KWAZULU-NATAL PROVINCE

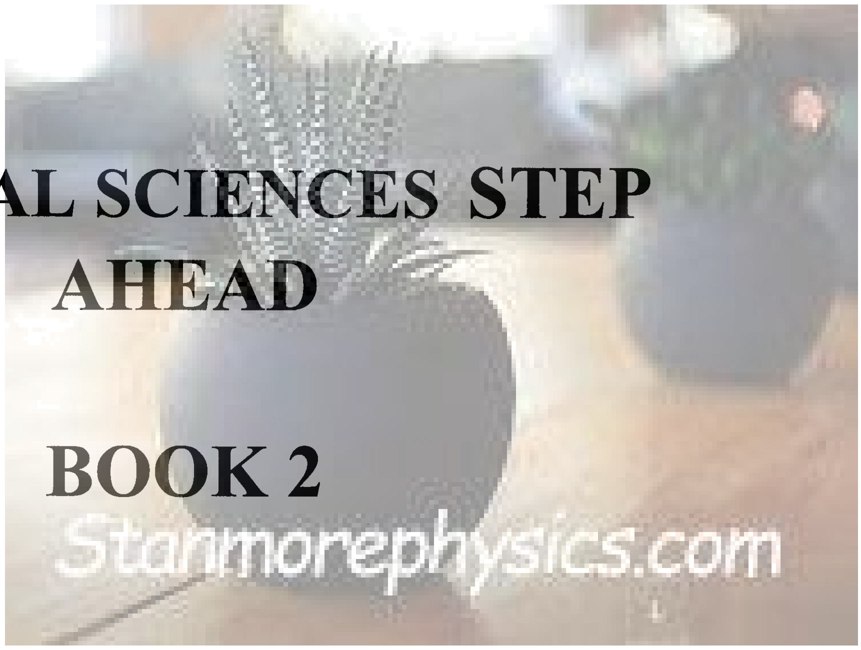
EDUCATION
REPUBLIC OF SOUTH AFRICA

CURRICULUM GRADE 10 -12 DIRECTORATE

NCS (CAPS)

LEARNER SUPPORT DOCUMENT

GRADE 11



PHYSICAL SCIENCES STEP AHEAD

BOOK 2

2022

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

PREFACE

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

Activities serve as a guide on how various topics are assessed at different cognitive levels and also 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.
- Valence electrons or outer 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.
- 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
- Intramolecular bond - bond which occurs between atoms within molecules
- Ionic bond - a transfer of electrons and subsequent electrostatic attraction
- Metallic bond - metallic bonding as the bond between positive ions and delocalised valence electrons in a metal

MOLECULAR STRUCTURE

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

CHEMICAL BONDS

- 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 on 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.
    - $\Delta EN = 0$: Non-polar (pure) covalent
    - $\Delta EN < 1$: Weakly polar covalent
    - $\Delta EN > 1$:polar covalent
    - $\Delta EN > 2,1$: Ionic (transfer of electrons)
    - $\Delta EN > 3$: purely ionic

- Polar bond a bond in which the electron density is shared unequally between the two atoms.
  Example: H-Cl
- Non-polar bond is a bond in which the electron density is shared equally between the two atoms
  Example: H -H
- EN (Cl) > EN (H): Electrons shift towards chlorine. Chlorine is slightly negative (δ−) and hydrogen is slightly positive (δ+). EN (H) = EN (H): Bonding electrons are evenly shared. Charge is evenly distributed and no dipole formed
- 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)

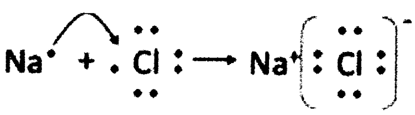
- Covalent bonding is the sharing of electrons between two atoms to form a molecule..
- Non-polar (pure) covalent: An equal sharing of electrons
  E.g., H-P bond: ΔEN = EN(P) - EN(H) = 0
- Weak polar covalent
  E.g., H - Br bond: ΔEN = EN(Br) - EN(H) = 0,7
- Polar covalent: An unequal sharing of electrons leading to a dipole forming
  E.g., H - O bond: ΔEN = EN(O) - EN(H) = 1.4

Ionic Bonding (between metals and non-metals)

- Ionic bonding is a transfer of electrons and subsequent electrostatic attraction.

Formation of ionic bond:

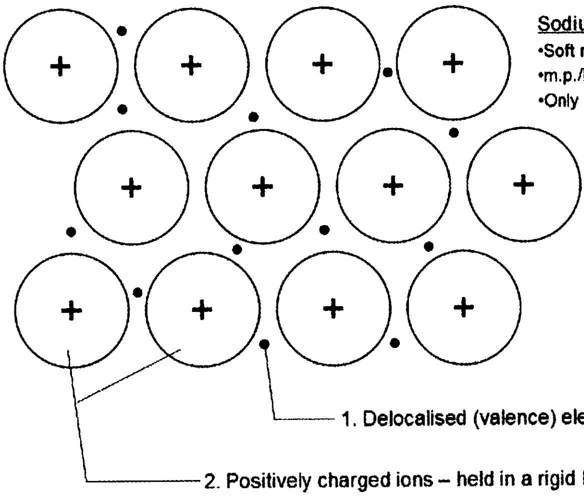
- Ionic bonding involves a complete transfer of electron(s).
- Metal atom gives electrons to non-metal.
- Metal forms a positive cation.
- Non-metal forms a negative anion.
- Electrostatic attraction of ions leads to formation of giant crystal lattice.



Metallic Bonding (between metals)

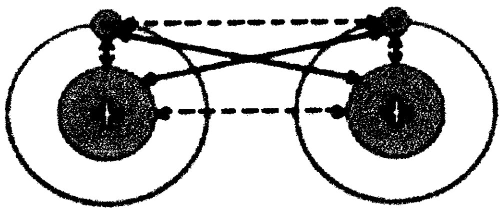
- Metallic bonding forms between the positive metal kernels and the sea of delocalized electrons.
- The metal atoms release their valence electrons to surround them.
- There is a strong but flexible bond between the positive metal kernels and a sea of delocalised electrons

Metallic Bonding



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.

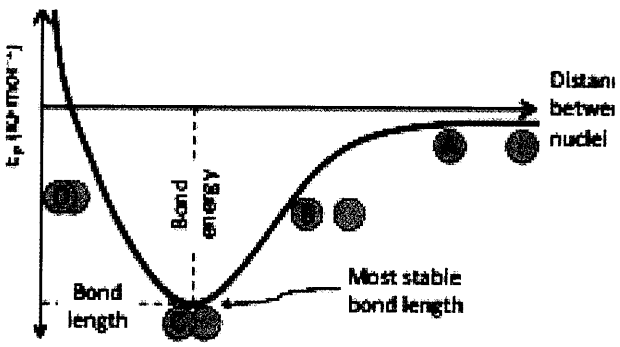
As the atoms get closer, the attractive forces get stronger until the minimum possible potential energy is reached (bond energy). The distance between the nuclei of the atoms at the minimum potential energy is the bond length. If the two atoms get closer than the bonding length, they will be forced apart 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 …

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 …

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 Consider the reaction represented by the equation below: (2)

$2H_2(g) + O2(g) \rightarrow 2H2O(g)$ $\Delta H = -469$kJ/mol

The total energy absorbed when bonds are broken in TWO moles of H2 and ONE mole of O2 is 1 371 kJ/mol.

What is the bond energy in kJ/mol for each O–H bond in the water molecule?

A. 920

B. 499

C. 460

D. 184

1.4 If the total bond enthalpy for methane (CH4) is 1652 kJ mol^{-1} and ethane (C2H6) is 2826 kJ mol^{-1}, what is the strength of a C–C bond?

A. 1.71 kJ mol^{-1}

B. 348 kJ mol^{-1}

C. 1174 kJ mol^{-1}

D. 4478 kJ mol^{-1} (2)

[8]

QUESTION 2

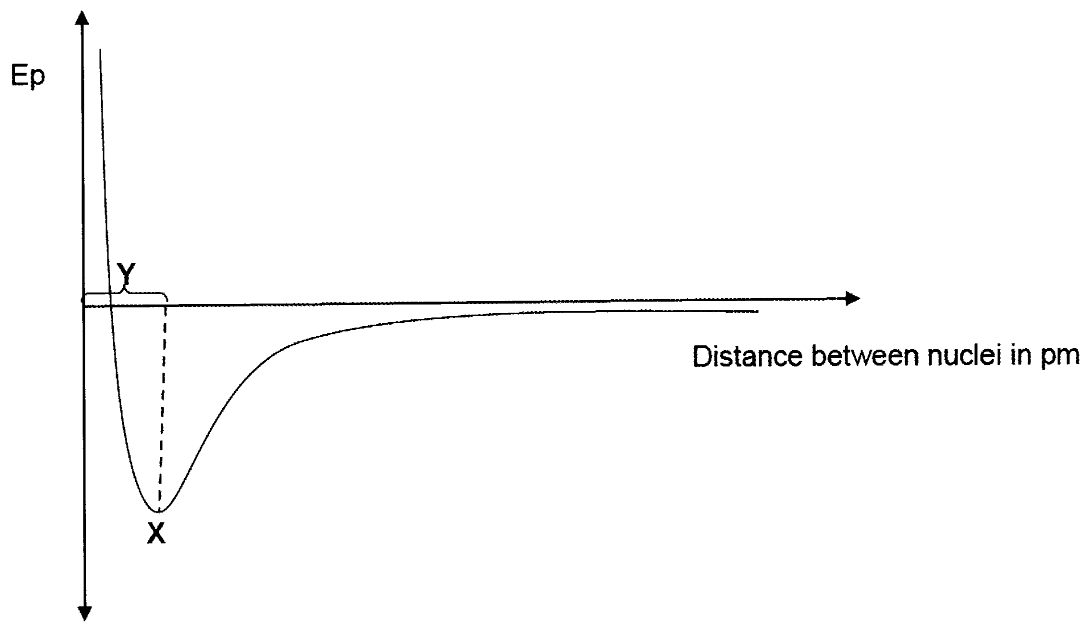
Electronegativity of atoms may be used to explain the polarity of bonds.

2.1 Define the term electronegativity. (2)

2.2 Draw the Lewis diagram of an oxygen difluoride molecule. (2)

2.3 Calculate the electronegativity difference between O and F in oxygen difluoride and predict the polarity of the bond. (2)

2.4



2.4.1 What does 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)

[13]

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

3.3

3.3.1 Draw the Lewis diagram for H_3O^+. (1)

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

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

3.4.1 Define the term electronegativity. (2)

3.4.2 Calculate the difference in electronegativity between:

3.4.2.1 C and O in CO_2 (1)

3.4.2.2 H and O in H_2O (1)

[11]

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 a 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.

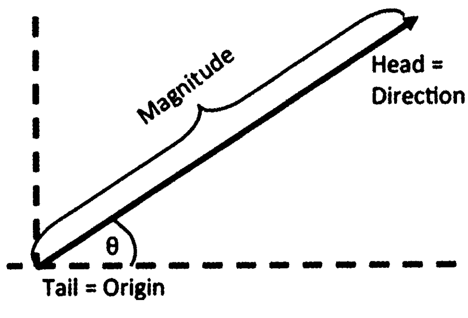
- An **equilibrant** is one vector, which cancels out the effect that the two or more vectors actually have on a body. It is equal in size to the resultant but opposite in direction.

- 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).

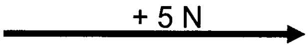
Graphical Representation of a vector

- 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.



