KWAZULU-NATAL
DEPARTMENT OF EDUCATION

PHYSICAL SCIENCES
GRADE 11
SUPPORT MANUAL
2020 JIT TERM 2

Table of Contents

Notes to the teacher: How to use this document

- The document contains short notes to highlight prior knowledge, which should help you measure the learner's understanding of basic concepts. For instance, the learner needs to have an understanding of the principle of conservation of charge and quantisation of charge.
- Within the notes, there are definitions in which key words are highlighted as they need to be stressed to the learner.
- The notes lead the learner to Quick Tasks (class activities), in which the learner is assisted to build understanding of the concept.
- There are identified misconceptions and addressed in the notes – e.g. it is highlighted in the notes that **electrons (not protons)** are gained or lost for a material to either be positively or negatively charged.
- Find in the document a highlight stressing the difference between EMF and potential difference.
- It is your duty to make use of simulations and videos to help the learner **see** practical activities performed.
- The document uses the words like REMEMBER! To draw the learner's attention to an important point.
- Then there are structured questions designed to check if the learner did gain a good grasp of conceptual understanding to solve problems.
- Ultimately, please note that this document almost always tries to help you lead the learner into knew knowledge as opposed to just telling them "facts".

ELECTRICITY AND MAGNETISM

Electrostatics

What you already know:

- Two types of charge – **positive** charge (on a **proton**) and **negative** charge (on an **electron**) on all materials.
- A **positively-charged** material has **fewer electrons than** protons, while a negatively-charged material has **more electrons than** protons. (Remember! The number of electrons transferred from one object to another can be determined using the principle of conservation of charge and the principle of quantisation of charge.)

Quick practical task: Rub a plastic ruler on hair, then bring the ruler closer to pieces of paper without touching the paper. Describe what happens. Why does this happen?

Electric Field

What you need to know:

- In the space around each charge or charged material is an **electric field**, described as the region in space in which an electric charge experiences a force.
- The **direction** of the electric field at a point is the direction in which a **positive test charge** would **move** if placed at that point. I.e. **moves away** from a **positive** charge, but **moves towards** a **negative** charge.
- The electric field is mainly indicated as **straight radial** (coming from the centre) **lines** around the charge, with **arrow heads** indicating the **direction.** The direction is **towards** (**attraction**) a **negative charge** and **away from** (**repulsion**) a **positive charge**. *(diagrams)*

Quick Task 1:

- *Assume the following two dots represent two charges in space – one positive, the other negative and are far enough apart to have negligible effects on each other.*
- *Draw the electric field lines around each charge.*
- *Briefly explain why you drew them like you did.*
- *Now assume that the two charges are slowly brought closer to each other.*
- *Draw another two dots and show how you think the field lines would now look like between and around the two charges.*

(Note for the teacher: Make the two charges have like charges and repeat the questions for the leaners.)

Home task: Investigate what happens when a plastic rod or ruler (both charged and uncharged) is brought near water running from a tap. Hint: open the tap such that the water runs slowly and smoothly from the tap.

Electrostatic Force and Coulomb's Law of Electrostatics

- Remember! A force is a push or a pull – electrostatic force is no different! A pull (**attraction**) or a push (**repulsion**) albeit **without physical contact** necessary, between two charged objects. *(Remember the ruler and paper pieces)*

- The electric field causes charged objects to exert electrostatic forces on each other without being in physical contact! – **a non-contact force** (also called a field force).
- Charles de Coulomb was able to conclude from studying this force, that:

The magnitude of the electrostatic force between two point charges is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square distance between them.

This is called **Coulomb's Law of Electrostatics**

Electrostatic force is F , units Newton (N); charge is Q, units Coulomb (C); distance r, units metre (m)

Quick task 2:

- *Use the symbols above to write down the mathematical relationship described in Coulomb's Law. Separate your answer as follows:*
  - *First, write the relationship between the electrostatic force and the product of the magnitudes of the charges, then draw a graph (labelled) to represent the relationship. Discuss how it looks like and why.*
  - *Secondly, write the relationship between the force and the square distance and draw a graph for the relationship. Why does the graph look the way it does? What would the graph of force against* $\frac{1}{r^2}$ *look like? Explain.*
  - *Lastly, combine the relationships into one.*

We can calculate the magnitude of the electrostatic force using:

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

where **k** is **Coulomb's constant** and equal to $\mathbf{9\times10^9\ N.m^2.C^{-1}}$

Worked Examples

Worked example 1: [in one dimension (1D)]

Two point-like charges carrying charges of +3 nC and −5 nC are 2m apart. Determine the magnitude of the force between them and state whether it is attractive or repulsive.

Answer

Step 1: Determine what is required.

We are required to find the force between two point charges given the charges and the distance between them.

Step 2: Determine how to approach the problem

We can use Coulomb's Law to find the force.

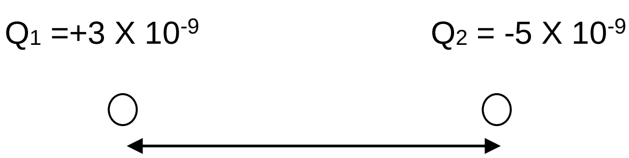
$$F = \frac{kQ_1Q_2}{r^2}$$

Step 3: Determine what is given
We are given:

- Q_1 = +3 nC = $+3 \times 10^{-9}$C
- Q_2 = -5 nC = -5×10^{-9}C
- r = 2m

We know that $k = 9 \times 10^9 \text{ N} \cdot \text{m}^2 \cdot \text{C}^{-2}$.

Draw the diagram.



Step 4: Check units and convert them.

- Q_1 = +3 nC = $+3 \times 10^{-9}$C
- Q_2 = -5 nC = -5×10^{-9}C

Step 5: Determine the magnitude of the force.
Using Coulomb's Law we have.

$$F = \frac{kQ_1Q_2}{r^2}$$

$$= \frac{(9,0 \times 10^9)(3 \times 10^{-9})(5 \times 10^{-9})}{(2)^2}$$

$$= 3,38 \times 10^{-8} \text{ N}$$

Thus the magnitude of the force is $3,38 \times 10^{-8}$N. However, since both point charges have opposite signs, the force will be attractive.

Worked example 2 [in one dimension (1D)]

The charges on two small objects, A and B, are -8µC and -2µC respectively. A and B are 340 cm apart.

1.1 Calculate the force exerted by the charges on each other.

Solution

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

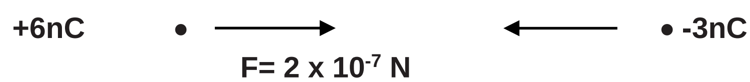
$= 9x10^9 \frac{x (-8 \times 10^{-9}) \times (-2 \times 10^{-9})}{(340 \times 10^{-2})^2}$

$= -1,25 \times 10^{-8}$N

$= 1,25 \times 10^{-8}$N repulsion

Worked example 3 [in one dimension (1D)]

Calculate the distance between two point charges of + 6 nC and – 3 nC respectively if they exert a force of 2 x 10 $^{-7}$ N on each other.



Solution

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

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

$r^2 = 0,81$

$r = 0,9$ m

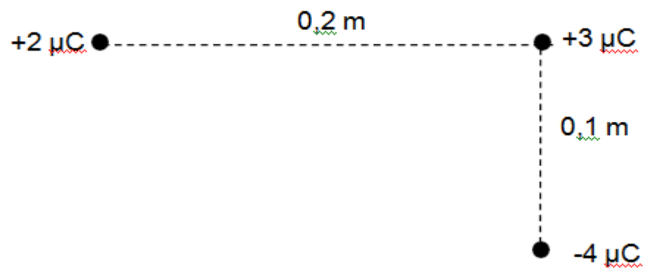
Worked example 4 [in two dimensions (2D)] - Nov 2014(Question 9)

Two point charges of +2 μC and +3 μC are placed a distance of 0, 2 m apart. **P** is a point on the line joining the two charges, a distance of *x* m from the 3 μC charge such that the ***net electric field at point P*** is zero.

4.1 Define the term *electric field at a point* in words. (2)

4.2 Calculate the distance **x**. (7)

A -4 μC charge is now placed a distance of 0,1 m from the +3 μC charge as shown in the sketch below.



4.3 Calculate the *magnitude* of the electrostatic force experienced by the +3 μC charge due to the presence of the other two charges. (5)

[14]

SOLUTION

Electric field at a point is defined as the force acting per unit charge. OR
It is the force experienced by a unit positive charge placed at that point.

$E_{net} = 0$

OR

$E_1 + E_2 = 0$

$$\frac{kQ_1}{r_1^2} + \frac{KQ_2}{r^2_2} = 0 \checkmark$$

$$\frac{(9\times10^9)(2\times10^{-6})}{(0,2-x)^2} \checkmark - \frac{(9\times10^9)(3\times10^{-6})}{x^2} \checkmark = 0$$

$$\frac{2}{(0,2-x)^2} = \frac{3}{x^2}$$

Taking square root

$$\frac{1,414}{(0,2-x)^2} = \frac{1,732}{x^2}$$

$x = 0,11$ m✓

$F = \frac{kQ_1Q_2}{r^2}$ ✓

Force experienced by the +3 µC charge due to the + 2 µC charge = $F_{3,2}$

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

= 1,35 N to the right (east)

Force experienced by the +3 µC charge due to the presence of the - 4 µC charge = $F_{3,-4}$

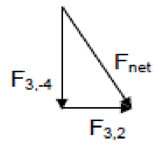
$F_{3,-4} = 9 \times 10^9 \frac{(4 \times 10^{-6})(3 \times 10^{-6})}{(0,1)^2}$

= 10,8 N downwards

$F_{net} = \sqrt{F_1^2 + F_2^2}$

$= \sqrt{(10,8)^2 + (1,35)^2}$ ✓

= 10,88 N ✓



ELECTRIC FIELD

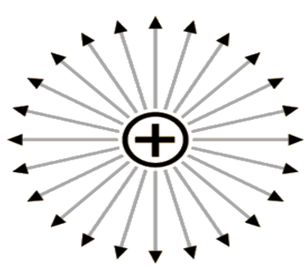
An electric field is a region in space in which an electric charge experiences a force.

The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point.

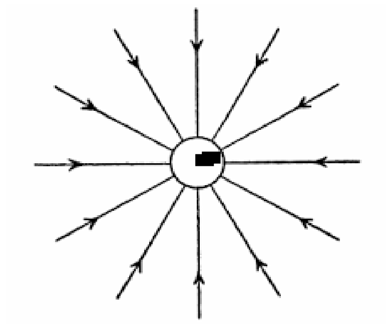
Some important points to remember about electric fields:

- They originate and end perpendicularly to the surface of the charged objects.
- Field lines never cross.
- They are most dense (closer to each other) where the field is the strongest and is least dense (further from each other) where the field is the weakest.
- They surround the charged object in three dimensions. We only draw a few lines in one plane

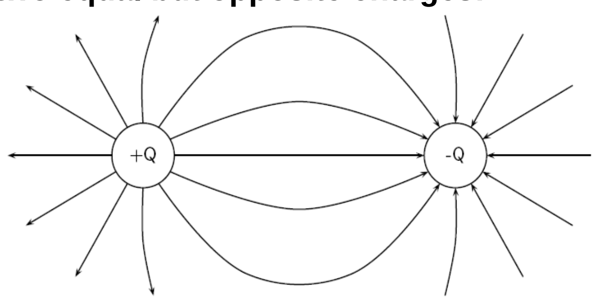
Electric field lines around a positive point charge:



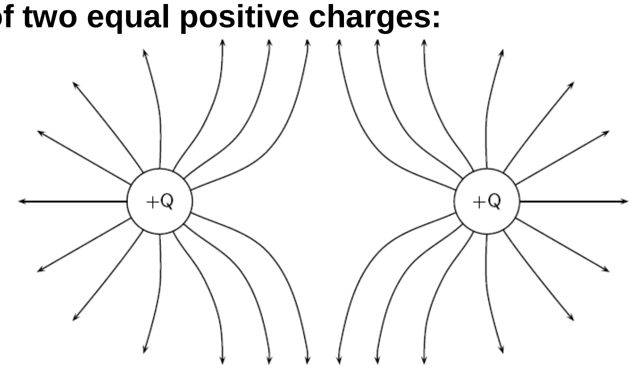
Electric field lines around a negative point charge:



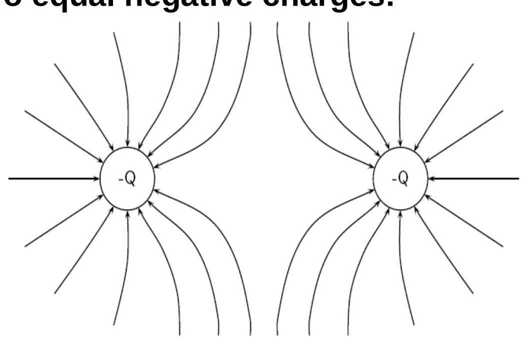
Electric field lines of two equal but opposite charges:



Electric field lines of two equal positive charges:



Electric field lines of two equal negative charges:



Electric field strength at a point

The electric field strength at a point is the electrostatic force experienced per unit positive charge placed at that point.

The test charge placed at a point in electric field will experience a force; the magnitude of the force experienced will depend on the distance of the test charge(q) away from the charge(Q) setting the field.

$$Electric\ field\ strength = \frac{force}{charge}$$

In symbols: $E = \frac{F}{Q}$

Solve problems using the equation : $E = \frac{F}{Q}$

Unit :

- The unit for electric field strength (E) is newton per coulomb($N \cdot C^{-}$) if the electrostatic force F acts on the charge in Newton (N), the charge Q is in coulomb (C).

Direction:

- Remember! Electric field strength is a **vector quantity**.
- A direction of electric field (by conversion) is the direction of the electrostatic force that a positively charged particle will experience at that point.
- The positively charged particle will thus move in the direction of the field and a negatively charged particle will move against the field.

The force experienced by a test charge when placed in an electric field is given by:

$$F = qE$$

Worked example 1

If the magnitude of the electric field strength (intensity) is 3×10^{6} $N \cdot C^{-1}$ at a point, calculate the magnitude of the force acting on a charge of – 7 nC placed at that point.

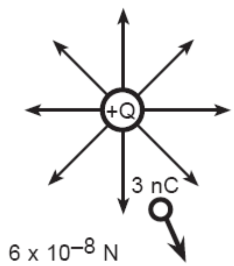
Solution

$$F = qE$$

$$= 7 \times 10^{-9} \times 3 \times 10^{6}$$

$$= 0.021 \text{ N}$$

Electric field strength at a point due to a number of point charges



From Coloumb's Law:

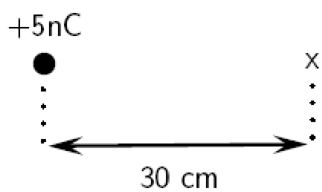
$F = \frac{kQq}{r^2}$ (If we make the one charge Q and the other q.)

From the definition of electric field strength: F = Eq

Therefore, the electric field can be calculated as $E = \frac{kQ}{r^2}$ (where Q is the charge setting the field).

Worked Example 2

Calculate the electric field strength 30cm from a 5nC charge.



Solution

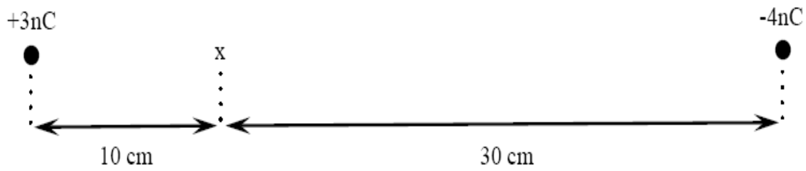
$E = \frac{kQ}{r^2}$

$= \frac{(9 \times 10^{-9)}\ (5 \times 10^{-9}}{(0,3)^2}$

$= {}^{=}5 \times 10^{-16}$ N·C^{-1}

Worked example 3

R and S are two points in the electric field of a small negatively charged sphere Q, Two charges of Q_1 = +3nC and Q_2 = −4nC are separated by a distance of 40cm. What is the electric field strength at a point that is10cm from Q1 and 30cm from Q_2? The point lies between Q_1 and Q_2.



Solution

$E = \frac{kQ}{r^2}$

$= \frac{(9 \times 10^9)(3 \times 10^{-9})}{(0,1)^2}$

$= 2,70 \times 10^3 \text{ N·C}^{-1}$

Then for **Q_2:**

$E = \frac{kQ}{r^2}$

$= \frac{(9 \times 10^9)(4 \times 10^{-9})}{(0.3)^2}$

$= 4,00 \times 10^2 \text{ N·C}^{-1}$

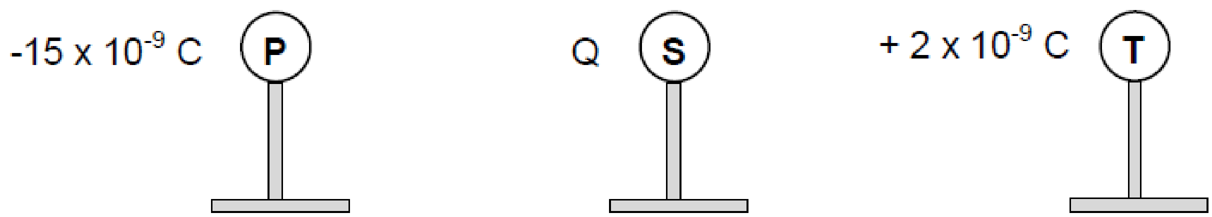
Add the two electric fields because both are in the same direction.
The field is away from Q_1 and towards Q_2.
Therefore,

$E_{total} = 2,70 \times 10^3 + 4,00 \times 10^2 = 3,10 \times 10^3 \text{N·C}^{-1}$

ACTIVITIES

ACTIVITY 1 (DBE: NOV 2018)

Three small identical metal spheres, **P**, **S** and **T**, on insulated stands, are **initially neutral**. They are then charged to carry charges of -15×10^{-9} C, Q and $+2 \times 10^{-9}$ C respectively, as shown below.

