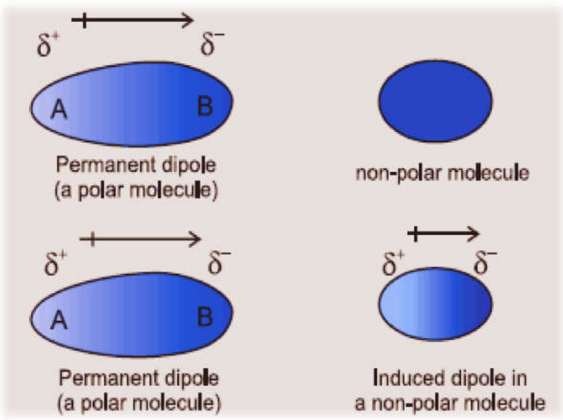
INDUCED - DIPOLE FORCES

- An ion-induced dipole attraction is a weak attraction.
- It results when the approach of an ion induces a dipole in an atom or in a non-polar molecule by disturbing the arrangement of electrons in the non-polar species.



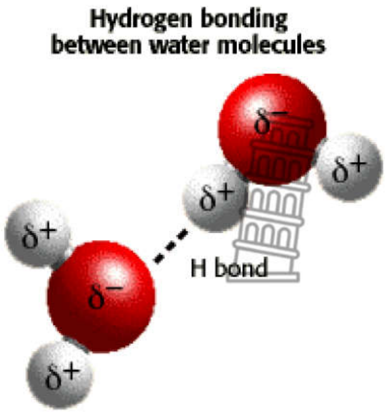
DIPOLE – INDUCED DIPOLE FORCES

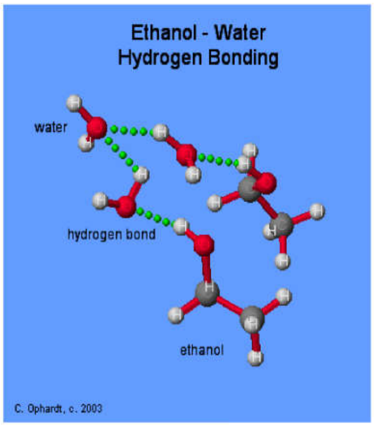
- A dipole-induced dipole attraction is a weak attraction
- It results when a polar molecule induces a dipole in an atom or in a non-polar molecule by disturbing the arrangement of electrons in the non-polar species

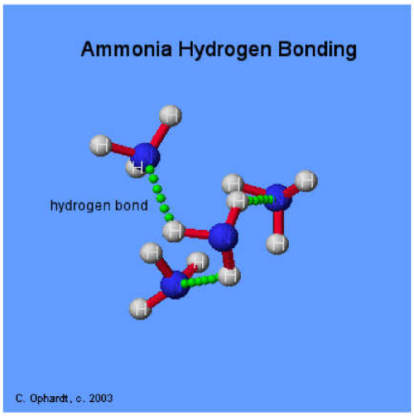


HYDROGEN BOND

- The hydrogen bond is a special dipole-dipole interaction between the hydrogen atom in a polar N-H, O-H or F-H bond and an electronegative O, N or F atom.







A – H ----B or A – H-------- A

A and B are O, N and F

INTERMOLECULAR FORCES AND PHYSICAL PROPERTIES

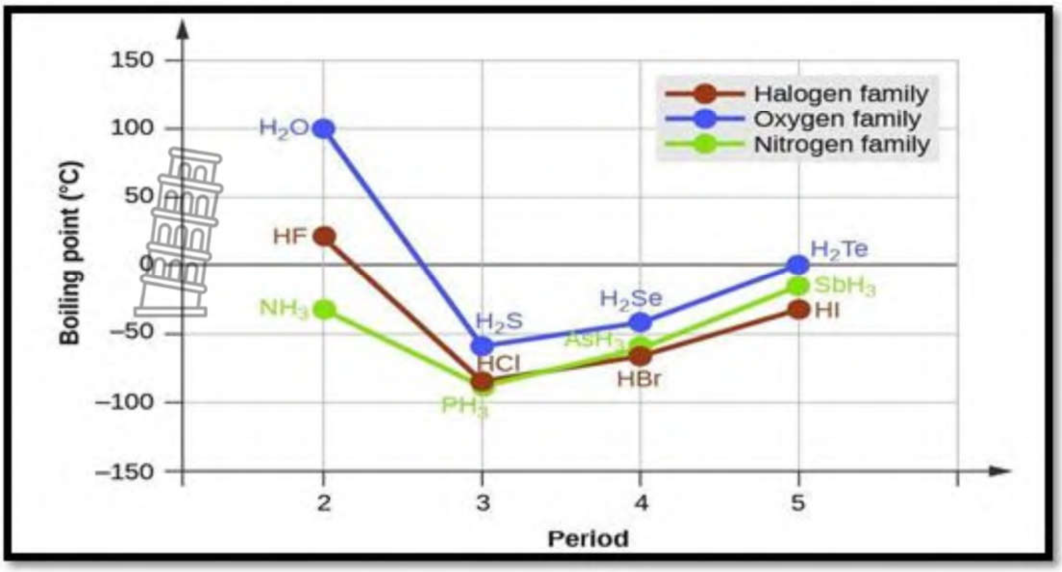
Boiling point and melting point

- 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).
- In hydrogen bonding, the resulting partially positively charged H atom on one molecule could interact strongly with a lone pair of electrons of a partially negatively charged O, N, or F atom on adjacent molecules.
- Hydrogen bonding increases the boiling point considerably.
- The strength of London dispersion forces appears to increase with increasing molecular weight due to the increase in surface area.
- As a result, compounds of higher molecular weights will generally boil at higher temperatures.
- Branched hydrocarbon normally has a smaller surface area than its respective straight-chain isomer, and therefore, a lower boiling point.

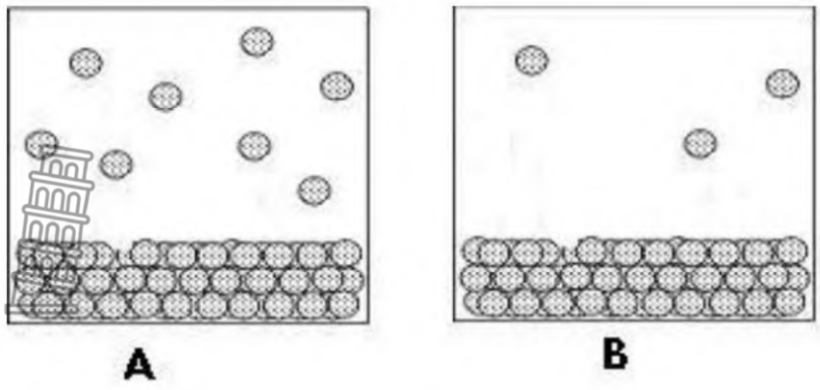


Solubility

- 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, nonpolar 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.

Vapor Pressure

- Vapor 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

ACTIVITIES: 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]
QUESTION 2		
Given the following diagram: H—Cl- - -H—Cl		
2.1	Name the molecule and circle it on the diagram	(2)
2.2	Label the interatomic forces (covalent bonds)	(1)
2.3	Label the intermolecular forces	(1)
		[4]
QUESTION 3		
Label the intermolecular forces HCl, CO_2, I_2, H_2O, KI (aq), NH_3, NaCl(aq), HF, $MgCl_2$ in CCl_4, NO, Ar, SiO_2		
3.1	Complete the table below by placing each molecule next to the correct type of intermolecular force.	(11)

Type of force Molecules	Type of force Molecules
Ion-dipole	
Ion-induced-dipole	
Dipole-dipole (no hydrogen bonding)	
Dipole-dipole (hydrogen bonding)	
Induced dipole	
Dipole-induced-dipole	

3.2	In which one of the substances listed above are the intermolecular forces:		
	3.2.1	strongest	(2)
	3.2.2	weakest	(3)
			[16]

QUESTION 4

Use your knowledge of different types of intermolecular forces to explain the following statements:

4.1	The boiling point of F2 is much lower than the boiling point of NH3	(2)
4.2	Water evaporates slower than carbon tetrachloride (CCl_4).	(2)
4.3	Sodium chloride is likely to dissolve in methanol (CH_3OH)	(2)
		[6]

QUESTION 5

The following table gives the melting points of various hydrides:

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

5.1	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)
5.2	Draw a graph to show the melting points of the hydrides.		(4)
5.3	Explain the shape of the graph		(2)
5.4	The respective boiling points for four chemical substances are given below:		

Hydrogen sulphide	−60 ℃
Ammonia	−33 ℃

Hydrogen fluoride	20 ℃
Water	100 ℃

	5.4.1	Which substance has a lowest vapour pressure?	(1)
	5.4.2	Which one of the substances exhibits the strongest forces of attraction between its molecules in the liquid state?	(1)
	5.4.3	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)
	5.4.4	The shapes of the molecules of hydrogen sulphide and water are similar, yet their boiling points differ. Explain.	(3)
	5.4.5	Susan states that van der Waals forces include ion-dipole forces, dipole-dipole forces, and induced dipole forces.	
		Simphiwe states that van der Waals forces include ion-dipole forces, ion-induced dipole forces and induced dipole forces. Who is correct and why?	(3)
			[19]

QUESTION 6

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)

6.1	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)
6.2	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)
6.3	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)
		[10]

QUESTION 7

Learners conduct an experiment to investigate the effects of intermolecular forces on boiling points. They use 20 mℓ of each of the following compounds in their investigation: water, sunflower oil, nail polish remover, glycerine, and methylated spirits. The results are shown in the diagram below.

NAME OF COMPOUND	BOILING POINT (˚C)
water	93
sunflower oil	230
nail polish remover	56
glycerine	290
methylated spirits	62

7.1	Define the term *boiling point.*	(2)
7.2	Formulate an investigative question for this experiment.	(2)
7.3	In which compound in the table above will the strongest intermolecular forces occur? Give a reason for the answer.	(2)
7.4	The learners now use 40 mℓ of each of the compounds above in the experiment. Will it affect the boiling points? Choose YES or NO. Give a reason for the answer.	(2)
7.5	Methylated spirit is highly flammable. State TWO safety precautions that should be taken when using methylated spirits in the laboratory.	(2)
7.6	Which compound in the table above will have the highest rate of evaporation? Give a reason for the answer.	(3)
7.7	Sunflower oil is a non-polar compound with induced dipole forces between the molecules, while water is a polar molecule with hydrogen bonds between its molecules. Explain why the boiling point of sunflower oil is higher than the boiling point of water.	(2)
		[15]

QUESTION 8

Consider the list of six substances with their formulae and boiling points in the table below.

NAME OF SUBSTANCE	FORMULA	BOILING POINT (°C)
Water	H_2O	100
Ethanol	CH_3CH_2OH	78
Bromine	Br_2	58,8
Iodine	I_2	184,3
Ammonia	NH_3	-33,3
Phosphine	PH_3	-87,7

8.1 Explain why ethanol is soluble in water. Refer to the relative strength of the intermolecular forces in ethanol and water. (3)

8.2 Explain why the boiling point of iodine is higher than that of bromine. Refer to the intermolecular forces present in EACH substance in the explanation. (2)

8.3 Explain why phosphine will evaporate faster than ammonia by referring to the types of intermolecular forces present in EACH substance. (4)

8.4 Water, ethanol, and bromine are all liquids at room temperature.

Which ONE will have the highest vapour pressure? (1)

8.5 Give a reason for the answer to QUESTION 8.4 by referring to the relative strength of the intermolecular forces and boiling points. (2)

[12]

QUESTION 9

9.1 The reaction below is used in the Haber process to manufacture ammonia.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

(3)

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

SUBSTANCE	BOILING POINT(°C)
H_2	252,9
N_2	195,8
NH_3	33,3

Refer to the intermolecular forces and explain the difference in boiling point between NH_3 and N_2.

9.2	Write down the FORMULA of the substance in the table that will have the lowest melting point.	(1)
9.3	Explain why H_2 will evaporate faster than N_2. Refer to the type and relative strength of the intermolecular forces.	(3)
9.4	Write down the FORMULA of the substance in the table that will have the highest vapour pressure. Explain your answer.	(3)
		[10]

QUESTION 10

The melting points and boiling points of four substances (A, B, C and D) are shown in the table below:

	SUBSTANCES	MELTING POINTS(°C)	BOILING POINT(°C)
A	HF	-183,11	19,54
B	HCl	-114,2	-81,7
C	CS_2	-111	46,0
D	CO_2	-56,6	-78,5

10.1	Define the term *melting point*	(2)
10.2	Explain the difference in melting points of HF and HCl by referring to the type of intermolecular forces	(4)
10.3	Which one of the substances (A, B, C and D) above is a liquid at 25**°C**	(1)
10.4	Explain why CS_2 has a higher boiling point than CO_2	(3)
10.5	Which one of the substances above (A, B, C and D) has the highest vapour pressure? Give a reason for the answer by referring to the data in the table	(2)
		[12]

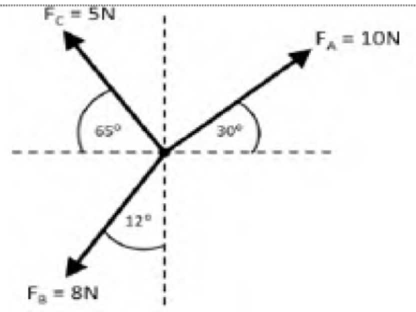
QUESTION 11

Consider the following three compounds:

Substance: <u>*Methanol*</u>
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	
11.1	Identify the inter-molecular forces found in methane gas.	(1)
11.2	Explain how these forces are formed.	(2)
11.3	By identifying and comparing the intermolecular forces, provide a detailed explanation for:	
	11.3.1 the difference in boiling points of methane and tetrachloromethane	(3)
	11.3.2 the fact that methanol is miscible (dissolves) in water, but Tetrachloromethane	(4)
		[10]

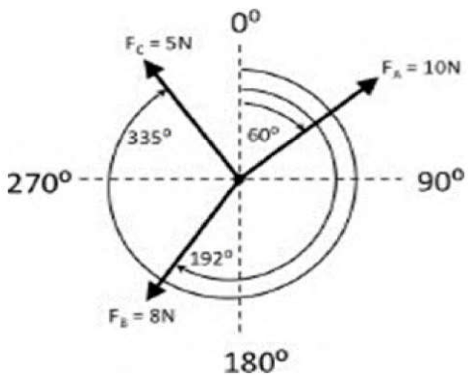
VECTORS IN 2 DIMENSIONS
Vector- A physical quantity with magnitude and direction. (*Example: force, velocity, acceleration, etc.)*
Scalars- A physical quantity with magnitude only. (*Example: time, charge, work. Energy, distance, speed etc.)*
○ A vector has magnitude and direction.
○ Vectors can be used to represent many physical quantities that have a magnitude and direction, like forces.
○ Vectors may be represented as arrows where the length of the arrow indicates the magnitude and the arrowhead indicates the direction of the vector.
○ Vectors in two dimensions can be drawn on the Cartesian plane.
○ Vectors can be added graphically using the head-to-tail method or the tail-to-tail method.
○ A closed vector diagram is a set of vectors drawn on the Cartesian using the tail-to-head method and that has a resultant with a magnitude of zero.
○ Vectors can be added algebraically using Pythagoras' theorem or using components.
○ The direction of a vector can be found using simple trigonometric calculations.
○ The components of a vector are a series of vectors that, when combined, give the original vector as their resultant.
○ Components are usually created that align with the Cartesian coordinate axes
• A **resultant** is one vector, which has the same effect on a body as the two or more vectors that are actually acting on that body. It starts at the beginning of the first vector and ends at the end of the last one.
• An **equilibrant** is one vector, which cancels out the effect that the two or more vectors actually have on a body. It is equal in size to the resultant but opposite in direction.
• Positive (+) and negative (-) signs are used to indicate direction in vectors. (Not their magnitude.)
• Arrows are used in vectors to give magnitude (length of arrow) and direction (head of arrow).
Graphical Representation of a vector
• Vector is represented by an arrow
• The length of an arrow represents the size (magnitude) of the vector
• The arrow-head represents the direction of the vector.
Three methods to describe the direction of a vector that is not horizontal or vertical
• X and Y axes
• Bearing
• Compass Reading
On a graph



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)

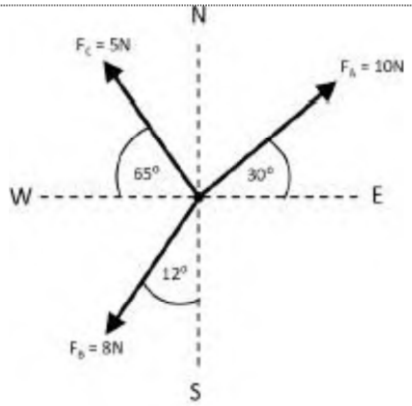
Bearing

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°
F_A : 10 N on a bearing of 60°

Compass (Cardinal points or directions)



NB: The 30^0 N of E means you start from east and move 30^0 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

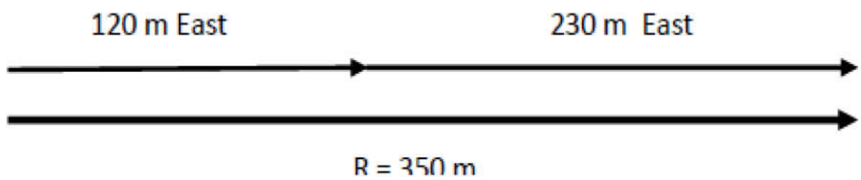
- Define a resultant as the vector sum of two or more vectors, i.e., a single vector having the same effect as two or more vectors together.
- Resultant vector is greatest when vectors are in the same directions
- Resultant vector is smallest when vectors are in the opposite directions

Two vectors acting in the same direction :(one dimension)

- A girl walks 120 m due East and then 230 m in the same direction. What is her resultant displacement?
- By calculation:

  Sign of direction: Take to East to be +

  R = 120 m + 230 m = 350 m East
- By construction:

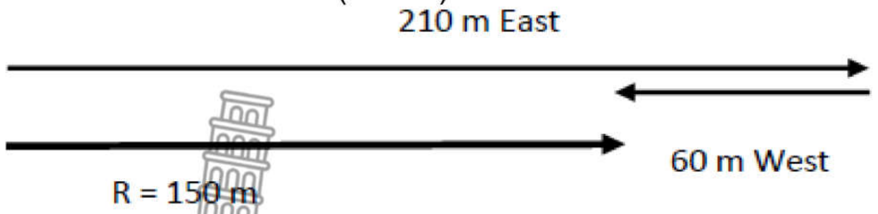


B. Two vectors acting in opposite direction (one dimension)

- A boy walks 210 m due East. He then turns and walk 60 m due West. Determine his resultant displacement.

- By calculation: (taking East as positive)

  R = 210 m + (- 60 m) = 150 m East



- **Multiple vectors acting in different directions (one dimension)**

Determine the resultant(net) force when 8 N force acts to the right, a 10 N force acts to the right, a 25 N force acts to the left and a 12 N force acts to the left

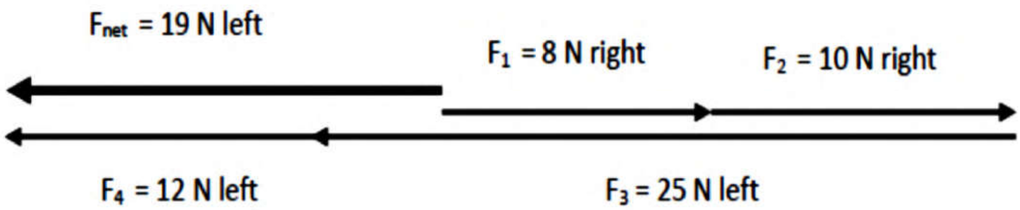
- Let to the right be **positive**

By Calculation: F_{net} = F1 + F2 + F3 + F4

= 8 + 10 + (-25) +(-12)

= -19 N

F_{net} = 19 N left

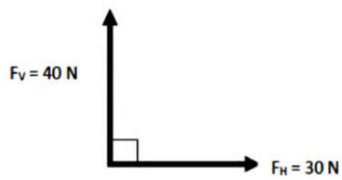


Vectors in Two Dimensions

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: $R_y = R_{y1} + R_{y2}$

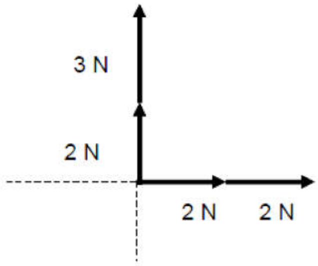
Worked Example 1

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

$R_y = R_{y1} + R_{y2}$

$R_y = 2 + 3$

$R_y = 5\ N\ upwards$



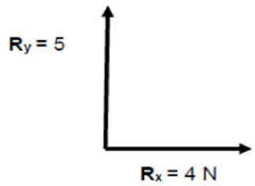
$R_x = R_{x1} + R_{x2}$

$R_x = 2 + 2$

$R_x = 4\ N\ right$

Worked Example 2

Graphical representation of Rx and Ry



- Pythagoras theorem is used to calculate the magnitude of the resultant.
- Considering the vector diagram above we can use Pythagoras theorem as follows:

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

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

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

$$= 6.40\ N$$

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

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

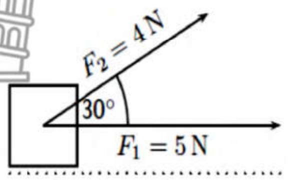
$$\theta = 51.24°$$

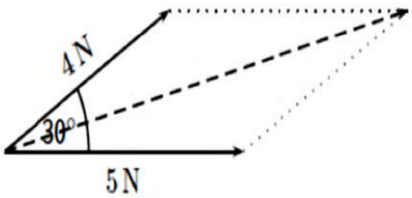
Worked Example 3

A force of F1 = 5 N is applied to a block in a horizontal direction. A second force F2 = 4 N is applied to the object at an angle of 30º above the horizontal. Determine the resultant of the two forces**, by accurate scale drawing.**

Step 1: Draw rough sketches of the vector diagrams:

Note: Forces are NOT perpendicular





Step 2: Choose the suitable scale. e.g., 1 cm: 1 N

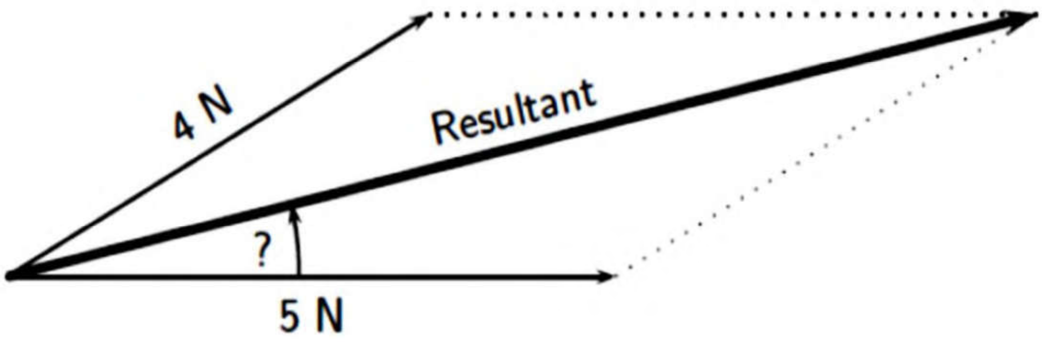
Step 3: Draw the first vector (F1) on the horizontal, according to the scale.