Examples

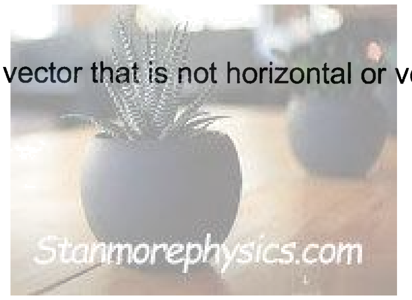
right is +



left is –

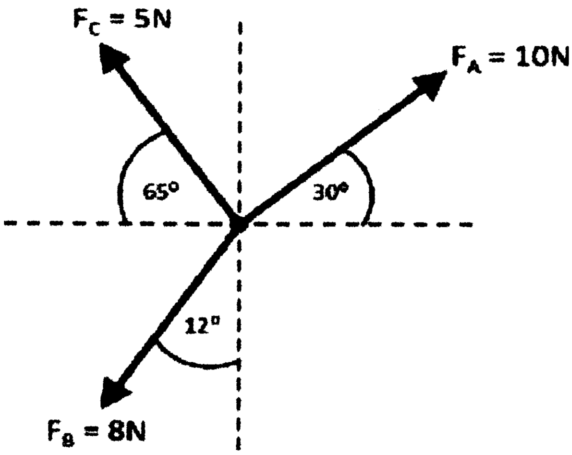
- 3 N

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

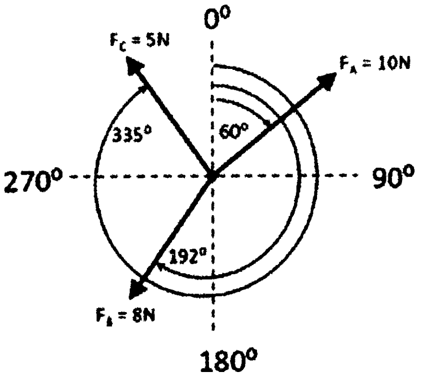


F_A: 10 N at 30° above the positive x- axis (horizontal axis)
F_B: 8 N at 12o left of the negative y- axis (vertical axis)
F_C: 5 N at 65o above the negative x- axis (horizontal axis)

Bearing

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

Use North as 0^{O} and always measure **clockwise**



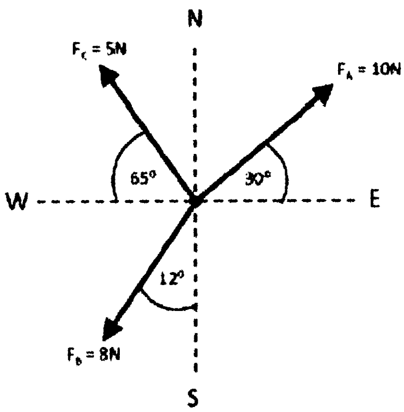
F_A : 10 N on a bearing of 60°

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

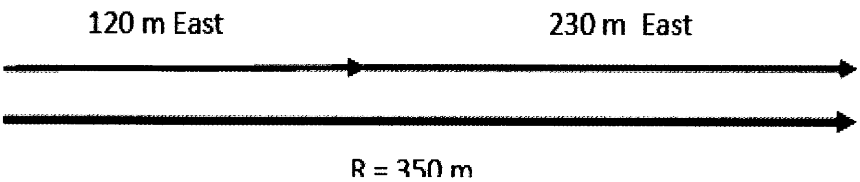
Two vectors acting in the same direction :(one dimension)

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

  Sign of direction: Take to East to be +

  R = 120m + 230m = 350m East

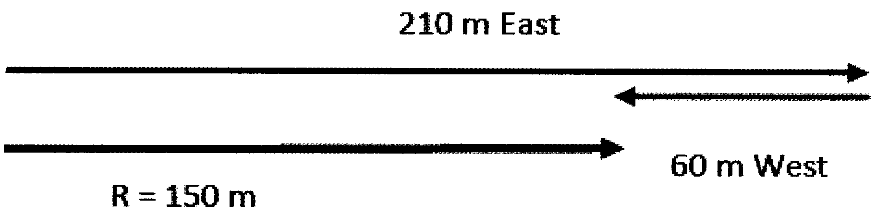
- By construction:



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

- A boy walks 210m due East. He then turns and walk 60m due West. Determine his resultant displacement.
- By calculation: (taking East as positive)

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

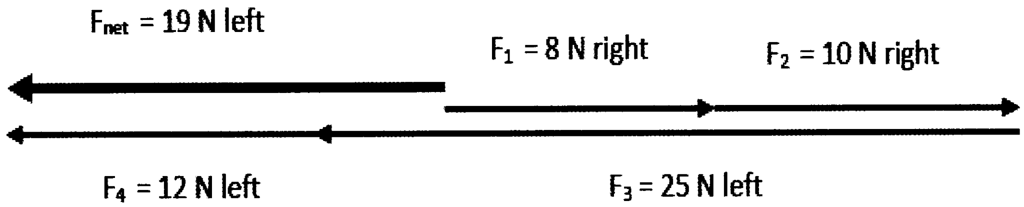
  Let to the right be **positive**

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

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

  = -19 N

  F_{net} = 19 N left

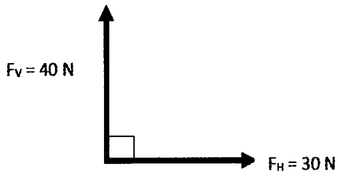


Vectors in Two Dimensions

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

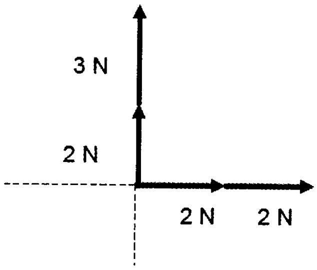
Two forces of 3N and 2N apply an upward force to an object. At the same time, two forces each of 2N act horizontally to the right. Find the resultant force acting on the object.

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

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

$R_y = 2 + 3$

$R_y = 5\ N\ upwards$



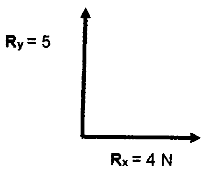
$R_x = R_{x1} + R_{x2}$

$R_x = 2 + 2$

$R_x = 4\ N\ right$

Worked Example

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:

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

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

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

$$R=6.40\ N$$

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

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

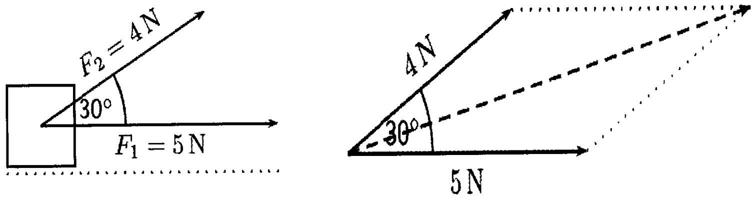
$\theta = 51.24^0$

Worked Example

A force of F1 = 5N is applied to a block in a horizontal direction. A second force F2 = 4N is applied to the object at an angle of 30° 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., 1cm: 1N

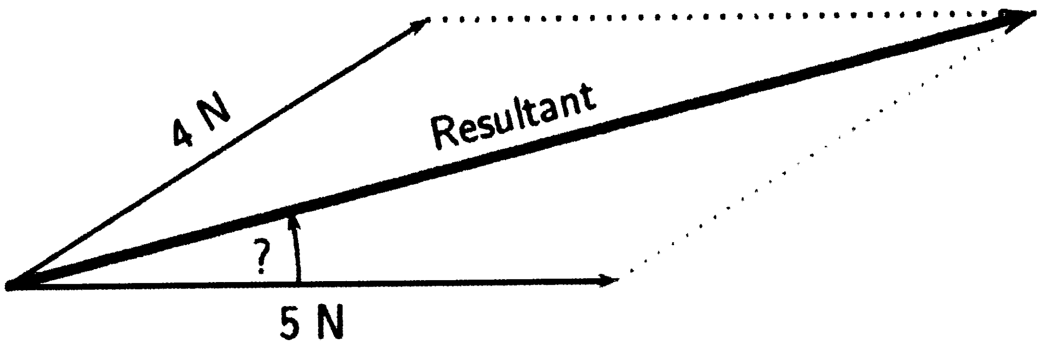
Step 3: Draw the first vector (F1) on the horizontal, according to the scale.

Step 4: Draw the second scaled vector (F2) 30° 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 8,7N, 13, 3° 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. 10mm: 10N
- 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.

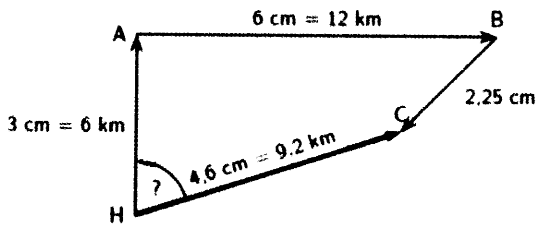
Worked Example

A ship leaves a harbour H and sails 6km north to port A. From here the ship travels 12 km east to port B, before sailing 5,5 km at 450 south-west to port C.

Determine the ship's restaurant displacement using the tail-to-head technique.

Solution

Using a scale 1cm: 2km, 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, 3°.

Worked Example

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

1. What was the total distance he walked?

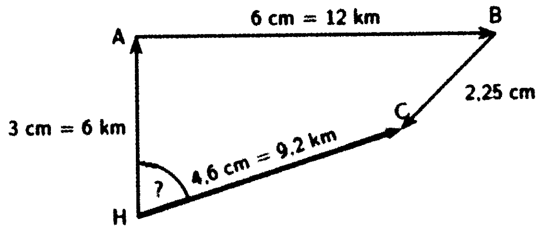
2. Determine by construction his resultant displacement?

3. Calculate determine the direction of the resultant.

4. Calculate the magnitude of resultant displacement

Solution

Using a scale 1cm: 2km, 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, 3^{o}.

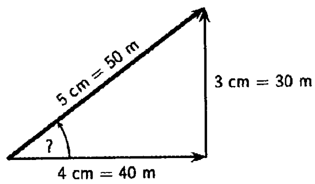
Worked Example

A man walks 40m East, then 30m 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: 1cm: 10m



The resultant is 50m, 37^{o} from the horizontal

Tan $\Phi = \frac{30}{40}$

$\Phi = 36{,}87^{o}$

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

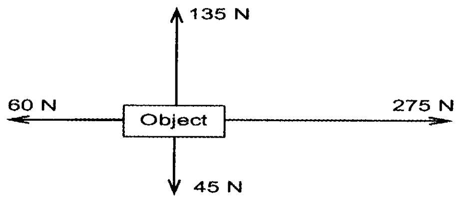
$= 40^2 + 30^2$

$= 2500$

R = 50m

CO-LINEAR VECTORS

- Co-linear vectors are simply vectors that lie in the same straight line. They either act in the same direction or in the opposite directions.



- The 60 N and 275 N force vectors act along the horizontal axis (x-axis). It is essential to use signs (+ and -) to indicate the direction of vectors which act in the same line.

- The resultant horizontal force (Rx) is the vector sum of the forces acting along the horizontal (or *x*-) axis: $\boldsymbol{R_x}$ **= (+275) + (- 60) = +215 N**. The positive sign (+) in the answer indicates that the resultant horizontal force acts to the right: ***Rx*** **= 215 N to the right.**

  The 135 N and 45 N forces act in the vertical direction (y-axis).

  The 135 N force acts upwards and is represented as +135 N.

  The 45 N force acts downwards and is represented as –45 N.

- The resultant vertical force (Ry) is the vector sum of the forces acting in the vertical direction.

$$R_y = (+135) + (-45) = +90 \text{ N upwards}$$

CONCEPT

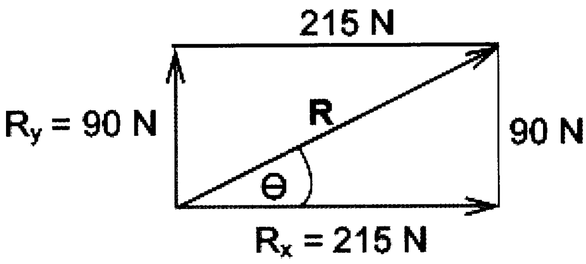
- We have now simplified the given force diagram to just two perpendicular force vectors.
- The resultant force can be found by drawing a neat vector diagram using the tail-to-tail

  method or the tail-to-head method.