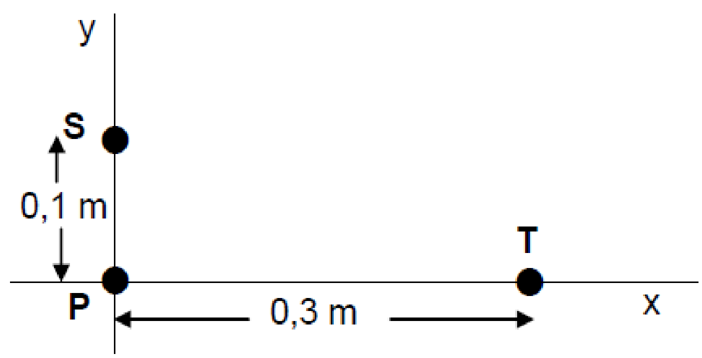


The charged spheres are brought together so that all three spheres touch each other at the same time, and are then separated. The charge on each sphere, after separation, is -3×10^{-9} C.

1.1 Determine the value of charge Q. (2)

1.2 Draw the electric field pattern associated with the charged spheres, **S** and **T** , **after they are separated** and returned to their original positions. (3)

The spheres, each with the **new charge** of -3×10^{-9} C, are now placed at points on the *x*-axis and the *y*-axis, as shown in the diagram below, with sphere **P** at the origin.



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

Calculate the magnitude of the:

1.4 Net electrostatic force acting on sphere **P**. (5)

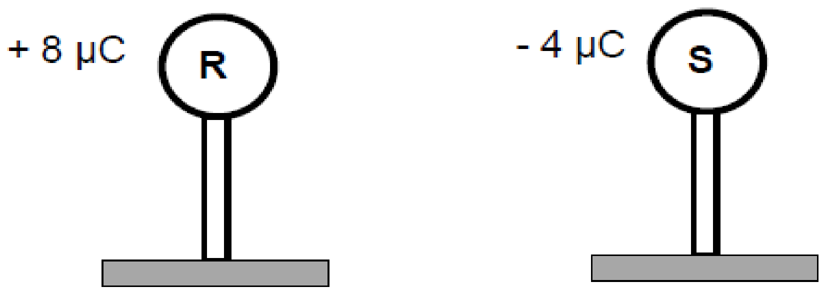
1.5 Net electric field at the origin due to charges **S** and **T**. (3)

1.6 One of the charged spheres, **P** and **T**, experienced this very small increase in mass **after it was charged initially.**

1.6.1 Which sphere P or T, experienced this very small increase in mass?(1)
1.6.2 Calculate the increase in mass by the sphere in QUESTION 1.6.1 (3)

<u>ACTIVITY 2</u> (DBE: NOV 2014)

The diagram below 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.



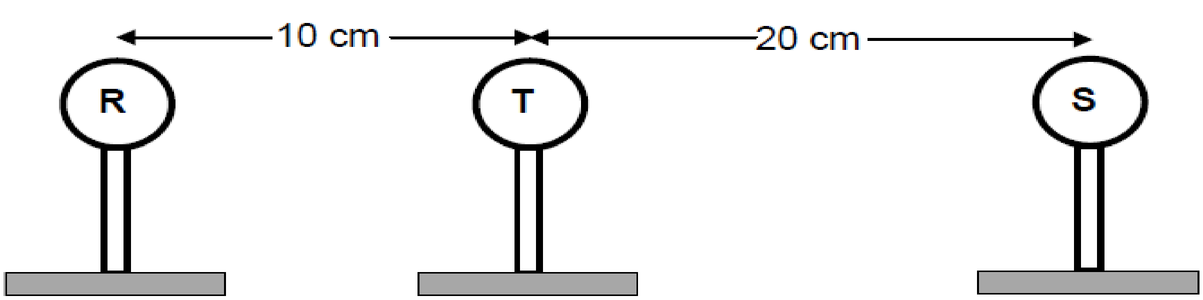
2.1 Explain why the spheres were placed on wooden stands. (1)

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

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

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

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



2.4 Draw a free-body diagram showing the electrostatic forces experienced by sphere T due to spheres R and S. (2)

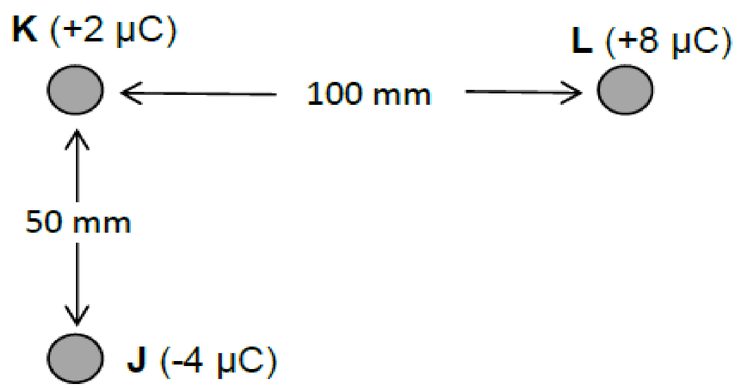
2.5 Calculate the net electrostatic force experienced by T due to R and S. (6)

2.6 Define the *electric field at a point.* (2)

2.7 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)

<u>ACTIVITY 3</u> (METRO CENTRAL 2016)

Three charges J, K and L are arranged on a horizontal plane so that angle JKL is a 90° angle. The charges are -4 μC, +2 μC and +8 μC respectively. J and K are 50 mm apart and K and L are 100 mm apart. J and L are fixed in position while K is free to move.



3.1 Calculate the magnitude of the electrostatic force between charges J and K. (4)

3.2 Draw a free-body diagram showing the electrostatic forces exerted on K due to charges J and L. Also show on the vector diagram how the net force can be determined (3)

3.3 Calculate the magnitude and direction of the net electrostatic force exerted on K due to charges J and L. (4)

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

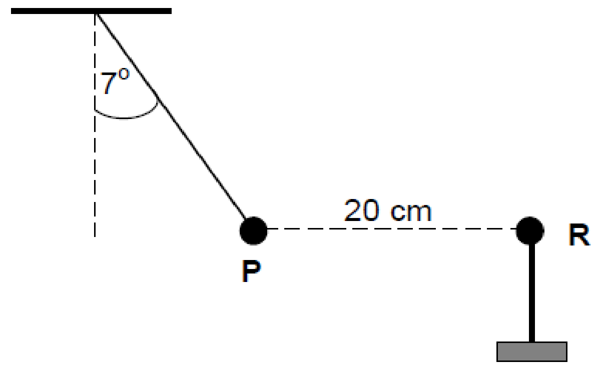
3.5 Calculate the magnitude of the net electric field at K. Give your answer in scientific notation. (3)

<u>ACTIVITY 4</u> (DBE: NOV 2015)

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. Another sphere, **R**, with a charge of – 0,9 μC, on an insulated stand, is brought close to sphere **P**. As a result sphere **P** moves to a position where it is 20 cm from sphere **R**, as shown below. The system is in equilibrium and the angle between the string and the vertical is 7°.

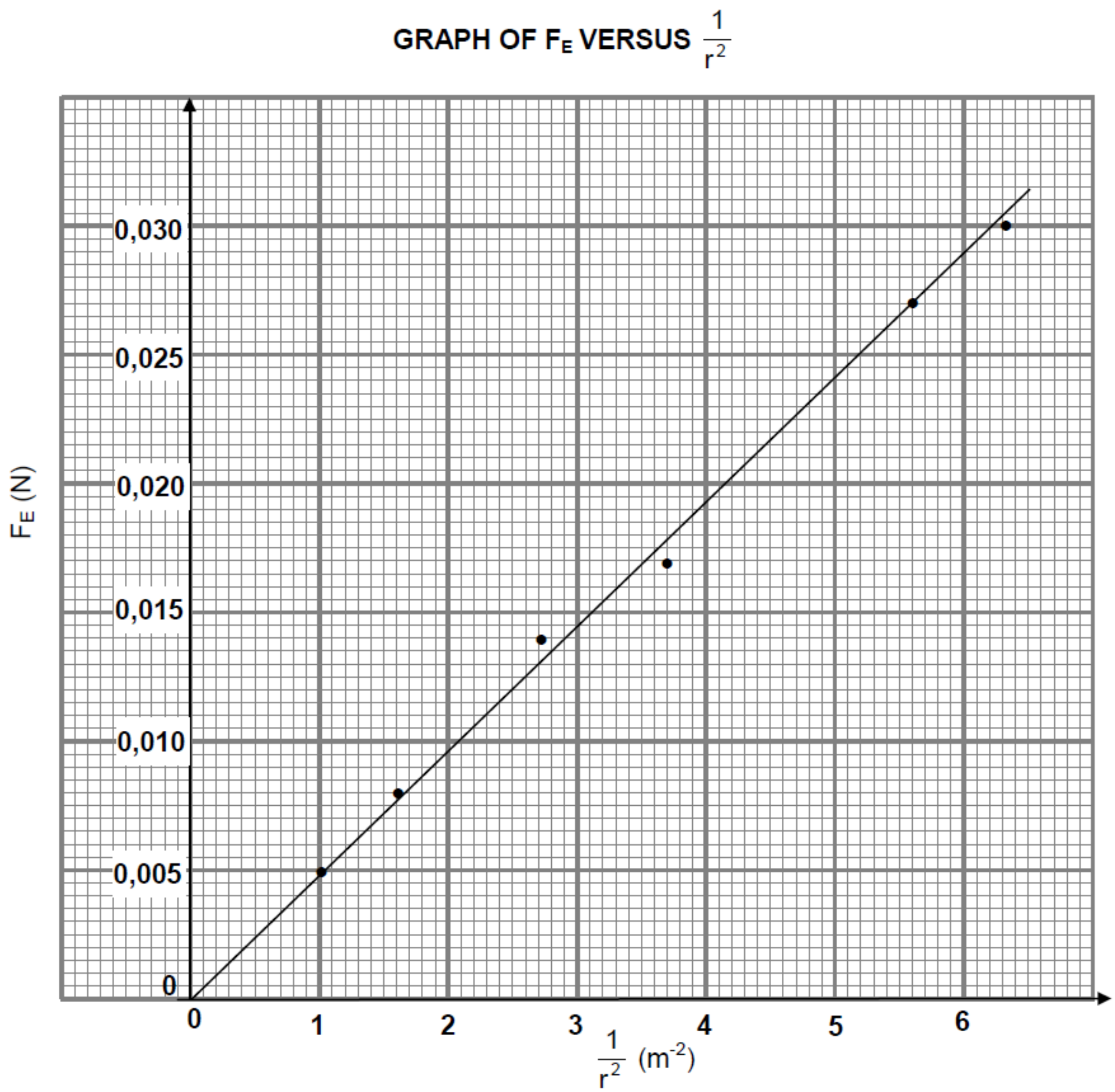


4.1 Draw a labelled free-body diagram showing ALL the forces acting on sphere **P**. (3)

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

<u>ACTIVITY 5</u> (DBE: NOV 2016)

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



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

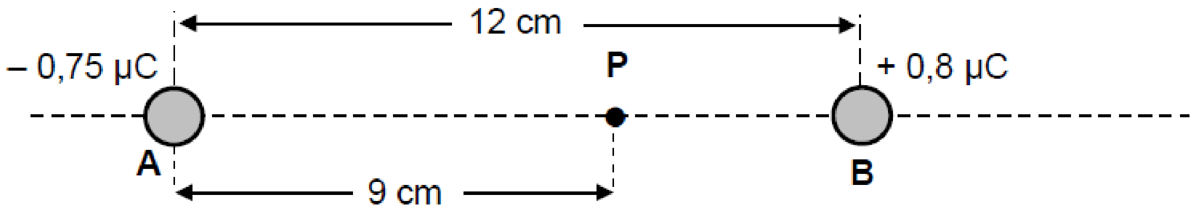
5.1.2 What relationship between the electrostatic force F_E and the square of the distance, r^2, between the charged spheres can be deduced from the graph?(1)

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

5.2 A charged sphere, A, carries a charge of – 0,75 µC.

5.2.1 Draw a diagram showing the electric field lines surrounding sphere A.(2)

Sphere A is placed 12 cm away from another charged sphere, B, along a straight line in a vacuum, as shown below. Sphere B carries a charge of +0,8 µC. Point P is located
9 cm to the right of sphere A.



5.2.2 Calculate the magnitude of the net electric field at point P. (5)

Electric Circuits

What you already know:

- Electric charge flows when electrical potential energy between two points in a conductor differs.
- Electromotive force (emf) is provided by a power source, like a cell (or generator). EMF is described as the **work done per unit charge** by the power source and is measured in **Joule per Coulomb** ($J.C^{-1}$) or Volt (V).
- When no charge is flowing, a voltmeter connected across the cell would record the **EMF**, but once there is charge flowing, then the voltmeter reads the **terminal potential difference** (V).
- Potential difference (voltage) across the ends of a conductor is the **energy transferred (work done) per unit electric charge** flowing through the conductor.

Quick task 1: Write down the equation for potential difference as described above. State which symbol represents potential difference, energy transferred and charge.

- The **rate of flow of electric charge** is called current, symbol I.

*Quick task 2: Explain what the word **rate** mean in the description of current. Also, write an equation to represent the description.*

- *Deduce the unit of measure for current **from the description above**.*
- *Use your equation to calculate the current when 1800 C of charge flow for 2 minutes in a conductor.*

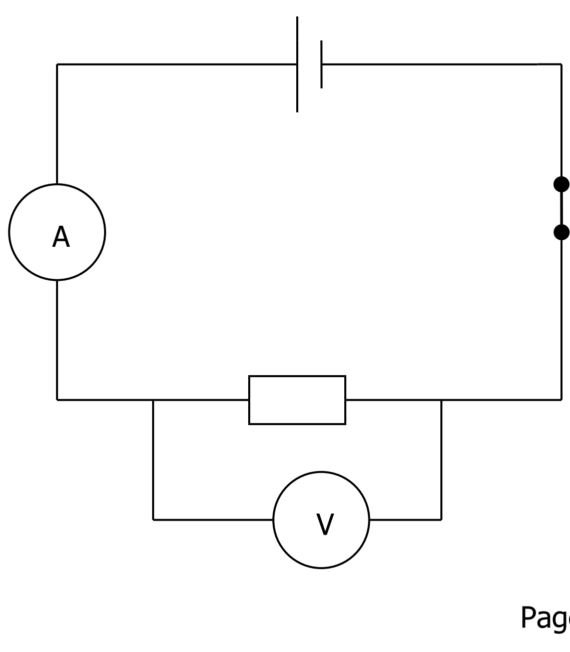
- Remember the two circuit connections. i.e. **series** connection and **parallel** connection.

Quick task 3: Explain how two resistors connected in parallel differ from resistors connected in series in terms of current and potential difference (voltage)

What you need to know:

- Ohm's law states: The **potential difference** across a conductor is **directly proportional** to the **current** in the conductor at **constant temperature.**
- This law describes the **relationship between** the **current** flowing through a conductor **and** the **potential difference.**
- By increasing the number of cells in the circuit we are able to increase the voltage across the ends of the conductor. This increased voltage is measured using a voltmeter connected across the ends of the conductor. This changes the current flowing through the conductor, which is measured using an ammeter.

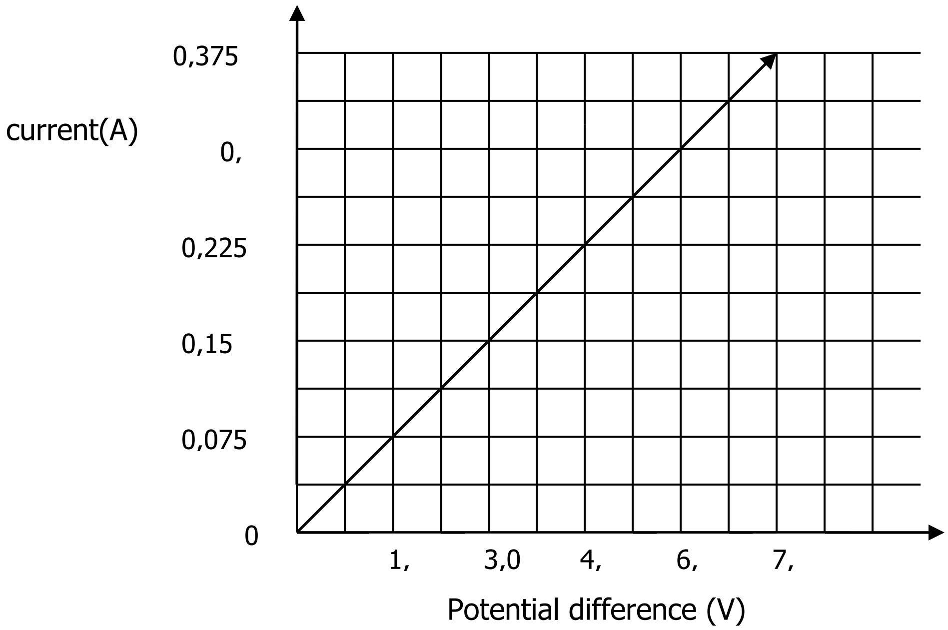
Quick task 4: Draw a sketch (no values necessary) graph to illustrate the relationship between voltage and current. Remember! Label your axis.