Step 4: Draw the second scaled vector (F2) 30º above the horizontal.

Step 5: Complete the parallelogram and draw the diagonal (which is the resultant)

Step 6: Use the protractor to measure the angle between the horizontal and the resultant

Step 7: Apply scale and convert the measured length to the actual magnitude.



The resultant is 8,7 N, 13,3º above the horizontal.

GRAPHICAL DETERMINATION OF THE RESULTANT VECTOR

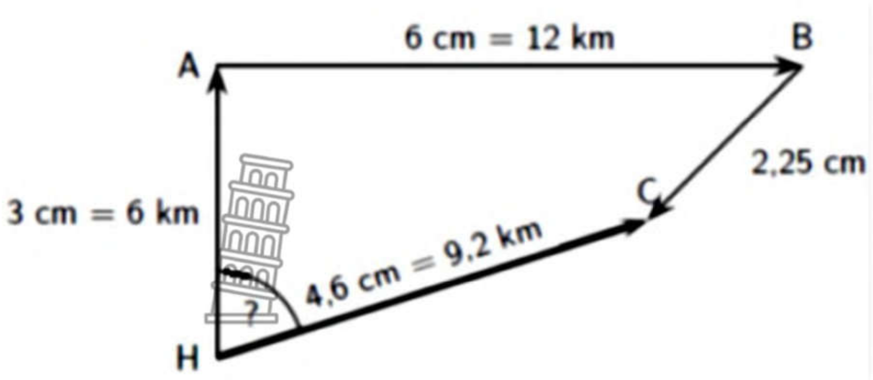
Tail-to-head method is used to find the resultant of two or more consecutive vectors (vectors that are successive)

Steps to be followed:

- Choose the suitable scale e.g., 10 mm : 10 N
- Accurately draw the first vector as an arrow according to chosen scale and in the correct direction Draw the second vector by placing the tail of the second vector at the tip of the first vector {tail – to – head method}
- Complete the diagram by drawing the resultant from the tail of the first vector to the head of the last vector.
- Make sure that you measure the angles correctly with a protractor.
- Always add arrow heads to vectors to indicate the direction.
- Measure the length and direction of the resultant vector.

Worked example 4

Using a scale 1 cm : 2 km, the accurate drawing of vectors is:



Measure the angle between the North line and the resultant with a protractor to find that the direction of the resultant displacement:

NOTE: Resultant displacement of the ship is 9,2 km on a bearing of 72, 3º.

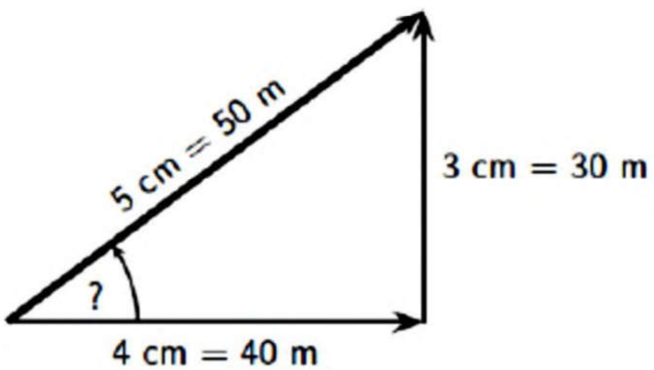
Worked Example 5

A man walks 40 m East, then 30 m North. Use a scale of 1 cm: 10 m and answer the following questions:

1. What was the total distance he walked?
2. Determine by construction his resultant displacement?
3. Calculate determine the direction of the resultant.
4. Calculate the magnitude of resultant displacement

Solutions:

Scale: 1 cm : 10 m



The resultant is 5 0m, 37º from the horizontal

$tan\ \theta = \frac{30}{40}$

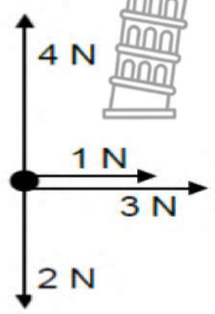
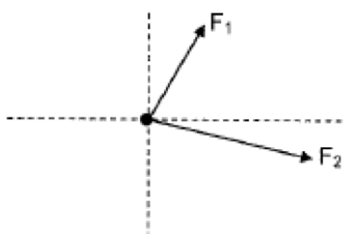
$\theta = 36{,}87^0$

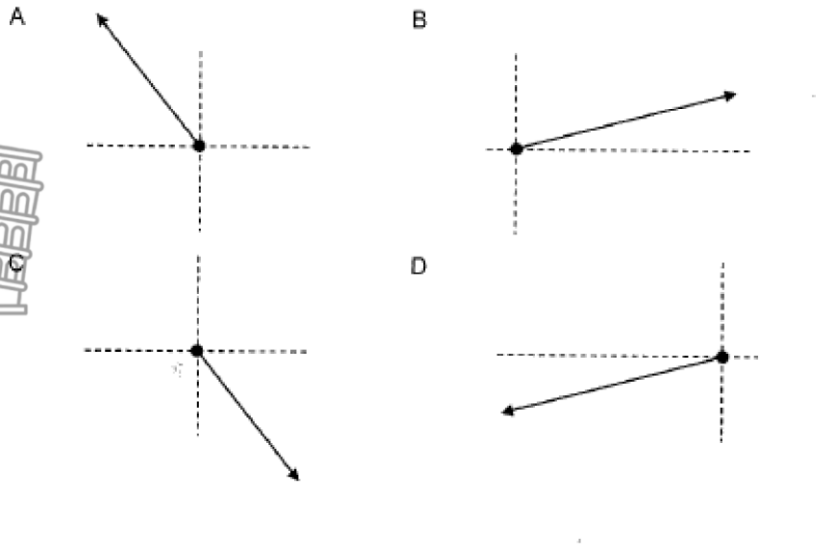
$R^2 = x^2 + y^2$

$R^2 = 40^2 + 30^2$

$R^2 = 2500$

$R = 50\ m$

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?		



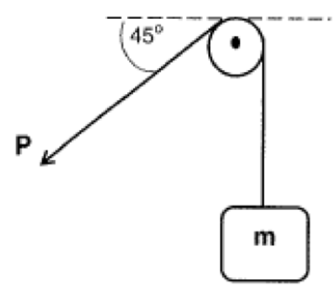
(2)

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

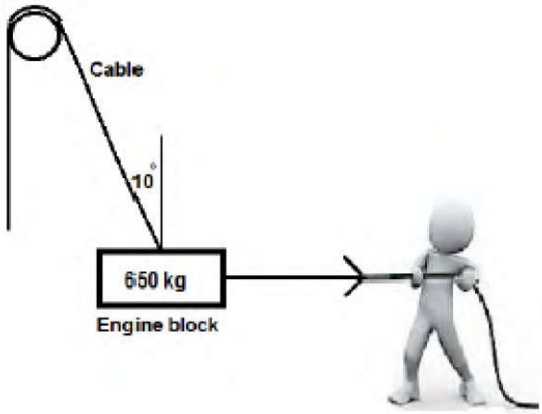


The magnitude of force **P** in the strings is…..

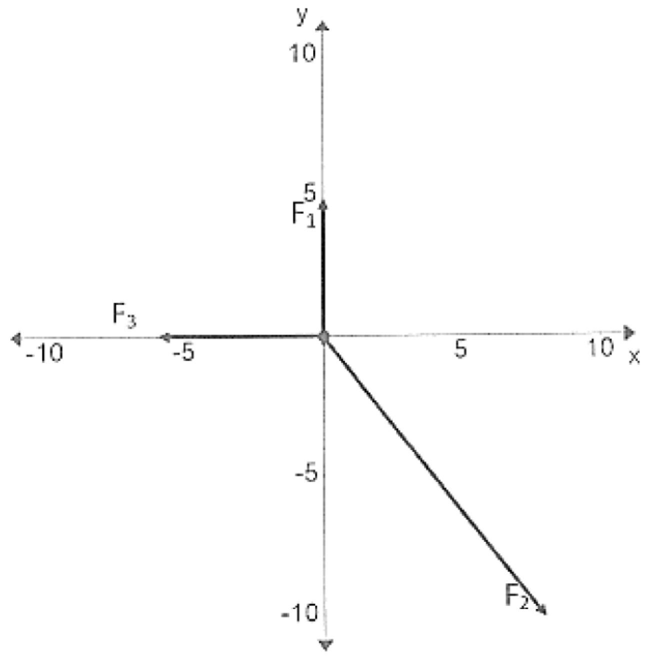
A	Mg
B	mg sin45°
C	$\frac{1}{2}\,mg$
D	Mg tan45°

(2)

[10]

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. Indicate the magnitude of at least ONE angle	(4)
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 whether or not the cable will snap.	(4)
		[13]

QUESTION 3
Three forces F_1, F_2 and F_3 act at a point, as shown on the Cartesian plane in the diagram below.

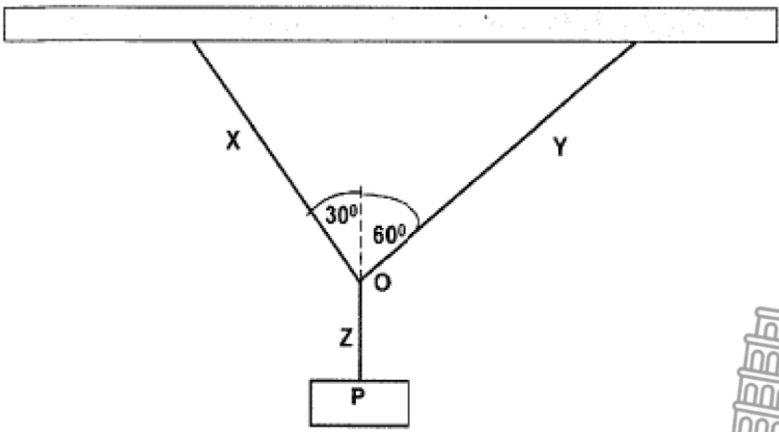


Scale: 1 square unit represents 1 N

3.1	Define the “resultant vector”	(2)
3.2	Write down the X-component and Y-component for force F_2	(2)
3.3	Calculate the NET horizontal component for the forces F_1, F_2, and F_3	(1)
3.4	Calculate the NET vertical component for the forces F_1, F_2, and F_3	(1)
3.5	Calculate the magnitude and direction of the resultant forces of these three forces	(4)
		[10]

QUESTION 4

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.



4.1	Define the term resultant vector	(2)
4.2	Draw a closed vector diagram to show all the forces acting at point O Indicate two angles in your diagram	(4)

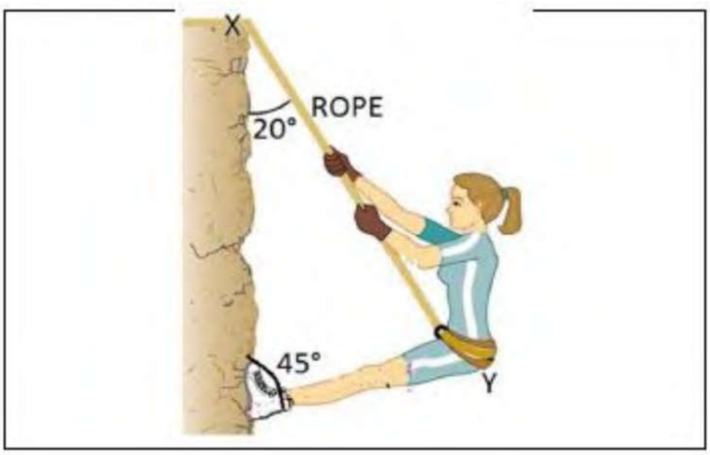
4.3	Using the vector diagram in **QUESTION 4.2**, identify the string that exerts the largest force on point O. Give a reason for the answer.	(2)

The mass of object P is 0,25 kg.

4.4	Calculate the magnitude of forces X **and** force Y.	(4)
		[12]

QUESTION 5

During a mountain climbing exercise, Ferial, mass 50 kg, is suspended from an inelastic piece of nylon rope, fixed to a vertical cliff at X on the cliff. She pushes her legs against the cliff so that they make an angle 45° with the cliff, as indicated in the figure. The angle that the rope makes with the cliff is 20°

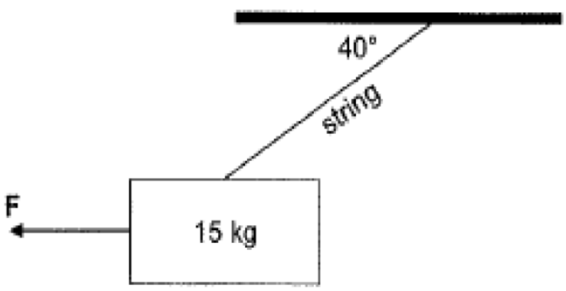


Point **Y** is in equilibrium

5.1	Explain what is meant by Point Y is in equilibrium		(1)
5.2	Draw a FORCE DIAGRAM showing all the forces acting on point Y.		(3)
5.3	Determine by means of ACCURATE CONSTRUCTION and MEASUREMENT. (use the scale 10 mm : 50 N and indicate at least TWO angles)		
	5.3.1	The magnitude of the force exerted by her legs	(8)
			[12]

QUESTION 6

A billboard, mass 15 kg, is suspended from a roof by means of a light inextensible string. Force **F** pulls the billboard sideways, as shown in the diagram below.



When the angle between the roof and the string is 40°, a closed vector diagram is obtained for all the forces acting on the billboard.		
6.1	What deduction can be made when the forces acting on an object forms a closed vector diagram?	(2)
6.2	Calculate the weight of the billboard	(2)
6.3	Draw a labelled closed vector diagram of ALL the forces acting on the billboard. Indicate the value of one of the angles.	(4)
6.4	Calculate the tension in the string	(2)
6.5	The magnitude of force **F** is equal to the magnitude of the horizontal component of the tension in the string. Give a reason why these two forces are NOT considered to be an action-reaction pair according to Newton's Third Law	(1)
		[11]

NEWTON'S LAWS

At the end of the session learners must:

- Define normal force, frictional force, static frictional force and kinetic frictional force
- Solve problems using $f_k = \mu_k N$
- Draw the force diagram and free-body diagram
- Resolve a two-dimensional force into its parallel (x) and perpendicular (y) components
- Determine the resultant/net force of two or more forces.
- State Newton's first, second and third law of motion
- State Newton's Law of Universal Gravitation
- Calculate acceleration due to gravity on a planet
- Calculate the weight of an object on other planets with different values of gravitational acceleration
- Describe weight and mass
- Explain weightlessness

CORE CONCEPTS AND DEFINITIONS NB: (In relation to Examination guidelines)

Normal force, N - the force or the component of a force which a surface exerts on an object with which it is in contact, and which is always perpendicular to the surface.

- **Frictional force**, f - the force that opposes the motion of an object and which acts parallel to the surface.
- **Static frictional force**, f_s is the force that opposes the tendency of motion of a stationary object relative to a surface.
- **Kinetic frictional force**, f_k - is the force that opposes the motion of a moving object relative to a surface.
- **Newton's First Law of Motion**:

A body will remain in its state of rest or motion at constant velocity unless a non-zero resultant/net force acts on it.

- **Newton's Second Law of Motion**:

When a resultant/net force acts on an object, the object will accelerate in the direction of the force at an acceleration directly proportional to the force and inversely proportional to the mass of the object.

- **Newton's Third Law of Motion**:

When object A exerts a force on object B, object B **Simultaneously** exerts an oppositely directed force of equal magnitude on object A.

- **Newton's Law of Universal Gravitation**:

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

- **Weight -** the gravitational force, in newton (N), exerted on an object.
- **Mass -** the amount of matter in a body measured in kilogram (kg).
- **Weightlessness -** the sensation experienced when all contact forces are removed i.e. no external objects touch one's body.

Newton's First Law

A body remains in its **state of rest**

→ $v_i = v_f = 0$ m.s^{-1}

Acceleration = 0 m.s^{-2}

Resultant force = 0 N

A body continues to move with a **constant velocitv**

→ There is no change in velocity ($v_i = v_f$)

Acceleration = 0 m.s^{-2}

Resultant force = 0 N

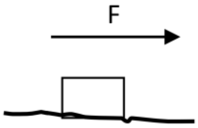
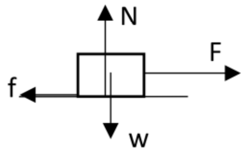
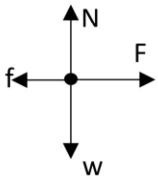
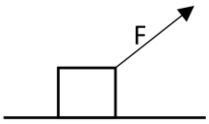
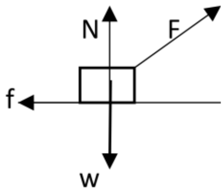
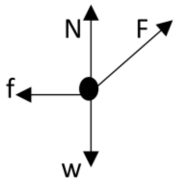
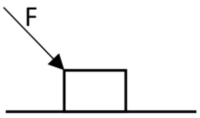
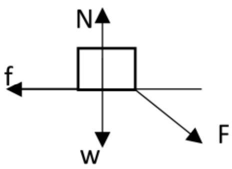
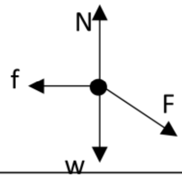
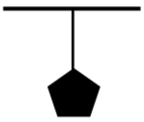
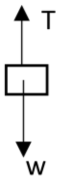
Newton's Second Law of Motion

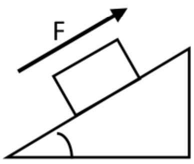
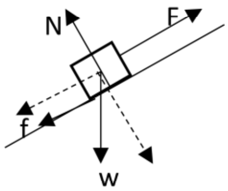
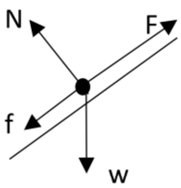
- When a resultant/net force acts on an object, the object will accelerate in the direction of the force at an acceleration directly proportional to the force and inversely proportional to the mass of the object
- Mathematically expressed as: F_{net} = ma

Where:

- F_{net} is the net force act on an object, measured in Newton's (N)
- *a* object's acceleration, measured in metres per second squared (m.s^{-2})
- *m* the mass of the object, measured in kilograms (kg)
- A net force acts on an object. $F_{net} \neq 0$ N Forces acting on the object are not balanced Net force cause the object to accelerate in the direction of the force. Acceleration and net force go in the same direction. There is a change in velocity ($v_i \neq v_f$). a ≠ 0 m.s^{-2}
- $\boldsymbol{a}$ is directly proportional to $\boldsymbol{F_{net}}$, when the net force increases, the acceleration also increases. vice versa
- $\boldsymbol{a}$ is inversely proportional to m. When the mass increases, the acceleration decreases.

FREE BODY DIAGRAMS/FORCE DIAGRAMS VS THE NET FORCE

Plane	Diagram	Force diagram	Free-body diagram	F_{net}=ma
Horizontal (frictional)				F_{net}=ma F+(-f)=ma **(N=w=mg)**
Horizontal at an angle (frictional)				F_{net}=ma $F_{//}$-f=ma **(N=w-$F_{\perp}$)**
Horizontal at an angle (frictional)				F_{net}=ma $F_{//}$-f=ma **(N=w+$F_{\perp}$)**
Vertical				F_{net}=ma w-T=ma

Inclined (frictional)				F_{net}=ma
				F-f-$w_{//}$=ma
				$w_{//}$= mg sin θ
				$w_{\perp}$= mg cos θ
				(N=$w_{\perp}$= mg cos θ)

Newton's Third Law of Motion:
When object A exerts a force on object B, object B **Simultaneously** exerts an oppositely directed force of equal magnitude on object A.

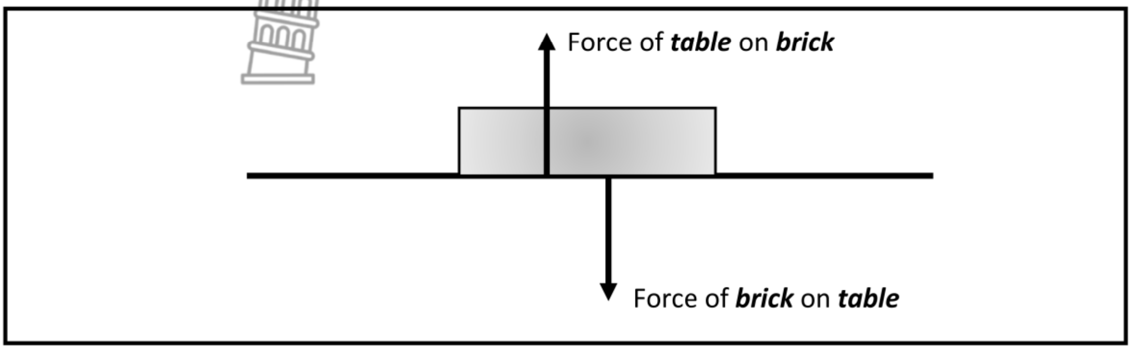
- The forces are **equal in magnitude**
- The forces act in the same straight line but in the **opposite directions** on different objects

- The forces do not cancel each other, as they act on **different objects**

For any two objects **A** and **B**: $F_{AonB} = -F_{BonA}$

Worked example

The force diagram shows the pair of forces when a brick rests on the table



Newton's Law of Universal Gravitation:

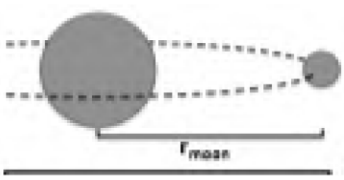
Each body in the universe attracts every other body with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

$$F = G\frac{m1m2}{r2}$$

- F = force of attraction between objects (N)
- G = universal gravitational constant (6,67 $\times 10^{-11}$ $N \cdot m^2 \cdot kg^{-2}$)
- m = object mass (kg)
- r = distance between object centres (m)

- A uniform sphere of matter attracts a body that is outside the shell as if all the sphere's mass was concentrated at its centre.