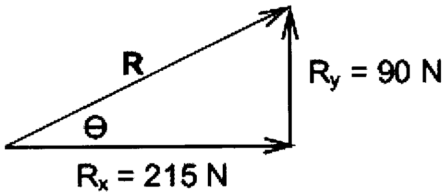
Tail-to-tail method

- Place the tails of the two vectors together (tail to-tail) in the Cartesian plane and complete the parallelogram by drawing in the opposite sides. The opposite sides are PARALLEL and EQUAL IN LENGTH to each other.

Tail- to head



Tail-to-head



The resultant force (R) is the diagonal of the parallelogram. Draw in the diagonal of the parallelogram. The diagonal MUST start from the TWO TAILS of the given forces.
Use Pythagoras to calculate the magnitude of the resultant force (R).
$R^2 = 90^2 + 215^2$
$R^2 = 54325$
R $=\sqrt{54325}$ =233.07N
Use a trig. ratio to find the angle θ: tan Θ = $\frac{opposite}{adjacent} = \frac{90}{215}$ = 0.42
$\tan^{-1}(0.42) = 22.71°$

ACTIVITIES: VECTORS

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 Which of the following pairs can be classified as vectors?

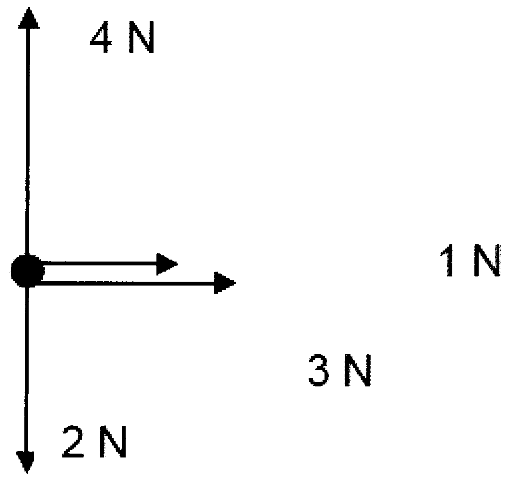
A Frictional force and mass

B Mass and inertia

C Inertia and weight

D Weight and frictional force (2)

1.2 Four forces act on a point, as indicated in the diagram. 1 N 3 N 4 N 2



The magnitudes of the components of the resultant (net) force in the horizontal (FX) and vertical (FY) 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)

1.3 Two forces, F1 and F2, act on a point. If F1 and F2 act in the same direction the maximum resultant has a magnitude of 13 N. If forces F1 and F2 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.

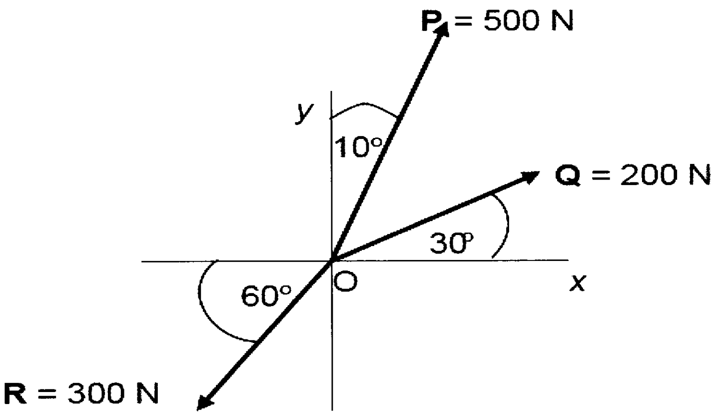
B 16 and 10.

C 3 and 10.

D D 10 and 7. (2)

QUESTION 2

Three forces, P, Q and R, of magnitudes 500 N, 200 N and 300 N respectively, act on a point O in the directions shown in the diagram below. The forces are NOT drawn to scale.

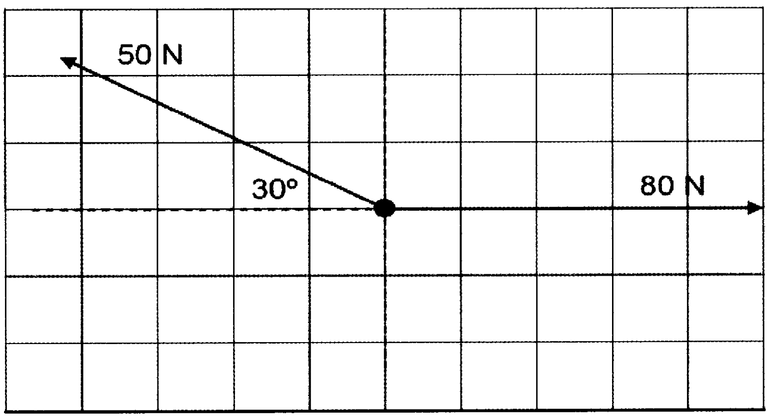


2.1 Refer to the information in the diagram above and give a reason why forces P, Q and R are classified as vectors. (2)

2.2 Determine the magnitude and direction of the resultant force, either by CALCULATION or by ACCURATE CONSTRUCTION AND MEASUREMENT. (Use scale 10 mm = 50 N.) (8)

QUESTION 3

Two forces, of magnitudes 50 N and 80 N, act at a point on a Cartesian plane in the directions shown in the sketch below.



3.1 Give the correct term for the following description: (1)
A single vector having the same effect as two or more vectors together.

3.2 Calculate the:

3.2.1 Magnitude of the vertical component of the 50 N. (2)

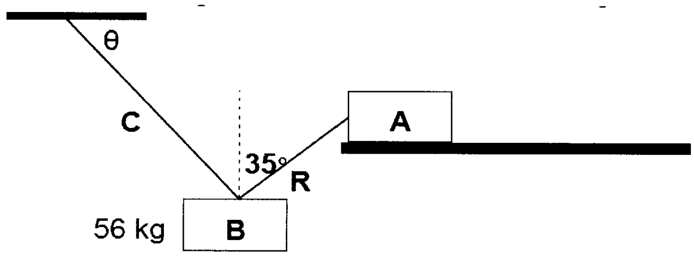
3.2.2 Magnitude of the resultant (net) force. (5)

3.2.3 Direction of the resultant (net) force. (2)

[10]

QUESTION 4

Block A, which is at rest on a horizontal rough surface, is used as an anchor to hold block B, with a mass of 56 kg, in the air at a certain height above the ground. The two blocks are connected with rope R, which makes an angle of 35° with the vertical. Block B is suspended from the ceiling with cable C. Refer to the diagram below.



Block A experiences a frictional force of magnitude 200 N. The system is stationary.

4.1	Define the term resultant vector.	(2)
4.2	What is the magnitude of the resultant force acting on block B?	(1)
4.3	Draw a labelled free-body diagram indicating all the forces acting on block B.	(3)
4.4	Determine the horizontal component of the force in rope R.	(1)
4.5	Calculate the vertical component of the force in cable C.	(4)
4.6	Calculate the angle θ between the cable and the ceiling.	(2)

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 = μN
- 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 - 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**:

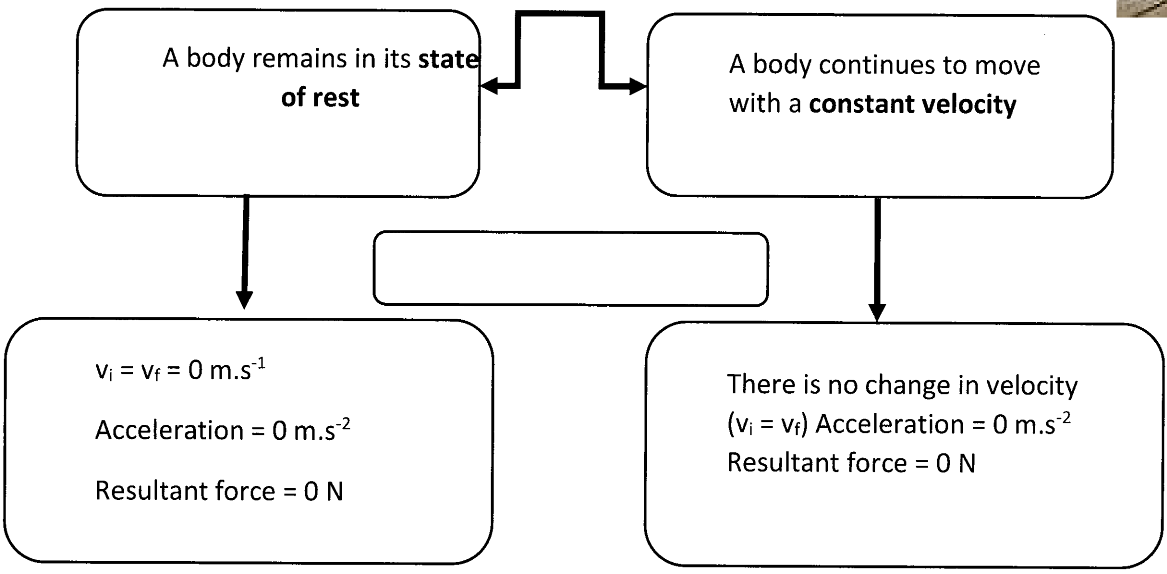
When object A exerts a force on object B,object B **Simultaneously** exerts an oppositely directed force of equal magnitude on object A.

- **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



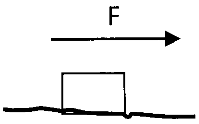
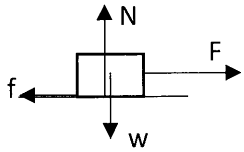
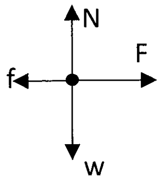
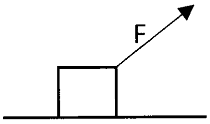
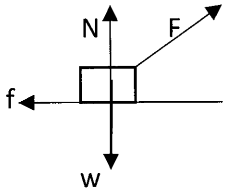
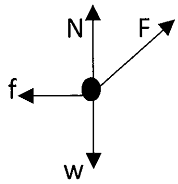
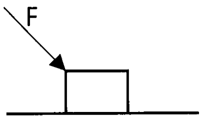
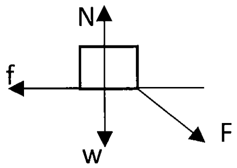
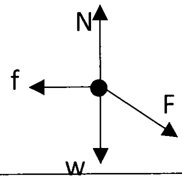
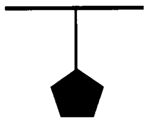
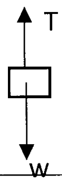
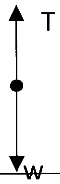
Newton's Second Law of Motion

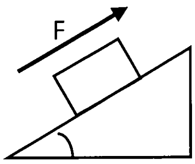
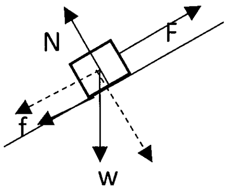
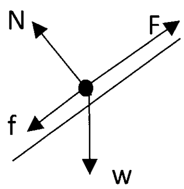
- When a resultant/net force acts on an object, the object will accelerate in the direction of the force at an acceleration directly proportional to the force and inversely proportional to the mass of the object
- Mathematically expressed as: $F_{net} = ma$

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 ($v_i \neq v_f$). $a \neq 0$ m.s^{-2}
- a is directly proportional to F_{net} When the net force increases, the acceleration also increases. vice versa
- 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
				$w_{//}$=mgSinθ
				$w_{\perp}$=mgCosθ
				(N=$w_{\perp}$=mgCosθ)

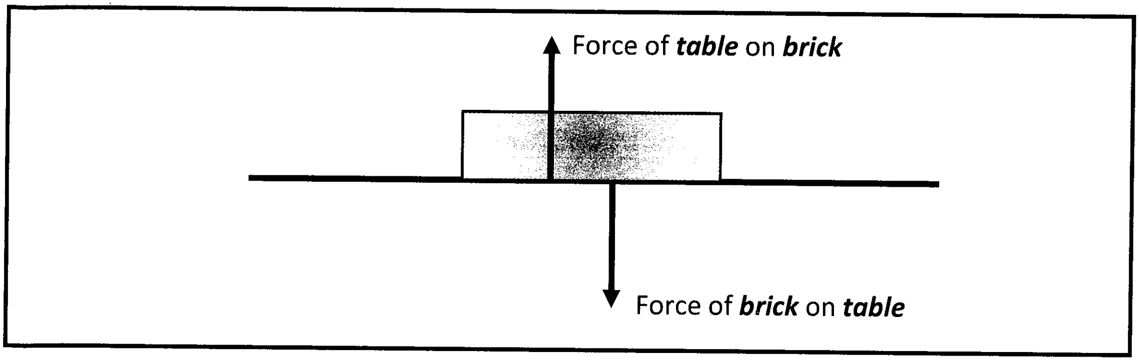
Newton's Third Law of Motion:
When object A exerts a force on object B, object B **Simultaneously** exerts an oppositely directed force of equal magnitude on object A.