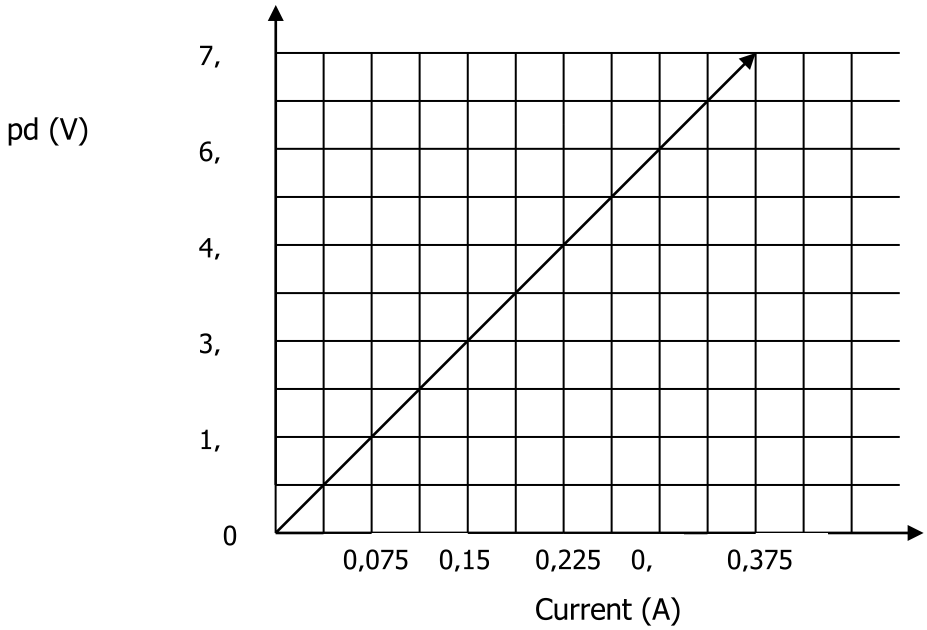
By increasing the number of cells in the circuit we are able to increase the p.d. across the ends of the conductor. This increased p.d. is measured using a voltmeter connected across the ends of the conductor. This changes the current flowing through the conductor, which is measured using an ammeter.
If an experiment was conducted using 5 cells, each of emf 1,5V, the following is a possible set of results that could be obtained.

p.d. (V)	***I (A)***
1,5	0,075
3,0	0,15
4,5	0,225
6,0	0,3
7,5	0,375

A graph of p.d. (x-axis) vs current (y-axis) gives the following



From the above graph, the potential difference across the ends of the conductor is directly prportional to the current flowing through the conductor.
NB: Potential difference is an independent variable
The folowing graph is drawn:



The gradient of this graph is a constant and yields: $R = \frac{\Delta V}{\Delta I}$

- R is the resistance of the conductor.
- Resistance is measured in Ohms (Ω)

Resistance

As charge flows, there is **opposition** to it. Remember what this opposition is called? **Resistance! (R)**
The unit of measure for resistance is Ohm (Ω). Pause and remind yourself of the factors that affect the resistance.

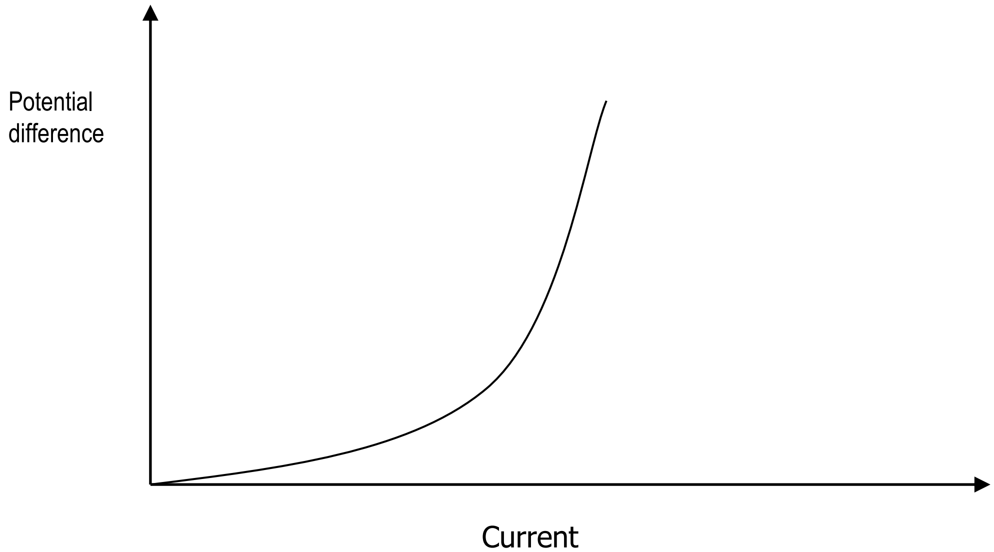
Resistance in a wire is the opposition of a wire to the flow of electricity. It is caused by collisions between the electrons and the atoms in the wire. The hotter the wire, the more chance there is of a collision. Therefore hot wires have more resistance.

One Ohm: A conductor has a resistance of one ohm if a current of one ampere passes through it when a p.d. of one volt is maintained across its ends.

Ohmic and non-Ohmic conductors:
Conductors that obey Ohm's Law are said to be Ohmic conductors, for example a piece of nichrome wire.

Conductors that do not obey Ohm's Law are said to be non-Ohmic conductors, example diodes.

A graph of potential difference vs current flowing for a diode may look like



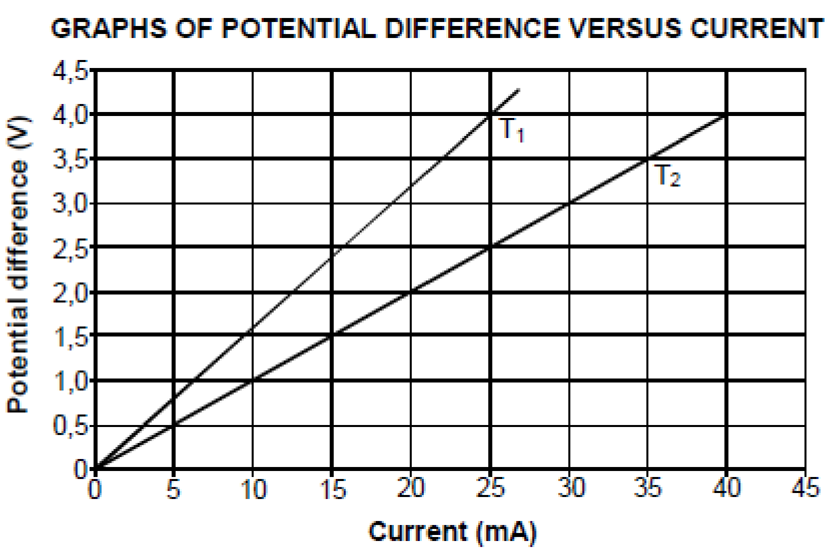
this:

Factors affecting the resistance of a conductor:

- Length of the conductor. The longer the conductor the greater the resistance.
- Cross sectional area. The greater the cross sectional area of a conductor the lesser the resistance.
- Temperature. An increase in temperature of a conductor increases resistance.
- Kind of material used

WORKED EXAMPLE 1(NOV 2013 DBE)

The two graphs below represent the relationship between potential difference and current in a metal wire at two different constant temperatures, T_1 and T_2.



1.1 Calculate the resistance of the metal wire at temperature T_1. (3)

1.2 Which graph was obtained at the higher temperature?
Give a reason for the answer. (3)

1.3 The metal wire is an ohmic conductor. Justify this statement by

1.4 Calculate the power dissipated in the metal wire when the current in it is 25 mA at temperature T_2. (3)

referring to the graphs. (1)

.2

.2.1 Both switches open:

$R = 6\ \Omega + 1\Omega + 2\Omega = 9\ \Omega$ ✓

$R = \frac{V}{I}$ ✓

$9 = \frac{4,5}{I}$ ✓

$\therefore I = 0,5\ A$ ✓ (4)

.2.2 Both switches closed:

$V_{6\Omega} = IR = (0,5)(6) = 3\ V$ ✓

$V_{2\Omega} = 4,5 - 3 = 1,5\ V$ ✓

$I_{2\Omega} = \frac{V}{R} = \frac{1,5}{2} = 0,75\ A$ ✓

$I_R = 0,75 - 0,5 = 0,25\ A$ ✓

$R = \frac{V}{I} = \frac{3}{0,25}$ ✓ $= 12\ \Omega$ ✓

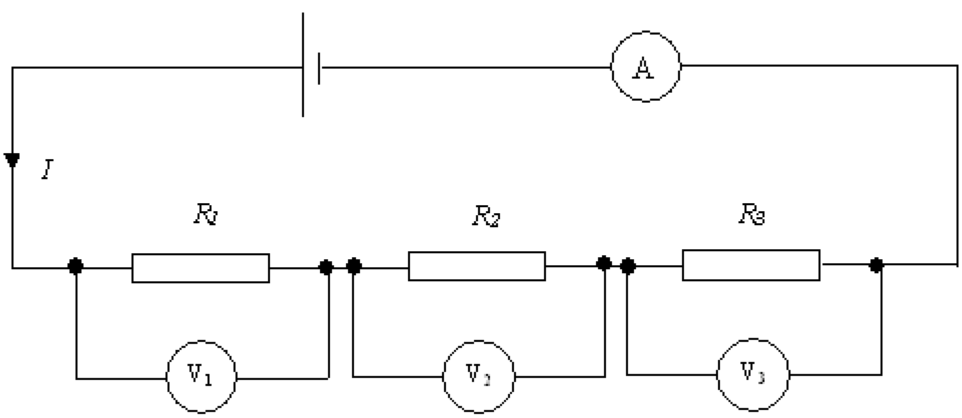
(6)

[20]

Series and Parallel Circuits

Series Circuits

In a **series** circuit, the electrons in the current have to pass through all the components, which are arranged in a line. Consider a typical series circuit in which there are three resistors of value R_1, R_2, and R_3. The values may be the same, or different.



There are two key points about a series circuit:

- The **current** throughout the circuit is the same
- The **voltages** add up to the battery voltage.

Therefore:

$V_T = V_1 + V_2 + V_3$

From Ohm's Law we know:

- $V_T = IR_T$;
- $V_1 = IR_1$;
- $V_2 = IR_2$;
- $V_3 = IR_3$

$\Rightarrow IR_T = IR_1 + IR_2 + IR_3$

Therefore: $R_T = R_1 + R_2 + R_3$

Parallel Resistors

Parallel circuits have their components in parallel **branches** so that an individual electron can go through one of the branches, but not the others. The current splits into each of the branches. Look at this circuit:

In this case, the current will split into three pathways. For a parallel circuit we know two things:

- The voltage across each branch is the same
- The currents in each branch add up to the total current.

From this we can write: $I_{tot} = I_1 + I_2 + I_3$

From Ohm's Law, I = V/R, we can write:

$$I_T = \frac{V}{R_T};\quad I_1 = \frac{V}{R_1};\quad I_2 = \frac{V}{R_2};\quad I_3 = \frac{V}{R_3}$$

$$\Rightarrow \frac{V}{R_T} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

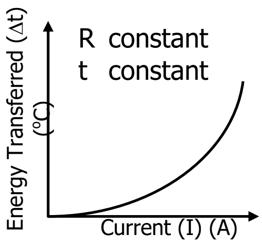
$$\Rightarrow \frac{1}{R_{Tot}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

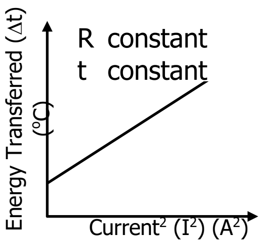
This is true for any number of parallel resistors.

Relationship between Energy Transferred and the Current

From the experimental investigation it was found that the energy transferred is directly proportional to the current squared.

energy transferred (Q) α I^2

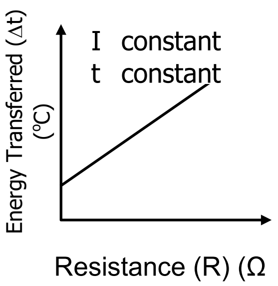




Relationship between Energy Transferred and the Resistance

From the experimental investigation it was found that the energy transferred is directly proportional to the resistance.

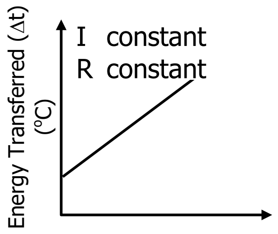
Energy transferred(Q) α R



Relationship between Energy Transferred and the Time

From the experimental investigation it was found that the energy transferred is directly proportional to the time.

energy transferred (Q) α t



From these experiments we can conclude the following:

$$W \;\alpha\; I^2$$
$$W \;\alpha\; R$$
$$W \;\alpha\; t$$

Combining these relationships we have

$$W \;\alpha\; I^2Rt \text{ or } W = kI^2Rt$$

In SI units, the value of k is 1

Hence $W = I^2Rt$

W Electric work done in J
I Current in A
R Resistance in Ω
t Time in s

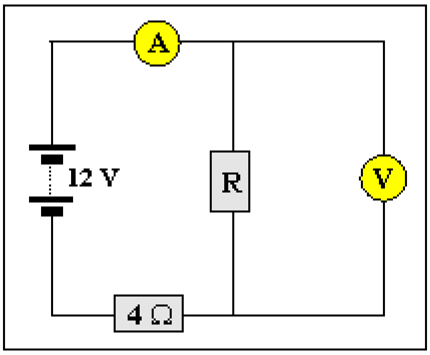
Using previous equations, V = IR, W = VQ and Q = It, we can write the above equation in many forms together with equations for power (P = W)

Work Done	Power
$W = I^2Rt$	$P = I^2R$
$W = VIt$	$P = VI$
$W = \frac{V^2t}{R}$	$P = \frac{V^2}{R}$

ACTIVITIES

MULTIPLE CHOICE QUESTIONS

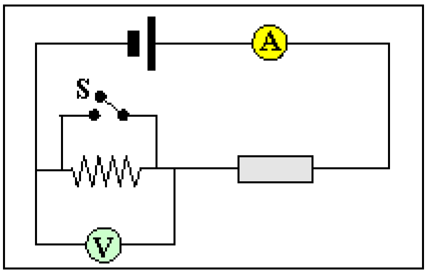
1.1 In the circuit shown, the resistance of the ammeter, the battery and the connecting wires are negligible. The voltmeter has a very high resistance. The ammeter reads 1,5 A. What is the reading on the voltmeter?



A 4 V
B 6 V
C 8 V
D 12 V

1.2 What will happen to the voltmeter and ammeter readings if the switch S is closed?

	voltmeter reading	ammeter reading
A	becomes zero	remains the same
B	becomes zero	increases
C	remains the same	decreases
D	decreases	increases



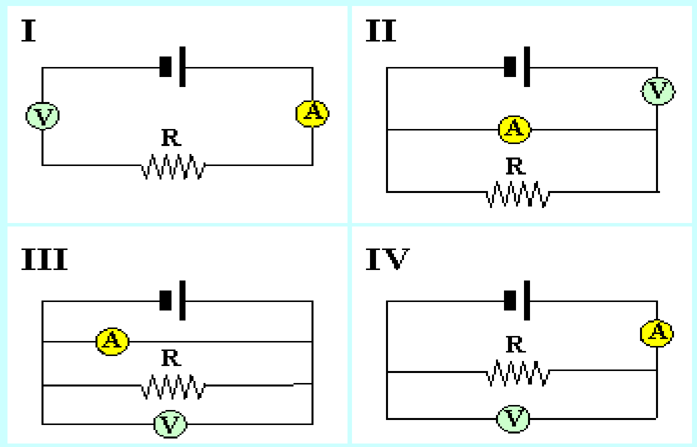
1.3 Which one of the circuits shown in the diagram below can be used to determine the resistance of R?

A I

B II

C III

D IV



1.4 A battery is connected to a small lamp. If a second identical lamp is connected in series with the first, what will happen to the current provided by the battery?

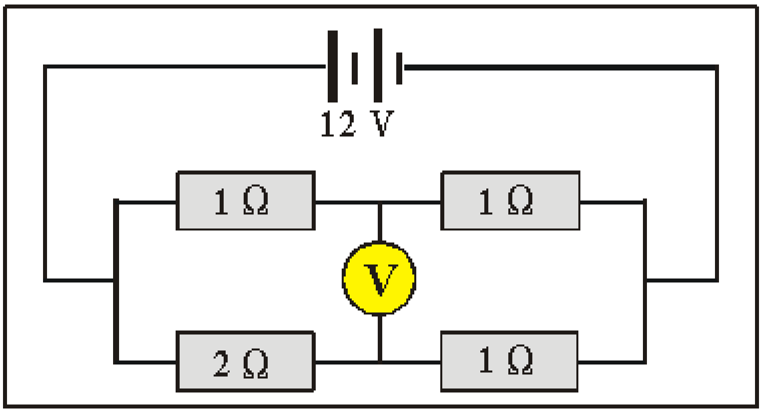
A it will decrease
B it will remain the same
C it will increase
D it will become zero

1.5 Two light bulbs are marked 230 V; 75 W and 230 V; 150 W. If the first bulb has a resistance R, then the resistance of the second is …

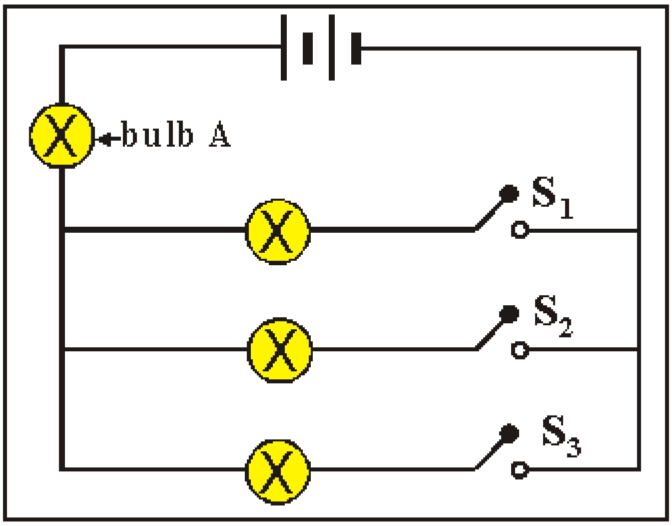
A ¼ R
B ½ R
C 2 R
D 4 R

1.6 Consider the electric circuit shown in the diagram at the right.
The reading on the voltmeter V is ...

A 0 V
B 2 V
C 4 V
D 6 V



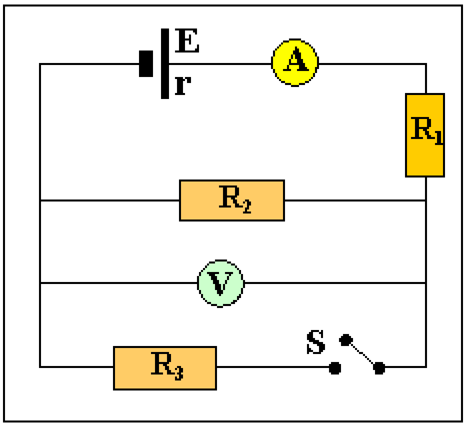
1.7 Gugu connected four identical light bulbs in a circuit as shown to the right. She observes that the brightness of bulb A varies if some of the switches are closed. In which case will bulb A burn brightest?