- Thus, the distance is determined between the centres of the two bodies.



The radius of the earth is added to the distance between the earth and the moon.	The radius of object (man) on the earth is negligibly small.

KNOW THE DIFFERENCE!
g vs G

- g: Gravitational acceleration (9,8 m·s^{-2} on earth)
- g is the acceleration due to gravity on a specific planet.
- G: Universal gravitational constant (6,67×10−11 N·m^2·kg−2)
- Proportionality constant which applies everywhere in the universe.

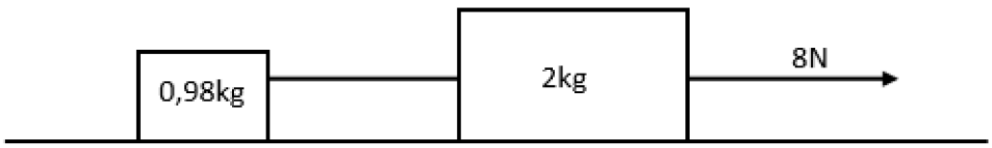
Mass vs Weight

- Mass (kg):
  A scalar quantity of matter which remains constant everywhere in the universe.
- Weight (N)
  Weight is the gravitational force the Earth exerts on any object. Weight differs from planet to planet. F_g = mg. Weight is a vector quantity.

ACTIVITIES- NEWTONS LAWS

QUESTION 1

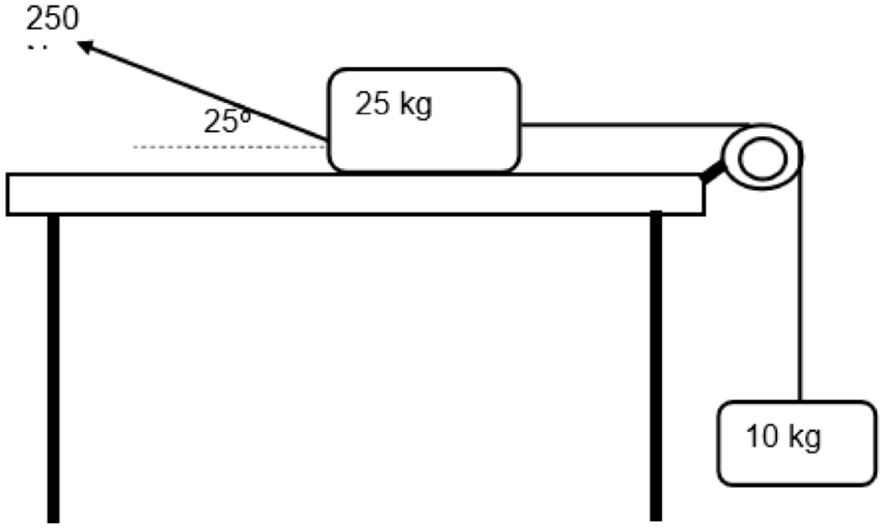
An 8 N force pulls horizontally on a block of mass 2 kg. The block slides on a smooth horizontal surface. The first block is connected by a horizontal weightless inelastic string to a second block of mass 0.98 kg on the same surface.



1.1	Draw a free-body diagram for each block	*(7)*
1.2	Determine the acceleration of the blocks. **(Application of Newton's Second Law and solving simultaneous equations.)**	*(7)*
1.3	Determine the tension in the string. **(Simultaneous equations)**	*(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. **(The impact of the mass/weight on horizontal forces)**	*(1)*

QUESTION 2

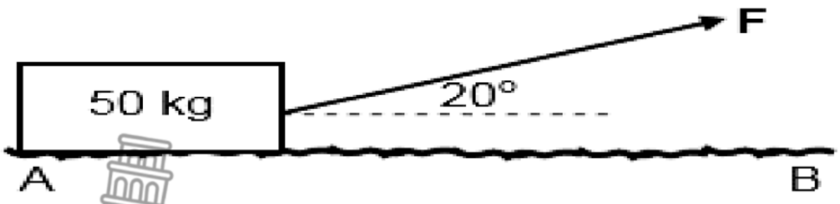
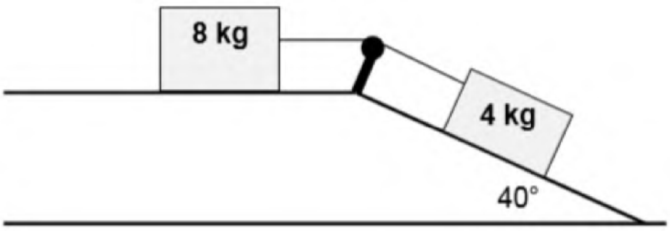
A 250 N force is applied on a block of mass 25 kg. The 25 kg block is connected to a 10 kg block by a light inextensible string through a frictionless pulley as shown on the diagram below. The 250 N force acts at an angle of 25o to the horizontal so that the system of blocks accelerates to the left. 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 **(Resolution of vectors and collinear vectors)**	(3)
	2.3.2	Acceleration of the system of blocks **(Application of Newton's Second Law and solving simultaneous equations.)**	(7)

QUESTION 3

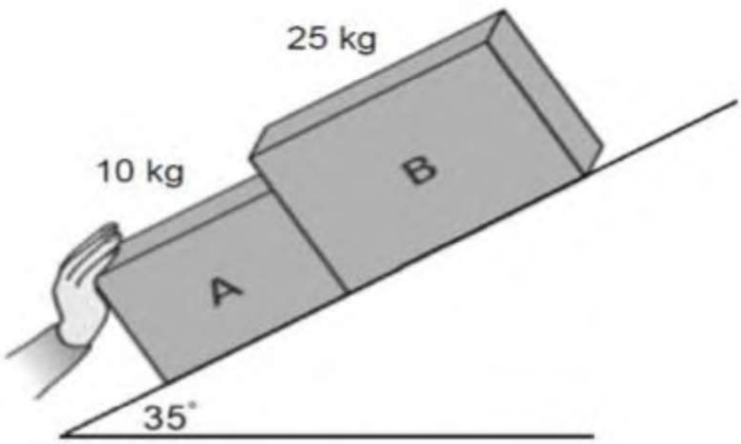
A constant force, F, pulls a 50 kg block at a **constant speed** over a rough horizontal surface, AB, as shown in the diagram below. The coefficient of kinetic friction (μ_k) between the block and the surface is 0.4.

			
3.1		Draw a labelled free-body diagram showing ALL the forces acting on the block.	(4)
3.2		State Newton's first law of motion in words.	(2)
3.3		Calculate the magnitude of the:	
	3.3.1	Force **F** **(Resolution of vectors and trig ratios.)**	(6)
	3.3.2	Normal force **(Collinear vectors)**	(2)
	3.3.3	Frictional force **(Using $f_k = \mu_k N$ to calculate the frictional force)**	(2)
	QUESTION 4 Two blocks, of mass 8 kg and 4 kg respectively, are joined with an inelastic string of negligible mass. The string runs over a frictionless pulley. The 8 kg block is on a horizontal surface while the 4 kg block is on an inclined plane of 40° with the horizontal. The coefficient of kinetic friction for both blocks is 0.2. The 4 kg block accelerates down the slope. 		
4.1		State Newton's Second Law of Motion in words.	(2)
4.2		Draw a labelled free-body diagram of ALL the forces acting on the 4 kg block.	(4)

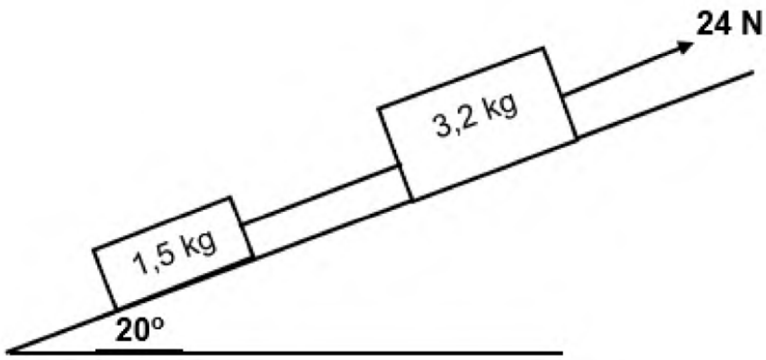
4.3		Calculate the frictional force between the surface and the 4 kg block. **(Using $f_k = \mu_k N$ to calculate the frictional force and resolving weight into components.)**	(4)
4.4		Calculate the magnitude of the acceleration of the system. **(Application of Newton's second law and solving simultaneous equations.)**	(6)
4.5		How will the acceleration compare if the positions of the 8 kg block and 4 kg block are switched? Choose from GREATER THAN, LESS THAN or THE SAME. Explain the answer. **(Weight is dependent on the mass of an object.)**	(4)

QUESTION 5

Two blocks, A and B, are placed on an inclined rough surface that makes an angle of 35° with the horizontal. Nceba is applying a force F on block A to push the system up the incline. Block B experiences a frictional force of 15 N.

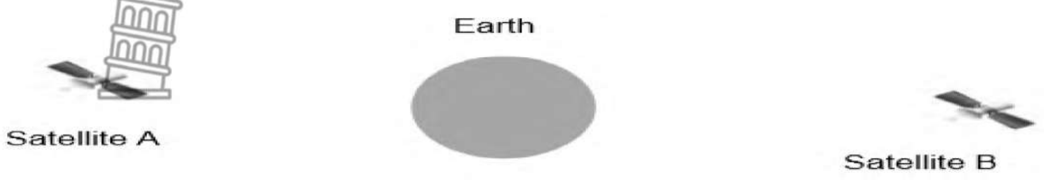


5.1	State Newton's Third law of motion in words	(2)
5.2	Draw a labelled free-body diagram of all the forces acting on block B.	(4)
5.3	If the system accelerates at 1.5 m.s^{-2} up. Calculate the force exerted by block B on block A. (**Application of Newton's Second and Third Law of Motion)**	(6)

5.4	If block A experiences a frictional force of 4,5N when the system was accelerating at 1.5m.s^{-2}, calculate magnitude of the force applied by Ncenda. **(Application of Newton's Second Law of Motion)**		(4)
	QUESTION 6 Two blocks of masses 1,5kg and 3,2kg 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 25o to the horizontal at a CONSTANT VELOCITY as shown on the diagram below. The 1,5kg box experiences a constant frictional force of 2 N as it moves up the incline.		
			
6.1	State Newton's Second Law of Motion in words.		(2)
6.2	Draw a labelled free-body diagram of all forces acting on the 1,5kg block.		(4)
6.3	Calculate the:		
	6.3.1	Tension in the string connecting the blocks **(Value of the net force at constant velocity and components of weight.)**	(5)
	6.3.2	Coefficient of kinetic frictional force between the 3,2kg block and the surface **(Application of Newton's Second Law and solving simultaneous equations.)**	(6)

QUESTION 7

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.



7.1		State Newton's Universal Gravitational Law in words.	(2)
7.2		Explain the term weightlessness	(2)
7.3		Calculate the force between the Earth and Satellite A. **(Application of Newton's Universal Gravitational Law)**	(4)
7.4		What distance above the surface of the Earth should Satellite B be to experience the same force towards the Earth as Satellite A?	
		Choose from: GREATER THAN, LESS THAN or EQUAL TO the distance above the Earth. Explain how you arrived at the answer. **(Relationship between universal gravitational force, the product of masses of the two bodies and the distance.)**	(2)

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)

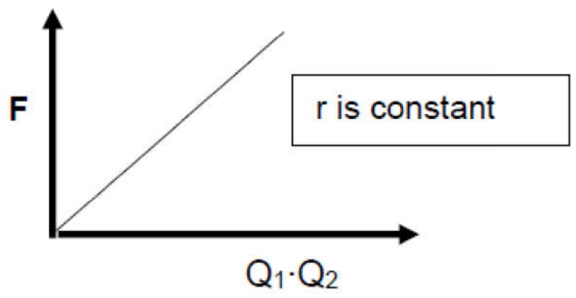
COULOMB'S LAW

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.

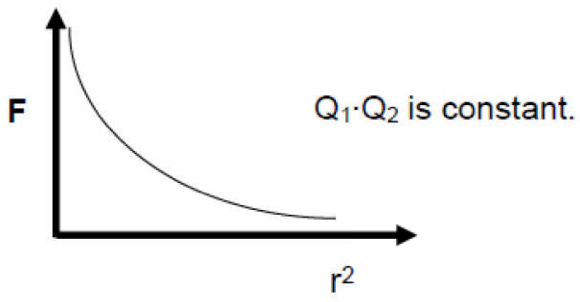
$$\mathbf{F = k\frac{Q_1Q_2}{r^2}}$$

Graphical representation of Coulombs law:

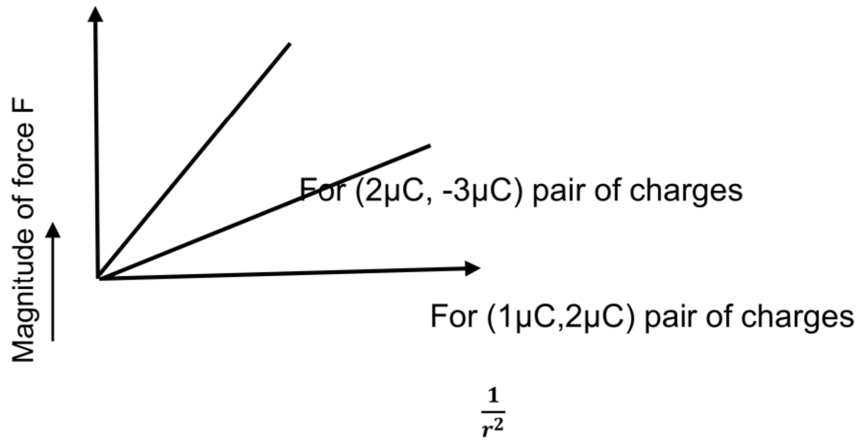
- The electrostatic force is directly proportional to the product of the charges ($F \alpha\, Q_1 \cdot Q_2$)



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

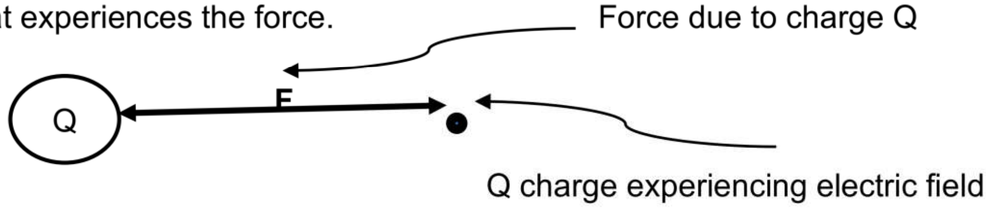


- Electrostatic force is directly proportional to the inverse of a square of a distance.



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

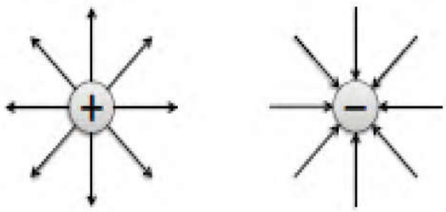
$E = \frac{F}{q}$

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

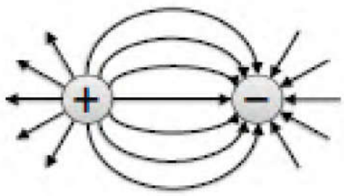
$E = 4 \times 10^5\ NC^{-1}$ to the right

ELECTRIC FIELD PATTERN

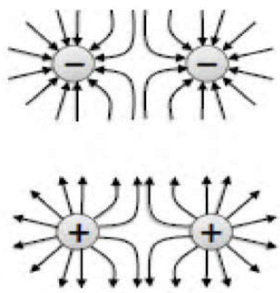
- Field lines around the single point charge



- Field lines between two unlike charges



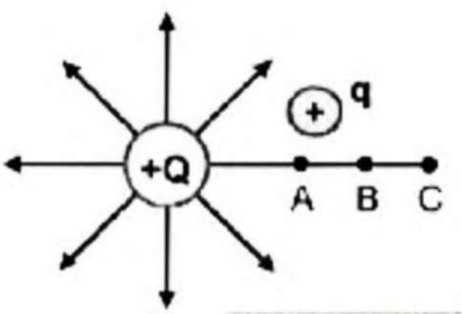
- Electric Field Lines between the two like charges



ELECTRIC FIELD STRENGTH

- **The electric field strength 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`

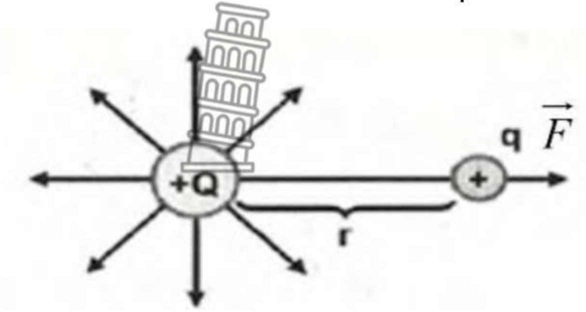
$$\mathbf{E = \frac{F}{q}}$$



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

- **Electric field strength at distance r from point charge Q**

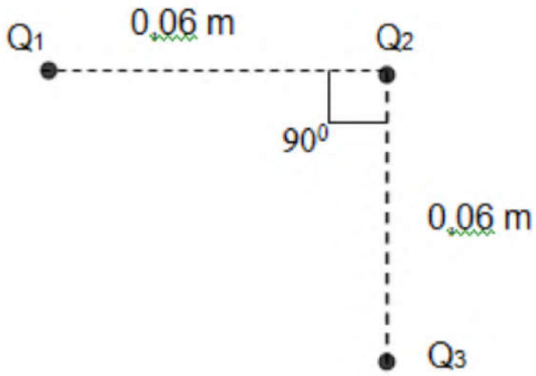
- If a test charge q is placed at a distance r from a charge Q, the magnitude of the electrostatic force F that Q and q are exerting on each other is:



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

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.

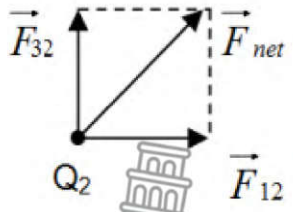


1.1	State Coulomb's Law in words.	(2)
1.2	Draw a free body diagram to show the forces acting on the point charge Q_2 and find the resultant force that acts on Q_2 graphically. Ignore gravitational force.	(3)
1.3	Calculate the magnitude of the resultant force that acts on point charge Q_2.	(6)

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

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

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

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

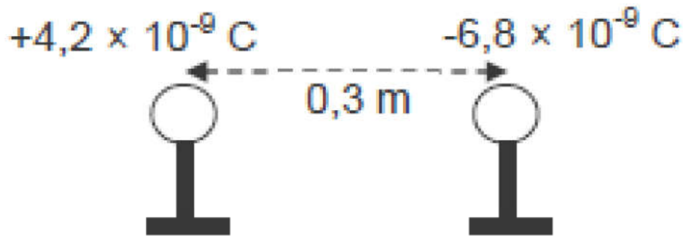
$$F_{net} = \sqrt{\left(\frac{162\times10^{-3}}{3,6\times10^{-3}}\right)^2 + \left(\frac{162\times10^{-3}}{3,6\times10^{-3}}\right)^2}$$

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

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

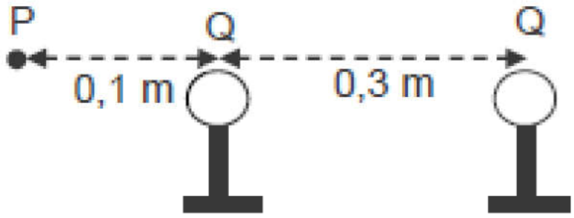
WORKED EXAMPLE 2

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)

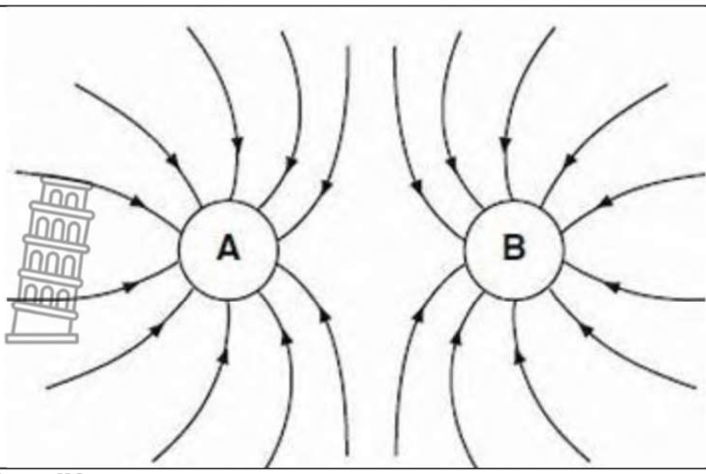
The two spheres are allowed to touch and are then returned to their original positions.