- 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 xample

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



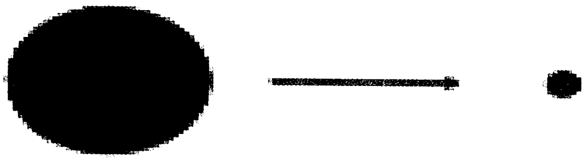
Newton's Law of Universal Gravitation:

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.

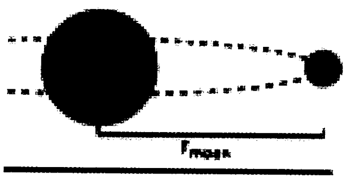
$$F = G\frac{m1m2}{r2}$$

- 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)

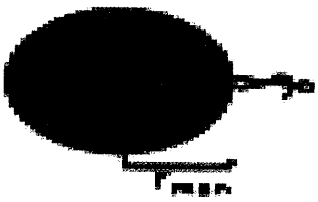
- A uniform sphere of matter attracts a body that is outside the shell as if all the sphere's mass was concentrated at its centre.



- 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·m2·kg−2)
- Proportionality constant which applies everywhere in the universe.

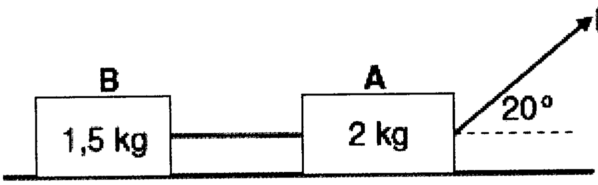
Mass vs Weight

- 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. Fg = mg. Weight is a vector quantity.

ACTIVITIES- NEWTONS LAWS

QUESTION 1

A light inelastic string connects two blocks of mass 1,5 kg and 2 kg respectively. A force is applied at an angle of 20° on block A.



If a force F of 8,25 N is applied on block A, the blocks move at a CONSTANT VELOCITY on the rough surface.

1.1 Calculate the horizontal component of the applied force F. (2)

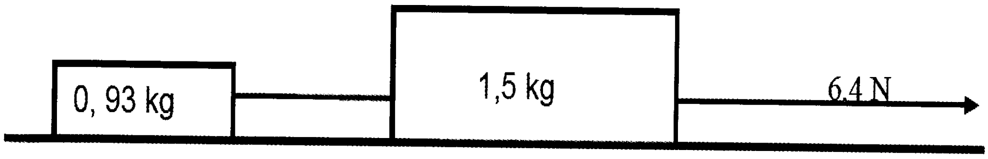
1.2 Calculate the horizontal component of the applied force F. (3)

1.3 Calculate the coefficient of kinetic friction between the blocks and the rough surface. (4)

1.4 How will the frictional force on block A change if the angle of the force changes to 15°? Write down INCREASES, DECREASES or REMAINS THE SAME. (1)

QUESTION 2

A 6, 4 N force pulls horizontally on a block of mass 1, 5 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, 93 kg on the same surface.



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

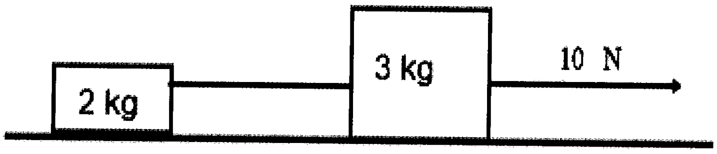
2.2 Determine the acceleration of the blocks. (7)

2.3 Determine the tension in the string. (3)

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

QUESTION 3

Two wooden blocks of masses 2kg and 3kg respectively are placed on a rough horizontal surface. They are connected by a string. A constant horizontal force of 10N is applied to the second string attached to 3kg mass as shown in the diagram below. Assume that both strings are inextensible.



The system moves towards the right with a CONSTANT VELOCITY

3.1 Define the term kinetic frictional force. (2)

3.2 What is the magnitude of the net force acting on the system? (1)

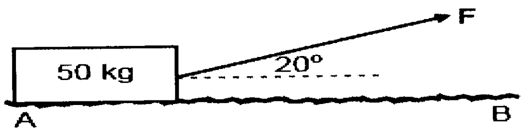
3.3 Draw a labelled free-body diagram showing ALL the forces acting on the 3kg block as it moves towards the right. (5)

3.4 Calculate the coefficient of kinetic friction between the surface and the two wooden blocks. (4)

3.5 The 10N force is increased to 30N so that the system now accelerates. Calculate the acceleration of the system. (5)

QUESTION 4

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 (μk) between the block and the surface is 0,4.



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

4.2 State Newton's first law of motion in words. (2)

4.3 Calculate the magnitude of the:

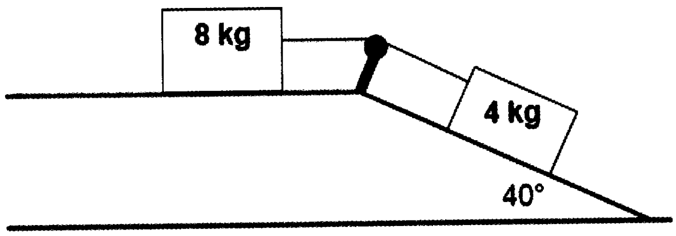
4.3.1 Force **F** (6)

4.3.2 Normal force (2)

4.3.3 Frictional force (2)

QUESTION 5

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.



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

5.2 Draw a labelled free-body diagram of ALL the forces acting on the 4 kg block. (4)

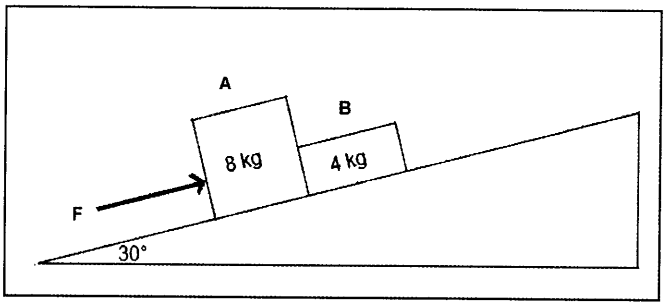
5.3 Calculate the frictional force between the surface and the 4 kg block. (4)

5.4 Calculate the magnitude of the acceleration of the system. (6)

5.5 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. (4)

QUESTION 6

Two objects, A and B, of mass 8 kg and 4 kg respectively, are in contact. They lie on a plane inclined at 30° to the horizontal. A force, F, applied parallel to the incline, pushes on the objects as shown in the diagram below.



6.1 State Newton's Second Law of motion in words. *(2)*

The magnitude of kinetic frictional force acting on object A is 6,8 N and on object B is 3,4 N.

6.3 Draw a labelled free-body diagram showing ALL the forces acting on block B as it as it moves up the incline. (4)

Calculate the:

6.3.1 Magnitude of F if the system moves up the inclined plane at CONSTANT VELOCITY. (5)

6.3.2 Coefficient of kinetic friction for B. (3)

(4)

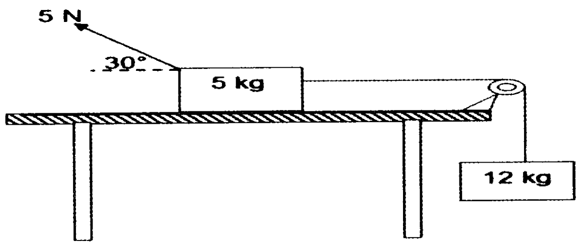
6.4 The angle between the incline and the horizontal changes to 35°.

6.4.1 How will the answer in QUESTION 2.3.2 be affected? Write down INCREASES, DECREASES or REMAIN THE SAME. (1)

6.4.2 How will the magnitude of the kinetic frictional force on object B be affected? Write INCREASES, DECREASES or REMAIN THE SAME. Explain your answer. (3)

QUESTION 7

A 5 kg block, resting on a rough horizontal table, is connected to a 12 kg block by a light inextensible string that passes over a light frictionless pulley. A 5 N force is applied to the 5 kg block at 30° to the horizontal as shown in the diagram below.



7.1 Write down Newton's Second Law of motion in words. (2)

7.2 Draw a free-body diagram of all forces acting on the 5 kg block. (5)

7.3 The coefficient of kinetic friction (μk) between the 5 kg block and the surface is 0,2.

Use Newton's Laws to calculate the magnitude of the:

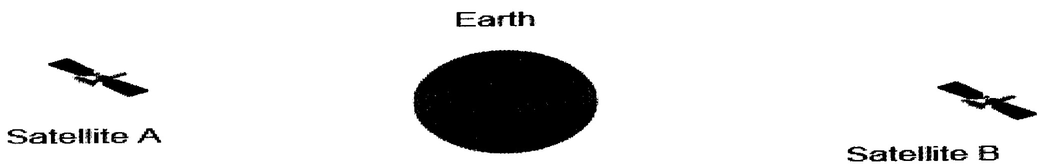
7.3.1 Normal force acting on the 5 kg block (3) (3)

7.3.2 Kinetic frictional force acting on the 5 kg block (2)

7.3.3 Acceleration of the 5kg block. (4)

QUESTION 8

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.



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

8.2 Explain the term weightlessness (2)

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

8.4 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. (4)

QUANTITATIVE ASPECTS OF CHEMICAL CHANGE

The mole

- The mole is the SI unit for the amount of substance (describe a 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).

The mole - mass relationship is summarized 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}.

Example 1

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

Solution:

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

Example 2

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

Solution:

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

$\therefore 5 = \frac{295{,}5}{M}$:

M = $\frac{295}{5}$

M = 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 particles is an amount of 6, 02 $\times$ 10^{23} particles.

6, 02 $\times$ 10^{23} is known as Avogadro's number ($N_{A.}$)

WORKED EXAMPLES

Calculate the number of moles in:

1. 2,5 g of NH_3

2. 213 of Cl_2

Solutions

1. Molar mass of NH_3

M_{NH3}= 14 + 3(1)

= 17 $g.mol^{-1}$

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

$n = \frac{m}{M} = \frac{2.5}{17}$ = 0,15mol

2. Molar mass of Cl_2

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

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

Practise exercises

1. Calculate the number of moles in:

(i) 213 g of Cl_2

(ii) 128 g of SO_2

(iii) 39,5 g $KMnO_4$

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

2. Calculate the mass of:

(i) 0,2 mol of NH_3

(ii) 0.7 mol of O_2

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

(iv) 3,5 mol of Fe

3. Calculate the molar mass for each of the following

(i) $MgCl_2$

(ii) Ca

(iii) CO_2

(iv) $CaCO_3$

Relationships derived from Balanced Chemical Equation

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

The Mole and the Gases

AVOGADRO'S LAW:

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

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

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

N_2	+	$2O_2$	→	$2NO_2$
1 mol	+	2 mol	→	2 mol
1(22,4dm^3)	+	2(22,4dm^3)	→	2(22,4dm^3)

- The Molar volume of ANY gas at STP (Standard Temperature and Pressure) is given the symbol V_m (V_m = 22,4 dm^{3}mol^{-1})
- STP – T = 273K(0^{0}C) and P = $1{,}01\times10^5$ Pa
- For any gas at STP $\mathbf{n} = \frac{V}{V_m}$
- Where : n - number of moles of gas
  - V – Volume of gas sample
  - V_m – molar Volume of gas (22, 4 dm^{-1}.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 EXAMPLES

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.
$$n = \frac{V}{Vm}$$
$V = 0{,}2X22{,}4$= 0,448 dm^3

2. [convert units first]

V= 60/1000 = 0,06 dm^3

$$n = \frac{V}{Vm} = \frac{0,06}{22.4} = 0,0027\ mol$$

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

$$m = 0,0027\ X\ 17,03 = 0.046\ g$$

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 EXAMPLES

1. Calculate the concentration of a solution of calcium chloride made by dissolving 5,55 g 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. $c = \frac{m}{MV}$

$$0.4 = \frac{m}{(159,5)(0,2)}$$

m = 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 combine.