A S_1 closed with S_2 and S_3 open
B S_1 and S_2 closed with S_3 open
C S_1, S_2 and S_3 closed
D S_1, S_2 and S_3 open

The information given in the box refers to questions 8 and 9:

The battery in the circuit has an internal resistance r and an emf E. The resistance of the ammeter and the conductors is negligible and the voltmeter has a high resistance



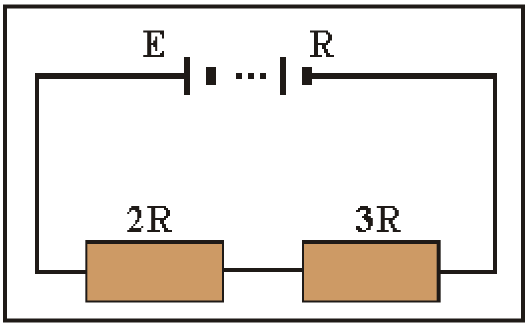
1.8 When the switch S is closed, the …

	voltmeter reading	ammeter reading
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

1.9 When the switch S is closed the power in the resistors R_1 and R_2 …

	power in R_1	power in R_2
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

1.10 Two resistors of resistance 2R and 3R are connected in series with a battery, which has an emf of E and an internal resistance R. What is the potential difference across the resistor of resistance 2R?

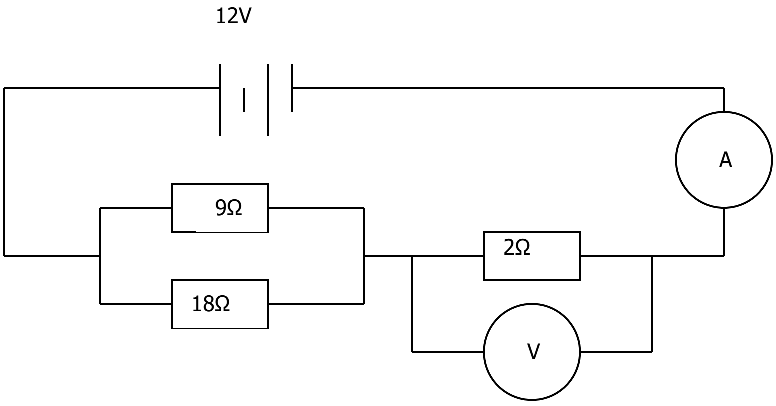


A E/3
B 2E/5
C E/2
D 2E

SECTION B

ACTIVITY 1

The ammeter and the battery have negligible internal resistance as indicated in the diagram below. The potential difference across the battery is 12 V.



Calculate:

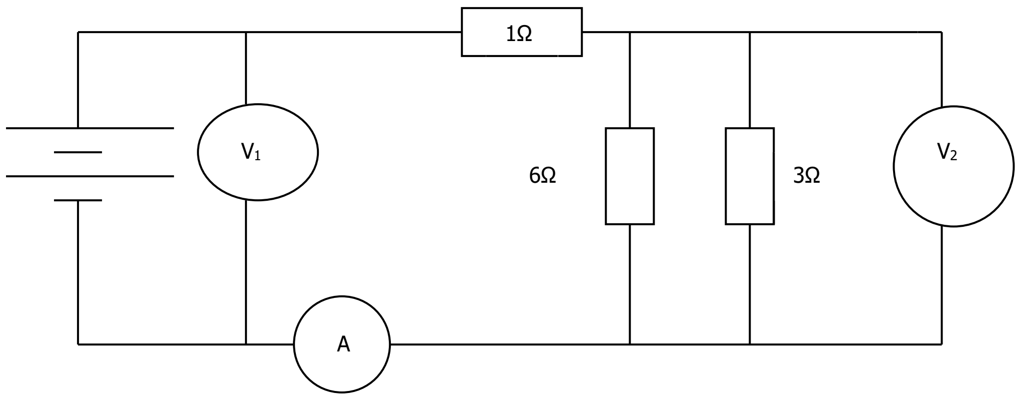
1.1 the equivalent resistance of the circuit

1.2 the voltmeter reading

1.3 the heat produced in 1 minute in the 2 Ω resistor.

ACTIVITY 2

A circuit is connected as shown in the diagram below. The battery has an emf of 12 V and a significant internal resistance.



The reading on the ammeter is 3 A.
Calculate the:

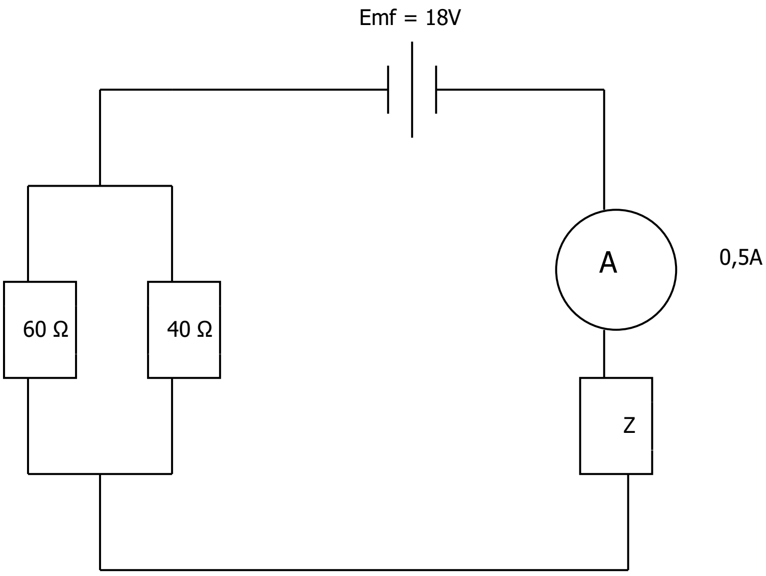
2.1 reading on voltmeter V_1

2.2 reading on the voltmeter V_2

2.3 energy transferred in the 3 Ω resistor in 2 minutes

ACTIVITY 3

In the given circuit, the battery has an emf of 18 V. The resistor Z is of unknown value. The ammeter reads 0,5 A



3.1 What is meant by the emf of a battery?

3.2 Calculate the equivalent resistance of the parallel branch.

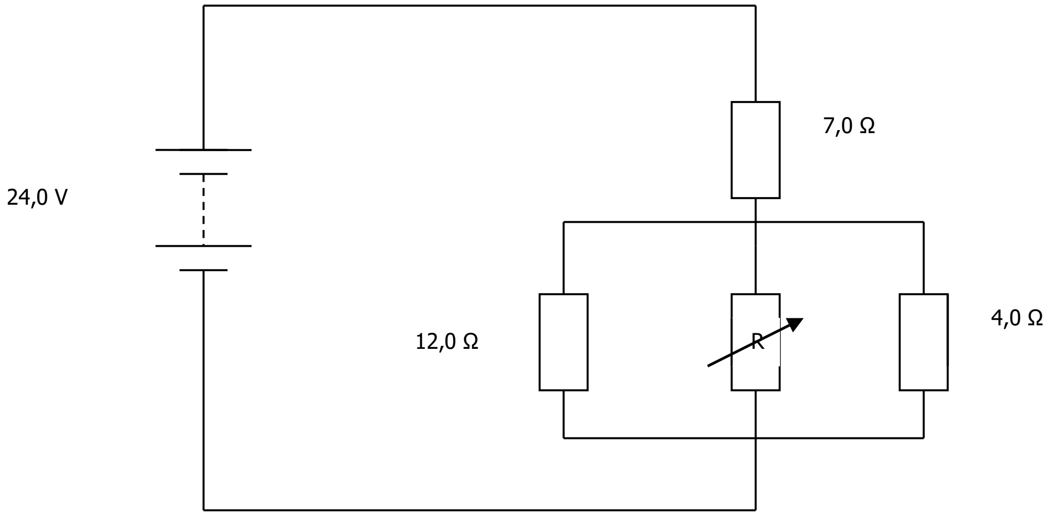
3.3 Calculate the potential difference across the parallel branch.

3.4 If the potential difference across Z is 3V, calculate the value of Z.

3.5 Calculate the power developed in the 60 Ω resistor.

ACTIVITY 4

The circuit shown below consists of a number of resistors connected to a 24,0V battery of negligible internal resistance. The resistor marked R is a variable resistor with values of resistance from zero to infinity.



The variable resistor R is set so that the battery supplies power to the resistors at a rate of 60,0W.

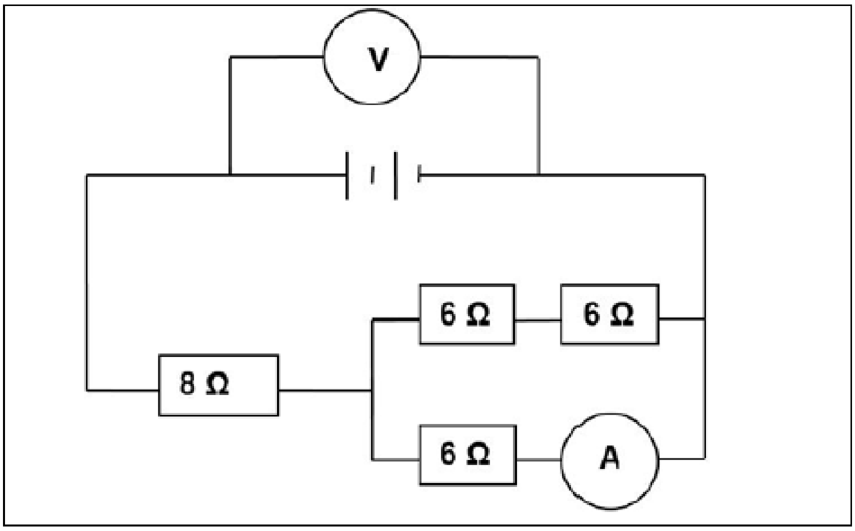
4.1 Define the resistance of a conductor.

4.2 Calculate the potential difference across the 7,0 Ω resistor.

4.3 Find the value of R.

ACTIVITY 5 **(EC- N0V 2015)**

In the circuit below, the resistance of the battery, ammeter and connecting wires can be ignored



The power of the 8 Ω resistor is 0, 5 W.

5.1 Calculate the reading on the:

5.1.1 voltmeter (V) (8)

5.1.2 ammeter (A) (4)

5.2 A television is labeled: 240 V; 750 W.

5.2.1 Calculate the resistance of the television's resistor. (4)

5.2.2 Calculate the costs of using the television for 6 hours if electricity costs R1,04 per kWh. (3)

[19]

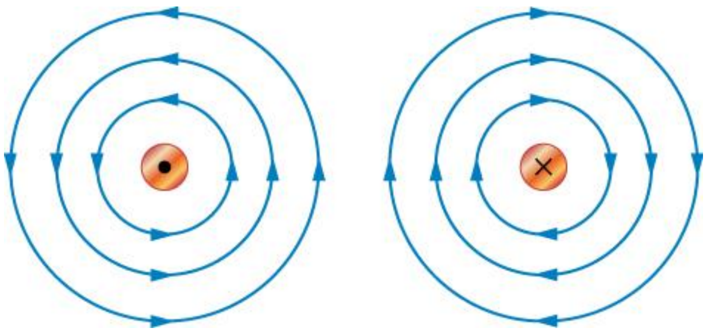
ELECTROMAGNETISM

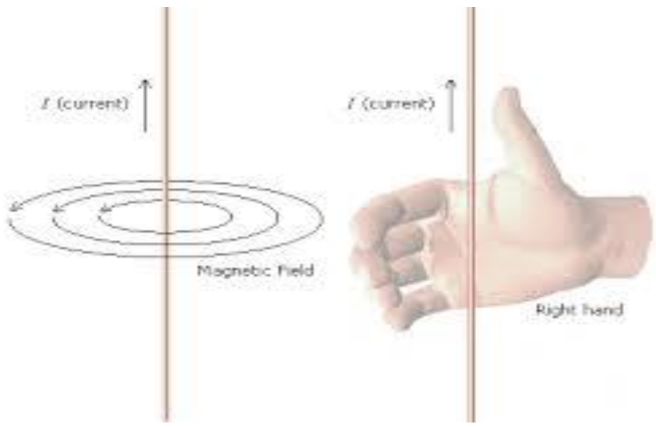
- **Magnetic field associated with current-carrying conductors**

1. Magnetic field around a straight conductor

Magnetic field lines produced by the current form circles with, with the wire at the centre (illustrated below).

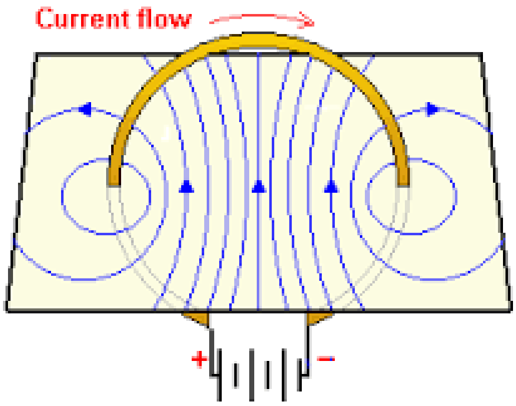
Right Hand rule is used to determine the direction of the field.
The current going into the paper (into the page) is represented by $\otimes$ and the current leaving the page (out of page) is represented by $\odot$.





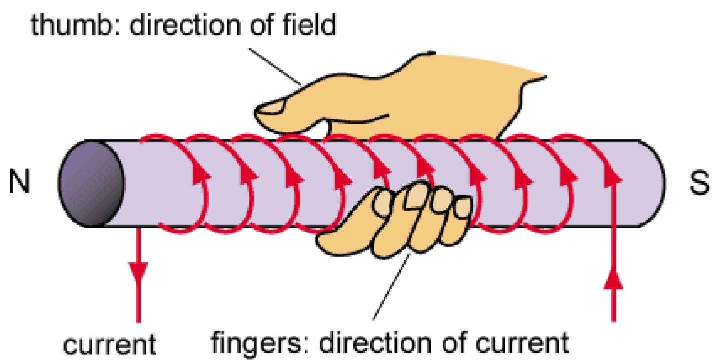
2. Magnetic field around a circular wire (loop)

Magnetic field lines closest to the wire are circular.
Magnetic field lines at the centre of the loop are straight and parallel to each other.



3. Magnetic around a solenoid (cylindrical coil of wire)

- Magnetic field lines form closed loops.
- On the outside of the solenoid, the direction of the field is from north to south (like in a bar magnet).
- Inside the solenoid the direction of field is south to north.
- The polarity of the current carrying solenoid is determined by Right Hand Rule.
- Thumb is pointing at the direction of the field.
- Curved fingers are pointing in the direction of conventional current.



FARADAYS LAW

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

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

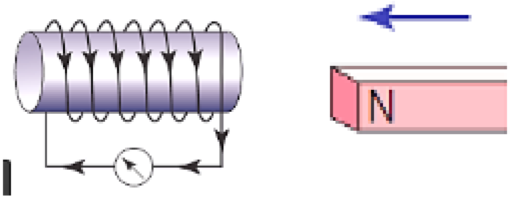
- ε is the induced emf
- ΔΦ is the change magnetic flux.
- N is the number of loops
- Emf has a negative sign because it opposes the change in flux

‘

Current induced by changing magnetic field

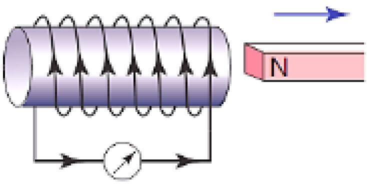
- When there is a change in magnetic field around the conductor, current is induced.
- Current is induced when there is relative motion between the coil and the magnet
- No current is induced if magnet is held stationary in the coil.
- The direction of induced current is determined by Right Hand Rule.
- If thumb points in the direction of field, curved fingers point in the direction of current and vice versa.
- The induced current flows in a direction so as to set up the magnetic field to oppose the change in magnetic flux.

Figure 1:
Magnet moving into the solenoid



- The distance between the magnet and the solenoid decreases and so magnetic flux inside the solenoid increases.
- The magnetic field of the magnet is towards left.
- To oppose this increase towards left, the field produced by induced current is towards right.