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)
		[15]

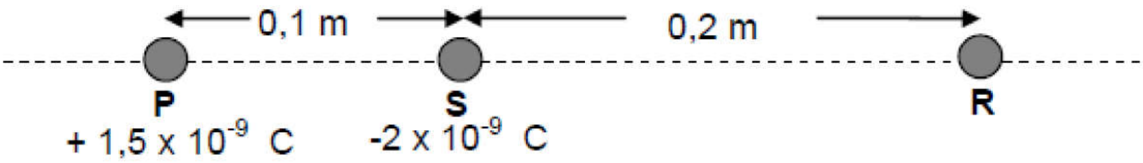
SOLUTION 2

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	$E_{net} = \frac{KQ_1}{r^2} + \frac{KQ_2}{r^2}\checkmark$ $E_{net} = \frac{(9\times10^9)(5{,}5\times10^{-9})}{(0.4)^2}\checkmark - \frac{(9\times10^9)(5{,}5\times10^{-9}}{(0.3)^2}\checkmark$ $E_{net} = -2{,}41 \times 10^2$ $E_{net} = 2{,}41$ N·C$^{-1}\checkmark$ *left* □	(5)
		[15]

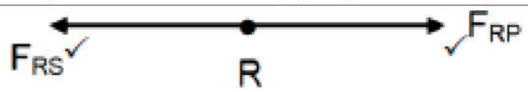
WORKED EXAMPLE 3

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

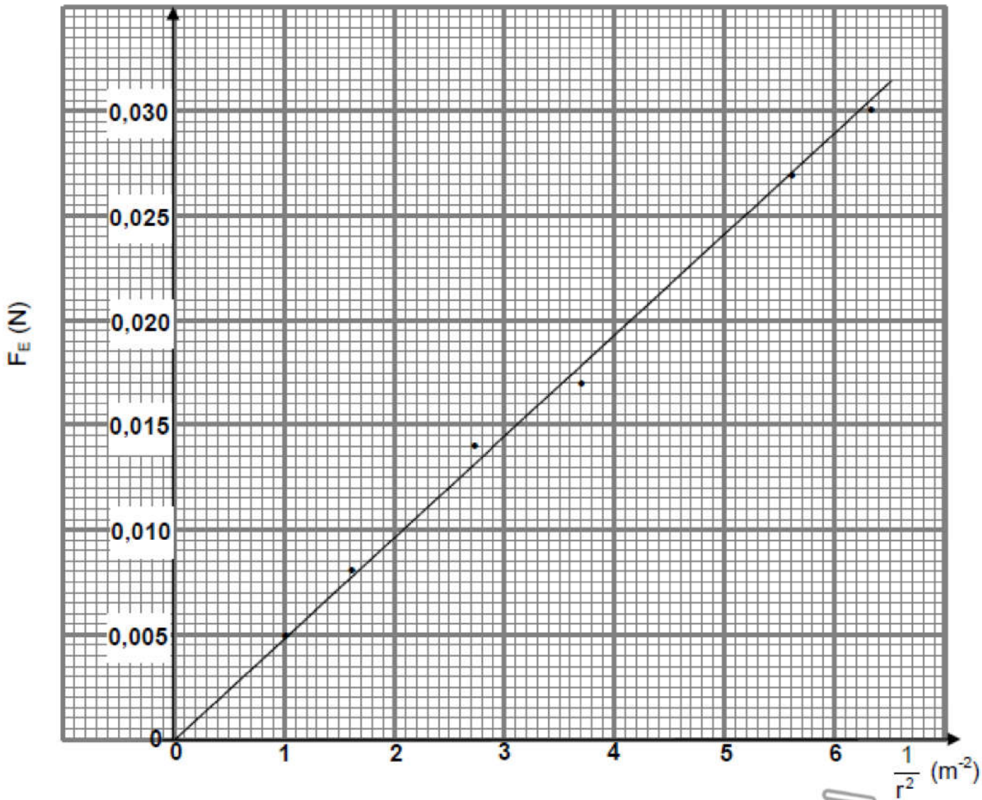
3.1	The magnitude of the electrostatic force exerted by two-point charges (Q_1 and Q_2) on each other is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them	(2)
3.2		(2)
3.3	To the right as positive✓	(1)

	$F = k\dfrac{Q_1Q_2}{r^2}$ ✓ $F_{netR} = F_{PR} + F_{SR}$ $F_{net} = \dfrac{kQ_1Q_2}{r^2} + \dfrac{kQ_1Q_2}{r^2}$ ✓ $-1{,}27\times10^{-6} = \left\{\dfrac{(9\times10^9)(1{,}5\times10^{-9})(Q)}{(0{,}3)^2} ✓ - \dfrac{(9\times10^9)(2\times10^{-9})(Q)}{(0{,}2)^2} ✓\right\}$ ✓ $-1{,}27 \times 10^{-6} = 150Q - 450Q$ ✓ ∴ $4{,}23 \times 10^{-9}$ C ✓	(6)

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.

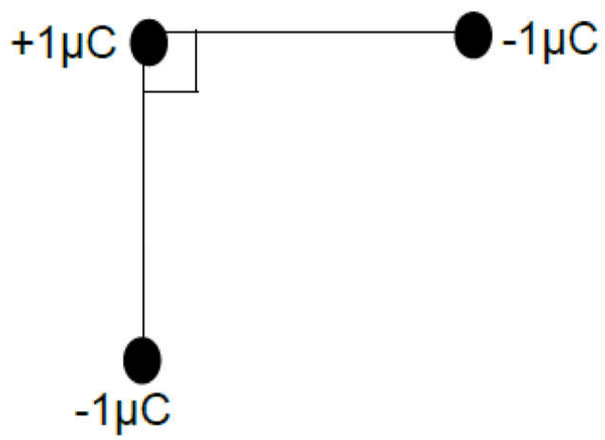
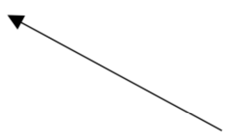
Graph of F_E versus $\frac{1}{r^2}$

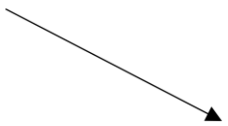


4.1	Write down the dependent variable of the experiment.	(1)
4.2	What relationship between the electrostatic force F_E and the square of the distance, r^2, between the charged spheres can be deduced from the graph?	(1)
4.3	Use the information in the graph to calculate the charge on each sphere.	(6)

SOLUTION 4

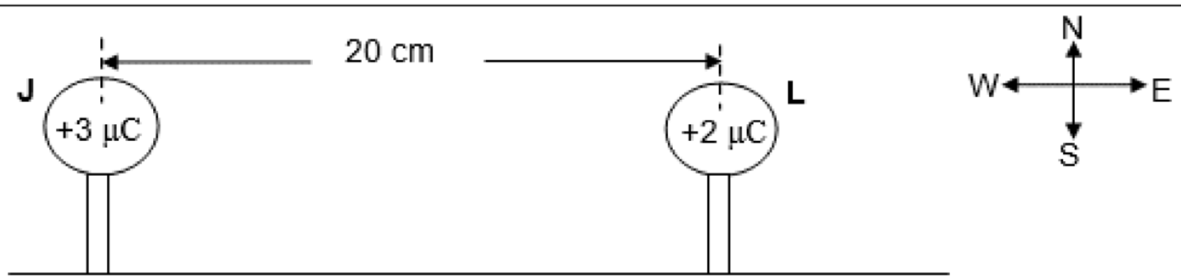
4.1	F_E/Electrostatic force	(1)

4.2	The electrostatic force is inversely proportional to the square of the distance between the charges.		(1)
4.3	$\text{Slope} = \frac{\Delta F_E}{\Delta \frac{1}{r^2}}$ ✓ $= \frac{0{,}027 - 0}{5{,}6 - 0}$ ✓ $= 4{,}82 \times 10^{-3}\ \text{N·m}^2$ $\text{Slope} = F_E r^2 = kQ_1Q_2 = kQ^2$ ✓ $\therefore 4{,}82 \times 10^{-3}$ ✓ $= \underline{9 \times 10^9\ Q^2}$ ✓ $\therefore Q = 7{,}32 \times 10^{-7}\ \text{C}$ ✓		(6)
			[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)
			[6]

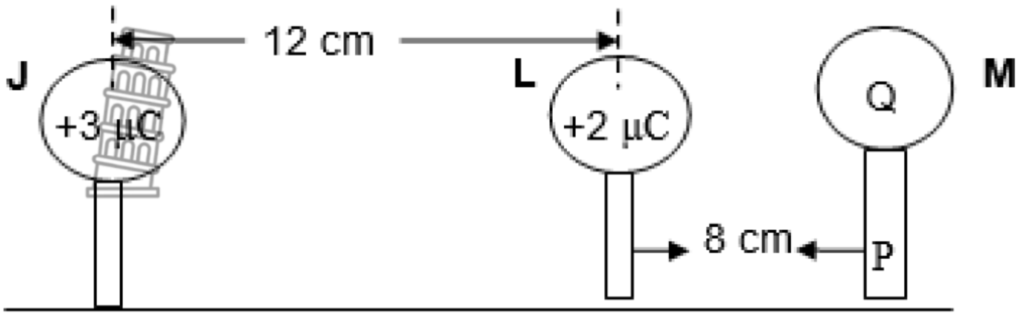
QUESTION 2

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)

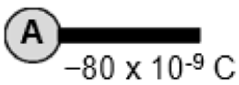
Sphere **L** is now placed 12 cm away from sphere **J**. Another sphere **M** with a charge of -8 µC is brought into contact with sphere **L**. **After contact**, sphere **M** is placed on a wooden stand **P**, 8 cm from sphere **L**, as shown in the diagram.



	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)
			[19]

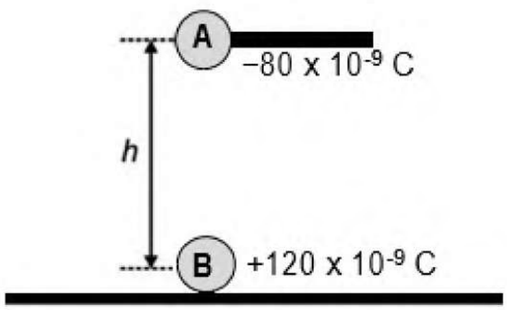
QUESTION 3

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 $+120 \times 10^{-9}$ C. Sphere **A** is slowly brought closer to sphere **B** in order to pick it up. Ignore the effects of air resistance.



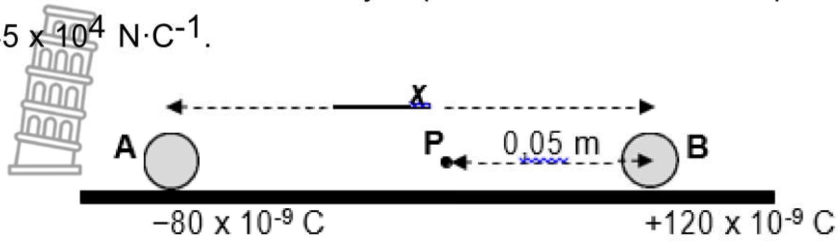
3.3	Draw a diagram that shows the electric field pattern between spheres **A** and **B**.	(3)

At a certain height **h** Sphere **B** is <u>just</u> 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)

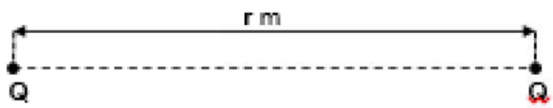
Sphere **A** is now placed on the horizontal insulated surface, a distance ***x*** from sphere **B** as shown in the diagram below. **P** is a point between **A** and **B,** 0,05 m from **B**. The magnitude of the **net** electric field intensity at point **P** as a result of the presence of spheres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



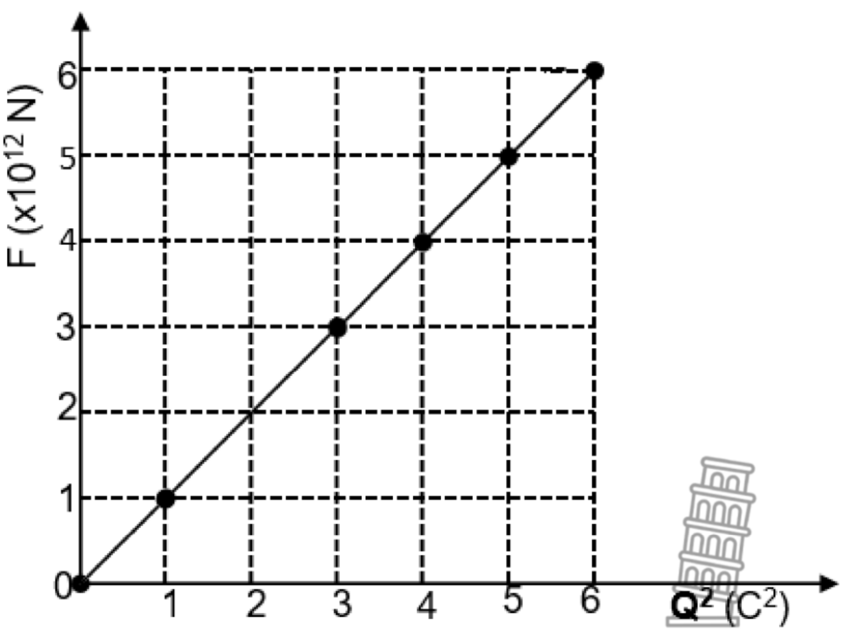
3.6	Draw a labelled vector diagram indicating the directions of the electric field at point **P** as a result of spheres **A** and **B** respectively.	(2)
3.7	Calculate the distance ***x*** between spheres **A** and **B**	(6)
		[22]

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.



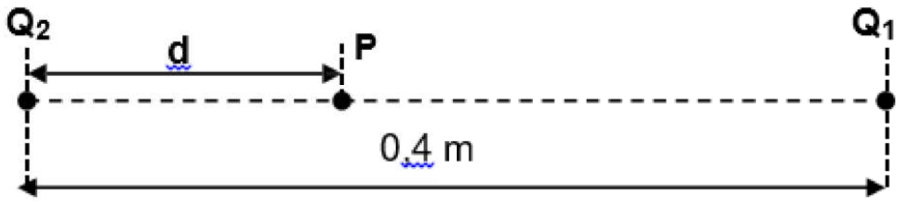
The graph below shows the relationship between the electrostatic FORCE **F**, exerted by one point charge on the other, and the PRODUCT of the two charges, **Q^2.**



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, $\mathbf{Q^2}$.	(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)

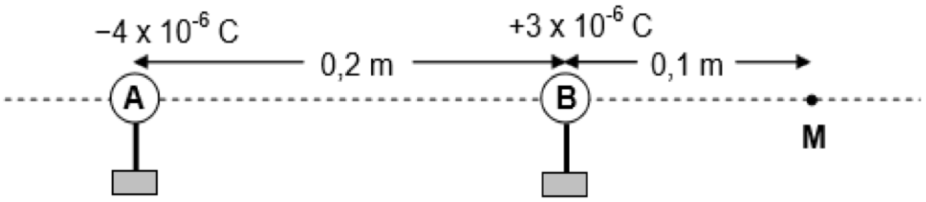
Two point charges, $\mathbf{Q_1}$ = +8 μC and $\mathbf{Q_2}$ = +2 μC, are separated by a distance of 0,4 m, as shown in the diagram below.



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)
			[19]

QUESTION 5

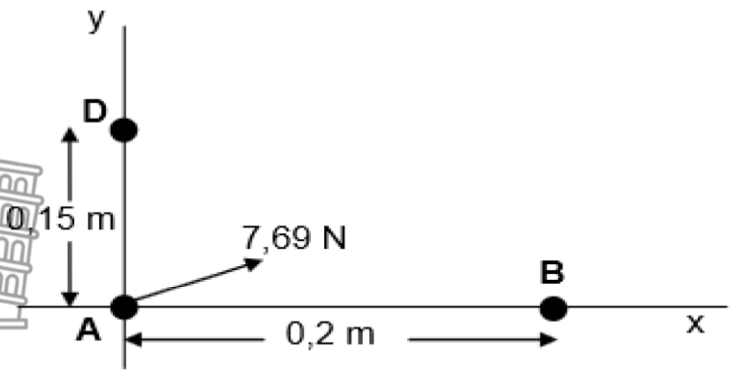
Two small, charged spheres, **A** and **B**, are placed on insulated stands, 0,2 m apart, as shown in the diagram below. They carry charges of -4×10^{-6} C and $+3 \times 10^{-6}$ C respectively.



M is a point that is a distance of 0,1 m to the right of sphere **B**.

5.1	Calculate the number of electrons in excess on sphere **A**	(3)
5.2	Calculate the magnitude of the electrostatic force exerted by sphere **A** on sphere **B**.	(3)
5.3	Describe the term *electric field*.	(2)
5.4	Calculate the magnitude of the net electric field at point **M**.	(5)

Charged spheres **A** and **B** and another charged sphere **D** are now arranged along a rectangular system of axes, as shown in the diagram below.

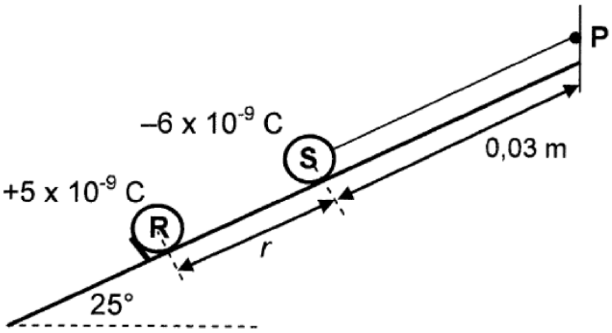


The net electrostatic force experienced by sphere **A** is 7,69 N in the direction as shown in the diagram above.

5.5	Is the charge on sphere **D** POSITIVE or NEGATIVE?	(1)
5.6	Calculate the magnitude of the charge on sphere **D**.	(3)
		[17]

QUESTION 6

Two charged spheres, R and S are both stationary on a smooth, insulated surface inclined at an angle of 25° to the horizontal. Spheres S, of mass 0,01 kg and carrying a charge of -6×10^{-9}C, is connected to a 0,03 m long, light inextensible string attached to point **P** at the top of the incline. Spheres **R**, carrying a charge of $+5 \times 10^{-9}$C, is held such that the distance between the centres of the spheres is r, as shown in the diagram below.
Ignore the effects of friction.

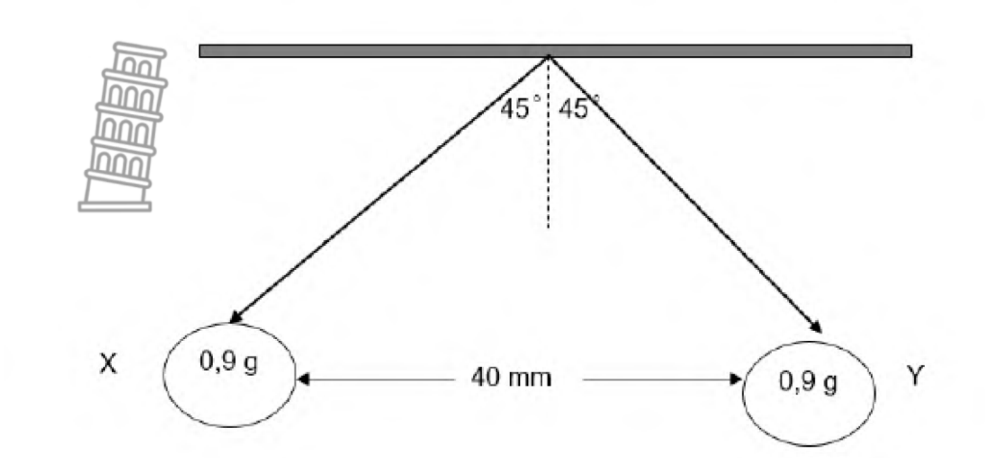


Sphere **R** exerts an electrostatic force of magnitude 1.2 $\times 10^{-3}$N on sphere S

6.1	State Coulomb's law in words		
6.2	Calculate the distance r between the spheres		
6.3	Draw a labelled free-body diagram for sphere **S**		
6.4	Calculate:		
	6.4.1	Tension in the string	(4)
	6.4.2	Net electric field at a point **P**	(5)
			[18]

QUESTION 7

Two small identical metal spheres, X and Y, each with a mass of 0,9 g hang from the same fixed point from threads of equal length. When the spheres receive equal charges, they repel each other and come to rest with their centres 40 mm apart and the threads making an angle of 45° with the vertical.



7.1	State *Coulomb's law* in words.		(2)
7.2	Draw a force diagram to show all the forces acting on Y.		(3)
7.3	Calculate the:		
	7.3.1	Magnitude and direction of electrostatic force that X exerts on Y.	(3)
	7.3.2	Charge on each sphere.	(3)
			[11]

ELECTRIC CIRCUITS

PRIOR KNOWLEDGE (GRADE 10)

- **Potential difference**

The energy transferred per unit electric charge flowing through it.

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

V: Potential difference in Volts (V)
W: Energy in Joules (J)
Q: Electric charge in Coulombs (C)

- **Emf (Electromotive force)**

The maximum work done per unit charge by the source (battery).
It is equal to the potential difference measured across the terminals of a battery when no charges are flowing in the circuit.

- **Terminal potential difference (V)**

The voltage measured across the terminals of a battery when charges are flowing in the circuit.

- **Electric current (I)**

The rate of flow of charge.

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

I: Electric current in Amperes (A)
Q: Electric charge in Coulombs (C)
Δt: Time in seconds (s)

- **Resistance**

The resistance is the opposition to the flow of electric charges.
It is the ratio of the potential difference across a resistor to the current in the resistor.

$\mathbf{R} = \frac{\mathbf{V}}{\mathbf{I}}$ R: Resistance in Ohms (Ω)

Resistors in series

The current is the same through each resistor in a series circuit.
A series circuit is a potential difference divider because the total potential difference is equal to the sum of the potential differences across all the individual components.

$R_s = R_1 + R_2 + \dots$
$V_s = V_1 + V_2 + \dots$
$I_T = I_1 = I_2 = \dots$

Resistors in parallel

The potential difference is the same across resistors connected in parallel.
A parallel circuit is a current divider because the total current in the circuit is equal to the sum of the branch currents.

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

$V_p = V_1 = V_2 = \ldots$

$I_p = I_1 + I_2 + \ldots$

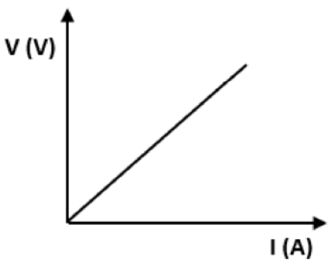
Grade 11 concepts

- **Ohm's law**

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

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

- Graphical representation of Ohm's law



- **Ohmic conductor**

A conductor which obeys Ohm's law

- **Non – Ohmic**

A conductor which does not obey Ohm's law

- **Power**

Is the rate at which work is done (or energy is transferred)

$$P = \frac{W}{\Delta t}$$

P: Power in Watt (w)
W: Energy in Joules (J)
Δt: time (s)

The following formulae can be used to calculate Power.

$P = VI$

$P = I^2R$

$$P = \frac{V^2}{R}$$

- **Energy**

Energy is the ability to do work

Energy can be calculated as

$W = P\,\Delta t$

Knowing that

W: energy in Joules (J)

P: Power in Watts (w)

Δt: Time in seconds (s)

Other formulae to consider:

$W = VI\Delta t$

$W = I^2R\Delta t$

$W = \frac{V^2}{R}\,\Delta t$

- **Cost of electricity**

To calculate the cost of electricity, the energy has to be expressed in Kilowatt – hour.

$W = P.\,\Delta t$

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

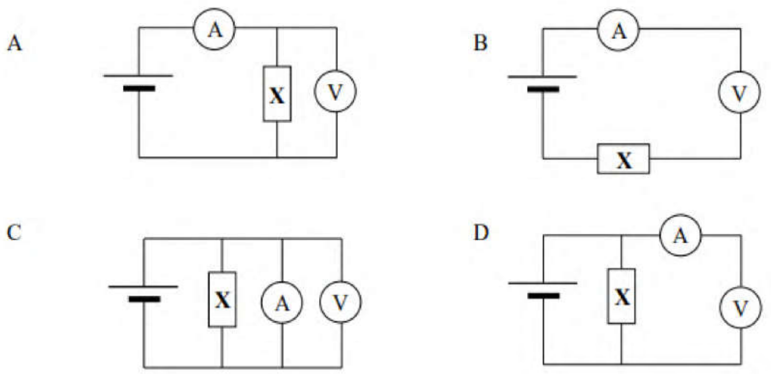
Main aspects addressed in each sub-question:

- 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.