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 determine the empirical formula

STEP 1

Find the mass

Convert the percentage mass into grams by assuming 100 g of a given sample.

STEP 2

Calculate the mole of each element by using the formula n= m/M

STEP 3

Determine the empirical formula by dividing each number of moles by the smallest number of moles to get the simplest whole number ratio.

WORKED EXAMPLES

1. 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

2. 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.

SOLUTION

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.

STEPS TO DETERMINE MOLECULAR FORMULA

STEP 1

Find 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

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

Determine the molecular formula of butene.

Step 1 Empirical formula given CH_2.

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

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

Step 4 $CH_2 \times 4 = C_4H_8$

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 EXAMPLES

1. A 8,4 g sample of nitrogen reacts with 1,5 g 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 **1.2.1** 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 : H_2

1 : 3

0,3 : x (cross multiply)

$$\therefore x = 0,9\ mol$$

If all nitrogen is used, 0,9 mol 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:

H_2 : NH_3

3 : 2

0.75 : x (cross multiply)

∴ x = 0,5 mol

n(NH_3) $= \frac{m}{M}$ $\therefore m = (0,5)(17) = 8,5\ g$

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 = $\frac{\text{Mass of pure substance}}{\text{Mass of impure substance}} \times 100$

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 = $\frac{\text{Actual yield}}{\text{Theoritical yield}} \times 100\%$

❖ Percentage yield is usually determined using mass, but can also be determined with moles 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

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

An excess of $Pb(NO_3)_2$ reacts with 0,75 g of KI according to the reaction:
$Pb(NO_3) + KI \rightarrow PbI_2 + KNO_3$
After titration and drying, a mass of 0,583 g of PbI_2 is measured.
Determine the percentage yield of PbI_2
SOLUTIONS

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

$$n(KI) = \frac{m}{M} = \frac{0.75}{166} = 4{,}52X10^{-3}mol$$

Step 3: (use stoichiometric ratio)

From the balance equation
(n)KI : (n)PbI_2
2 : 1
$4.52X10^{-3}$:?
(n)PbI_2= $\frac{1}{2}(4{,}52X10^{-3}) = 2{,}26X10^{-3}\ mol$

Step 4: (convert the number of moles to mass)

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

$$2.26X10^{-3} = \frac{m}{461}$$

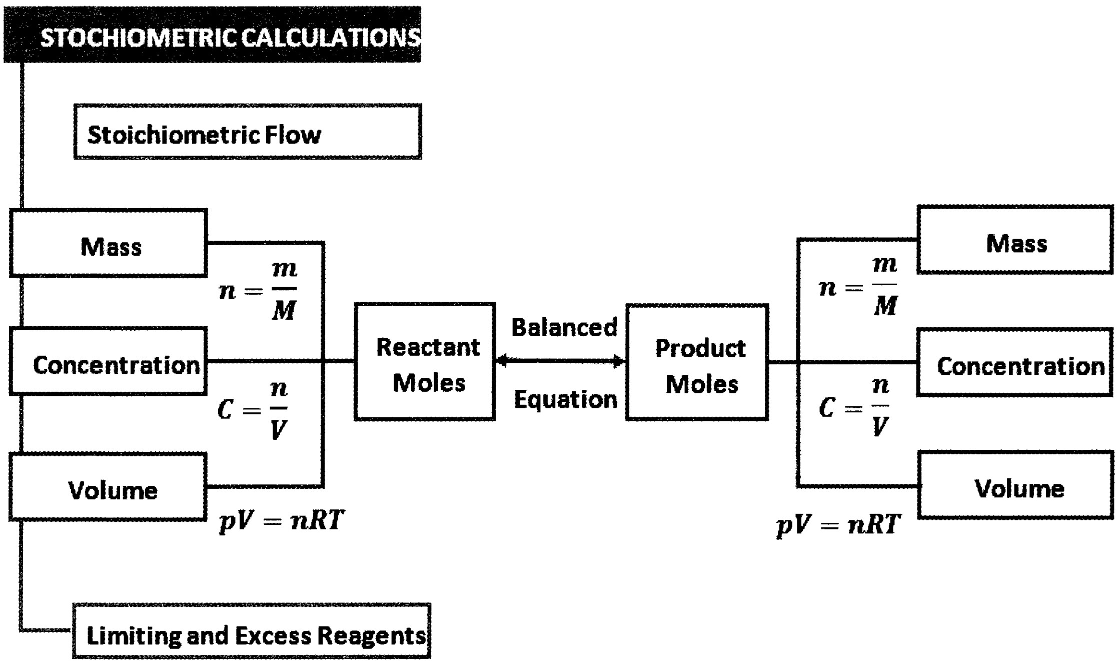
$$m = 1{,}04\ g$$

Step 5: (percentage yield)

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

$$Percentage\ yield = \frac{0{,}583}{1.04}X100$$

$$Percentage\ yield = 56{,}1\%$$



ACTIVITIES :QUANTITATIVE ASPECTS OF CHEMICAL CHANGE

REVISION OF GRADE 10 STOICHIOMETRY

1.1 Calculate the molar mass for each of the following:

1.1.1 Ca (1)

1.1.2 $MgCl_2$ (2)

1.1.3 H_2SO_4 (2)

1.1.4 $Ca(NO_3)_2$ (2)

1.2 Determine the percentage composition for each of the following substances:

1.2.1 $MgCl_2$ (2)

1.2.2 $CuSO_4$ (2)

1.3 Given 80 g of NaOH

1.3.1 Calculate the number of moles of 80 g of NaOH. (3)

1.3.2 Calculate the number of NaOH particles in 80 g of NaOH. (3)

1.4 Given 0,05 kg of $CaCO_3$.Calculate

1.4.1 The number of moles of 0, 05 kg of $CaCO_3$. (2)

1.4.2 The number $CaCO_3$ particles in 0, 05 kg of $CaCO_3$. (2)

1.5 Given 11, 2 dm^3 of nitrogen gas at STP. Calculate

1.5.1 The number of moles of 11, 2 dm^3 of nitrogen gas at STP. (2)

1.5.2 The number of N_2 (g) molecules at STP. (2)

1.5.3 The number of nitrogen(N) atoms at STP (2)

MOLAR VOLUME OF GASES

2.1. Choose the correct answer

2.2.

2.1.1 ….of a gas is the volume of one mole of a substance at STP. (2)

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

2.1.2 Equal volumes of all gases at the same temperature and pressure contain the same number of... (2)

A. Protons
B. Neutrons
C. Electrons
D. Molecules

2.2

2.2.1 Calculate the number of moles of water in 12 dm^3 of water vapour at STP. (3)

2.2.2 Calculate the volume of hydrogen gas that combines with 12 cm^3 of chloride. (3)

CONCENTRATION

3.1 3.1.1 Calculate the concentration of a solution of calcium chloride made by dissolving 5, 55 g of dry $CaCl_2$ crystals in enough water to make 750 cm^3 of solution. (3)

3.1.2 What mass of copper (II) sulphate must be dissolved in 200 ml water to yield a 0, 4 $mol.dm^{-3}$ solution? (3)

3.2

3.2.1 How many moles of chloride ions are present in 111 g of calcium chloride? (2)

A 0,5

B 2

C 1

D 1,47

3.2.3 What amount of oxygen gas (in moles) contains 1,8 x 10^{22} molecules? (2)

A 0,03

B 33,34

C 1,2 X 10^{24}

D 1,08 $X0^{46}$

3.3 A solution of $Mg(OH)_2$ is made up so that it will have a volume of 0,25 dm^3 and a concentration of 0,5 $mol.dm^{-3}$. The solution is made up using distilled water. (2)

3.3.1 Define the term *concentration.* (1)

3.3.2 Name the solute used to make this solution. (5)

3.3.3 Calculate the mass of solid $Mg(OH)_2$ required to make up the solution. (3)

3.4. 20 cm^3 of a 0,1 $mol{\cdot}dm^{-3}$ nitric acid solution neutralises 25 cm^3 sodium carbonate solution according to the following balanced equation:

$2HNO_3(aq) + Na_2CO_3(aq) \rightarrow 2NaNO_3(aq) + H_2O(\ell) + CO_2(g)$

3.4.1 Write down the NAME of the salt formed in the reaction. (5)

3.4.2 Calculate the mass of sodium carbonate used to prepare 250 cm^3 of sodium (3) carbonate solution of this concentration.

EMPIRICAL FORMULA

4.1 Methyl benzoate is a compound used in the manufacture of perfumes. It is found that a 5,325 g sample of methyl benzoate contains 3,758 g of carbon, 0,316 g of hydrogen and 1,251 g of oxygen.

4.1.1 Define the term *empirical formula* (2)
4.1.2 Determine the empirical formula of methyl benzoate (5)
4.1.3 If the molar mass of methyl benzoate is 136 $g.mol^{-1}$, what is its molecular formula? (3)

4.2 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.

4.2.1. Determine the empirical formula of CADAVERINE. (5)

STOICHIOMETRIC CALCULATIONS

5.1. 8 g of zinc react completely with an excess hydrochloric acid at STP to form hydrogen gas.

5.1.1 Calculate the mass of hydrochloric acid that reacts. (4)

5.1.2 Calculate the volume of hydrogen gas that is produced. (3)

5.2 Sodium thiosulphate, $Na_2S_2O_3(s)$, reacts with 200 cm^3 of a hydrochloric acid solution, HCℓ(aq), of concentration 0,2 $mol{\cdot}dm^{-3}$ according to the following balanced equation:

$$Na_2S_2O_3(s) + HC\ell(aq) \rightarrow NaC\ell(aq) + S(s) + SO_2(g) + H_2O(\ell)$$

5.2.1 Define the term *concentration of a solution* (2)
5.2.2 Write down the balance chemical equation. (3)
5.2.3 Calculate the number of moles of HCℓ(aq) added to the sodium thiosulphate. (3)
5.2.4 Calculate the volume of $SO_2(g)$ that will be formed if the reaction takes place at STP. (3)

EXPERIMENTAL YIELD

6.1. An excess of $Pb(NO_3)_2$ reacts with 0,75 g of KI according to the reaction:

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

After titration and drying, a mass of 0,583 g of PbI_2 is measured.