Figure 2
Magnet pulled out from the solenoid



- The distance between the magnet and the solenoid increases and so the magnetic flux inside the solenoid decreases.
- To oppose this decrease, the field produced by induced current flowing in the direction indicated is towards left.

Factors influencing the magnitude of the induced current

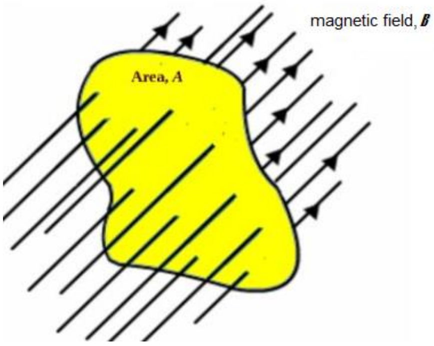
- Strength of magnetic field- the stronger the magnet, the greater the induced current.
- The number of turns in the coil- the greater the number of turns the greater the induced current.
- The speed at which magnet and coil are moved relative to each other. The higher the speed, the greater the induced current.

Magnetic flux

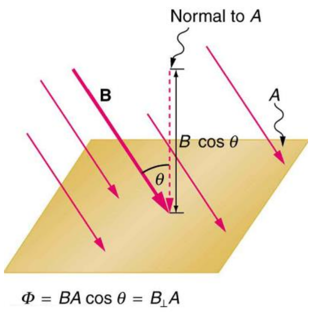
Magnetic flux (Φ)is the product of the component of magnetic field (B cos θ) perpendicular to a surface and the area(A) of the surface the field passes through

.

Φ =BA cos θ



Θ is the angle between the magnetic field and the normal to the cross sectional area.



Unit of magnetic flux is weber (Wb).
1 Wb = 1 T

Worked example 1

A 200-turn circular coil is placed in a magnetic field such that the field is perpendicular to the surface of each loop of the coil at all times. As the coil rotates, the magnetic field changes at a constant rate from 0, 22 T to 0, 42 T in 3, 2 x 10^{-2} s. The emf induced in the coil during this time is -15, 2 V.

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

1.2 Calculate the:

1.2.1 Change in magnetic flux through the circular loop. (4)

1.2.2 Radius of the coil. (4)

1.3 The coil now rotates in the opposite direction and the magnetic field changes from 0,42 T to 0,22 T in the same time interval. Write down the induced emf. (1)

Solution

1.1 The magnitude of the induced emf across the ends of a conductor is directly proportional to the rate of change in the magnetic flux linkage with the conductor.

1.2 .1 $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$

$-15,2 = -(200)\frac{\Delta\Phi}{3,2 \times 10^{-2}}$

$\Delta\Phi$= 2.43 X 10^{-3} Wb or 2, 43 x 10^{-3} $v.s^{-1}$

1.2.2 $\Delta\Phi = (Bf - Bi)A\cos\theta$

$2.432 \times 10^{-2} = (0,42 - 0,22)\,A\cos 0°$

$A = 0,012\ m^2$

Area of circle = πr^2

$0.012 = \pi r^2$

$r = 6,22 \times 10^{-2}\ m$

1.3 15, 2 V

ACTIVITIES

ACTIVITY 1

A single circular loop of wire, 12 cm in diameter, is placed in a 0, 6 T magnetic field. It is removed from the magnetic field in 0, 04 s.

1.1 Calculate:

1.1.1 The flux which is linked to this coil. (4)

1.1.2 The average induced emf. (4)

1.2 How does the *emf* change if …

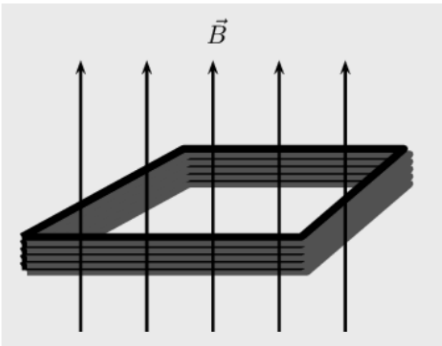
(Write only INCREASES, DECREASES or REMAINS THE SAME)

1.2.1 the magnetic field strength changes to 0,5 T? (1)

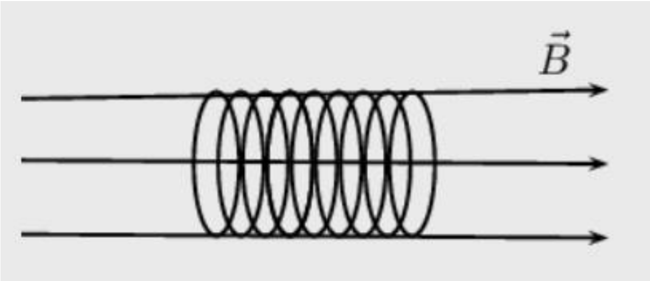
1.2.2 the coil is removed from the field in 0,02 s? (1)

ACTIVITY 2

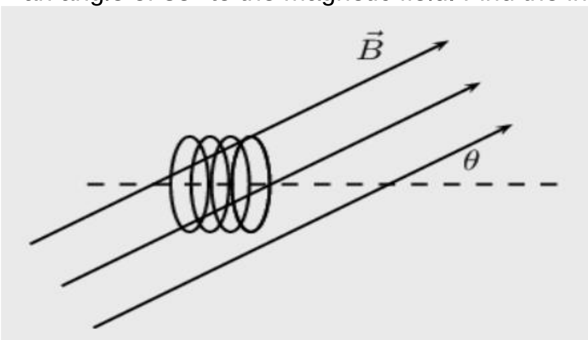
2.1 Consider a flat square coil with 5 turns. The coil is 0,50 m on each side and has a magnetic field of 0,5 T passing through it. The plane of the coil is perpendicular to the magnetic field: the field points out of the page. Use Faraday's Law to calculate the induced emf, if the magnetic field is increases uniformly from 0,5 T to 1 T in 10 s. Determine the direction of the induced current.



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



2.3 Consider a circular coil of 4 turns with radius 3×10^{-2} m. The solenoid is subjected to a varying magnetic field that changes uniformly from 0, 4 T to 3, 4 T in an interval of 27 s. The axis of the solenoid makes an angle of 35° to the magnetic field. Find the induced emf.

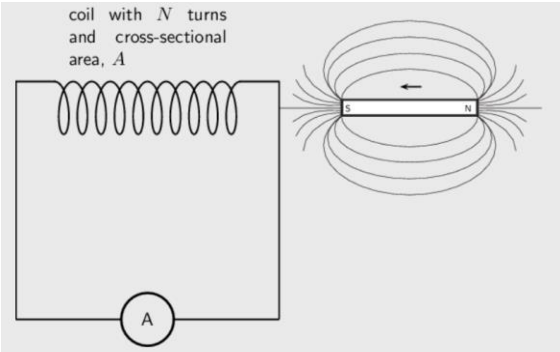


ACTIVITY 3

3.1 State Faraday's Law of electromagnetic induction in words and write down a mathematical relationship.

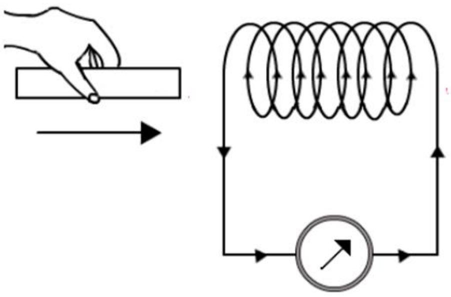
3.2 Describe what happens when a bar magnet is pushed into or pulled out of a solenoid connected to an ammeter. Draw pictures to support your description.

3.3 Use the Right Hand Rule to determine the direction of the induced current in the solenoid below



ACTIVITY 4 (Nov 2014 DBE)

In the diagram below a bar magnet is being pushed into a coil. The current induced in the coil is in the direction indicated.



4.1. Write down the polarity (north pole or south pole) of the end of the coil facing the bar magnet, as the bar magnet approaches the coil. (2)

4.2 Which end of the bar magnet is approaching the coil? Write down only NORTH POLE or SOUTH POLE (1)

4.3. Write down what will be observed on the galvanometer if the bar magnet is held stationary inside the coil. Give a reason for the answer. (2)
Faraday's law of electromagnetic induction plays a very important role in the generation of electricity.

4.4 Write down Faraday's law of electromagnetic induction in words. (2)

A coil of 100 turns, each of area 4,8 x 10^{-4} m^2, is made from insulated copper wire. The coil is placed in a uniform magnetic field of 4 x 10^{-4} T in such a way that the angle between the magnetic field and the normal to the plane of the coil is 30°. The coil is then rotated so that the angle changes to 70° in a time interval of 0,2 s.

Calculate the:

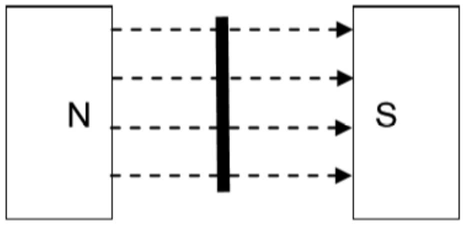
4.5 Magnitude of the emf induced in the coil (5)

4.6 Current induced in the coil if it has an effective resistance of 2 Ω (3)

[15]

<u>ACTIVITY 5</u>(DBE: NOV 2018)

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



An emf of 7 V is induced in the coil.

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

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

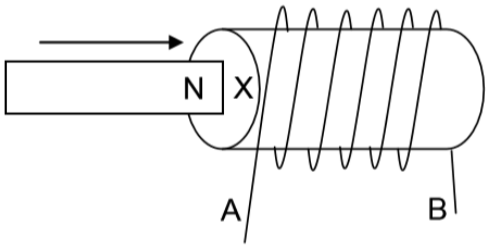
5.3 Calculate the magnitude of the magnetic field. (4)

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

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

5.5 Explain the answer to QUESTION 5.4. (1)

The north pole of a bar magnet is pushed into a solenoid, as shown in the sketch below.

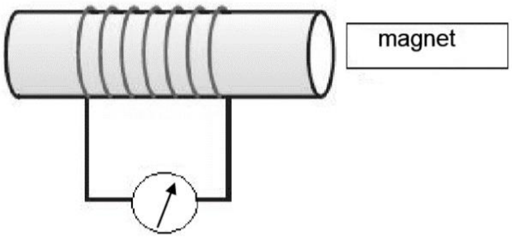


5.6 Which pole will be induced at point X? Write only NORTH or SOUTH. (1)

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

<u>ACTIVITY 6</u> (DBE: NOV 2015)

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



6.1.1 State TWO ways in which the deflection on the galvanometer can be increased. (2)

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

6.2.1 Calculate the magnetic flux linkage. (3)

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

6.2.2 Calculate the number of turns in the coil. (1)

SOLUTIONS

ACTIVITY 1

1.1

$Q_{net} = \dfrac{Q_1 + Q_2 + Q_3}{3}$

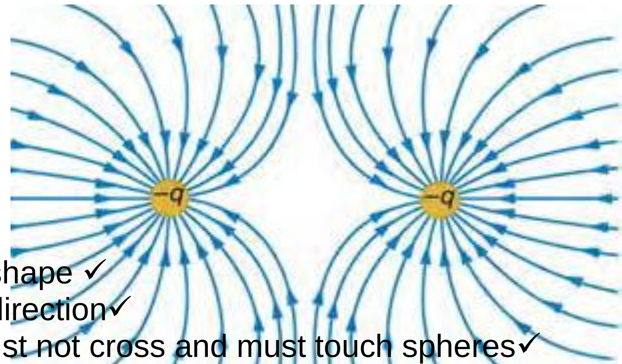
$-3 \times 10^{-9} = \dfrac{15\times10^{-9} + Q + 2\times10^{-9}}{3}$

1 mark for any

$Q = +4 \times 10^{-9}$ C ✓

(Award full marks if only correct answer) (2)

1.2



NOTES

Correct shape ✓

Correct direction ✓

Lines must not cross and must touch spheres ✓ (3)

1.3 The magnitude of the electrostatic force exerted by one point charge (Q1) on another point charge (Q2) is directly proportional to the product of the (magnitudes) of the charges and inversely proportional to the square of the distance (r) between them ✓✓ (2)

NOTE: -1 for each key word/phrase omitted.

1.4

$F = \dfrac{kQ_1Q_2}{r^2}$ ✓

$F_{SP} = \dfrac{(9\times10^9)(3\times10^{-9})(3\times10^{-9})}{(0,1)^2}$ ✓

= 8,1 x 10-6 N downwards

$F_{TP} = \dfrac{(9\times10^9)(3\times10^{-9})(3\times10^{-9})}{(0,3)^2}$ ✓

= 9×10^{-7} N left (0,9 X 10-6 N to the left)

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

$F_{net} = \sqrt{(8,1\times10^{-6})^2 + (0,9\times10^{-6})^2}$ ✓

Or

$F_{net} = \sqrt{(81\times10^{-7})^2 + (9\times10^{-7})^2}$

1 mark for any
1 punt vir enige

Fnet = 8,15 x 10-6 N / 81,49 x 10-7 N ✓ (5)

1.5

POSITIVE MARKING FROM 1.4	
$E = \frac{F}{q}$ ✓ $= \frac{8,15 \times 10^{-6}}{3 \times 10^{-9}}$ ✓ = 2,72 x 10^3 N.C^{-1} ✓	$E_s = \frac{kQ}{r^2}$ $= \frac{(9 \times 10^9)(3 \times 10^{-9})}{(0,1)^2}$ = 2 700 N.C^{-1} $E_T = \frac{kQ}{r^2}$ $= \frac{(9 \times 10^9)(3 \times 10^{-9})}{(0,3)^2}$ = 300 N.C^{-1} $E_{net} = \sqrt{E_S^2 + E_T^2}$ $= \sqrt{(2700)^2 + (30)^2}$ = 2716,62 N.C^{-1}

(3)

1.6.1 Sphere✓ (1)

1.6.2

$n_e = \frac{q}{q_e}$

$= \frac{-15 \times 10^{-9}}{-1,6 \times 10^{-19}}$ ✓

= 9,38 x 10^{10}

mass gained = $n_e m_e$ ✓

m gained = (9,38 x 10^{10})(9,11 x 10^{-31})

= 8,55 x 10^{-20} kg ✓ (85,45 x 10^{-21} kg) (3)

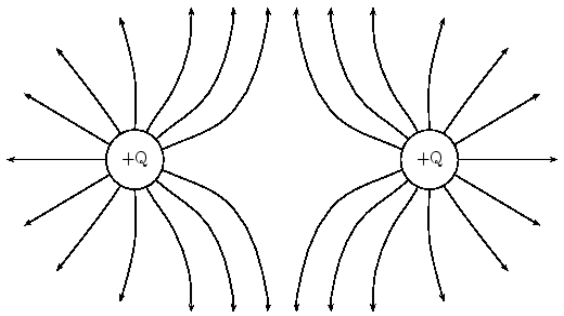
ACTIVITY 2

7.1 To ensure that charge does not leak to the ground/insulated. ✓

(1)

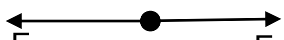
7.2 Net charge = $\frac{Q_R + Q_S}{2} = \frac{+8+(-4)}{2}$ ✓= 2µC✓ (2)

7.3



Criteria for sketch:	Marks
Correct direction of field lines	✓
Shape of the electric field	✓
No field line crossing each other / No field lines inside the spheres/	✓

7.4



(2)

7.5

OPTION 1/*OPSIE 1*

$F = k\dfrac{Q_1Q_2}{r^2}$ ✓

$F_{ST} = (9\times10^9)\dfrac{(1\times10^{-6})(2\times10^{-6})}{(0,2)^2}$ ✓ ✓ $= 0,45$ N / $4,5\times10^{-1}$ N left

OR/*OF*

$F_{TS} = \dfrac{1}{4}F_{RT} = \dfrac{1}{4}(1,8) = 0,45$ N

$F_{RT} = 9\times10^9\times\dfrac{(2\times10^{-6})(1\times10^{-6})}{(0,1)^2}$ ✓ $= 1,8$ Nright

OR/*OF*

$F_{RT} = 4F_{ST} = 4(0,45) = 1,8$ N right /

$F_{net} = F_{ST} + F_{RT} = \underline{1,8 + (-0,45)}$ ✓

$= \underline{1,35\ N}$ or towards sphere S / or <u>right</u> *S* ✓ (6)

OPTION 2/*OPSIE 2*

$E_R = \frac{kQ}{r^2} = \frac{(9\times10^9)(2\times10^{-6})}{(0,1)^2}$ ✓= $1,8 \times 10^6$ N.C^{-1} right

$E_s = \frac{kQ}{r^2} = \frac{(9\times10^9)(2\times10^{-6})}{(0,2)^2}$ ✓= $4,5 \times 10^5$ N.C^{-1} left

$E_{net} = 1,8 \times 10^6 - 4,5 \times 10^5$ ✓= $1,35 \times 10^6$ N.C^{-1}right

F = EQ ✓= $(1,35 \times 10^6)(1 \times 10^{-6})$ ✓
= 1,35 N towards sphere S ✓ (6)

7.6 Force experienced✓per unit positive charge✓placed at that point. (2)

7.7

OPTION 1/*OPSIE 1*

$E = \frac{F}{q}$ ✓= $\frac{1,35}{1\times10^{-6}}$ ✓=$1,35 \times 10^6$ N·C^{-1}✓ (3)

OPTION 2/*OPSIE 2*

$E_R = \frac{kQ}{r^2}$ ✓= $\frac{(9\times10^9)(2\times10^{-6})}{(0,1)^2}$ ✓= $1,8 \times 10^6$ N·C^{-1} right

$E_s = \frac{kQ}{r^2} = \frac{(9\times10^9)(2\times10^{-6})}{(0,2)^2}$ = $4,5 \times 10^5$ N·C^{-1} left