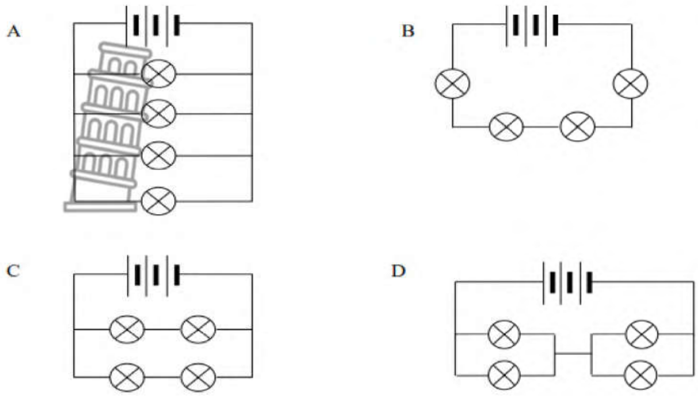
WORKED EXAMPLES

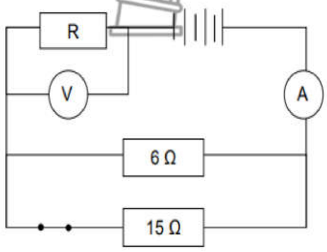
QUESTION 1: MULTIPLE CHOICE QUESTIONS

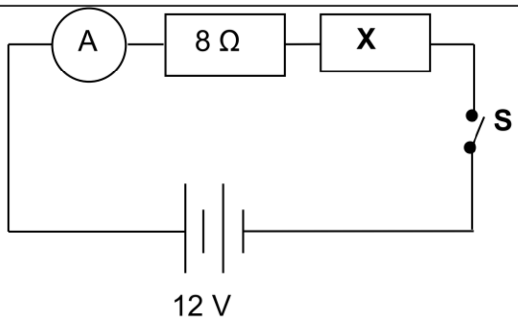
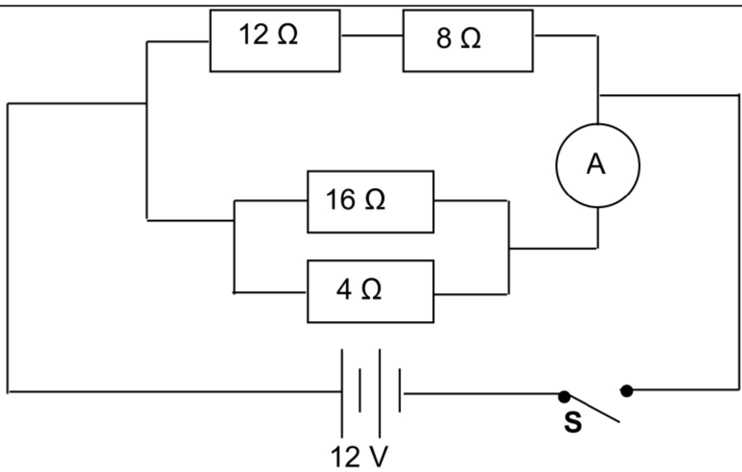
1.1. Which ONE of the circuits below can be used to measure the current in a conductor X and the potential difference across its ends?



(2)

1.2		A set of identical light bulbs are connected as shown in the circuit diagrams below. The internal resistance of the battery is negligible. In which ONE of these circuits will the light bulbs glow the brightest?  	(2)
1.3		When a resistor of resistance R is connected to a battery of emf and negligible internal resistance, the power dissipated in the resister is P. If the resistor is replaced with a resistor of resistance 2R, without changing the batter, the power dissipated will be… A. ¼ P B. ½ P C. 2 P D. 4 P	(2)
1.4		The minimum resistance that can be obtained by connecting two 4Ω resistors is A. 0,5 Ω B. 2.0 Ω C. 3.0 Ω D. 8.0 Ω	(2)
1.5		One volt is… A. One coulomb of charge per joule B. One joule per coulomb of charge C. One joule coulomb of charge D. One joule per second	(2)
SOLUTIONS TO QUESTION 1			
1.1		**A** ✓✓	
1.2		**A** ✓✓	
1.3		**D** ✓✓	
1.4		**B** ✓✓	
1.5		**B** ✓✓	

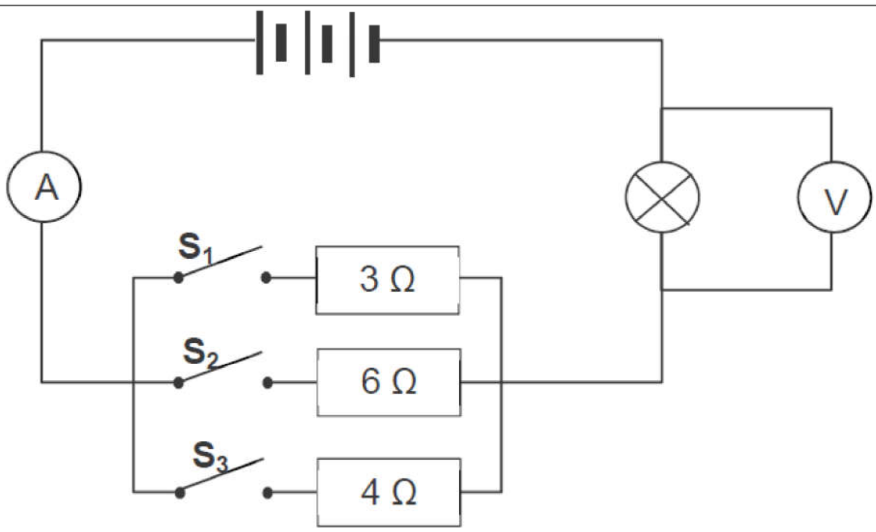
QUESTION 3			
3.1	The circuit below consists of a 6 Ω and 15 Ω resistor connected in parallel and an unknown resistor R, in series. An ammeter, a high-resistance voltmeter, a closed switch and battery are connected, as shown. The resistance of the battery and wires can be ignored.  The total power dissipated in the parallel part of the circuit is 50 W.		
	3.1.1	Define the term power.	(2)
	3.1.2	Calculate the effective resistance of the parallel combination. **(Total resistance of parallel connection)**	(2)
	3.1.3	Calculate the potential difference across the resistors in parallel. **(Relationship between Power, voltage and resistance)**	(3)
	3.1.4	Calculate the current through resistor R. **(Current in series connection)**	(3)
	The switch in the circuit is now OPENED.		
	3.1.5	How will the reading on the voltmeter (V) be influenced? Choose from INCREASE, DECREASE or REMAIN THE SAME. **(Influence of number of resistors connected in parallel on the total resistance and the current. Application of ohm's law)**	(1)
	3.1.6	Explain the answer to QUESTION 3.1.5.	(3)
			[14]
SOLUTIONS			
3.1			
	3.1.1	Power is the rate at which work is done or energy is transferred.	
	3.1.2	$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$ $\frac{1}{R_p} = \frac{1}{6} + \frac{1}{15}$ ✓ Rp = 4, 29 Ω ✓	(2)
	3.1.3	$P = \frac{V^2}{R}$ ✓ $50 = \frac{V^2}{4{,}29}$ ✓ V = 14, 65 V	(3)

	3.1.4	V = I.R ✓ 14, 65 = I x 4, 29 ✓ 3, 41 A ✓	(3)
	3.1.5	Decreases ✓	(1)
	3.1.6	The total resistance increases ✓ The current in the circuit decreases ✓ The resistance of R is constant, then the potential difference across R Decreases ✓	(3)
		ACTIVITIES	
	QUESTION 1		
1.1	The circuit below is used to determine the resistance of resistor **X**.		
			
	The 12 V battery has negligible internal resistance. When switch **S** is closed, the reading on the ammeter is 0,5 A.		
	1.1.1	State Ohm's law in words.	(2)
	1.1.2	Calculate the resistance of resistor **X**.	(5)
1.2	Study the circuit below. The battery has an emf of 12 V with negligible internal resistance.		
			
		Switch **S** is closed.	
	1.2.1	Write down the potential difference across the 4 Ω resistor.	(1)

	1.2.2	Calculate the reading on the ammeter.	(5)
	1.2.3	Calculate the energy dissipated in the 12 Ω resistor in 2 minutes.	(5)
			[18]

QUESTION 2

Three resistors, of resistances 3 Ω, 4 Ω and 6 Ω, and a bulb are connected in a circuit, as shown below. Initially all the switches, **S1**, **S2** and **S3**, are open. The internal resistance of the battery and the resistance of the connecting wires may be ignored.



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

Switch **S1** is now closed and the voltmeter and ammeter readings are recorded. The voltmeter and ammeter readings, when both switch **S1** and switch **S2** are closed, are then recorded, as well as the readings when all three switches, **S1**, **S2** and **S3**, are closed.

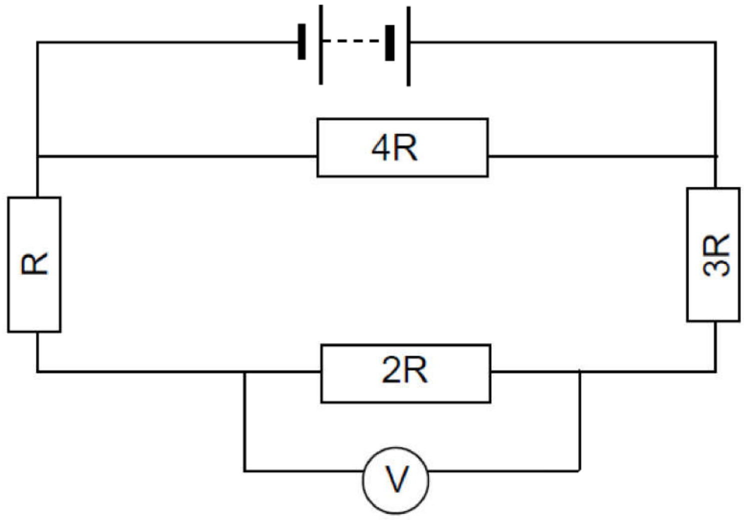
The results obtained are shown in the table below.

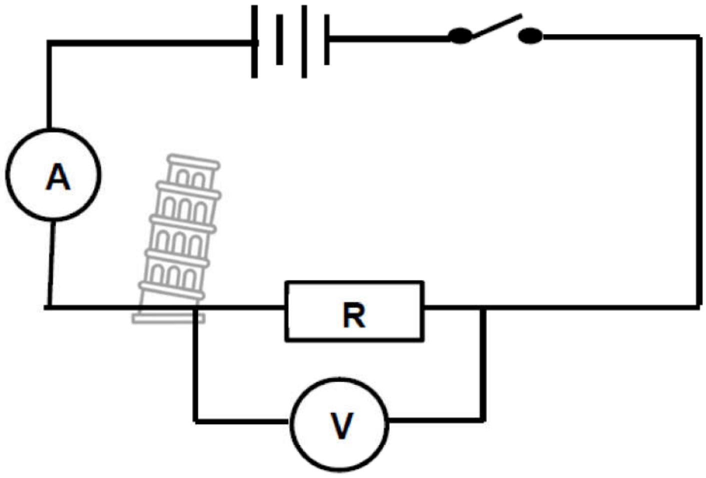
SWITCHES CLOSED	VOLTMETER READING (V)	AMMETER READING (A)
S_1	4,8	2,4
S_1 and S_2	6	3
S_1, S_2 and S_3	7,2	3,6

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

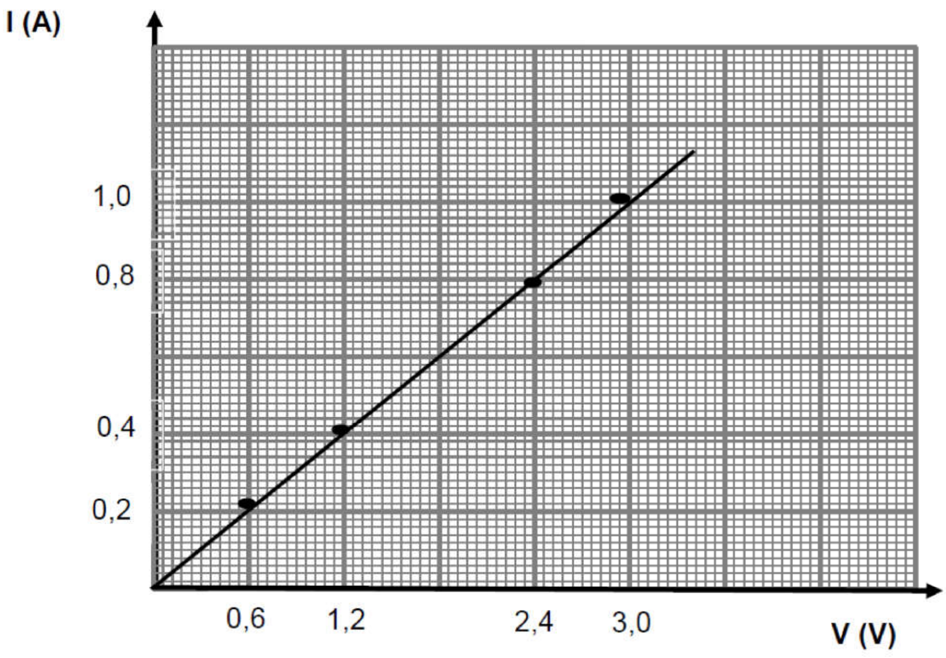
2.3 Calculate the:

	10.2.1	Resistance of the bulb	(3)
	10.2.2	Potential difference of the battery	(4)

2.4	Define the term *power*.	(2)
2.5	Calculate the power dissipated in the 6 Ω resistor when ONLY SWITCHES **S**1	(4)
2.6	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)
2.7	Explain the answer to QUESTION 2.6.	(2)
		[20]
	QUESTION 3	
	Consider the circuit diagram below. The internal resistance of the battery and any resistance in the wires can be ignored.	
		
3.1	Calculate the value of resistor R if the total resistance of the circuit is 4,8 Ω.	(3)
3.2	Calculate the reading on the voltmeter if the current through the 4R resistor is 1,8 A.	(5)
3.3	Calculate the energy converted in resistor 4R in 2 minutes.	(3)
	The 4R resistor is replaced with an ammeter.	
3.4	How will the reading on the voltmeter be influenced? Write only INCREASE, DECREASE or STAY THE SAME.	(1)
3.5	Explain the answer to QUESTION 3.4.	(2)
		[14]
	QUESTION 4	
4.1	A learner sets up the circuit below to investigate the relationship between current and potential difference across the ends of a conductor. She closes the switch and records the ammeter and voltmeter readings. She repeats the experiment three times; each time she increases the number of cells in the circuit. Then she reads and records the ammeter and voltmeter readings.	

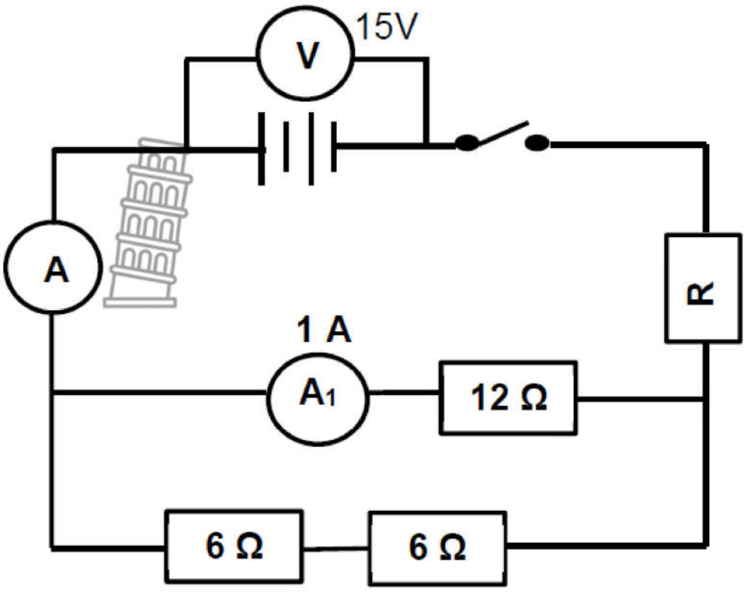


A graph of her results is shown below.

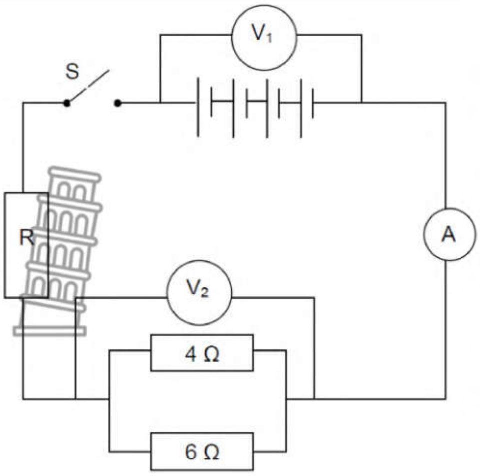


	4.1.1	Which physical quantity does the gradient of the graph represent?	(1)
	4.1.2	Use the information from the graph to calculate the resistance of the resistor that the learner used in the investigation.	(3)

4.2 The battery in the circuit diagram below has negligible internal resistance. The resistance of resistor **R** is unknown. When the switch is closed, the voltmeter reads 15 V and the ammeter A1 reads 1 A.



	4.2.1	Current in ammeter A	(3)
	4.2.2	Resistance of resistor R	(5)
	The resistor **R** of unknown resistance is now removed from the circuit. How will this change in the circuit affect the reading of the ammeter A?		
4.3	Answer INCREASE, DECREASE or REMAIN THE SAME. Explain your answer.		(2)
4.4	The power rating on an electric stove is 1 500 W. If the stove is used for 3 hours and 30 minutes, calculate how much it will cost to use the stove. 1 unit of electricity (1 kWh of electricity) costs R1,15.		(3)
			[17]
	QUESTION 5		
	An experiment is done to verify that the potential difference across a conductor is directly proportional to the current in the conductor if the temperature stays constant. Four cells, each with an emf of 1,5 V, are connected in series with an ammeter, switch S and a combination of a resistor R and resistors of 4 Ω and 6 Ω, as shown in the diagram. Voltmeters V1 and V2 are connected across the battery and the parallel resistors respectively. The internal resistance of the battery and wires are negligible.		



5.1	Which law is represented by the underlined phrase above?	(1)
	The switch is now closed and six resistors (R1–R6), each with a different resistance, are placed in the place of R, one at a time. The voltmeter and ammeter readings are recorded. The results are as follows:	

RESISTORS AT R	READING ON VOLTMETER V_2 (V)	READING ON AMMETER (A)
R_1	1,2	0,5
R_2	1,4	0,6
R_3	1,9	0,8
R_4	2,4	1
R_5	2,9	1,2
R_6	3,6	1,5

5.2	Use the attached graph paper and draw a graph of potential difference versus current using the data in the table.	(4)
5.3	What does the gradient of the graph represent?	(1)
5.4	If voltmeter V2 is only connected across the 4 Ω resistor, how will the gradient of the graph change? Write down only INCREASES, DECREASES or STAYS THE SAME.	(1)
5.5	If the 4 Ω resistor is removed, how will the gradient of the graph change? Write down only INCREASES, DECREASES or STAYS THE SAME.	(1)
5.6	Calculate the resistance of resistor R_3 using the values in the table.	(5)
5.7	Calculate the energy dissipated in resistor R_4 in 10 seconds.	(3)
		[16]

	QUESTION 6		
	A geyser, labelled 2 000 W, is used for an average of 5 hours per day. The cost of electricity is 80 cents per kWh.		
	6.1	Calculate the energy used by the geyser for 5 hours per day.	(4)
	6.2	Calculate the cost of electricity to operate the geyser for a month with 30 days.	(2)
			[6]

ELECTROMAGNETISM

PRE – KNOWLEDGE

Magnetic field

A region in space where a magnet or ferromagnetic material will experience a force (non-contact).

Ferromagnetic materials

Materials that are strongly attracted by magnets and are easily magnetised.

Magnetic force.

A non-contact force that a magnet exert on another magnet or a ferromagnetic material.

Poles of a magnet

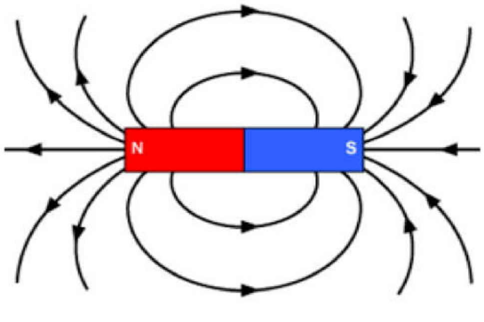
A magnet has two poles namely the NORTH and the SOUTH pole.

Like poles repel

Unlike poles attract

- **Properties of magnetic field lines**
  - The more closely spaced the field lines are at a point the stronger the field at that point.
  - Arrows drawn on the field lines indicate the direction of the field.
  - The direction of a magnetic field points from the North to the South Pole.
  - Magnetic field lines never cross.

Magnetic field pattern around a single bar magnet



- A current passing through a conductor produces a magnetic field around that conductor
- A changing magnetic flux induces a current in a conductor.

Magnetic field associated with current-carrying conductors

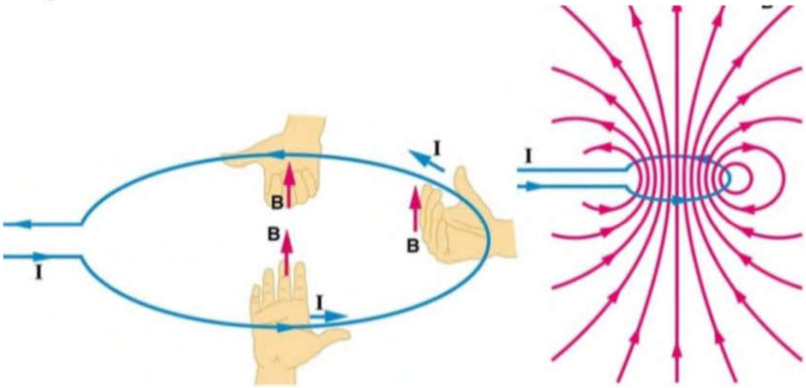
Use of the right hand rule to determine the direction of the magnetic field (B) associated with a:

- **Straight current-carrying conductor**

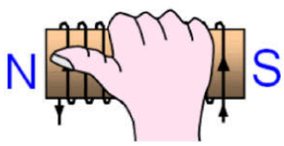
  The magnetic field made by a current in a straight conductor curls around the conductor in a ring.