6.1.1 Determine the percentage yield of PbI_2 (6)

6.2

It is found that 40 cm^3 of a 0,5 $mol.dm^{-3}$ sodium hydroxide solution is needed to neutralise 20 cm^3 of the vinegar with a mass of 20,8 g. Vinegar is a solution of ethanoic acid in water. The balanced chemical equation for this reaction is:

$$NaOH + CH_3COOH \rightarrow CH_3COONa + H_2O$$

6.2.1 Calculate the number of moles of sodium hydroxide that reacted. (3)

6.2.2 Calculate the mass of ethanoic acid present in the vinegar. (4)
6.2.3 Calculate the percentage (by mass) of ethanoic acid present in the (2)

6.3 37 g C react with an excess of oxygen and produce 65 dm^3 CO_2 gas at STP. The balanced equation for the reaction is as follows:
$C(s) + O_2(g) \rightarrow CO_2(g)$
6.3.1 Calculate the percentage purity of the carbon (5)

6.4 22,5 dm^3 H_2 and 30 dm^3 N_2 is placed in a container and produces 12 dm^3 NH_3. The balanced equation for the reaction is

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

6.4.1 Calculate the percentage yield for this reaction. (5)

REACTING SOLUTIONS- STANDARD SOLUTION

7.1 25 cm^3 of HCl of concentration 0, 12 $mol.dm^{-3}$ reacts with 28.4cm^3 NaOH to form water and NaCl. Calculate the concentration of sodium hydroxide. (3)

7.2 30 cm^3 of HCl of concentration 0, 5 $mol.dm^{-3}$ is diluted with 100 ml of water. Calculate the concentration of the diluted solution. (3)

7.3 25 cm^3 of $BaCl_2$ reacts with 20 cm^3 of a standard solution of 0, 05 $mol.dm^{-3}$ sulfuric acid to form barium sulphate and hydrochloric acid.
7.3.1 Define the term standard solution. (2)
7.3.2 Write down the balanced equation (3)
7.3.3 Calculate the concentration of barium chloride solution. (3)
7.3.4 Calculate the mass of the precipitate ($BaSO_4$) that formed (3)

7.4 30 ml of a NaOH solution with concentration of 0, 2 $mol \cdot dm^{-3}$ is mixed thoroughly with 50 ml of a NaOH solution with a concentration of 0, 3 $mol \cdot dm^{-3}$. Calculate the concentration of the final solution. (5)

7.5 25 g NaCl is added to 100 cm of a NaCl solution with a concentration of 0, 5 $mol \cdot dm^{-3}$ and thoroughly mixed. Assume that the volume of the solution does not change. Calculate the concentration of the final solution (7)

LIMITING REACTIONS

8.1. 50 g of magnesium carbonate is added to 500 cm^3 of hydrochloric acid with a concentration of 0, 75 $mol.dm^{-3}$. The equation for the reaction is given below:

$$MgCO_3(aq) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(aq) + H_2O$$

The carbon dioxide gas is collected at STP.

8.1.1. What are the standard conditions used when conducting an experiment at STP? (2)
8.1.2. Determine which reactant is the limiting reactant. (6)

8.2. Consider the following balanced chemical reaction:

$2HNO_3\ (aq) + Ca(OH)_2\ (aq) \rightarrow Ca(NO_3)_2\ (aq) + 2H_2O\ (l)$

25, 0 ml of the nitric acid of concentration of 0, 15 mol.dm^{-3} reacts with the calcium hydroxide solution.

8.2.1. How many moles of the acid are used? (2)

8.2.2. What mass of calcium hydroxide reacted with the nitric acid? (3)

8.2.3. 13, 6 ml of calcium hydroxide solution was used. What was the concentration of the calcium hydroxide solution? (4)

MORE COMPLEX STOICHIOMETRIC CALCULATIONS

9.1

9.1.1 Define the term concentration. (2)

9.1.2 Eight (8) grams of $Na_2S_2O_3$ is dissolved in water to prepare 500 cm^3 of solution. Calculate the concentration of the $Na_2S_2O_3$ solution (3)

9.1.3 A 10 g sample of a compound contains 2, 66 g of potassium, 3, 54 g of chromium and 3, 81 g of oxygen.

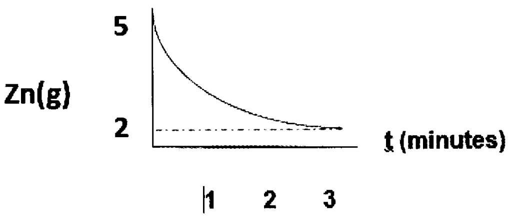
9.1.3.1 Define the term empirical formula (2)

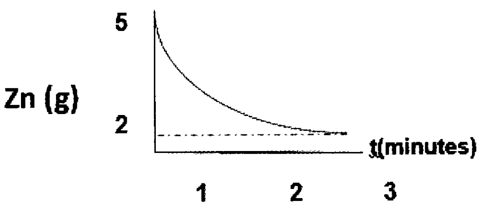
9.1.3.2 Determine the empirical formula of this compound. (7)

9.2 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





9.2.1 Name the substance that is the limiting reagent (1)

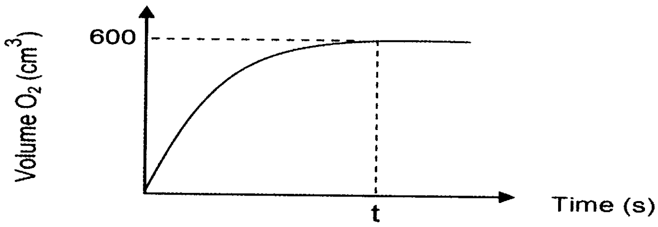
9.2.2 Calculate the initial concentration of the sulphuric acid if 50 cm^3 of the acid was used. (5)

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

$H_2O_2(aq) \rightarrow H_2O + O_2$

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.

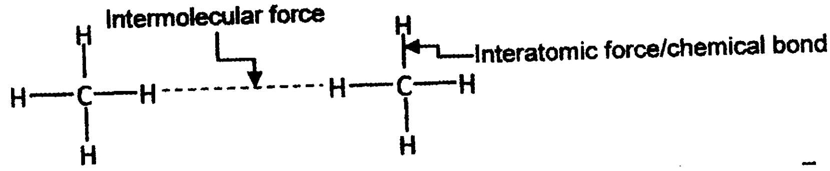
9.3.1 Balance the equation given above. (2)

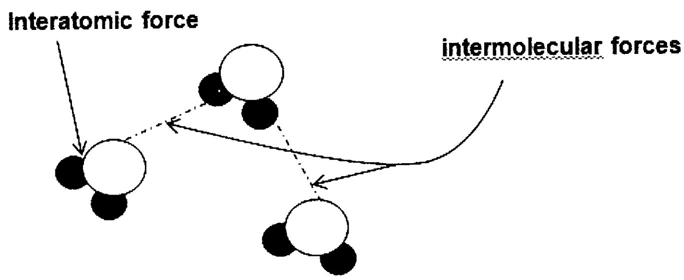
9.3.2 Using the information from the graph, calculate the mass of hydrogen peroxide that decomposed (5)

INTERMOLECULAR FORCES

- The forces of attraction between molecules in a substance
- The intermolecular forces are **weaker** than interatomic forces.

Examples

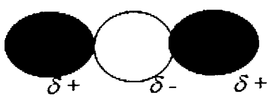
1. 

2. 

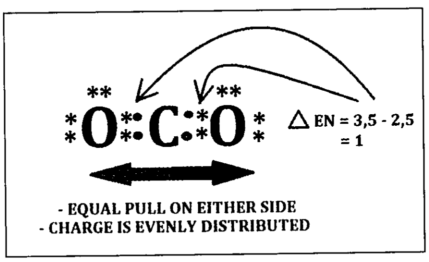
- The strength of intermolecular forces determines the physical properties (boiling points, melting point, evaporation, etc.) of a molecular substance.

- 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

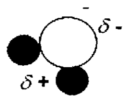


- Difference in electronegativity (ΔEN) = 3,5 – 2,5 = 1,0 → bond between C and O is polar but both ends of CO_2 are ∂+ and the molecule is linear. The molecule is therefore non-polar.



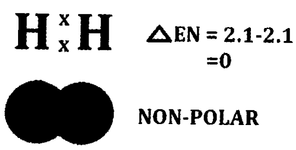
Polar molecule

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



- ΔEN = 3,5 – 2,1 = 1,4. The two bonds (between H and O atoms) are polar.
- H_2O molecule has H-end being ∂+ and O-end being ∂-, they are called **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.
  - The electro-negativity between the two atoms is zero, this explains why the interatomic bond in Hydrogen molecule is non-polar



TYPES OF INTERMOLECULAR FORCES

1. Van der **Waals forces:**

   van der Waals force is a weak attraction between molecules The force of attraction is between polar and non-polar molecules

   (a) **Dipole-dipole force** is an attraction between polar molecules.
   Examples: 1: between molecules of HCℓ
   Example: 2. When HCℓ dissolves in water

   Dipole-dipole forces are the strongest intermolecular forces

   (b) **Dipole-induced dipole force** is a weak force of attraction that exist when a polar causing a distortion in arrangement of electrons in a non-polar molecule. Temporary dipoles are induced in a non-polar molecule e.g. mixture of HCℓ and argon.

   (c) **Induced dipole forces (London forces)** occurs between atoms or molecules of non-polar substances e.g.
   Between atoms of noble gases, molecules of diatomic molecules (H_2; N_2; O_2; F_2; $C\ell_2$), non-polar compounds (CH_4; $CC\ell_4$; BF_3), between molecules of CO_2(s) – dry ice
   Induced dipole forces are the **weakest** van der Waals forces

2. **Hydrogen bond** is a special type of dipole-dipole force. Hydrogen bond is a force attraction between a hydrogen atom bonded to oxygen, nitrogen or fluorine in a molecule to a lone pair of an adjacent molecules e.g. between H_2O molecules, between HF molecules.
   Hydrogen bonds are the **strongest** intermolecular forces.

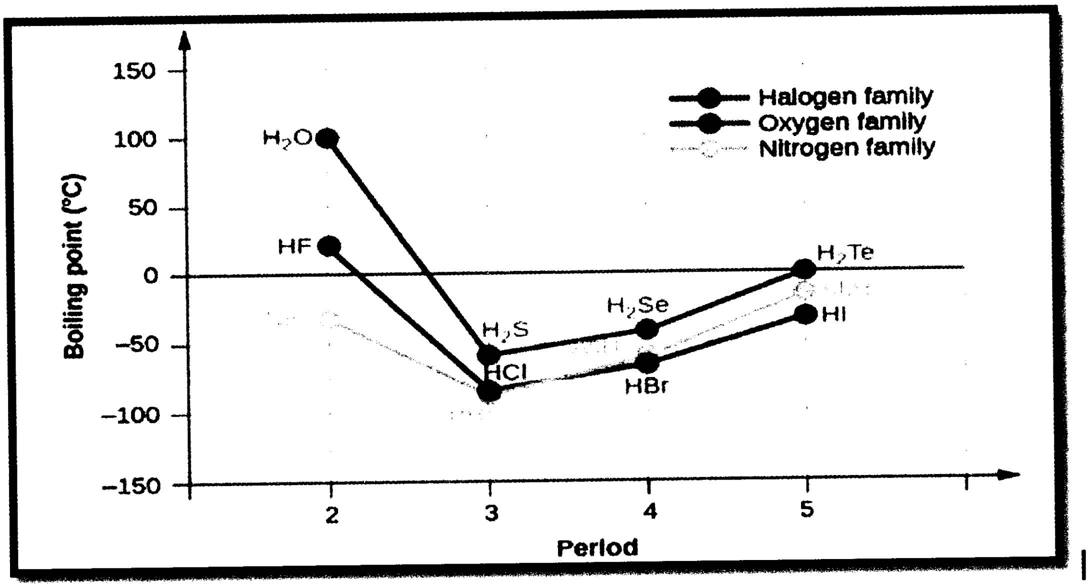
3. **Ion-dipole force** is the attraction of an ion with a positive or negative charge and the oppositely charged end of the dipole of polar molecule e.g. NaCℓ dissolved in water

4. **Ion-induced dipole force** is an attraction between an ion and a non-polar molecule. As an ion approaches a non-polar molecule, it causes a distortion in the arrangement of the arrangement of the electrons of non-polar molecules. Momentary dipoles are induced in non-polar molecules e.g. dissolving NaCℓ in hexane (C_6H_{14})

PHYSICAL STATE AND DENSITY EXPLAINED IN TERMS OF THESE INTERMOLECULAR FORCES

Boiling Point

- The hydrogen bonds between highly polar water molecules are stronger than normal dipole-dipole forces and more energy is needed to break these bonds. Energy needed for molecules to evaporate, is called heat of vaporization. 40,7 kJ·mol^{-1} energy is needed for water molecules to evaporate – hence the higher than expected boiling point.



ACTIVITIES: INTERMOLECULAR FORCES

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)

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)

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)

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)

5. Calvin and Jason are helping their dad tile the bathroom floor. Their dad tells them to leave small gaps between the tiles. Why do they need to leave these small gaps? (2)

6. Hope returns home from school on a hot day and pours herself a glass of water. She adds ice cubes to the water and notices that they float on the water.