$E_{net} = 1,8 \times 10^6 - 4,5 \times 10^5 = 1,35 \times 10^6$ N·C^{-1}✓ (3)

OPTION 3/*OPSIE 3*

$E = \frac{F}{q}$ ✓= $\frac{1,8}{1\times10^{-6}}$ ✓=$1,8 \times 10^6$ N·C^{-1}

$E = \frac{F}{q} = \frac{0,45}{1\times10^{-6}}$ = $4,5 \times 10^5$N·C^{-1}

$E_{net} = 1,8 \times 10^6 - 4,5 \times 10^5 = 1,35 \times 10^6$ N·C^{-1}✓ (3)

[19]

<u>ACTIVITY 3 (METRO CENTRAL 2016 Grade 12)</u>
<u>ACTIVITY 4</u> (NOV 2015)
<u>ACTIVITY 5</u> (NOV 2016)

5.1.1 F_E/Electrostatic force ✓ (1)

5.1.2 The electrostatic force is inversely proportional to the square of the distance between the charges ✓

OR

The electrostatic force is directly proportional to the inverse of the square of the distance between the charged spheres (charges). ✓

OR

$F \propto \frac{1}{r^2}$ ✓

OR

They are inversely proportional to each other (1)

5.1.3

<u>OPTION 1</u>

> 1 mark for using slope

Slope = $\frac{\Delta F_E}{\Delta \frac{1}{r^2}}$ ✓ = $\frac{(0,027 - 0)}{(5,6 - 0)}$ ✓

= $4,82 \times 10^{-3}$ N·m^2 ($4,76 \times 10^{-3} - 5 \times 10^{-3}$)

Slope = $F_E r^2 = kQ_1Q_2 = kQ^2$ ✓

$4,82 \times 10^{-3}$ ✓ = $9 \times 10^9 Q^2$ ✓

∴ $Q = 7,32 \times 10^{-7}$ C ✓

<u>OPTION 2</u>

Accept any pair of points on the line

$F = \frac{kQ_1Q_2}{r^2}$ ✓

( ) ✓ = $(9 \times 10^9)Q^2$ ✓ ( ) ✓✓

$Q = 7,32 \times 10^{-7}$ C ✓ ($7,32 \times 10^{-7} - 7,45 \times 10^{-7}$ C)

Examples

$(0,005)$ ✓ = $(9 \times 10^9)Q^2$ ✓ (1) ✓✓

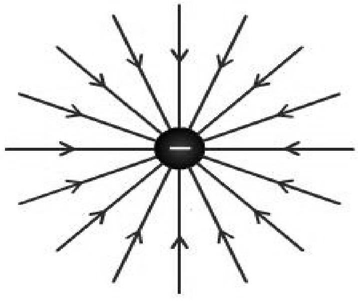
$Q = 7,45 \times 10^{-7}$ C ✓

$(0,027)$ ✓ = $(9 \times 10^9)Q^2$ ✓ $\left(\frac{1}{5,6}\right)$ ✓✓

$Q = 7,32 \times 10^{-7}$ C ✓ (6)

5.2.1

Criteria for drawing electric field:	Marks
Direction /*Rigting*	✓
Field lines radially inward/*Veldlyne radiaal inwaarts*	✓



7.2.2 $E = \frac{kQ}{r^2}$ ✓

Take right as positive

$E_{PA} = \frac{(9 \times 10^9)(0,75 \times 10^{-6})}{(0,09)^2}$ ✓

$= 8,33 \times 10^5\ N \cdot C^{-1}$ to the left

$E_{PB} = \frac{(9 \times 10^9)(0,8 \times 10^{-6})}{(0,03)^2}$ ✓

$= 8 \times 10^6\ N \cdot C^{-1}$ to the left

$E_{net} = E_{PA} + E_{PC}$

$= [-8,33 \times 10^5 + (-8 \times 10^6)]$ ✓ — 1 mark for the addition of same signs

$= -8,83 \times 10^6$

$= 8,83 \times 10^6\ N \cdot C^{-1}$ ✓

Take left as positive

$E_{PA} = \frac{(9 \times 10^9)(0,75 \times 10^{-6})}{(0,09)^2}$ ✓

$= 8,33 \times 10^5\ N \cdot C^{-1}$ to the left

$E_{PB} = \frac{(9 \times 10^9)(0,8 \times 10^{-6})}{(0,03)^2}$ ✓

$= 8 \times 10^6\ N \cdot C^{-1}$ to the left

$E_{net} = E_{PA} + E_{PC}$

$= (8,33 \times 10^5 + 8 \times 10^6)$ ✓ — 1 mark for the addition of samesigns

$= 8,83 \times 10^6\ N \cdot C^{-1}$ ✓

(5)
[17]

OHMS LAW

ACTIVITIES

MULTIPLE CHOICE QUESTIONS

1.1 B
1.2 B
1.3 C
1.4 A
1.5 B
1.6 B
1.7 C
1.8 B

1.9 C
1.10 A

SECTION B
ACTIVITY 1
1.1

$$\frac{1}{R_T{}^{//}} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$= \frac{1}{9} + \frac{1}{18}$$
$$= \frac{3}{18}$$
$$\therefore \frac{1}{R_T{}^{//}} = \frac{18}{3}$$
$$= 6\Omega$$

Now:

$$R_T = 6\Omega + 2\Omega$$
$$= 8\Omega$$

1.2 $I = \frac{V}{R} = \frac{12}{8} = 1{,}5A$

$V = IR = 1{,}5 \times 2 = 3V$

1.3 $W = VIt = 3 \times 1{,}5 \times 60 = 270J$

ACTIVITY 2
2.1

$$\frac{1}{R_T{}^{//}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{6} + \frac{1}{3} = \frac{1+2}{6} = \frac{3}{6}$$

$$\therefore R_T{}^{//} = \frac{6}{3} = 2\Omega$$

$$R_T = 2 + 1 = 3\Omega$$

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

$$\therefore V_1 = IR = 3 \times 3 = 9V$$

2.2

$$R = \frac{V}{I}$$
$$V_2 = IR_T{}^{//} = 3 \times 2 = 6V$$

2.3 $W = \frac{V^2 t}{R} = \frac{6^2 \times 2 \times 60}{3} = 1440J$

ACTIVITY 3

3.1 Emf of a battery is a measure of the total amount of energy which can be supplied by the battery per unit charge

3.2

$$\frac{1}{R_T^{//}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{1}{60} + \frac{1}{40}$$

$$= \frac{5}{120}$$

$$\therefore R_t^{//} = \frac{120}{5} = 24\Omega$$

3.3 $V = IR = 0{,}5 \times 24 = 24V$

3.4 $R = \frac{V}{I} = \frac{3}{0{,}5} = 6\Omega$

3.5 $P = \frac{V^2}{R} = \frac{12^2}{60} = 2{,}4W$

ACTIVITY 4

4.1 Resistance is the opposition of the conductor to the flow of electricity.

4.2

$$P = VI$$

$$\therefore I = \frac{P}{V} = \frac{60{,}0}{24} = 2{,}5A$$

$$V = IR = 2{,}5 \times 7{,}0 = 17{,}5V$$

4.3

$$V_{//} = 24 - 17{,}5 = 6{,}5V$$

Now: $R_{//} = \frac{V}{I} = \frac{6{,}5}{2{,}5} = 2{,}6\Omega$

$$\frac{1}{R}=\frac{1}{r_1}+\frac{1}{r_2}+\frac{1}{r_3}$$

$$\therefore \frac{1}{2{,}6}=\frac{1}{12}+\frac{1}{4}+\frac{1}{R}$$

$$\frac{1}{2{,}6}=\frac{R+3R+12}{12R}$$

Now: $\frac{1}{2{,}6}=\frac{4R+12}{12R}$

$$\therefore 12R=10{,}4R+31{,}2$$

$$\therefore 1{,}6R=31{,}2$$

$$R=19{,}5\Omega$$

ACTIVITY 5

5.1.1 $P = I^2R$ ✓
$0{,}5 = I^2 8$ ✓
$I = 0{,}25$ A ✓

$\frac{1}{R_p} = \frac{1}{r_1} + \frac{1}{r_2}$ ✓ $= \frac{1}{6} + \frac{1}{(6+6)}$ ✓ $= \frac{3}{12}$ ✓ $\therefore R_p = 4\ \Omega$

$R_T = 8 + 4$ ✓ $= 12\ \Omega$

$V_T = I R_T = (0{,}25)(12) = 3V$ ✓ (8)

5.1.2 $V_p = IR$ ✓ $= (0{,}25)(4)$ ✓ $= 1V$
$I = \frac{V_p}{R} = \frac{1}{6}$ ✓ $= 0{,}17$ A ✓ (4)

5.2.1 $P = \frac{V^2}{R}$ ✓
750✓ $= \frac{240^2}{R}$ ✓
$R = 76{,}80\ \Omega$ ✓

OR

✓ $P = VI$

750 ✓ $= 240\,I$ ✓

$I = 3{,}13\ A$

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

$= \frac{240}{3{,}13}$

$= 76{,}80\ \Omega$ ✓ (4)

5.2.2 $E = P \times t = \underline{750 \times 6}$ ✓ $= 4\ 500\ Wh = 4{,}5\ kWh$

Cost $= \underline{4{,}5 \times 1{,}14}$ ✓ $=$ R 5,13 ✓

OR Cost = (0,75)(6) ✓ (1,14) ✓= R5,13) ✓

ELECTROMAGNETISM

ACTIVITTY 1

1 .1.1 $\Phi = BA\cos\theta$ ✓

$= (0{,}6)\,\pi r^2 \cos\theta$

$= \underline{(0{,}6)(\pi \times 0{,}06^2)}$ ✓ $\cos 0°$ ✓

$= (0{,}6)(0{,}01)$

$= 6{,}79 \times 10^{-3}\ Wb$ ✓ (4)

1 .1.2 **POSITIVE MARKING FROM QUESTION 12.1.1**

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

$= \frac{(-1)(0 - 6{,}79 \times 10^{-3})}{0{,}04}$ ✓ ✓

$= 0{,}17\ V$ ✓ (4)

1 .2.1 DECREASES ✓ (1)

1 2.2 INCREASES ✓ (1)

[10]

ACTIVITY 2

2.1

$$\begin{aligned}
\mathcal{E} &= N\frac{\Delta\phi}{\Delta t} \\
&= N\frac{\phi_f - \phi_i}{\Delta t} \\
&= N\frac{B_f A - B_i A}{\Delta t} \\
&= N\frac{A(B_f - B_i)}{\Delta t} \\
&= (5)\frac{(0{,}50)^2(1 - 0{,}50)}{10} \\
&= (5)\frac{(0{,}50)^2(1 - 0{,}50)}{10} \\
&= 0{,}0625 \text{ V}
\end{aligned}$$

2.2

$$\begin{aligned}
\mathcal{E} &= N\frac{\Delta\phi}{\Delta t} \\
&= N\frac{\phi_f - \phi_i}{\Delta t} \\
&= N\frac{B_f A - B_i A}{\Delta t} \\
&= N\frac{A(B_f - B_i)}{\Delta t} \\
(0{,}30) &= (9)\frac{(\pi r^2)(12 - 0{,}12)}{120} \\
r^2 &= \frac{(0{,}30)(120)}{(9)\pi(12 - 0{,}12)} \\
r^2 &= 0{,}107175 \\
r &= 0{,}32 \text{ m}
\end{aligned}$$

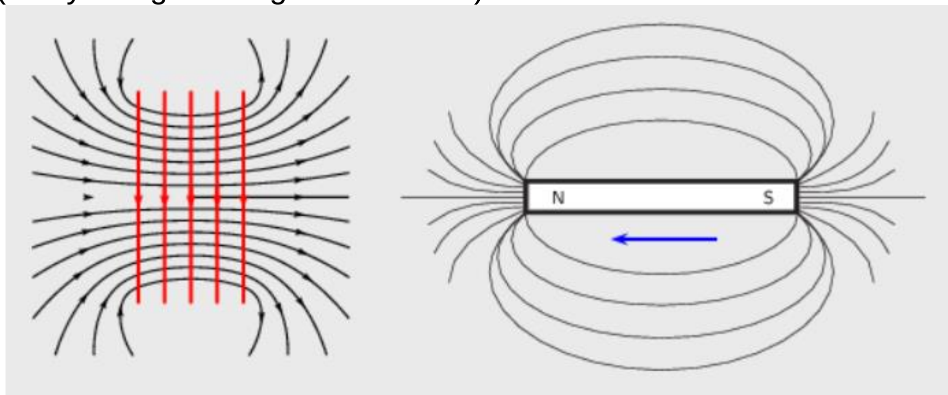
2.3

$$\begin{aligned}
\mathcal{E} &= N\frac{\Delta\phi}{\Delta t} \\
&= N\frac{\phi_f - \phi_i}{\Delta t} \\
&= N\frac{B_f A\cos(\theta) - B_i A\cos(\theta)}{\Delta t} \\
&= N\frac{A\cos(\theta)(B_f - B_i)}{\Delta t} \\
&= (4)\frac{(\pi(0{,}03)^2\cos(35))(3{,}4 - 0{,}4)}{27} \\
&= 1{,}03 \times 10^{-3} \text{ V}
\end{aligned}$$

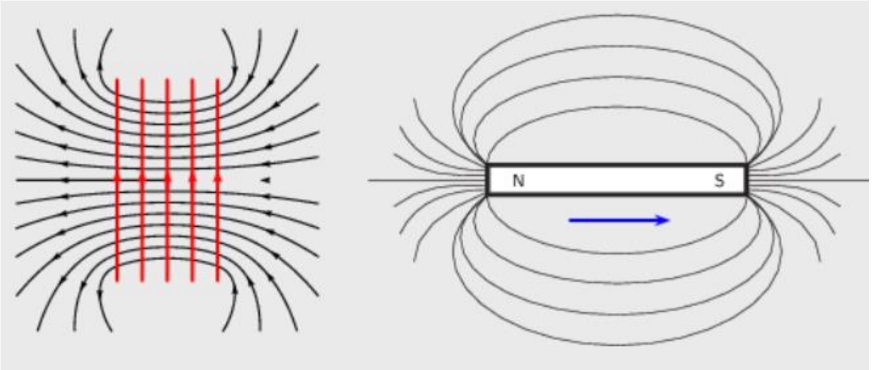
ACTIVITY 3

3.1 The emf, E , produced around a loop of conductor is proportional to the rate of change of the magnetic flux, φ, through the area, A, of the loop. This can be stated mathematically as: $\boldsymbol{\varepsilon = -N\frac{\Delta\Phi}{\Delta t}}$

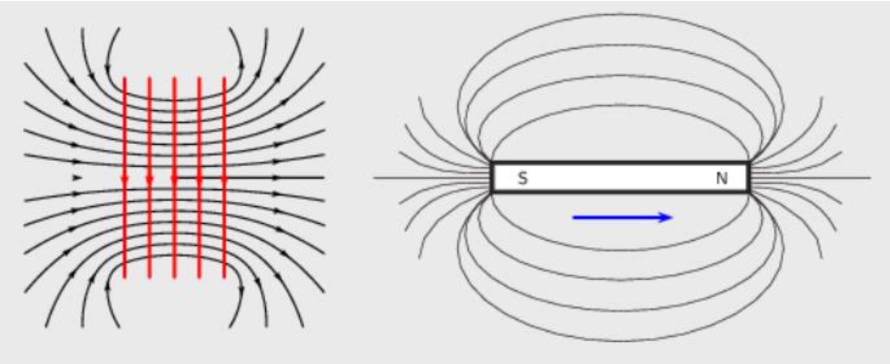
3.2 In the case where a north pole is brought towards the solenoid the current will flow so that a north pole is established at the end of the solenoid closest to the approaching magnet to repel it (verify using the Right Hand Rule):



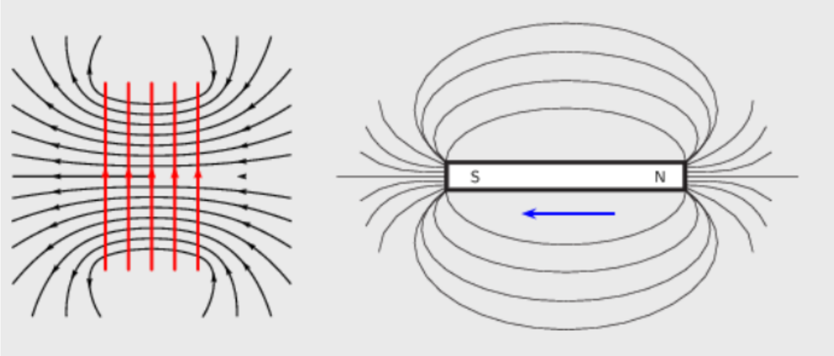
In the case where a north pole is moving away from the solenoid the current will flow so that a south pole is established at the end of the solenoid closest to the receding magnet to attract it:



In the case where a south pole is moving away from the solenoid the current will flow so that a north pole is established at the end of the solenoid closest to the receding magnet to attract it:



In the case where a south pole is brought towards the solenoid the current will flow so that a south pole is established at the end of the solenoid closest to the approaching magnet to repel it



Explain how it is possible for the magnetic flux to be zero when the magnetic field is not zero.

3.3 A south pole of a magnet is approaching the solenoid. Lenz's law tells us that the current will flow so as to oppose the change. A south pole at the end of the solenoid would oppose the approaching South Pole. The current will circulate into the page at the top of the coil so that the thumb on a right hand points to the left.