To determine the direction of the magnetic field around a straight conductor, point the right thumb in the direction of the current in the conductor and curl the fingers around the conductor. Your fingers will be curled in the same direction as the magnetic field around the conductor..

- **Current-carrying loop** (single turn)
  The right hand rule still applies like in a straight conductor. The magnetic field lines inside the loop have the same direction, and the field lines outside the loop have the same direction.



- **Solenoid**
  The direction of the magnetic field produced around a solenoid can be determined by wrapping the right hand around the solenoid with the fingers in the direction of the conventional current. The thumb points in the direction of the magnetic north pole.



- **Faraday's law**
  Faraday's law of electromagnetic induction states that the magnitude of the induced emf across the ends of a conductor is directly proportional to the rate of change in the magnetic flux linkage with the conductor.
  When a pole of a bar magnet moves into and out of the solenoid an emf get induced in the solenoid.
  $\mathcal{E} = -N \frac{\Delta\Phi}{\Delta t}$
  $\mathcal{E}$: emf in Volts
  N: The number of turns of the coil

ΔΦ: Change in the magnetic flux in webers (Wb)
Δt: time taken to change the magnetic flux in seconds (s)
The magnetic flux Φ is calculated as
$\Phi = BA\cos\theta$
Φ: magnetic flux in webers (Wb)
B: magnetic field in tesla (T)
A: Area of the coil in square meters (m^2)
ɵ: Angle between the magnetic field and the normal to the area of the coil.
(Normal is an imaginary line drawn perpendicular to the plane of the coil)

WORKED EXAMPLES

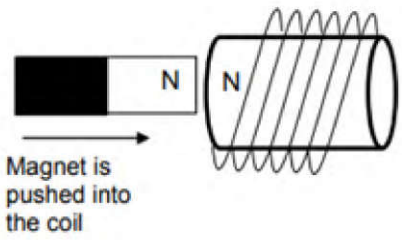
1.1 In the diagram below, the north pole of a bar magnet approaches end A of a solenoid.

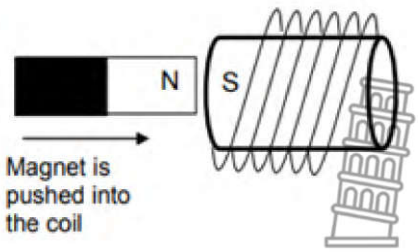
Which ONE of the following statements about the polarity of A and the direction of the magnetic field INSIDE the solenoid is CORRECT as the NORTH POLE approaches A?

	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

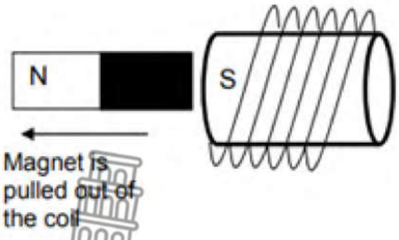
(2)

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

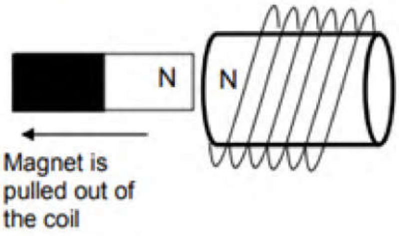
A


B


C



D



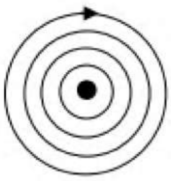
(2)

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?

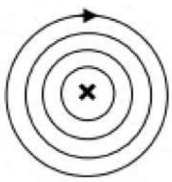
A. Rotating the coil slower
B. Decreasing the number of turns/windings of the coil
C. Increasing the speed of rotation of the coil
D. Changing the polarity of the magnets (2)

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

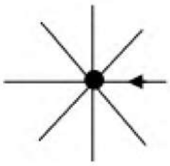
A



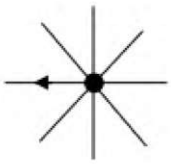
B



C



D



(2)

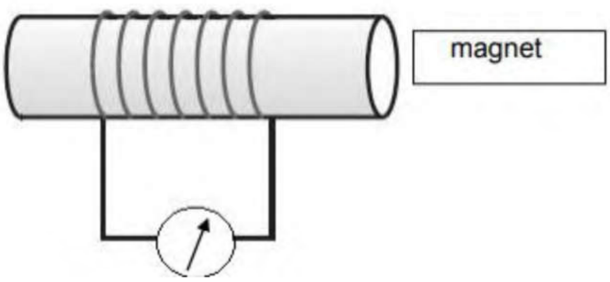
[8]

SOLUTIONS

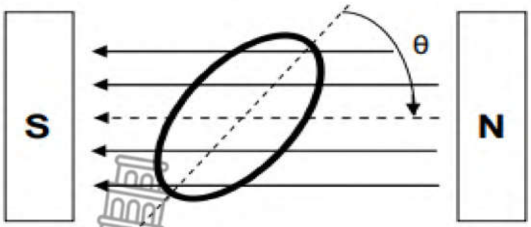
1.1	B ✓✓	
1.2	A ✓✓	
1.3	C ✓✓	
1.4	B ✓✓	**[8]**

QUESTION 2

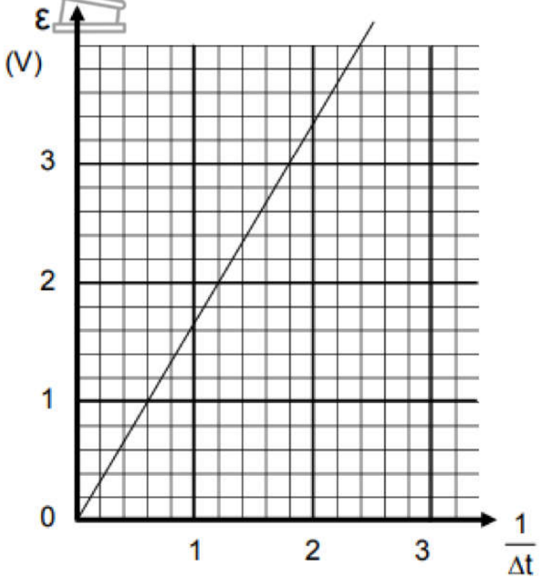
2.1 The arrangement of apparatus to demonstrate Faraday's law of electromagnetic induction is shown below.



	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 ө)**	(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)
			[11]
	SOLUTIONS		
	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)
			[11]
	PRACTICE ACTIVITIES		
	QUESTION 4		
	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.		

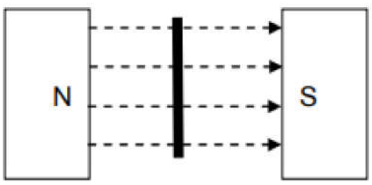


The graph below shows how the induced emf varies with the inverse of time.



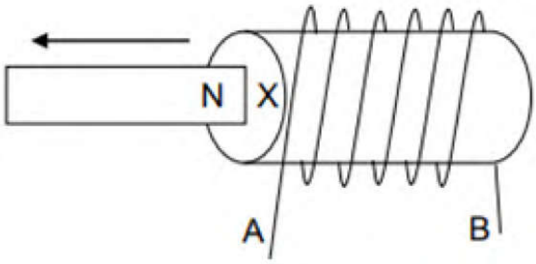
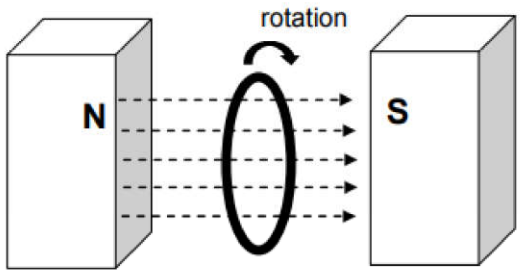
4.1	State Faraday's law in words	(2)
4.2	Use the information in the graph to calculate the change in magnetic flux when the emf is 3 V **(Interpretation of graph)**	(4
4.3	The coil rotates through an angle θ to a position where the magnetic flux becomes zero. Calculate angle θ. **(Calculating the change in magnetic flux)**	(5)
		[11]
	QUESTION 5	

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.

5.1	State Faraday's law of electromagnetic induction in words.	(2)
5.2	Calculate the change in the magnetic flux.	(3)
5.3	Calculate the magnitude of the magnetic field.	(4)

The coil is now rotated through an angle of 45º in 0,05 s			
5.4	How will the induced emf be affected? Write only INCREASE, DECREASE or STAY THE SAME.		(1)
5.5	Explain the answer to QUESTION 5.4		(1)
The north pole of a bar magnet is moved away from a solenoid, as shown in the sketch below. 			
5.6	Which pole will be induced at point X? Write only NORTH or SOUTH.		(1)
5.7	In which direction will the induced current flow? Write only FROM A TO B or FROM B TO A.		(1)
			[13]
QUESTION 6			
	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. 		
6.1	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)
6.2	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)
6.3	Which law can be used to explain the phenomenon described in QUESTION 3.2? Name and state the Law. **(Recall)**		()
6.4	6.4.1	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)
	6.4.2	Explain the answer to QUESTION 3.4.1	(2)

			[12]

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

$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

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.

$N_2 + 2O_2 \rightarrow 2NO_2$

1mol + 2mol → 2mol

$1(22,4dm^3) + 2(22,4dm^3) \rightarrow 2(22,4dm^3)$

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

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

- 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. $n = \frac{V}{Vm}$ = $0,2X22.4$ = 0,448 dm^3
2. [convert units first]
   V=60/1000 =0.06dm^3
   $$n = \frac{V}{Vm} = \frac{0.06}{22.4} = 0.0027\, mol$$
   $$n = \frac{m}{M}$$
   $$m = 0.0027X17.03 = 0.046g$$

- **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** – the concentration of solution is the number of mole per unit volume 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 of element	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.

Step 1:
Find the molar mass of the empirical formula

↓

Step 2:
Divide the given molar mass by the molar mass of the empirical formula that was calculated

↓

Step 3:
Determine the molecular formula by multiplying all subscripts in the Empirical formula by the whole number that you calculated in step 2

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 givenCH_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)

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

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

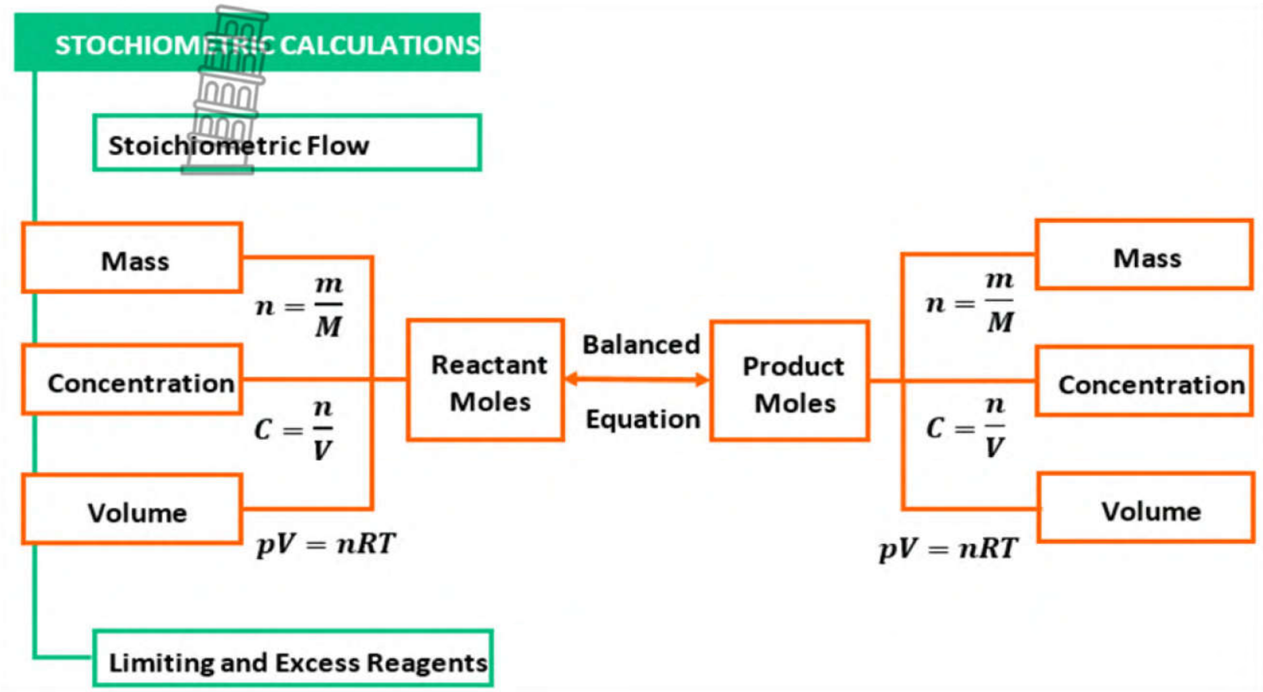
$$m = 1.04g$$

Step 5 : (percentage yield)

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

$$Percentage\ yield = \frac{0.583}{1.04} x100$$

$$Percentage\ yield = 56.1\%$$



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 x 10^{22} molecules? **A.** 0,03 **B.** 33,34 C. 1,2 X 10^{24}	

		D. 1,08 X0[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: $$2\ Na_3N\ (s) \longrightarrow 6Na\ (s) + N_2\ (g)$$		
	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)
			[11]
Questin 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.		**[10]**
	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)
			[10]
Question 3 – COMPLEX STOICHIOMETRIC CALCULATIONS			
	A sample of IMPURE calcium carbonate (limestone) of unknown mass required a continuous supply of strong heat to decompose according to the following equation: $$CaCO3(s) \longrightarrow CaO(s) + CO_2(g)$$ After the completion of reaction, 11,76 g CaO was produced. The percentage purity of calcium carbonate is found to be 80%		
	3.1	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)

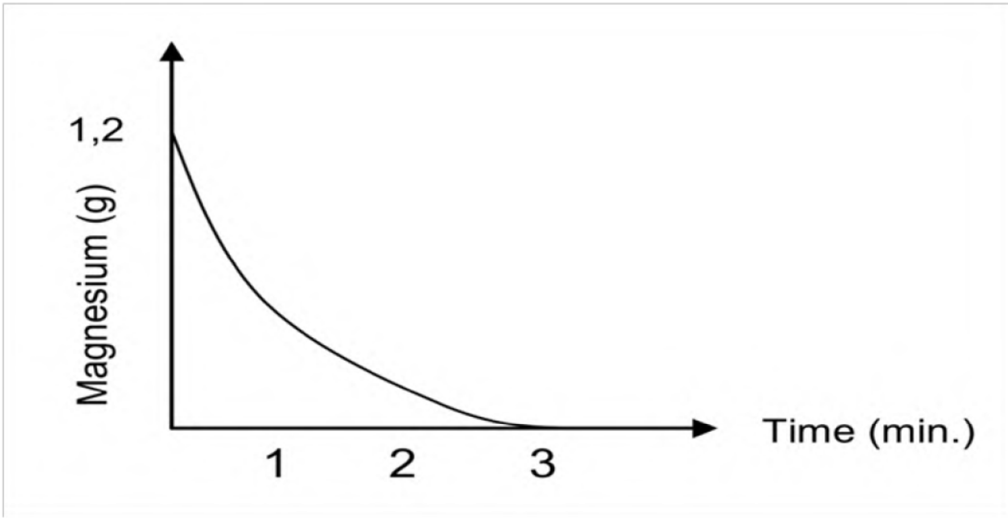
	3.2.2	Determine the limiting reagent.	(5)
	3.2.3	Calculate the mass of K_2S produced	(3)
			[11]

3.3 During the reaction In an experiment, a learner adds $500cm^3$ of hydrochloric acid ($HC\ell$) along with a concentration of $0.36mol.dm^{-3}$ 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:

$$Mg(s) + 2HC\ell_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

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]

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

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

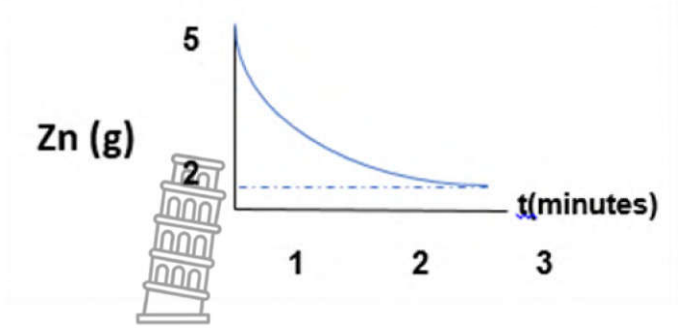
After titration and drying, a mass of 0.583g of PbI_2 is measured.

	3.4	Determine the percentage yield of PbI_2	(6)

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

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

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

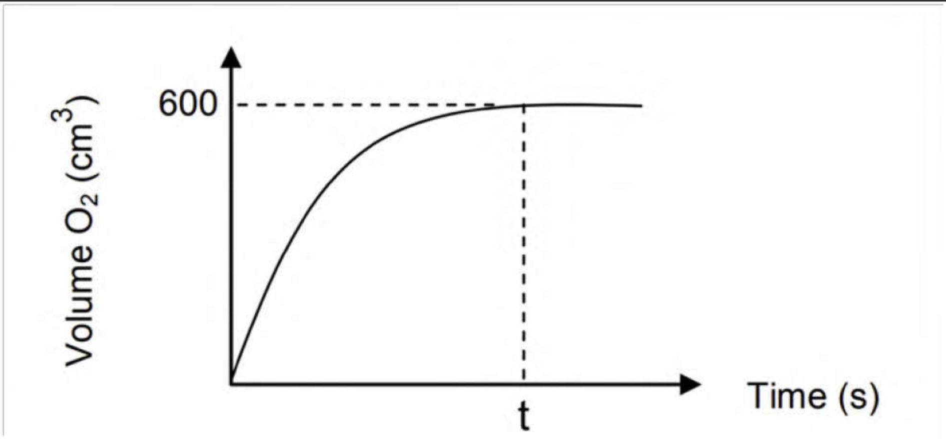


	3.5.1	Name the substance that is the limiting reagent. Give a reason for your answer.	(2)
	3.5.2	Calculate the initial concentration of the sulphuric acid if 50 cm^3 of the acid was used.	(6)
			[8]

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)
			[7]

IDEAL GASES & THERMAL PROPERTIES

TERM	DEFINITION
Boyle's Law	For a fixed amount of gas, at a constant temperature, volume is inversely proportional to pressure.
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. 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

- 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.

Boyle's Law and the kinetic theory of gases

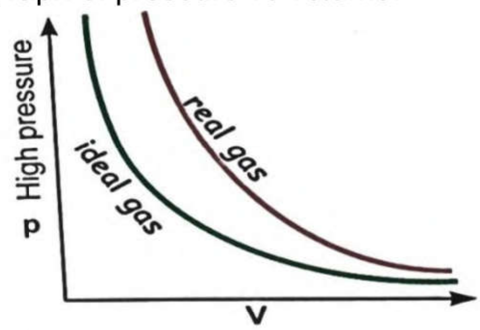
- The temperature of the gas stays constant.
- The gas molecules all have the same kinetic energy and move at the same average speed.
- Pressure of the gas is only determined by the number of collisions per unit time on the walls of the container.
- If the volume decreases there is less space in which the same number of molecules can move, as a result they will hit the walls of the container more often.
- Thus, the pressure increases with a decrease in volume

Deviation of gases at high pressure

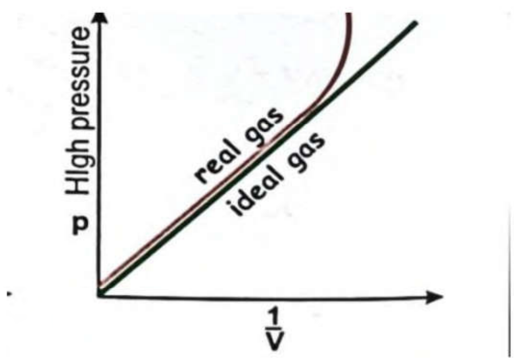
At high pressure:

- The gas molecules move very close together and the spaces between them are very small.
- The repulsive forces now exist between the gas molecules (Repulsive forces increases)
- The measured volume of the gas is greater than what Boyles law predicts for an ideal gas.
- The volume of the gas molecule contributes to the total volume of the gas.
- Thus, the volume of a gas increases with further increase in pressure

Graph of pressure vs volume:



Graph of pressure vs inverse of volume



Applications of Boyle's law

Heimlich manoeuvre is a first aid procedure used to treat upper airway obstructions by foreign objects.	
Spray paint: When pressure is exerted on top of the can, the volume inside the can gets reduced and the paint is thrown out with great pressure.	
Syringe: When the plunger is pushed down, the volume of the fluid reduces, thereby increasing the pressure.	
Inflating tyres: When air is pressed into flat tyres with the help of an air pump, the air molecules get tightly packed.	

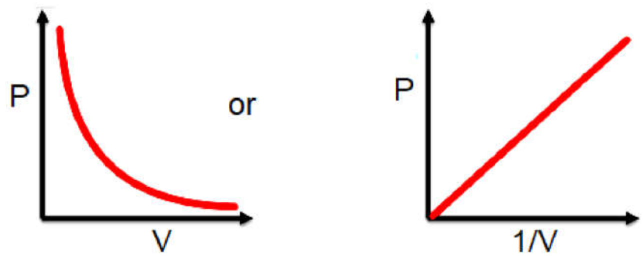
Boyle's law experiment

Purpose: To investigate relationship between pressure and volume at constant temperature

Variables:

- Independent variable: Volume
- Dependent Variable: Pressure
- Control Variable: Temperature, quantity of gas (number of moles of gas)

Graphical representation of results



Volume of the gas is inversely proportional to its pressure, i.e. as pressure increases, volume decreases.

Relationship between pressure and volume:

In symbols: $p \propto \frac{1}{V}$ $V \propto \frac{1}{p}$

Mathematically: $p \propto \frac{1}{V}$ $pV = k$ $V \propto \frac{1}{p}$ (k –proportionality constant)

- If the product of the pressure and volume of two sets of readings are taken, the following formulae will be obtained:
- $p_1V_1 = k$ $p_2V_2 = k$

$$p_1V_1 = p_2V_2$$

- The product of pV, is a constant value at a specific temperature, for all gases.
- When deducing SI units for constant k; it is found that k has the units of energy called Joules (J)
- $pV = k$
- $Pa.m^3 = k$
- $N.m^{-2}.m^3 = k$

- N.m = k
- J = k

Pressure

- Symbol: P, SI unit (Pa: $N \cdot m^{-2}$).
- Standard pressure is 101,3 kPa (equivalent to 1 atm).