6.1 What property of ice cubes allows them to float in the water? (1)

6.2 Briefly describe how this property affects the survival of aquatic life during winter (2)

7. Explain why this is important for life on earth. (2)

8. Give one word or term for each of the following descriptions:

8.1 Give one word or term for each of the following descriptions: (1)

8.2 A molecule that has an unequal distribution of charge. (1)

8.3 The amount of heat energy that is needed to increase the temperature of a unit mass of a substance by one degree. (1)

9. Refer to the list of substances below:

HCl, Cl_2, H_2O, NH_3 N_2, HF

Select the true statement from the list below:

A NH3 is a non-polar molecule

B The melting point of NH3 will be higher than for Cl2

C Ion-dipole forces exist between molecules of HF

D At room temperature N2 is usually a liquid (2)

9. The following table gives the melting points of various hydrides:

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

10.1 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)

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

10.3 Explain the shape of the graph *(2)*

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

10.4.1

Hydrogen sulphide	−60 °C
Ammonia	−33 °C

Hydrogen fluoride	20 °C
Water	100 °C

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

10.4.2 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)*

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

10.4.4 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.

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

Who is correct and why? *(3)*

11. 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 sulfide (H2S)	Hydrogen sulfide (H2S)
Helium (He)	Helium (He)
Methane (CH4)	Methane (CH_4)

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

11.2 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)*

11.3 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 actually exists in this compound? *(1)*

11.4 Khetang is looking at power lines around him for a school project. He notices that they sag slightly between the pylons. Why do power lines need to sag slightly? *(2)*

11.5 Briefly describe how the properties of water make it a good liquid for life on Earth. *(2)*

Briefly describe how the properties of water make it a good liquid for life on Earth.

ELECTROSTATICS

- **Principle of conservation of charge.**

$$Q_{new} = \frac{Q1 + Q2}{2}$$

- **Principle of charge quantization.**

$$n = \frac{Q}{q_e}$$

COULOMB'S LAW

- The electrostatic force between two point charges is directly proportional to the product of the two charges and inversely proportional to the square distance between them.
- Mathematical representation: F α Q_1Q_2, Fα$1/r^2$

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

Worked Examples:

Example 1
Two charges experience a force F when held a distance r apart. How would this force be affected if one charge is doubled, the other charge is tripled and the distance is halved?

Solution: F_{new} = 24F

Example 2
Two charges experience a force F when held a distance r apart. How would this force be affected if BOTH charges are doubled, and the distance is halved?

$$F = k\frac{q_1q_2}{r^2}$$

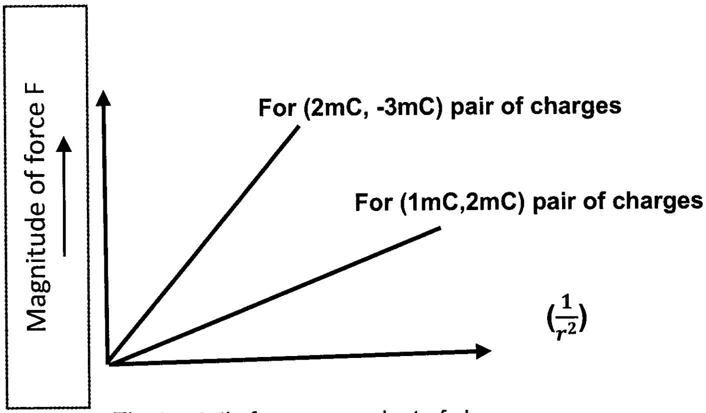
Solution: F_{new} = 16F

Example 3
Two charges experience a force F when held a distance r apart. How would this force be affected if one charge is halved, and the distance is doubled?

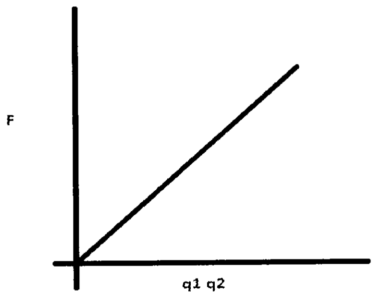
Solution: F_{new} = 1/4F

Graphical representation of Coulombs law:

- **Electrostatic force and $1/d^2$**



Electrostatic force vs product of charges

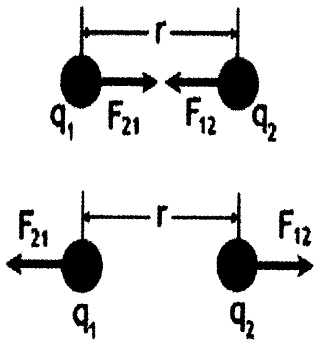


CALCULATIONS - Electrostatic force

- Electrostatic force is a vector quantity, therefore all vector rules can be applied:
  - Direction specific
  - Can be added or subtracted.
  - The force can be calculated using

F = $k\frac{q_1q_2}{r^2}$

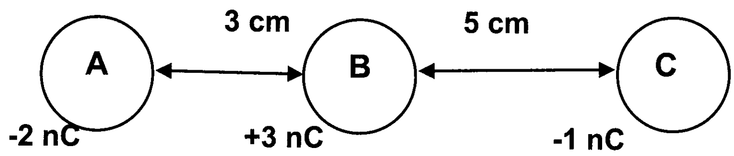
  - Substitute charge magnitude only.
  - Direction determined by charge (like charges repel, unlike charges attract).



- Both objects experience the EQUAL but opposite forces (Newton's Third Law of Motio

Example 4

Determine the resultant electrostatic force on Q_B.



$F_{AB} = k\frac{q_1 q_2}{r^2}$

$F = \frac{9 \times 10^9\ (2 \times 10^{-9})(3 \times 10^{-9})}{(3 \times 10^{-2})^2}$

F = 6 x 10^{-5} N left (A attracts B)

$F_{CB} = k\frac{q_1 q_2}{r^2}$

$F = \frac{9 \times 10^9\ (1 \times 10^{-9})(3 \times 10^{-9})}{(5 \times 10^{-2})^2}$

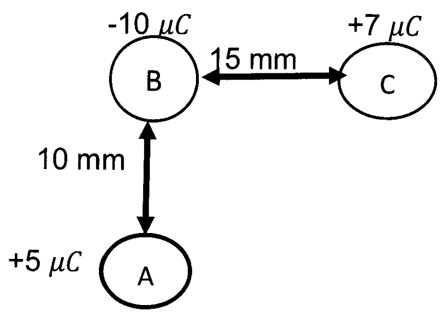
F = 1, 08 x 10^{-5} N right (C attracts B)

$F_{net} = F_{AB} + F_{CB}$

F_{net} = -6 x 10^{-5} + 1, 08 x 10^{-5}

= -4 x 10^{-5} ∴ F_{net} = 4, 92 x 10^{-5} N left

Example 5



$F_{AB} = k\frac{Q_A Q_B}{r^2}$

$F = \frac{9 \times 10^9\ (5 \times 10^{-6})(10 \times 10^{-6})}{(10 \times 10^{-3})^2}$

F = 4 500 N down (A attracts B)

$F_{CB} = k\frac{Q_C Q_B}{r^2}$

$F = \frac{9 \times 10^9\ (7 \times 10^{-6})(10 \times 10^{-6})}{(15 \times 10^{-3})^2}$

$58,11^0$

F = 2 800 N right (C attracts B)

$58,11^0$

$F^2_{net} = F^2_{AB} + F^2_{CB}$

$F_{net} = \sqrt{4500^2 + 2800^2}$

$\therefore F_{net} = 5\ 300$ N

$\tan\theta = \frac{0}{a}$

$\theta = \tan^{-1}\frac{Fab}{Fcb} = \frac{4500}{2800} =$

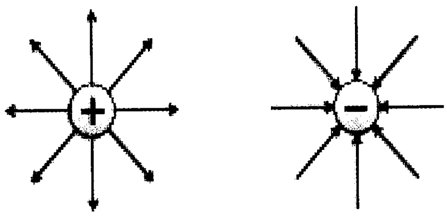
$\therefore F_{net} = 5\ 300$ N at

ELECTRIC FIELDS

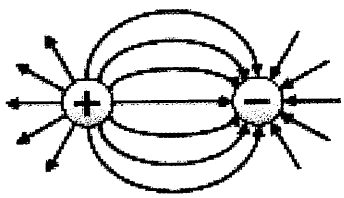
- An electric field is a region of space in which an electric charge experiences a force. The direction of the electric field at a point is the direction that a positive test charge (+1 C) would move if placed at that point.

ELECTRIC FIELD LINE PATTERNS

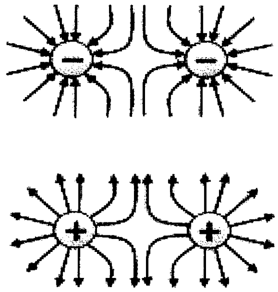
- Field lines around the single point charge



- Field lines between two unlike charges



- Electric Field Lines between the two like charges

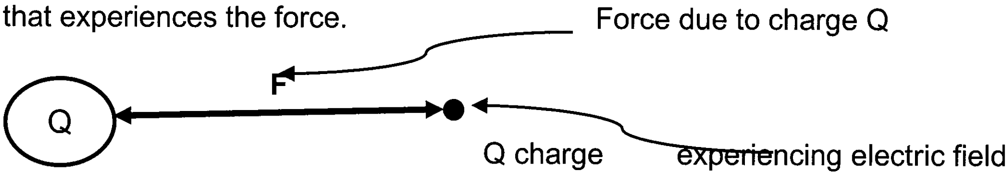


ELECTRIC FIELD STRENGTH

- Electric field strength at any point in space is the electrostatic force per unit positive charge experienced by a positive test charge at that point.

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

- **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 x 10^5 NC^{-1} to the right

Electric field strength at distance r from a point charge Q

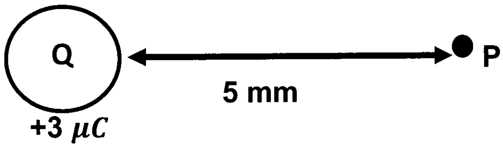
- If a test charge q is placed at a distance r from a charge Q, the electrostatic force that Q and q exert on each other is:

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

- Q is the charge that creates the electric field.

EXAMPLE:

Determine the electric field strength at point P due to charge Q.



E = $\frac{kQ}{r}$

E = $\frac{9 \, x \, 10^9 \, (3 \, x \, 10^{-6})}{(5 \, x \, 10^{-3})^2}$

E = 1, 08 x 10^9 NC^{-1} to the right

NOTE:

- Electric field strength is a VECTOR. All vector rules and calculations apply. (Linear addition, 2D arrangement, resultant vectors, etc.)

ACTIVITIES

ELECTROSTATICS

QUANTISATION OF CHARGE

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: (2)

A. 1/2F

B. F

C. 2F

D. 4F

(2)

1.2. Two charged objects on insulated stands have charges of **3Q** and **5Q** respectively. The

Objects are a distance **R** apart and exert a force **F** on each other. They are moved so that they are now 1/3 **R** apart. What is the new force that they exert on each other (2)

A **F**

B 1/**3 F**

C 3**F**

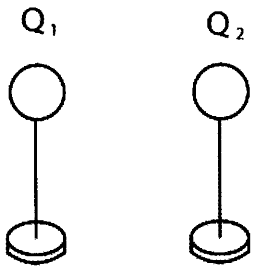
D 9**F**

(2)

2. Calculate the new charge on each of the spheres in the following diagram after they have touched.

(3)

3. Two metal spheres Q1 and Q2 on insulated stands, carry charges of +4 nC and −12 nC respectively.



3.1. Using free body diagram, show the electrostatic force on each sphere. (2)

3.2. State the Principle of conservation of charge. (2)

4. 4.1. A neutral object obtains a charge by gaining 1 800 electrons. What is the charge that the object obtains? (2)

4.2. Two metal spheres Q1 and Q2 on insulated stands, carry charges of +8 nC and −10 nC respectively. The two spheres are now brought together to touch each other. They are then placed back in their original positions.

Two metal spheres Q1 and Q2 on insulated stands, carry charges of +8 nC and −10 nC respectively. The two spheres are now brought together to touch each other. They are then placed back in their original positions.