CHEMICAL CHANGE

QUANTITATIVE ASPECTS OF CHEMICAL CHANGE

Stoichiometry is the most poorly answered question in grade 12.
Learners struggle with using ratios

Prior knowledge **:** Review grade 10 work

- Correct chemical formulae
- Balancing the equations with the phases

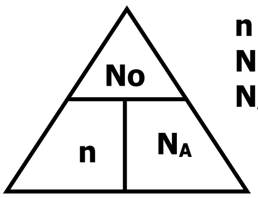
MOLE CONCEPT

1. The mole and Avogadro's Number (N_A)

Although atoms are too small to count individually, chemists need to know how many are present in a sample. To do this they use a set number of particles as a base unit of measurement. This unit is called a **mole**.

One MOLE of a substance contains the same number of particles as there are atoms in 12g of carbon-12, which is 6,02 x 10^{23}. This is called the AVOGADRO NUMBER (N_A).

2. Particle Formula : n= $\frac{m}{M}$



n = no. of moles
No. = no. of particles (atoms/ molecules/ions)
N_A = Avogadro's Number, 6,023 x 10^{23}

Example 1 1 mole of H_2O contains 6,023 x 10^{23} molecules of H_2O
1 mole of He contains 6,023 x 10^{23} atoms of He
1 mole of NO_3^- contains 6,023 x 10^{23} NO_3^- ions

Example 2

1. Calculate the number of moles represented by 1,204 x 10^{24} molecules of CO_2

$$n = \frac{N}{N_A} = \frac{1,204 \times 10^{24}}{6,02 \times 10^{23}} = 2 \text{ moles}$$

Calculator: 1,204 exp 24 ÷ 6,02 exp 23 = 2

2. Calculate the number of molecules in 0,5mol of SO_2 gas.

$N = n \times N_A = 0,5 \times 6,02 \times 10^{23} = 3,01 \times 10^{23}$ molecules of SO_2

Calculator: 0,5 x 6,02 exp 23 = 3,01 x 10^{23} (NOT 3^{23})

3. Calculate the number of **atoms** in 0,5 mol of SO_2 gas

1 molecule of SO_2 contains 3 atoms [i.e 1(S) + 2(O)]

Therefore, 3,01 x 10^{23} molecules of SO_2 contains 3 x 3,01 x 10^{23}) atoms = 9,03 x 10^{23} atoms

Note: Make sure the correct units are used

Activities on Particle Formula

1. Calculate the number of moles represented by
   - 1.1 $1,505 \times 10^{23}$ atoms of He
   - 1.2 $2,408 \times 10^{25}$ molecules of H_2O
   - 1.3 $3,01 \times 10^{21}$ molecules of CO
   - 1.4 $3,612 \times 10^{23}$ "molecules" of NaCℓ

2. Calculate the number of particles in
   - 2.1 0,2 mol NH_3
   - 2.2 5 mol O_2
   - 2.3 100 mol $CaSO_4$
   - 2.4 4 mol Ne

3. For each of the examples given in 2 determine the number of atoms present in the sample.

3. Relative Atomic Mass (R.A.M.)

The **R.A.M.** of an element (as given on the periodic table) is the average mass of all the isotopes of atoms of the element compared to an atom of carbon-12 (i.e it is how many times the average mass of one atom of the element is heavier than $^1/_{12}$ of the mass of a ^{12}C atom.)

4. Relative Formula Mass (R.F.M.)

The **R.F.M.** of a substance can be obtained by adding relative atomic masses of the constituent atoms, as given on the periodic table.

Example: R.F.M. of H_2SO_4 = 2(H) + S + 4(O) = 2(1) + 32 + 4(16) = 98u

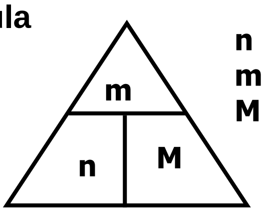
5. Molar Mass (M)

The molar mass of a substance is simply the Relative Formula Mass expressed in grams per mol ($g.mol^{-1}$) and it represents that mass of a particular substance which contains Avogadro's Number of particles.

Examples

Substance	Ar	H_2O	KF
R.F.M.	40u	18u	58u
Molar Mass (M)	$40 g.mol^{-1}$	$18 g.mol^{-1}$	$58 g.mol^{-1}$
Number of moles (n)	1 mole	1 mole	1 mole
Number of particles	$6,02 \times 10^{23}$ atoms	$6,02 \times 10^{23}$ molecules	$6,02 \times 10^{23}$ "molecules"

6. Mass Formula



n = no. of moles
m = mass
M = Molar mass (from Periodic Table)

Examples

1. Calculate the number of moles in 7g of nitrogen gas (N_2)

$$n = \frac{m}{M} = \frac{7}{28} = 0{,}25\text{mol}$$

2. Calculate the mass of 3 moles of oxygen molecules (O_2)

$m = n \times M = 3 \times 32 = 96\text{g}$

Activities Mass Formula

1. Calculate the number of moles represented by
   - 1.1 90g of H_2O
   - 1.2 3,4g of NH_3
   - 1.3 110g of CO_2
   - 1.4 4,9g of H_2SO_4

2. Calculate the mass of
   - 2.1 0,2 mol of Na_2CO_3
   - 2.2 10 mol of N_2O
   - 2.3 0,4 mol of H_2
   - 2.4 5 mol of H_2S

3. Calculate the number molecules in
   - 3.1 36g of H_2O
   - 3.2 2,2g of CO_2
   - 3.3 70g of N_2
   - 3.4 8,5g of K_2S

7. Molar Gas Volume (V_m)

Note : Only dm^3 is used with Molar gas volume (not cm^3 or m^3)

- One mole of any gas at STP will occupy a volume of 22,4 dm^3 (Avagadro's Law)
- STP = Standard Temperature (O °C / 273 K) and Pressure (101,3 kPa)

Examples

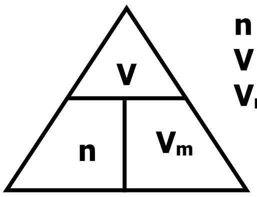
SUBSTANCE	O_2	CO_2	Ne
No. of moles (n)	1	1	1
Molar mass ($g.mol^{-1}$)	32	44	20
No. of particles	6,02 x 10^{23} molecules	6,02 x 10^{23} molecules	6,02 x 10^{23} atoms
Volume occupied at STP	22,4dm^3	22,4dm^3	22,4dm^3

Equal volumes of gases measured at the same temperature and pressure, contain the same number of molecules.

Example

5dm^3 of oxygen at 25°C and 80kPa pressure contains exactly the same number of molecules of 5dm^3 of hydrogen gas at 25°C and 80kPa

8. Volume Formula



n = no. of moles
V = volume measured in dm^3
V_m = molar volume at STP, 22,4dm^3

NOTE: To convert cm^3 to dm^3 divide by 1000, eg 200cm^3 = 0,2dm^3

Examples

1. Calculate the number of **moles** of gas in 11,2dm^3 of SO_2 at STP.

$$n = \frac{V}{V_m} = \frac{11,2}{22,4} = 0,5\text{mol}$$

2. Calculate the volume occupied by 4 mols of H_2 gas at STP

$$V = n \times V_m = 4 \times 22,4 = 89,6\text{dm}^3$$

3. Calculate the volume occupied by 11g of CO_2 gas at STP.

$$n = \frac{m}{M} = \frac{11}{44} = 0,25 \text{ mol}; \qquad V = n \times V_m = 0,25 \times 22,4 = 5,6\text{dm}^3$$

Activities Volume Formula

1. Calculate the number of moles in the following volumes of gas measured at STP.

1.1 56dm^3 1.2 1,12dm^3 1.3 44,8dm^3 1.4 672dm^3

2. Calculate the volume, at STP, occupied by

2.1 2 mol of Ne
2.2 0,1 mol of CO_2
2.3 34g of NH_3
2.4 4,214 x 10^{23} atoms of He

MOLE CALCULATIONS

As shown the number of **moles** can be calculated by three different methods:

- particle formula;
- the mass formula;
- the volume formula.

Since all three formulae contain the number of moles, it is best when solving the problems to always try and determine the **number of moles** first, after which the other information can easily be calculated.

- **AVAGADRO'S LAW** : one mole of any gas occupies the same volume at the same temperature and pressure.

Activities

1. Determine the number of moles in

1.1 60g of carbon
1.2 2,8g of N_2
1.3 8,8g of CO_2
1.4 10g of $CaCO_3$
1.5 3,01 x 10^{23} atoms He
1.6 1,505 x 10^{24} molecules H_2S
1.7 1,806 x 10^{22} atoms of Fe
1.8 2,408 x 10^{25} molecules of CH_4
1.9 11,2dm^3 NH_3 at STP
1.10 224dm^3 CO_2 at STP
1.11 5,6dm^3 O_2 at STP
1.12 448dm^3 Ne at STP
1.13 5,3g of Na_2CO_3
1.14 3,01 x 10^{24} molecules of H_2O
1.15 89,6dm^3 Ar at STP

2. Determine the mass of

2.1 0,5 moles $Mg(NO_3)_2$
2.2 3 moles of NaCℓ
2.3 20 moles of $CuSO_4$
2.4 224dm^3 CO_2 at STP
2.5 1,12dm^3 NH_3 at STP
2.6 6,02 x 10^{22} molecules of F_2
2.7 1,505 x 10^{23} molecules of NO_2
2.8 56dm^3 SO_2 at STP
2.9 2,408 x 10^{23} molecules of PH_3
2.10 44,8dm^3 NO at STP

3. Determine the volume, at STP,

3.1 6 moles of NH_4
3.2 0,4 moles N_2O_4
3.3 10 moles of O_2
3.4 14g N_2
3.5 6,8g H_2S
3.6 3,01 x 10^{23} molecules NO
3.7 9 x 10^{24} molecules SO_3
3.8 1,505 x 10^{26} atoms Ne

4. Determine the number of (A) molecules and B (atoms) in

4.1 0,1 moles of CH_4
4.2 50g of H_2
4.3 5 moles of N_2
4.4 112dm^3 N_2O at STP
4.5 340g NH_3
4.6 102g H_2S
4.7 4,9g H_2SO_4
4.8 4480dm^3 $Cℓ_2$ at STP
4.9 2,24dm^3 O_2 at STP

Stoichiometric Calculations

- Balanced equations contain the same number of each kind of atom on each side of the equation.
- The total calculated mass of the reactants is equal to the total calculated mass of the products in a balanced equation.
- The co-efficients in a **balanced** equation give mole relationships between reacting chemicals.
- The quantity of product formed in the reaction is determined by the reactant which is not in excess (i.e. limiting reactant).
- **Limiting reactant** is the reactant that is first used up.
- Excess reactant is the reactant that not completely used up.

Note : only moles can be used to determine LIMITING REAGENT and EMPERICAL FORMULAE

Example

	$N_2(g)$ +	$3H_2(g)$	→	$2NH_3(g)$	
Mole ratio	1 mol	3 mol		2 mol	
Mass ratio	28g	6g		34g	
Volume ratio	22,4dm^3	67,2dm^3		44,8dm^3	(at STP)

From the above equation, it can be said that one mole of N_2 will react with 3 moles of H_2 to form 2 moles of NH_3. Since the ratio in which the masses react is directly related to the mole ratio it is possible to relate these variables in a balanced equation by converting the given information to moles using one of the 3 mole formulae.

1.1 How many moles of NH_3 are formed when 6 moles of H_2 react with excess nitrogen? Rewrite the equation and fill in the mole ratio.

	$N_2(g)$	+	$3H_2(g)$	→	$2NH_3(g)$	
Mol ratio	1		3		2	
When H_2 = 6 mol	2		6		4	(x2)

4 mols of NH_3 are formed from 6 mols of H_2

1.2 What volume of NH_3 would be formed when 24g of H_2, react with excess N_2 at STP?

Step 1 **Convert given information to MOLES, if not already in moles**.
24g of H_2 $n = \frac{m}{M} = \frac{24}{2} = 12$mol of H_2

Step 2 **Find MOLE RATIO between what is given and what is required.**

Mole ratio	H_2	:	NH_3	
	3	:	2	(from balanced equation)
	12	:	8	(x4)

Step 3 Calculate the required quantity using the appropriate mole formula
Volume of 8 mols of NH_3? $V = n \times 22,4 = 8 \times 22,4 = 179,2dm^3$ of NH_3

1.3 What mass of N_2 is required to produce $4,48dm^3$ of NH_3 at STP?

Step 1 Convert given information to MOLES
$4,48dm^3$ of NH_3 $n = \frac{V}{22,4} = \frac{4,48}{22,4} = 0,2$ mols of NH_3

Step 2 Find MOLE RATIO between what is given and what is required.

Mol ratio :	N_2	:	NH_3	
	1	:	2	(from balanced equation)
	0,1	:	0,2	(x0,1)

Step 3 Calculate the required quantity using the appropriate mole formula
Mass of N_2 $m = n \times M = 0,1 \times 28 = 2,8g$ of N_2

Activities on mass-mass, volume-volume & mass-volume calculations

1. Consider the balanced equation: $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

1.1 How many moles of H_2O are formed when 5 moles of O_2 react with excess H_2?
1.2 What mass of H_2O is formed when 5 moles of O_2 react with excess H_2?
1.3 What mass of H_2 is needed to react with 64g of O_2?
1.4 What volume of O_2 at STP is required to react with $11,2dm^3$ of H_2?

1.5 What volume of H_2O is formed when 44,8dm^3 of O_2 react with excess H_2 at STP?

2. Consider the balanced equation: $\mathbf{4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O\ (g)}$

2.1 How many moles of NO are formed when 1 mole of O_2 reacts with excess NH_3?
2.2 What volume of NO is formed when 1 mole of O_2 reacts with excess NH_3 at STP?
2.3 What mass of H_2O is formed when 34g of NH_3 reacts with excess O_2?
2.4 What volume of NO is formed when 16g of O_2 react with excess NH_3 at STP?
2.5 What mass of NH_3 is needed to react with 224dm^3 of O_2 at STP?
2.6 425g of NH_3 and 80g of O_2 are allowed to react together. Which reactant is used up first and what mass of the other reactant is in excess?

3. Consider the balanced equation: $\mathbf{A\ell_4C_3(s) + 12H_2O(\ell) \rightarrow 3CH_4(g) + 4A\ell(OH)_3(s)}$
3.1 How many moles of CH_4 are formed when 4 moles of H_2O react with excess $A\ell_4C_3$?
3.2 What volume of CH_4 is formed when 4 moles of H_2O react with excess $A\ell_4C_3$ at STP?
3.3 What mass of $A\ell_4C_3$ is needed to form 4,8g of CH_4?
3.4 What volume of CH_4 is formed when 288g of $A\ell_4C_3$ react with excess H_2O?
3.5 What mass of $A\ell(OH)_3$ is formed from 108g of H_2O?
3.6 28,8g of $A\ell_4C_3$ is allowed to react with 45g of H_2O. Which reactant is used up first and what mass of the other reactant is in excess?

4. Consider the balanced equation: $SO_2(g) + 2H_2S \rightarrow 3S(s) + 2H_2O(\ell)$
4.1 How many moles of H_2S are needed to form 9 moles of S?
4.2 What mass of H_2S is needed to form 9 moles of S?
4.3 What volume of SO_2 is needed to form 3,6g of H_2O at STP?
4.4 What mass of S will be formed when 16g of SO_2 react with excess H_2S?
4.5 What volume of H_2S is needed to form 9,6g of S?
4.6 6dm^3 of SO_2 is allowed to react with 11,2dm^3 of H_2S at STP. Which reactant is used up first and what volume of the other reactant is in excess?

5. Consider the balanced equation: $\mathbf{N_2(g) + 3H_2 \rightarrow 2NH_3(g)}$

5.1 How many moles of NH_3 are formed from 12 moles of H_2?
5.2 What mass of N_2 is needed to form 4 moles of NH_3?
5.3 What volume of N_2 is needed to completely react with 1,5 moles of H_2?
5.4 What mass of NH_3 is formed when 2,8g of N_2 reacts with excess H_2?
5.5 What volume of H_2 is needed to form 5,6dm^3 of NH_3 at STP?
5.6 What mass of N_2 is needed to form 5,6dm^3 of NH_3 at STP?
5.7 44,8dm^3 of N_2 is allowed to react with 14g of H_2 at STP. Which reactant is used up first and what mass of the other is in excess?

Concentration of Solutions

Concentration of a solution refers to moles of a solute per unit volume of a solvent.
The concentration of a solution is determined by use of the following formulae:

$c = n/V$ and $n = m/M$ which combine to give $c = m/MV$

Symbol	Quantity	Unit
M	mass	G
M	molar mass	$g.mol^{-1}$
N	no. of moles	Mol
C	concentration	$mol.dm^{-3}$
V	volume	dm^3

To convert cm^3 to dm^3 divide by 1000

NOTE: **$1cm^3 = 1ml$; $1dm^3 = 1litre$**

Example 1: Calculating Concentration

Calculate the concentration of the solution formed when 10,6g of sodium carbonate (Na_2CO_3) is dissolved in water and the solution is made up to $200cm^3$.

Method A

M of Na_2CO_3 = 2(23) + 12 + 3(16) = $106g.mol^{-1}$

V = 200 ÷ 1000 = $0,2dm^3$

$n = \frac{m}{M} = \frac{10,6}{106} = 0,1mol$; $c = \frac{n}{V} = \frac{0,1}{0,2} = 0,5mol.dm^{-3}$

Method B

$c = \frac{m}{MV} = \frac{10,6}{106 \times 0,2} = 0,5mol.dm^{-3}$

Example 2: Calculating Mass

Calculate the mass of sodium hydroxide (NaOH) required to make a solution of concentration $0,1mol.dm^{-3}$ in a $250cm^3$ flask.