Temperature

- Symbol: T, SI unit Kelvin (K)
- Standard temperature is 0°C (273 K). T(K) = t (°C) + 273.

Volume

- Symbol: V, SI unit cubic metre (m^3) or litre (L).
- 1 $m^3 = 10^3$ L = 10^3 dm^3 = 10^6 ml = 10^6 cm^3

The General Gas Equation

- The three relationships discussed all apply only when considering the same amount of a gas.
- Use the general gas equation, $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ and the ideal gas equation:
  pV= nRT to solve problems.
- R represents molar gas constant, value 8.31 $J.K^{-1}.mol^{-1}$

NB: For pressure and volume any unit may be used, as long as the use is consistent. For temperature, the Kelvin scale must be used

Example 1	
State the assumptions of the ideal gas model.	(4)
	[4]
Solution	
• The particles are identical and are in constant motion.✓ • The gas particles are small and their volume is negligible.✓ • There are no intermolecular forces between the particles and they move in a straight line between collisions.✓ • The collisions between the particles, or the particles and the walls of the container are perfectly elastic. ✓	(4)
	[4]

Example 2		
The temperature of a sample of gas is increased.		
2.1	Explain, using the kinetic theory of gases, what happens to the average speed of the molecules of the gas.	(2)
2.2	State what happens to the pressure, assuming the volume of the container remains constant.	(1)
2.3	Explain the answer to QUESTION 2.2 above, in terms of the kinetic theory.	(2)
		[5]
Solutions		
2.1	The average speed of the molecules will increase. This is because temperature is a measure the average kinetic energy, which is ½ mv^2.	(2)
2.2	The pressure will increase.	(1)
2.3	The molecules will move more quickly, so they will collide with the walls of the container more frequently (i.e. more collisions per unit time.) Also, because their speed, on average, is higher, they will exert a greater force on the walls of the container.	(2)
		[5]
Example 3		
The volume of an enclosed mass of gas is decreased.		
3.1	Predict what will happen to the pressure of the gas.	(1)
3.2	Explain your answer to QUESTION 3.1, using the kinetic theory of gases.	(2)
		[3]
Solutions		
3.1	The pressure will increase.	(1)
3.2	Because the volume has decreased, the molecules have less space to move and so they collide more frequently with the wall of the container. Thus, the pressure increases.	(2)
		[3]
Example 4		
Helium gas can behave as an ideal gas		
4.1	Define an ideal gas	(2)

4.2	List THREE properties of an ideal gas	(3)
4.3	List two conditions when a real gas behaves like an ideal gas.	(2)
4.4	Write down the magnitude of the molar gas volume at STP.	(1)
		[8]
Solutions		
4.1	An Ideal gas is a theoretical gas which obeys the gas laws□ under all conditions of temperature and pressure. □	(2)
4.2	They occupy no volume. □ They exert no force on each other except during a collision. □ They are identical in all ways. □ All collisions of the molecules with themselves or with the walls of the container, are perfectly elastic. □ (Any THREE)	(3)
4.3	At a low pressure and high temperature□□	(2)
4.4	22.4 dm^3 □	(1)
		[8]
Example 5		
A sealed gas syringe contains 80 cm^3 air. The plunger is airtight but can move freely. The atmospheric pressure is 100 kPa.		
5.1	What is the pressure of the gas in this syringe?	(4)
5.2	What additional pressure must be exercised on the plunger so that the air is compressed to a volume of 50 cm^3 while the temperature remains constant.	(2)
		[6]
Solutions		
5.1	p_1= 100 kPa V_1= 80 cm^3 p_2=? V_2 = 50 cm^3 $p_1V_1 = p_2V_2$□ 100 x 80□ = p_2 x 50□ 8000 = 50p_2 $\frac{8000}{50} = p_2$ p_2= 160 kPa□	(4)
5.2	Since the atmospheric pressure is 100 kPa, the additional pressure exerted on the plunger must be: 160-100□ =160 kPa □	(2)
		[6]

ACTIVITIES

Multiple Choice Questions

QUESTION 1

1.1 The temperature of a gas is defined as …

A	the heat of the gas.
B	a measure of the average kinetic energy of the molecules of the gas.
C	a measure of the average speed of the molecules of the gas.
D	the product of the pressure and volume of the gas.

(2)

1.2 Which one of the following is NOT a property of an ideal gas?

A	The volume occupied by the ideal gas particles is negligible.
B	The collisions between the molecules are perfectly elastic.
C	There are no forces of attraction between the molecules.
D	The product of the pressure and the volume of the ideal gas is constant at constant temperature.

(2)

1.3 The behaviour of a real gas is approximately the same as that of an ideal gas under the following conditions of temperature and pressure:

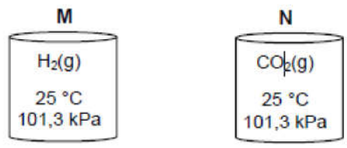
	Temperature	**Pressure**
A	High	High
B	Low	Low
C	High	low
D	Low	High

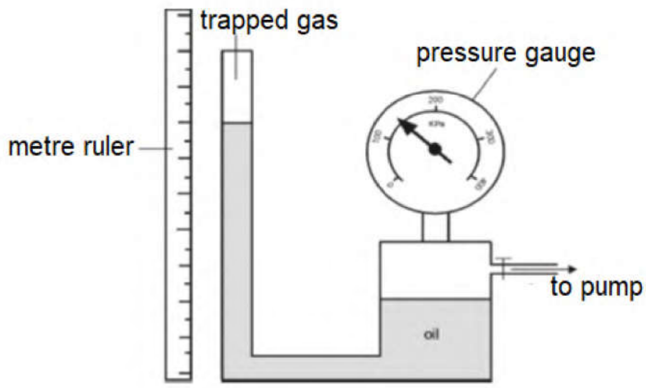
(2)

1.4 A cubic container is filled with a gas which exerts pressure **p**. What will the pressure exerted by the same amount of this gas be if the gas is placed in a cubic container whose side is half of that of the original container?

A	$\frac{1}{8}$ **p**
B	$\frac{1}{4}$ **p**
C	8**p**
D	4**p**

(2)

1.5	Two moles of H_2 gas at STP occupy a volume of ...		
	A	44,8 dm^3	
	B	11,2 dm^3	
	C	22,4 dm^3	
	D	2 dm^3	(2)
1.6	Two identical containers, **M** and **N**, are shown below. Container **M** contains H_2(g) and container **N** contains CO_2(g). Both gases are at a temperature of 25 °C and a pressure of 101,3 kPa.		
			
	Consider the following statements:		
	(i)	The average kinetic energy of the molecules is the same in both containers.	
	(ii)	Container **M** contains more gas molecules than container **N**.	
	(iii)	The mass of the gas in container **N** is greater than the mass of the gas in container **M**.	
	Which of the above statements is/are CORRECT?		
	A	(i) only	
	B	(iii) only	
	C	(i) and (ii) only	
	D	(i) and (iii) only	(2)
			[12]

Ideal Gases Structured Questions		
QUESTION 2		
The teacher demonstrates an experiment about gases to her Grade 11 class. The following diagram represents the apparatus she used. She attaches a bicycle pump to the apparatus. She then increases the pressure on the liquid when she applies pressure to the bicycle pump.		
		
2.1	Write an investigative question for the teacher's experiment.	(2)
2.2	Identify the independent & dependent variables in this experiment.	(2)
2.3	After each increase in pressure, explain why the teacher should leave the apparatus alone for a few seconds before she measures the volume of the gas.	(2)
2.4	Copy the following table. Calculate the values of 1/V to complete the table.	(4)

P (kPa)	V (cm^3)	1/V (cm^{-3})
105,0	30	
126,0	25	
157,5	20	
210,0	15	

2.5	Draw a graph of 1/V versus P.	(5)
2.6	State a conclusion to the experiment.	(2)
		[17]

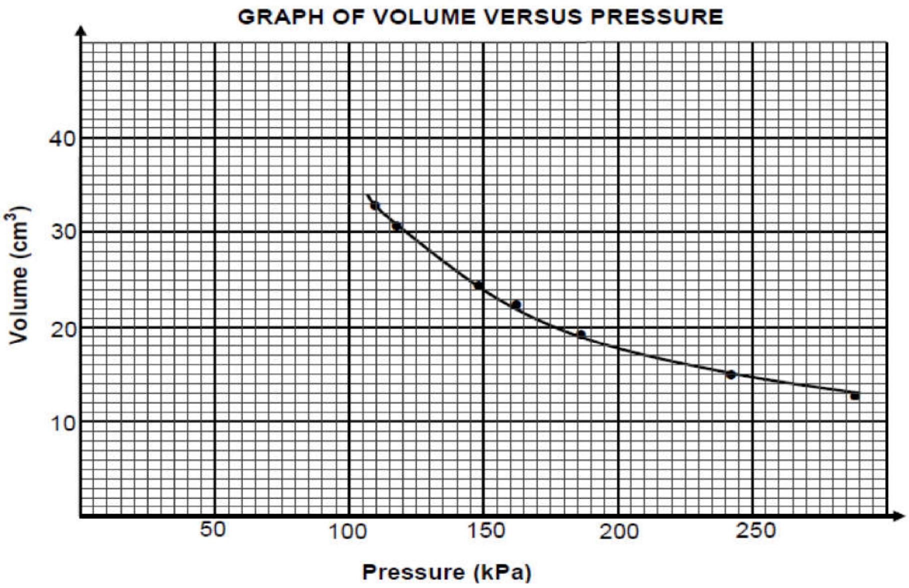
QUESTION 3

Carbon dioxide (CO_2) gas is produced as a result of the reaction between calcium carbonate and hydrochloric acid. The gas that is produced is collected in a 20 dm^3 container. The pressure of the gas is 105 kPa at a temperature of 200 °C.
Determine the mass of carbon dioxide that was produced. (6)

[6]

QUESTION 4

A fixed mass of oxygen is used to verify one of the gas laws. The results obtained are shown in the graph below.



4.1	Write down the:		
	4.1.1	A mathematical expression, in symbols, for the relationship between the variables shown in the graph	(1)
	4.1.2	The name of the gas law investigated	(1)
	4.1.3	Explain the relationship in QUESTION 4.1.1 in terms of the kinetic theory of gases.	(2)
4.2	Write down TWO variables that must be kept constant during this investigation and briefly describe how this is done.		(4)
4.3	From the graph, write down the volume of oxygen, in cm^3, when the pressure is 120 kPa.		(2)
4.4	Calculate the pressure, in kPa, exerted on the gas when it is compressed to 5 cm^3.		(4)
4.5	Write down TWO conditions under which oxygen gas will deviate from ideal gas behaviour.		(2)

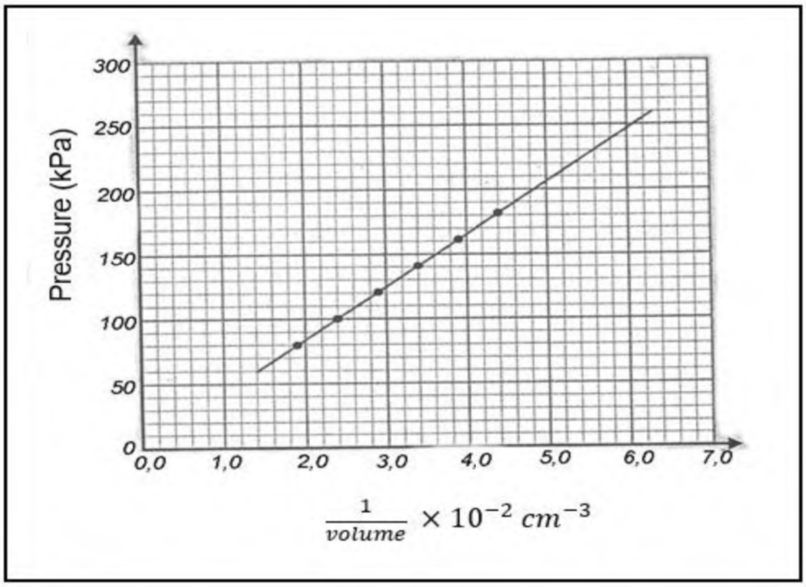
		[16]

QUESTION 5

A certain amount of gas is sealed in a container of which the volume can change. The relationship between the pressure and volume of the gas at 20 ºC is investigated. The results of the experiment are given in the table below.

PRESSURE (kPa)	VOLUME (dm^3)
70	174
95	128
130	93,6
165	74
205	59
240	51
260	47

5.1	Name the gas law that is represented by the results of the experiment.	(1)
5.2	Write down a hypothesis for the investigation.	(2)
5.3	Draw a graph of volume versus pressure on the ANSWER SHEET attached.	(3)
5.4	Calculate the volume of the gas at 300 kPa.	(3)
5.5	When the volume of the gas is measured at 300 kPa, it is 44 dm^3. Explain why the measured volume differs from the volume calculated in QUESTION 5.4.	(2)
5.6	Which temperature condition will cause a gas to deviate from ideal behaviour? Write only HIGH or LOW.	(1)
5.7	Explain the answer to QUESTION 5.6.	(2)
5.8	Calculate the number of moles of the gas in the container at the INITIAL pressure and volume.	(4)
		[18]

QUESTION 6		
An experiment was carried out to investigate the relationship between the pressure exerted by a gas and the volume of the gas. The following graph of Pressure (kPa) versus $\frac{1}{\text{Volume}}$ (cm^{-3}) for the air taken at 25 °C was drawn.		
		
6.1	Write down TWO controlled variables for this investigation.	(2)
6.2	Name the gas law that is being verified.	(1)
6.3	State ONE precaution that must be taken when carrying out this investigation.	(1)
6.4	What conclusion can be drawn from the results?	(2)
6.5	Calculate the gradient of the graph.	(3)
6.6	Using the gradient of the graph, calculate the number of moles of the gas that was used in this investigation.	(4)
		[13]

ENERGY AND CHEMICAL CHANGE

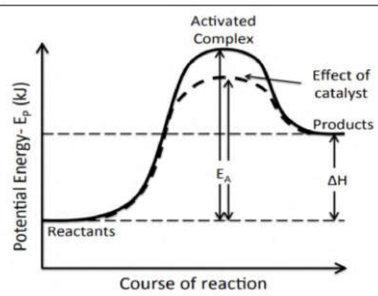
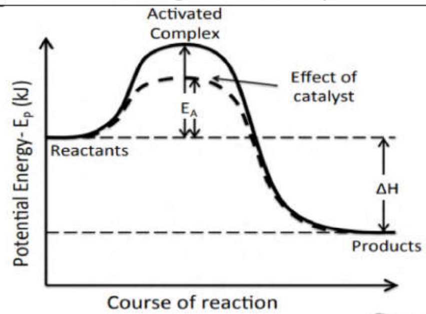
Energy changes in reactions related to bond energy changes

- The energy change that takes place occurs because of bonds being broken and new bonds being formed.
- When bonds are broken, energy is absorbed from the environment.
- When bonds are formed, energy is released into the environment.
- The net energy change will determine if the reaction is endothermic or exothermic.
- **Activation energy** is the minimum energy needed for a reaction to take place.

Activation energy=**A**ctivated **C**omplex – **R**eactant= **AC - R**

- **Heat of reaction** (ΔH) is the energy absorbed or released per mole in a chemical reaction. $\Delta H = H_{products} - H_{reactants}$, where $H_{products}$ and $H_{reactants}$ are the heat (energy) of the products and reactants respectively.

Different between exothermic and endothermic reaction

Endothermic reaction	**Exothermic reaction**
• Reactions in which energy is absorbed. **Energy absorbed=AC-P**	• Reactions in which energy is released. **ENERGY RELEASED=AC-P**
• More energy absorbed than released	• More energy released than absorbed
• ΔH > 0	• ΔH < 0
• Net energy change is energy absorbed from the environment	• Net energy change is energy released into the environment
• The environment's energy decreases	• The environment's energy increases
• Temperature of the environment decreases (test tube gets colder)	• Temperature of the environment increases (test tube gets hotter)
	
• Photosynthesis $6CO_2 + 6H_2O$+ light → $C_6H_{12}O_6 + 6O_2$;H>0	• Cellular respiration $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ • COMBUSTION $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

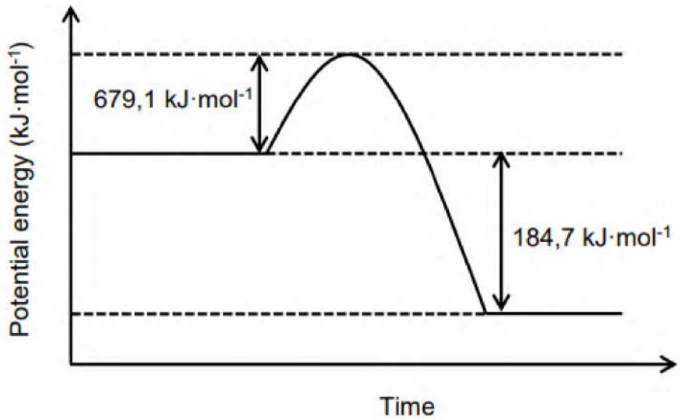
- NB: For endothermic reaction-A_E for forward reaction become energy released for reverse reaction which is exothermic reaction

	• For exothermic reaction-A_E for forward reaction become energy absorbed for reverse reaction which is endothermic reaction • For reverse reaction, energy of reactants become energy of products and energy of products become energy of reactants	

EXAMPLE 1:

The diagram shows the potential energy changes during the following chemical reaction:

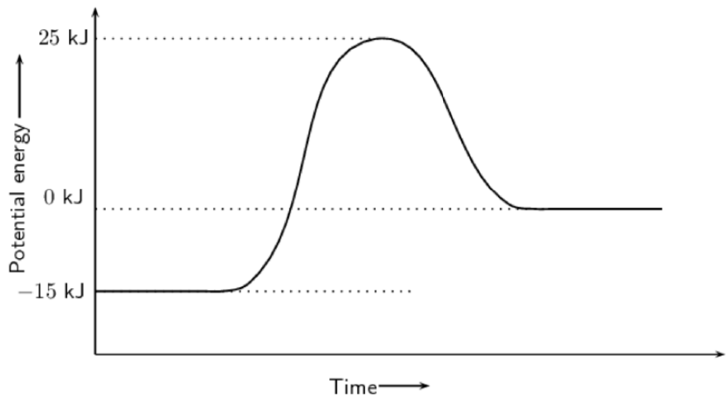
$$2H_2(g) + C\ell_2(g) \rightarrow 2HC\ell(g)$$

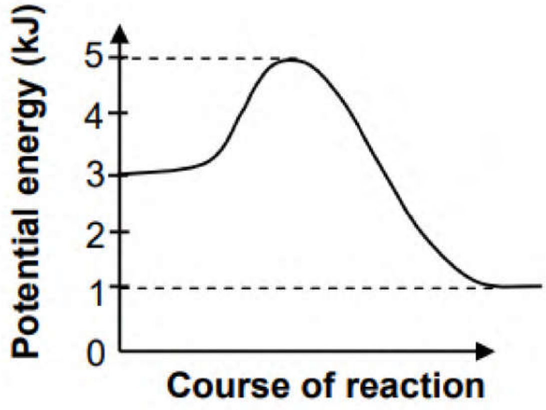


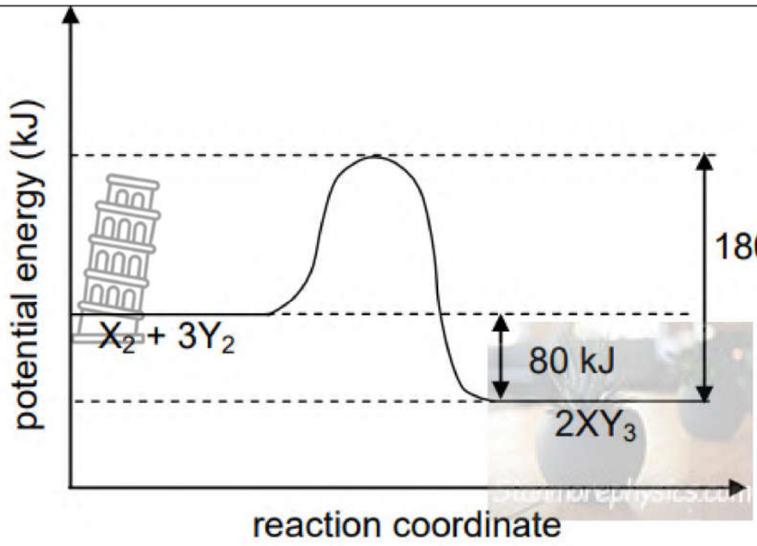
1.1	Define activation energy.	(2)
1.2	Is the reaction EXOTHERMIC or ENDOTHERMIC? Give a reason for the answer. **(read the shape of the graph and know how energy of reactant and affect enthalpy change)**	(2)
1.3	What is the total bond energy (H_2 and $C\ell_2$) of the reactants? Give a reason for the answer. **(concept of activation energy)**	(3)
1.4	Determine the energy released by the bond formation of the HCℓ molecule. **(a change between activated complex and product)**	(3)
1.5	What effect will the addition of a catalyst have on the value 184,7 kJ·mol^{-1}? Write down only INCREASE, DECREASE or NO EFFECT. Give a reason for the answer. **(effect of catalyst on the graph)**	(2)
		[12]

EXAMPLE 1 SOLUTION:

1.1	Minimum energy required to start a chemical reaction. ✓✓	(2)
1.2	Exothermic ✓ The total potential energy of the products is less than the total potential energy of the reactants. ✓ OR More energy is released than the energy taken in. OR The heat of the reaction is less than zero/negative.	(2)
1.3	679,1 kJ·mol-1 ✓ The energy needed to break all the bonds✓✓ / Activation energy	(3)
1.4	Bond formation = 184,7 + 679,1✓ Bond formation = 863,8 kJ·mol^{-1} 863,8 kJ·mol^{-1} is the energy released for two HCℓ molecules Bond energy for each HCℓ = 863,8 / 2 ✓	(3)

	Bond energy for each HCℓ = 431,9 kJ·mol⁻¹✓	
1.5	No effect. ✓ Catalyst only has an effect on the activation energy and no effect on the heat of the reaction ✓	(2)
		[12]
EXAMPLE 2		
The diagram shows the potential energy changes during the following chemical reaction: $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$		
		
	Consider the graph above and answer the following questions:	
2.1	Is the forward endothermic or exothermic reaction? Support your answer. **(read the shape of the graph and know how energy of reactant and affect enthalpy change)**	(2)
2.2	Write down the energy of reactant and energy of the product. **(understanding graph)**	(2)
2.3	Calculate the activation energy for forward reaction **(a change between activated complex and reactant)**	(2)
2.4	Write down the energy absorbed/released. **(a change between activated complex and product)**	(1)
2.5	Calculate the activation energy for reverse reaction. **(understanding of reactant and product interchange)**	(2)
2.6	Compare answers for 2.4 and 2.5 and make conclusion. **(relationship between energy absorbed and activation energy for reverse reaction)**	(2)
		[11]
EXAMPLE 2 SOLUTIONS		
2.1	Endothermic. ✓ $\Delta H > 0$✓, energy is absorbed. Energy of the product is greater than energy of reactant	(2)
2.2	energy of reactant= -15kJ✓ and energy of the product= 0 kJ✓	(2)
2.3	$\Delta H = H_{product} - H_{reactant}$✓ $= 0 - (-15) = +15$ kJ✓	(2)

2.4	energy absorbed=AC-P=25 – 0 = 25 kJ✓	(1)
2.5	activation energy=AC-R=25 – 0✓=25 kJ✓	(2)
2.6	Equal to. ✓ Energy absorbed for forward reaction (endothermic) become A_E for reverse reaction. ✓	(2)
		[11]
	QUESTION 1 MULTIPLE CHOICE QUESTIONS	
1.1	The graph below represents the relationship between potential energy and course of reaction for a certain chemical reaction.	
		