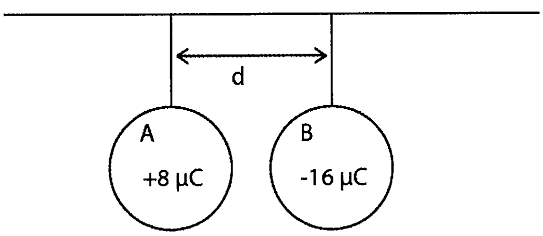
4.2.1 Calculate the new charge on each sphere. (3)

4.2.2 What quantity of charge is transferred between the two spheres during contact? (2)

COULOMB'S LAW

1. Two identical metal spheres, **A** and **B** have charges of +8 μC and -16 μC respectively.

They are suspended from a horizontal wooden pole and placed a distance *d* apart from each other, as shown below.'



Sphere **B** experiences an electrostatic force. In which direction does the force act? (1)

2. The spheres are touched together and then separated and placed the same distance *d* apart from each other.

2.´ When they touched each other, were electrons removed from or added to **A**? (4)

Give a reason for your answer.

2.2 Sphere **B** now experiences a force of 1,6 N. Calculate the distance *d*. (3)

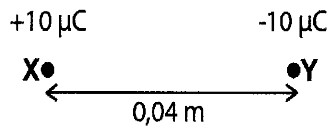
3. The centres of two identical metallic spheres, each carrying a charge Q, are placed a distance r apart. Which ONE of the following pairs of changes (that are made simultaneously) will double the electrostatic force that one charged sphere exerts on the other?

A.	Decrease the distance to $\frac{r}{2}$	Double the charge on each sphere
B.	Decrease the distance to $\frac{r}{2}$	Reduce the charge on one sphere to $\frac{Q}{2}$
C.	Double the distance to 2r	Double the charge on each sphere
D.	Decrease the distance to $\frac{r}{2}$	Reduce the charge on both spheres to $\frac{Q}{2}$

(2)

4. Two small metal spheres have charges of +2 pC and +5 pC respectively. If the force between the two charges is 9 x 10^{-12} N, calculate the distance between them. (4)

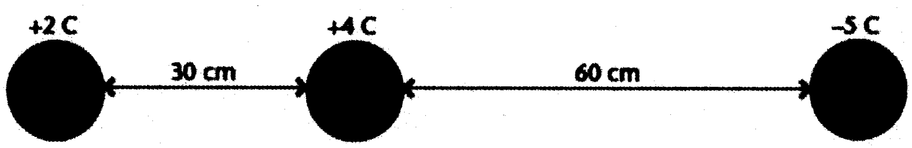
5. Two charged spheres X and Y are placed 0,04 m apart, as shown in the diagram below



Calculate the electrostatic force that **Y** experiences due to charge **X** (4)

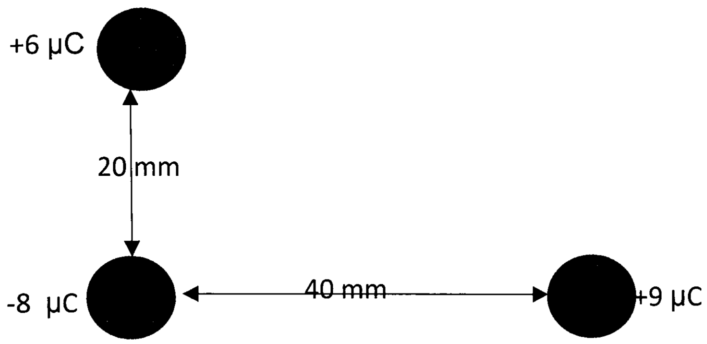
Thus state the force that **X** experiences due to **Y** (2)

6. Three point charges are in a straight line. The charges and distances between them are shown.



What is the resultant electrostatic force on Q_2 as a result of the other two charges? (4)

7. Three point charges Q1, Q2 and Q3 of magnitudes 6 µC, -8 µC and 9 µC respectively are placed in close proximity to one another as shown in the diagram below. The charges and distances between them are shown. What is the resultant electrostatic force on Q_2 as result of the other two charges?

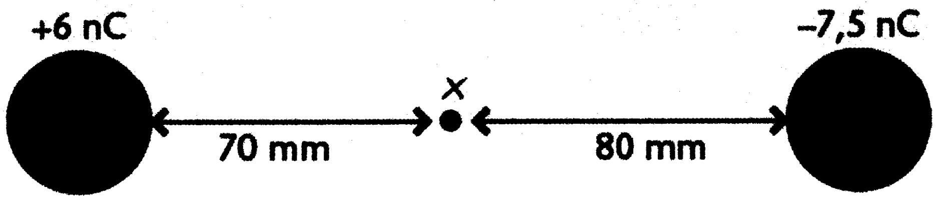


THE ELECTRIC FIELD

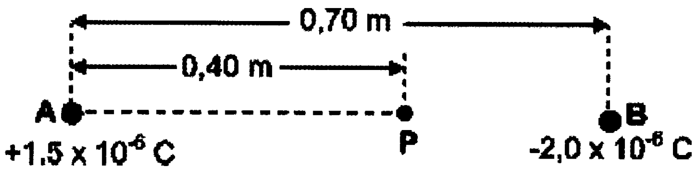
1. Define an electric field at a point. (2)
2. Draw the electric field pattern for a single positive point charge. (2)
3. Draw the resultant electric field pattern of the following charges (3)

4. A charge of 5 nC experiences a force of 4 x10^{-6} N at a point in an electric field. Calculate the strength of the electric field. (3)

5. Two charges, Q_1 of +6 nC and Q_2 of -7,5 nC are separated by a distance of 150 mm. What is the electric field strength at point X, which is 70 mm from Q1 and 80 mm from Q2? (6)



6. **A** and **B** are two small spheres separated by a distance of 0,70 m. Sphere **A** carries a charge of +1,5 x 10-6 C and sphere **B** carries a charge of -2,0 x 10-6 C. **P** is a point between spheres **A** and **B** and is 0,40 m from sphere **A**, as shown in the diagram below.



6.1 Calculate the magnitude of the net electric field at point P. (3)

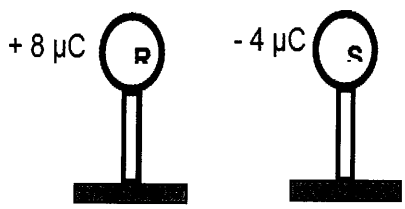
6.2 A point charge of magnitude 3,0 x 10^{-9}C is now placed at point **P**.

Calculate the magnitude of the electrostatic force experienced by this charge. (4)

ADDITIONAL ACTIVITIES

QUESTION 1

The diagram shows two small identical metal spheres, **R** and **S**, each placed on a wooden stand. Spheres **R** and **S** carry charges of + 8 μC and – 4 μC respectively. Ignore the effects of air.



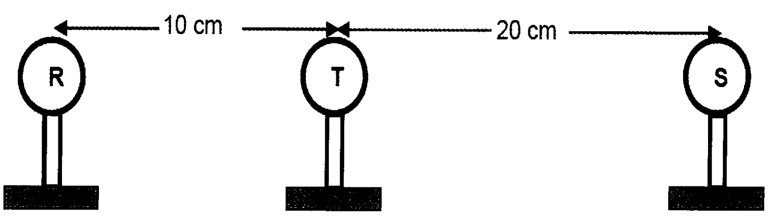
1.1. Explain why the spheres were placed on the wooden stands (1)

Spheres R and S are brought into contact for a while then separated by a small distance.

1.2. Calculate the net charge on each of the spheres. (2)

1.3. Draw electric field pattern due to two spheres R and S (3)

After **R** and **S** have been in contact and separated, a third sphere, **T**, of charge +1μC is now placed between them as shown in the diagram below.



1.4. Draw a free body diagram showing the electrostatic force experienced by sphere T due to sphere S and R (2)

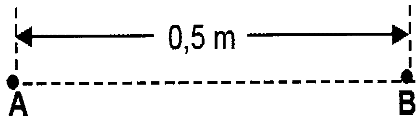
1.5. Calculate the net electrostatic force experienced by T due to R and S (6)

1.6. Define the electric field at a point (2)

1.7. Calculate the magnitude of the net electric field at the location of T due to R and S (Treat the spheres as if they were point charges) (3)

QUESTION 2

Two identical negatively charged spheres, **A** and **B**, having charges of the **same magnitude**, are placed 0, 5 m apart in vacuum. The magnitude of the electrostatic force that one sphere exerts on the other 144 N



2.1. State Coulomb`s law in words (2)

2.2. Calculate the:

2.2.1 Magnitude of the charge on each sphere (4)

2.2.2 Excess number of electrons on sphere B (3)

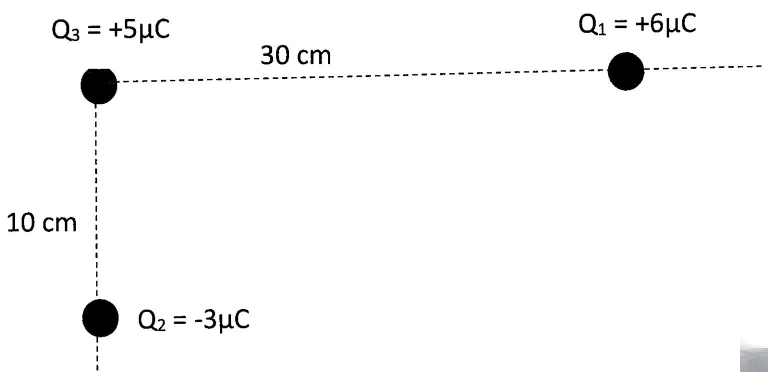
2.3. P is a point at a distance of 1m from sphere B to the right

2.3.1 What is the direction of the net electric field at point P? (1)

2.3.2 Calculate the number of electrons that should be removed from sphere B so that the net electric field at point P is 3×10^4 N.C^{-1} (8)

QUESTION 3

Three point charges, Q_1, Q_2 and Q_3 carrying charges of + 6 μC, -3 μC and +5 μC respectively, are arranged in space as shown in the diagram below. The distance between Q_3 and Q_1 is 30cm and that between Q_3 and Q_2 is 10 cm



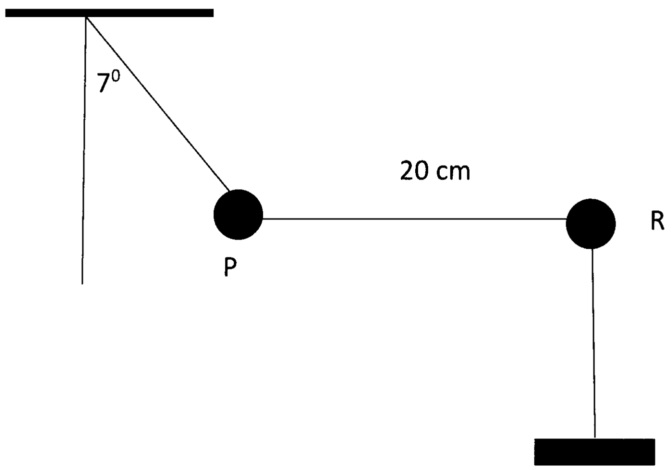
3.1 State Coulomb` law in words (2)

3.2. Calculate the net force acting on charge Q_3 due to the presence of Q_1 and Q_2

QUESTION 4

A very small graphite-coated sphere P is rubbed with a cloth. It is found that the sphere acquires a charge of +0,5 μC.

4.1 Calculate the number of electrons removed from sphere P during the charging process. (3)



Now the charged sphere P is suspended from a light, inextensible string as shown above. Another sphere R, with a charge of -0,9 μC, on an insulated stand, is brought close to P. as a result Sphere P moves to position where it is 20cm from sphere R, as shown above. The system is in equilibrium and the angle between the string and the vertical is 7^0.

4.2 Draw a labelled free-body diagram showing ALL the forces acting on sphere P (3)

4.3 State Coulomb` law in words (2)

4.4 Calculate the magnitude of the tension in the string. (5)

REFERENCES

Free State Revision Document, 2012