	The activation energy for the forward reaction is …	
	A 1 kJ	
	B 2 kJ	
	C 3 kJ	
	D 4 kJ	(2)
	(a change between activated complex and reactant)	
1.2	Consider the reaction represented by the equation below:	
	$2Fe(s) + 3CO_2(g) \rightarrow Fe_2O_3(s) + 2CO(g) \quad \Delta H = + 53,2$ kJ	
	Which ONE of the following statements is TRUE?	
	For each mole of Fe that reacts, ...	
	A 26,6 kJ of energy are released	
	B 26,6 kJ of energy are absorbed	
	C 53,2 kJ of energy are released	
	D 53,2 kJ of energy are absorbed	(2)
1.3	The diagram below shows the change in potential energy for a hypothetical reaction, represented by the following equation: $X_2(g) + 3Y_2(g) \rightarrow 2XY_3(g)$	

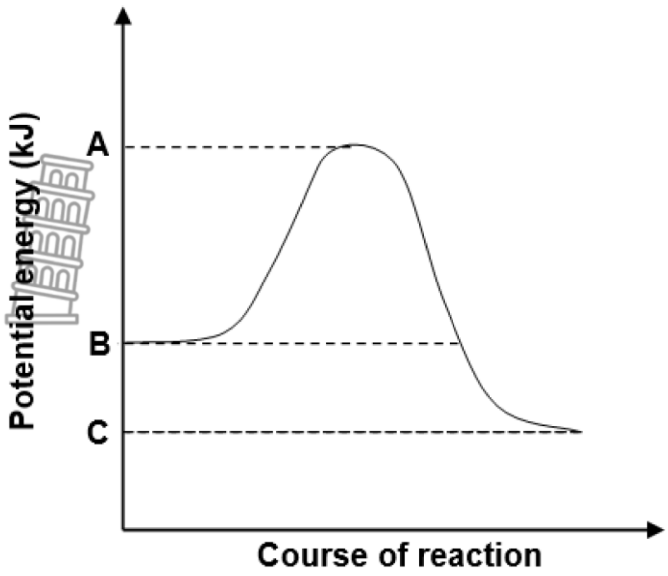


	The activation energy for the forward reaction is…		
	A	-80 kJ	
	B	80 kJ	
	C	100 kJ	
	D	180 kJ	(2)
1.4	Activation energy can best be described as the minimum energy required to …		
	A	cause effective collisions.	
	B	make reactant molecules collide.	
	C	increase the kinetic energy of reactant molecules.	
	D	change the orientation of reactant molecules.	(2)
1.5	n a chemical reaction, the difference between the potential energy of the products and the potential energy of the reactants is equal to the …		
	A	enthalpy of the reaction.	
	B	rate of the reaction	
	C	enthalpy change of the reaction.	
	D	total potential energy of the particles.	(2)

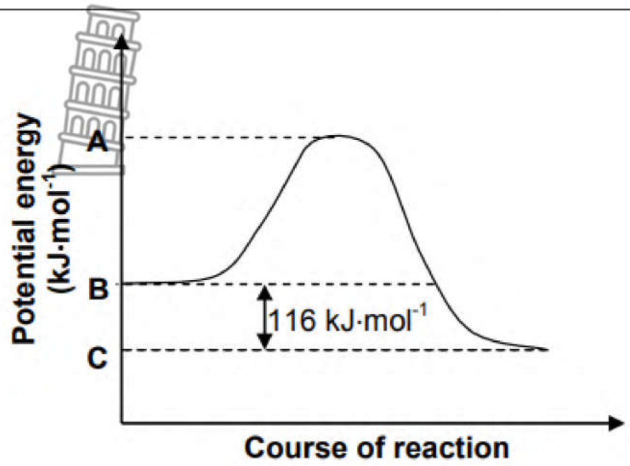
LONG QUESTIONS

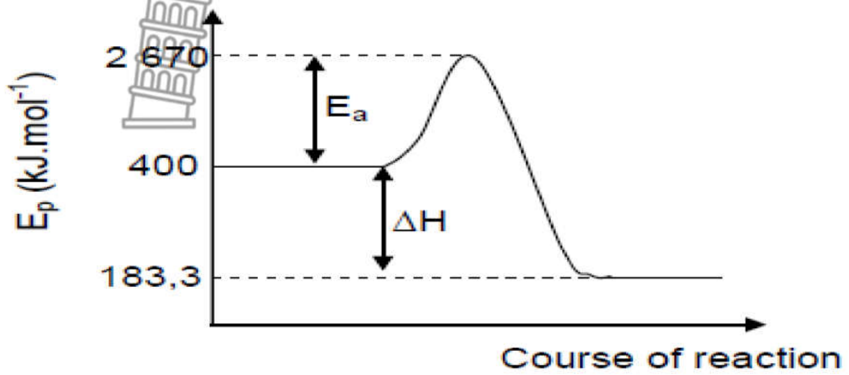
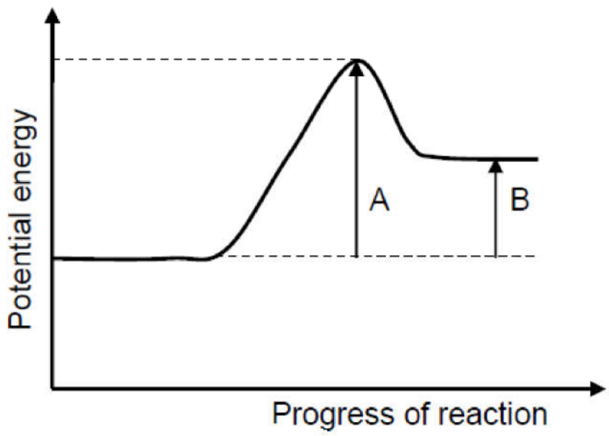
QUESTION 2

The graph below shows changes in the potential energy for the reaction between calcium carbonate and hydrochloric acid.



2.1	Is this reaction endothermic or exothermic? Give a reason for the answer.		(2)
2.2	Use the relevant energy values, **A**, **B** and **C**, to write down an expression for each of the following:		
	2.2.1	The energy of the activated complex	(1)
	2.2.2	∆H for the forward reaction	(1)
	2.2.3	The activation energy for reverse reaction	(1)
2.3	Define a catalyst.		(2)
2.4	What effect does a catalyst has on the activated complex?		(1)
			[8]
QUESTION 3			
Hydrogen gas and oxygen gas react to form water according to the following balanced equation:			
$2H_2(g) + O_2(g) \rightarrow 2H_2O(g) + 241{,}8\ kJ \cdot mol^{-1}$			
The activation energy (EA) for this reaction is 1 370 $kJ \cdot mol^{-1}$.			
3.1	Define the term activation energy.		(2)
3.2	Sketch a potential energy versus reaction coordinate graph for the above reaction. Clearly label the axes and indicate the following on the graph: • ΔH • EA for the forward reaction • Reactants (R) and products (P) • Activated complex (X)		(5)
3.3	Write down the value of the:		
	3.3.1	Heat of reaction	(1)
	3.3.2	Activation energy for the following reaction: $2H_2O(g) \rightarrow 2H_2(g) + O_2(g)$	(2)
			[10]
QUESTION 4			
A barium hydroxide solution, $Ba(OH)_2(aq)$, reacts with a nitric acid solution, $HNO_3(aq)$,			

according to the following balanced equation:			
$Ba(OH)_2(aq) + 2HNO_3(aq) \rightarrow Ba(NO_3)_2(aq) + 2H_2O(\ell)$			
The potential energy graph below shows the change in potential energy for this reaction.			
			
4.1	Is this reaction ENDOTHERMIC or EXOTHERMIC? Give a reason for the answer.		(2)
4.2	Use energy values A, B and C indicated on the graph and write down an expression for each of the following:		
	4.2.1	The energy of the activated complex	(1)
	4.2.2	The activation energy for the forward reaction	(1)
	4.2.3	ΔH for the reverse reaction	(1)
4.3	Calculate the amount of energy released during the reaction if 0,18 moles of $Ba(OH)_2(aq)$ reacts completely with the acid.		(3)
			[8]
QUESTION 5			
The equation for the combustion of butane gas is given below.			
butane(g) + $13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$ $\Delta H < 0$			
5.1	Define the term activated complex.		(2)
5.2	Is the combustion reaction of butane exothermic or endothermic? Give a reason for the answer.		(2)
5.3	Draw a sketch graph of potential energy versus course of reaction for the reaction above. Clearly indicate the following on the graph: • Activation energy • Heat of reaction (ΔH) • Reactants and products		(3)
			[7]
	QUESTION 6		

The following reaction between ammonia and oxygen takes place in a closed system at constant pressure and temperature:		
$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ 		
6.1	Define the term heat of reaction.	(2)
6.2	Give a reason why this reaction is exothermic.	(1)
6.3	Calculate the heat of reaction.	(3)
6.4	Redraw the graph and indicate with a dotted line the effect of a catalyst on the activation energy.	(2)
		[8]
QUESTION 7		
Plants manufacture their own food through the process of photosynthesis by making use of water, carbon dioxide and sunlight (energy). The balanced equation for this reaction is:		
	$6CO_2(g) + 6H_2O(\ell) \rightarrow C_6H_{12}O_6(s) + 6O_2(g) \quad \Delta H > 0$	
	The graph which follows represents the change in potential energy for one of the two reactions listed above.	
		
7.1	Is the process of photosynthesis an example of an ENDOTHERMIC or EXOTHERMIC reaction? Give a reason for your answer.	(2)
7.2	Does the above graph represent the change in potential energy for PHOTOSYNTHESIS or CELLULAR RESPIRATION? Briefly explain how you got to the answer you chose.	(3)

7.3	Supply labels for **A** and **B** which appear on the graph.	(2)
7.4	The reaction for cellular respiration is catalysed by enzymes. Explain how the enzymes will influence the rate of the reaction.	(2)
		[9]

TYPES OF REACTIONS

1. ACID 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

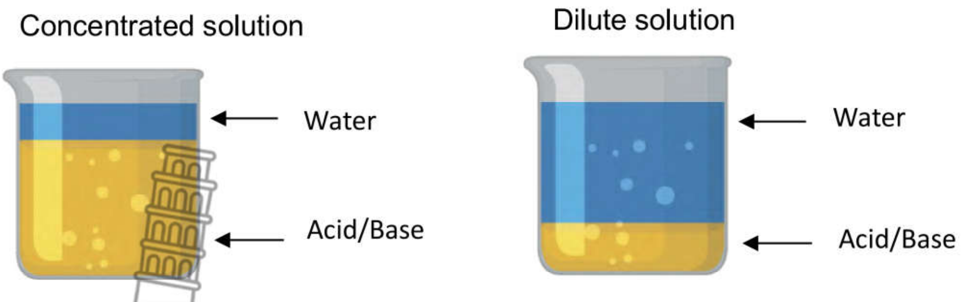
STRONG ACIDS	STRONG BASES
($HC\ell$)Hydrochloric acid (monoprotic) (HNO_3)Nitric acid(monoprotic) (H_2SO_4)Sulphuric acid (diprotic) (H_3PO_4)Phosphoric acid (triprotic)	(NaOH)Sodiumhydroxide (KOH)Potassiumhydroxide (LiOH) Lithium hydroxide $Ba(OH)_2$Bariumhydroxide
WEAK ACIDS	**WEAK BASES**
(CH_3COOH)Aceticacid $(COOH)_2$ 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.)

$NH_3(g) + H_2O(\ell) \rightarrow NH_3\ (aq) + OH^-(aq)$

$H_2SO_4(aq) + 2H_2O(\ell) \rightarrow 2H_3O^+(aq) + SO_2\ (aq)$ (H_2SO_4 is a diprotic acid.)

Dissociation equations

$$NaOH_{(aq)} \xrightarrow{H_2O} Na^+_{(aq)} + OH^-_{(aq)}$$

$$KOH_{(aq)} \xrightarrow{H_2O} K^+_{(aq)} + OH^-_{(aq)}$$

$$Mg(OH)_{2\,(aq)} \xrightarrow{H_2O} Mg^{2+}_{(aq)} + 2OH^-_{(aq)}$$

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. $H_2SO_4(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + HSO_2^-\,(aq)$
Acid 1 Base 2 Acid 2 Base 1

IV. $HSO_2^-\,(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + SO_2^-\,(aq)$
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_2^- is also an ampholyte because in reaction (III) it act as a base but in reaction (IV) it act as an acid and donates a proton to water.

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 HCℓ

acid + metal carbonate → salt + water + carbon dioxide

E.g. $2HC\ell\ (aq) + CaCO_3\ (s) \rightleftharpoons CaC\ell_2(aq) + H_2O\ (\ell) + CO_2(g)$

Examples:

$HC\ell(aq) + NaOH(aq) \rightarrow NaC\ell(aq) + H_2O(\ell)$
$HC\ell(aq) + KOH(aq) \rightarrow KC\ell(aq) + H_2O(\ell)$
$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(\ell)$
$HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(\ell)$
$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(\ell)$
$H_2SO_4(aq) + KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(\ell)$
$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(\ell)$
$2HC\ell(aq) + CaO(aq) \rightarrow CaC\ell_2(aq) + H_2O(\ell)$
$2HC\ell(aq) + MgO(aq) \rightarrow MgC\ell_2(aq) + H_2O(\ell)$
$2HC\ell(aq) + MgO(aq) \rightarrow MgC\ell_2(aq) + H_2O(\ell)$
$2HC\ell(aq) + CuO(aq) \rightarrow CuC\ell_2(aq) + H_2O(\ell)$
$2HC\ell(aq) + Na_2CO_3(aq) \rightarrow 2NaC\ell(aq) + H_2O(\ell) + CO_2(g)$
$2HC\ell(aq) + CaCO_3(aq) \rightarrow CaC\ell_2(aq) + H_2O(\ell) + CO_2(g)$

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

Example

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

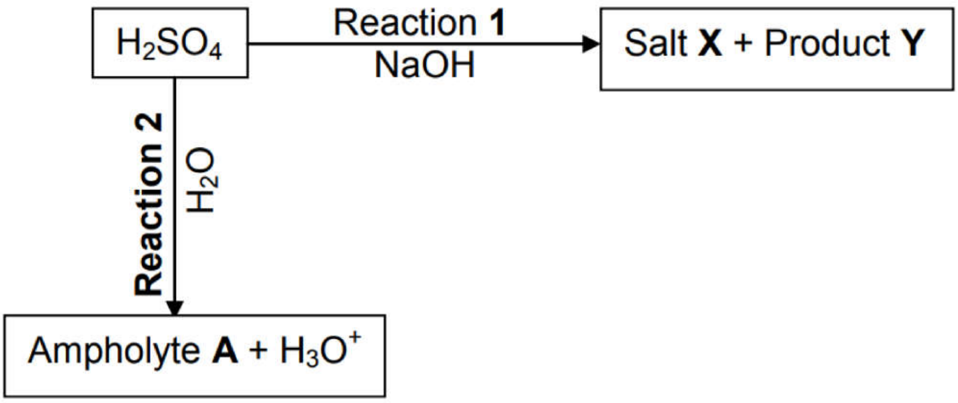
Solution: green

Activity 1

1.	Identify the conjugate acid base pair for the reactions below		
	1.1.	$H_2CO_3 + H_2O \rightarrow H_3O^+ + HCO3^-$	(2)
	1.2.	$H_2O + HCO_3^- \rightarrow H_3O^+ + CO3^{2-}$	(2)
	1.3.	$H_2SO_4 + 2H_2O \rightarrow 2H_3O^+ + SO4^{2-}$	(2)
		Solutions 1	
1.			
	1.1.	H_2CO_3 is the conjugate acid of HCO_3^- (base) OH^- is the conjugate base of H_2O (acid)	(2)
	1.2.	HCO_3^- is a conjugate acid of CO_3^{2-} base H_3O^+ is a conjugate acid of H_2O base.	(2)
	1.3.	SO_4^{2-} is a conjugate base for H_2SO_4 acid H_3O^+ is a conjugate acid for H_2O base	(2)

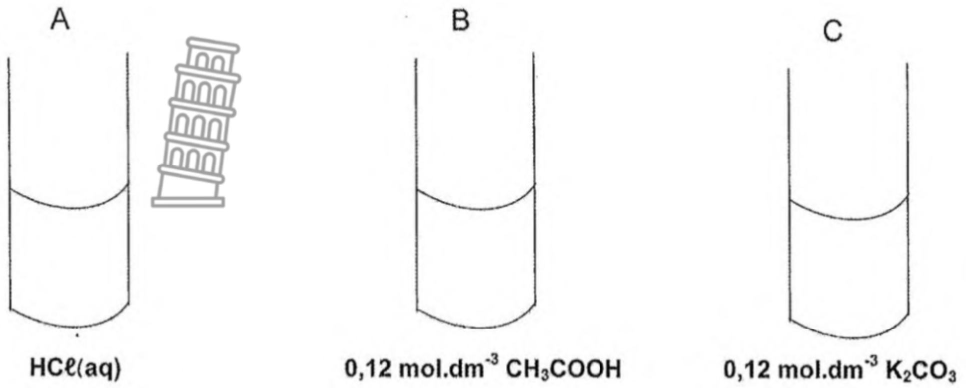
QUESTION 1: **Multiple choice questions**			
1.1	Consider the equilibrium $H_2SO_4 + HSO_3^- \rightleftharpoons HSO^-_4 + H_2SO_3$. The two Lowry-Brønsted bases are: (*conjugates*)		
	A.	HSO^-_4 and H_2SO_4	
	B.	HSO_3^- and HSO^-_4	
	C.	HSO_3^- and H_2SO_3	
	D.	HSO^-_4 and H_2SO_3	(2)
1.2	Water can act 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.	$H_2O(\ell) \rightleftharpoons H_2(g) + \frac{1}{2}O_2(g)$	
	D.	$H_2O(\ell) + C(s) \rightleftharpoons CO(g) + H_2(g)$	(2)
1.3	Consider the following equilibrium: $HC_2O^-_4 + HCO_3^- \rightleftharpoons H_2CO_3 + C_2O^{2-}_4$ 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)

			[14]
QUESTION 2 (*conjugates and ampholytes*)			
$\mathbf{NH_4^+}$ ions are mixed with $\mathbf{HCO_3^-}$ 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 act as both an acid and a base. It reacts with water according to the following balanced equation. $\mathbf{HSO_4^- + H_2O \rightarrow H_2SO_4 + OH^-}$		
	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)
			[12]
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)
			[23]
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)
			[26]

REDOX REACTIONS

Definitions and Key Concepts

- A **redox reaction** is a reaction in which there is a transfer of electrons between compounds and elements.
- **Oxidation** is the loss of electrons.
- **Reduction** is the gain of electrons.
- **Oxidation** shows an increase in oxidation number
- **Reduction** shows a decrease in oxidation number
- **An oxidising agent** is a substance that is reduced/gains electrons.
- **A reducing agent** is a substance that is oxidised/loses electrons.
- An **electrolyte** is a substance of which the aqueous solution contains ions OR a substance that dissolves in water to give a solution that conducts electricity.
- **Electrolysis** is the chemical process in which electrical energy is converted to chemical energy OR the use of electrical energy to produce a chemical change

Summary of notes

OIL: Oxidation is loss

RIG: Reduction is gain

LEO: Loss of electrons is oxidation

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. 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) chloride : 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: $X \rightarrow X^{2+} + 2e^-$ (electrons are shown as products)

Reduction half-reaction: $Y^{2+} + 2e^- \rightarrow Y$ (electrons are shown as reactants)

Nett ionic reaction: $X + Y^{2+} \rightarrow X^{2+} + Y$ (no electrons are shown in the reaction)

NOTE: The number of e^- must balance

Balance redox reactions by using half reaction from the table of Standard reduction potentials(Table 4B)

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 molecule (O_2)	(1)
3.	Consider the following UNBALANCED equation below: $Fe^{2+}(aq) + Cl_2(g) \longrightarrow Fe^{3+}(aq) + Cl^-(aq)$		
	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)

			[14]
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	$x+(-8)=-2$✓ $x=-2+8$ $x=+6$✓ ∴ The oxidation number of Sulphur in sulphate (SO_4^{2-}) ion is +6		(2)
2.2	$2(x)+7(-2)=-2$✓ $x=+6$ Oxidation number of $Cr_2O_7^{2-}$ = + 6 ✓		(2)
2.3	$2(1)+2(x)=0$✓ $2x=-2$ $x=-1$ ∴ Oxygen = -2 (except peroxides, eg. H_2O_2, = −1) ✓		(2)
2.4	Pure elements and diatomic elements (eg. O_2) = 0✓		(1)
	3.1	A reducing agent loses electrons. ✓✓	(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^- (aq) ✓✓	(2)
	3.2.5	$2Fe^{2+}$ (aq) + Cl_2 (g) ⟶ $2Fe^{3+}$ (aq) + $2Cl^-$ (aq) ✓✓	(2)
			[14]

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: $Zn (s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu (s)$ 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	(4)
2.3	Use oxidation numbers to explain your choice of oxidising agent in QUESTION 2.2.2.		(2)
			[14]
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)
		[12]

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.	(1)
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)
		[12]

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 Mn 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)
		[14]