Method A

M of NaOH = 23 + 10 + 1 = $40g.mol^{-1}$

V = 250 ÷ 1000 = $0,25dm^3$

n = c x V = 0,1 x 0,25 = 0,025mol

m = n x M = 0,025 x 40 = 1g

Method B

c = m/MV

0,1= m/40 x 0,25

m = 1g

Example 3 :Diluting a solution

20cm^3 of hydrochloric acid (HCl) of concentration 0,4mol.dm^{-3} is diluted by adding it to 80cm^3 of distilled water. Calculate the concentration of the diluted acid.
*__Please note that during dilution the moles of acid (solute) do not change.__

Method
The **number of moles of HCℓ stays the same** regardless of the amount of water added.
n = c x V = 0,4 x 0,02 = 0,008mol of HCl in original solution or $c_iV_i = c_fV_f$
The volume has increased, V_{new} = 0,02 + 0,08 = 0,1 dm^3 $0,4 \times 0,02 = c_f \times 0,1$
$c = \frac{n}{V} = \frac{0,008}{0,1}$ = 0,08mol.dm^{-3} c_f = 0,08 mol.dm^{-3}

Example 4 : Mixing solutions

200cm^3 of NaOH of concentration 0,2mol.dm^{-3} is added to 300cm^3 of Na_2CO_3 of concentration 0,15mol.dm^{-3}. Calculate the concentration of Na^+ ions in the solution.

Method
$NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-$
1 mol   1mol   1mol
n = c x V = 0,2 x 0,2 = 0,04 mol of NaOH, therefore, **0,04mol of Na^+ ions** (refer to dissociation equation)

$Na_2CO_{3(S)} \rightarrow 2Na^+_{(aq)} + CO_3^{2-}{}_{(aq)}$
1mol   2mol   1mol
n = c x V = 0,15 x 0,3 = 0,045mol of Na_2CO_3, therefore, (2 x 0,045) = **0,09mol of Na^+ ions** (refer to dissociation equation)

$c = \frac{n_{total}}{V_{total}} = \frac{0,04 + 0,09}{0,2 + 0,3} = \frac{0,13}{0,5}$ = **0,26 mol.dm^{-3}**

Activities : Concentration Calculations

1. Calculate the mass of NaOH in 100cm^3 of a solution of concentration 0,15mol.dm^{-3}.

2. Calculate the concentration of a solution containing 5,3g of Na_2CO_3 in 500cm^3 of water.

3. Calculate the concentration of 50cm^3 of a solution containing 0,49g of H_2SO_4 .

4. If 3,15g of HNO_3 was dissolved in 250cm^3 of solution what would the concentration be?

5. Calculate the mass of $CaSO_4$ needed to make 100cm^3 of a solution of concentration 0,2mol.dm^{-3}.

6. 87g of K_2SO_4 is dissolved to make a solution of concentration 0,8mol.dm^{-3}. What is the volume of this solution?

7. 2,84g of Na_2SO_4 is dissolved in water to form a solution of volume 250cm^3.
   7.1 Write an equation showing how the Na_2SO_4 dissociates in water.

   Calculate:
   7.2 the concentration of the Na_2SO_4 solution; and
   7.3 the concentration of Na^+ ions in the solution.

8. Calculate the concentration of NO_3^- ions in a solution containing 4,44g of $Mg(NO_3)_2$ in 200cm^3.

9. 36g of $MgSO_4$ and 19g of $MgCl_2$ are mixed together to form a solution of total volume 250cm^3. What is the concentration of Mg^{2+} ions in this solution?

10. 200cm^3 of a 0,25mol.dm^{-3} of NaOH is mixed with 300cm^3 of a 0,1mol.dm^{-3} solution of Na_2CO_3. Calculate the total concentration of Na^+ ions in this solution.

11. What volume of water must be added to 200cm^3 of a 0,56mol.dm^{-3} NaOH solution to change the concentration to 0,4mol.dm^{-3} ?

12. 150cm^3 of distilled water is added to 250cm^3 of NaOH which has a concentration of 0,1mol.dm^{-3}. What is the final concentration of the diluted NaOH?

Percentage Composition

This gives the percentage of each element which makes up a compound.

Example

Find the percentage composition of H_2SO_4

Molar mass of H_2SO_4 = 98 g.mol^{-1}

Mass of H 2 x 1 = 2g — % of H = $\frac{2}{98}$ x 100 = 2,04%

Mass of S 1 x 32 = 32g — % 0f S = $\frac{32}{98}$ x 100 = 32,65%

Mass of O 4 x 16 = 64g — % of O = $\frac{64}{98}$ x 100 = 65,31%

Empirical Formula

Define an empirical formula as the simplest whole-number ratio of atoms in a compound.
This is the simplest formula of a compound. The simplest ratio of the elements found from the % composition and the atomic masses of elements. The real formula can be a multiple of the simplest formula
Molecular formula: A chemical formula that indicates the type of atoms and the correct number of each in a molecule.Example

(a) The percentage composition of a compound is 80% C; 20% H. Find the empirical formula.

In 100g of the compound there are 80g C and 20g H , n =m/M,

Convert to moles : $n = \frac{80}{12}$ **= 6,66mol C;** $n = \frac{20}{1}$ **= 20 mol H**

Ratio $_nC$: $_nH$ = 6,66 : 20 (divide by the smallest number to get the simplified ratio)

Simplified ratio $= \frac{6,66}{6,66} : \frac{20}{6,66}$ **= 1 : 3**

Empirical formula = CH_3

(b) If the molecular mass of the above compound is $30 g.mol^{-1}$ find the true formula.

Molecular mass = $30 g.mol^{-1}$ (given)
Empirical formula mass = $15 g.mol^{-1}$

Number of formula units = 30/15 = 2

True formula = $2(CH_3) = C_2H_6$

Activities

1. Find the % composition of each element in ;
   a) $Cu(NO_3)_2$ b) caffeine $C_8H_{10}N_4O_2$

2. Find the percentage of water of crystallization in Epsom salts $MgSO_4.7H_2O$.

3. Ammonium nitrate NH_4NO_3 and ammonium sulphate $(NH_4)_2SO_4$ are both used as nitrogen fertilizers. Which compound contains the greater percentage of nitrogen?

4. Find the empirical formulae of the compounds which have the following percentage composition.
   Name these compounds.

4.1	54% Ca	43% O	2,7% H
4.2	63,4% Ag	8,25% N	28,35% O
4.3	56% Ba	29,2% Cl	14,8% H_2O

5. Compounds of hydrogen and boron are called boranes. One of these has the percentage composition 78,55% B and 21,45% H. If its molar mass is $28 g.mol^{-1}$ what is its molecular formula?

6. Xylene is the solvent used in marker pens. The % composition of xylene is 88,88% C and 11,11% H. If the molecular mass of xylene is $108 g.mol^{-1}$ find the empirical and molecular formula.

7. Gypsum (hydrated calcium sulphate) is heated to make Plaster of Paris. When 1g of gypsum was heated to drive off the water 0,79g of calcium sulphate remained.

7.1 How many moles of calcium sulphate are there in this sample?
7.2 How many moles of water are there in this sample?

Water of Crystallisation

One needs to be able to:

- explain the terms anhydrous, hydrated and water of crystallisation.
- calculate the formula of a hydrated salt.
- Anhydrous – has no water molecules
- Hydrated - has water molecules trapped in the molecule or compound.

Some substances can trap water molecules inside of them. The water contained is called the <u>water of crystallisation.</u>

There are two ways in which a formula can be written if it is a hydrated compound:

1) Empirical formula, which you know and love;
2) **Dot formula**, so copper sulfate pentahydrate becomes $\mathbf{CuSO_4 \bullet 5H_2O}$.

Example

A sample of hydrated calcium sulphate, $CaSO_4 \bullet xH_2O$, has a relative formula mass of 172. Calculate the value of x.

$$40+32 + (4\times16) + x(2+16) = 172$$
$$x = 2$$

Percentage Yield

Yield: the amount of product.
Theoretical yield: the amount of product we expect, based on stoichiometric calculations.
Actual yield: amount of product from a procedure or experiment (this is **given** in the question).

Percent yield = $\frac{actual\ yield}{theoretical\ yield} \times 100\%$

Example

What is the % yield of H_2O if 138 g H_2O is produced from 16 g H_2 and excess O_2?

Step 1: Write the balanced chemical equation

$$2H_2 + O_2 \rightarrow 2H_2O$$

Step 2: Determine actual and theoretical yield.

theoretical amount of water to be produced = $\frac{16 \times 36}{4}$ = 144 g

Step 3: Calculate % yield

$$\%\ yield = \frac{actual\ yield}{theoretical\ yield} \times 100\%$$
$$= \frac{138}{144} \times 100\%$$
$$= 95{,}83\%$$

Percentage Purity

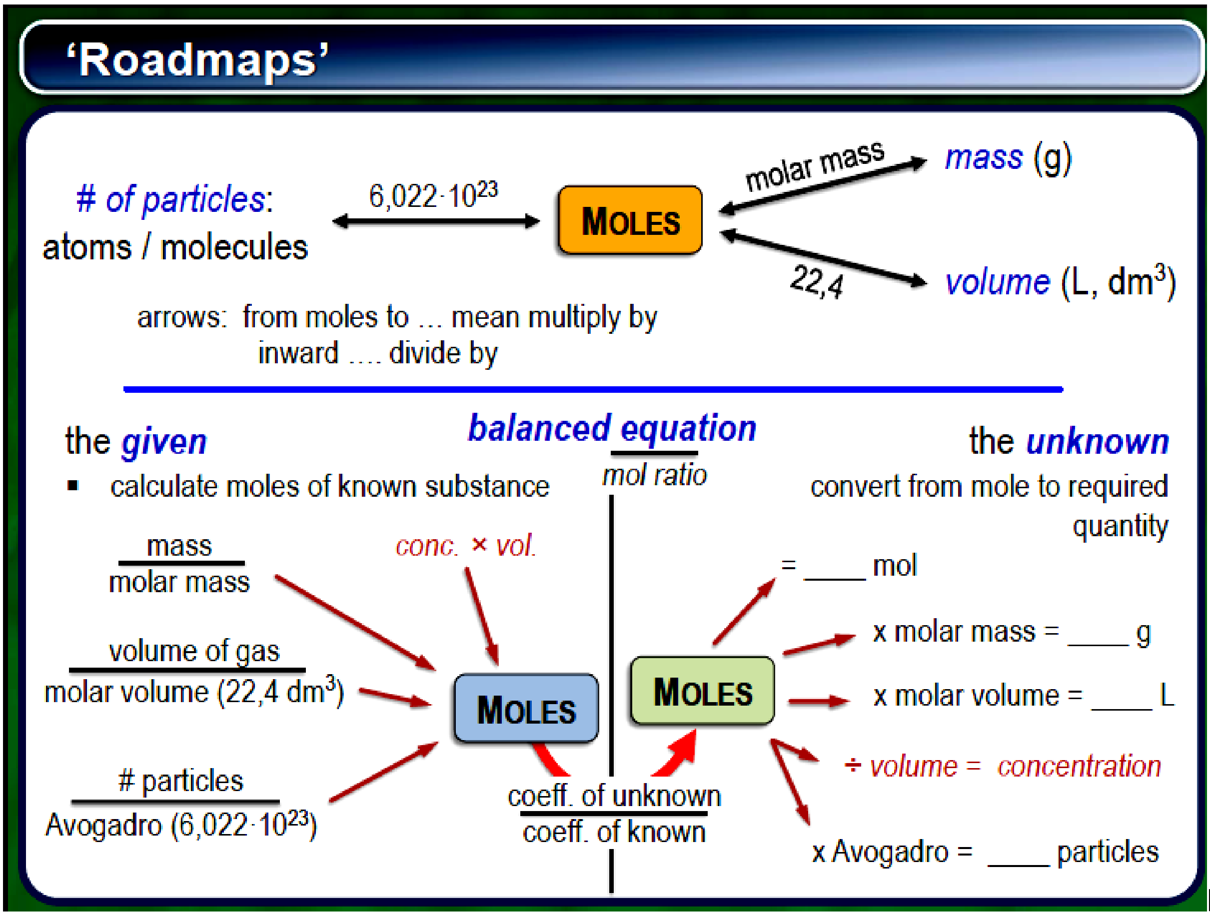
- Chemicals are a mixture of different compounds
- Chemical analysis can determine the composition of minerals
- Then composition can be used to work out purity of products.
- Can be calculated using:

% purity= $\frac{mass\ of\ pure\ products}{mass\ of\ the\ sample}$ x100%

Example

1) 3,68g of washing soda crystals($Na_2CO_3.5H_2O$) are dissolved in water and made up to a volume of 275cm^3. 25 cm^3 of this sample is neutralised by 23,5 cm^3 of HCl of concentration of 0,11 mol.dm^{-3}. Calculate the percentage purity of Na_2CO_3 in the commercial washing soda. **(6,88 %)**

2) An impure sample of table salt that is contaminated by sand has a mass of 5,5 g. The sample is dissolved in distilled water and then filtered. The residue that stays behind after being filtered is dried and its mass is 1,5g. Calculate the percentage purity of the table salt in the sample. **(27,28 %)**



PREVIOUS EXAM QUESTIONS

Question 5 (EC November 2016)

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

5.1.1 Define the term *empirical formula*. (2)

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

5.1.3 The molar mass of the compound is 28 g.mol-1. Determine by using calculations The values of **x** and **y**. (2)

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

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

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

5.2.1 Calculate the mass of the impure calcium carbonate. (6)

Question 5 (EC November 2012)

A learner wants to determine the molecular formula of a compound found in cigarettes. The learner asks for your help with the calculation. The following is known about the compound: It is responsible for cigarettes being such an addictive substance, it has a molecular mass of 162,2 g·mol-1 and its percentage composition is 74,07% **C**; 8,65% **H** and 17,28% **N**.

5.1 Name the compound being referred to here. (2)

5.2 As much as the substance referred to in QUESTION 5.1 is responsible for the addiction of smokers to cigarettes, it is used in some products to help them overcome their addiction. Name ONE example of such a product. (2)

5.3 Cigarette packs contain various warnings on them concerning the harmful effects of smoking. Name ONE harmful effect of smoking on humans. (1)

5.4 Show, by means of calculation, how you would go about helping the learner determine the molecular formula of this compound. (7)

Question 8 (GP June 2016)

8.1 A laboratory analysis of a compound shows that it has the following chemical composition:

Carbon: 76 % Hydrogen: 12,5% Oxygen: 11,5%

8.1.1 Determine the empirical formula for the compound. (5)

8.1.2 Determine the molecular formula if the molar mass of the compound is 282 $g.mol^{-1}$ (4)

8.2 14,5 g of iron reacts with 12 g of water during a corrosion reaction to form Fe_3O_4 and H_2, according to the following equation.

$$Fe + H_2O \rightarrow Fe_3O_4 + H_2$$

8.2.1 Balance the equation. (3)

8.2.2 Find the substance which is the limiting reactant? Show your calculations. (6)

8.2.3 Using the calculations in your answer to Question 8.2.2, determine the mass of Fe_3O_4 that will be formed. (3)

8.3 Chalk is almost pure calcium carbonate. If 10 g of chalk was reacted with an excess of dilute hydrochloric acid, 2.128 litres of carbon dioxide gas is collected at STP.

$$CaCO_3\ (s) + 2HCl\ (aq) \rightarrow CaCl_2\ (aq) + H_2O\ (l) + CO_2\ (g)$$

Determine the purity of calcium carbonate. (5)

Question 8 (Hilton College 2013)

8.1 When a 50 g sample of impure calcium carbonate is heated, 10 dm^3 of carbon dioxide, measured at STP, are evolved. Refer to the balanced chemical equation below and answer the questions that follow.

$$CaCO_3 \rightarrow CaO + CO_2.$$

8.1.1 Calculate the number of moles of carbon dioxide gas that forms? (2)
8.1.2 What mass of pure calcium carbonate has reacted? (3)
8.1.3 Calculate the percentage purity of calcium carbonate. (2)

8.2 40 cm^3 of sulphur dioxide react with 30 cm^3 of oxygen gas to form sulphur trioxide. Assume that the reaction has run to completion and all volumes are measured at the <u>same</u> temperature and pressure.

8.2.1 Write a balanced chemical equation for the reaction. (3)
8.2.2 Which of the reactants, sulphur dioxide or oxygen, is the limiting reagent? (2)
8.2.3 Calculate the volume of the remaining gases at the end of the reaction. (5)

8.3 Chromium, a transition element, forms a variety of compounds of various colours. Among these compounds sodium dichromate is commercially the most important compound. A chemical analysis revealed the following information about the chemical composition of sodium dichromate by mass:

Na: 17,5%
Cr: 39,7%
O: 42,8%

8.3.1 Define the concept empirical formula. (2)

8.3.2 Determine the empirical formula of the above compound. (5)

8.4 Muriatic acid, an industrial grade of concentrated HCℓ, is used to clean bricks and to etch cement for painting. Its concentration is 11,7 $mol \cdot dm^{-3}$.

8.4.1 How much water must be added to the <u>concentrated</u> muriatic acid to produce **5 litres** of a diluted muriatic acid of concentration 3,5 $mol \cdot dm^{-3}$ acid for routine use. (5)
8.4.2 Determine the volume of muriatic acid solution of concentration 11.7 $mol.dm^{-3}$ which contains 9,55 g of HCℓ. (3)

MATTER AND MATERIALS

Gas Laws

<u>Notes to the Teacher</u>

- Revise grade 9 concepts: matter, particle model of matter, temperature, pressure and volume.
  - Bring Apparatus or pictures of apparatus for measuring temperature, pressure and volume, and use them to stimulate discussion of these concepts.
  - Summarise the concepts by referring to grade 11 examination guidelines
- Define ideal gas as a theoretical gas which obeys the gas laws under all conditions of temperature and pressure, and distinguish it from real gases.
- Investigating relationship between pressure and volume:
  - Use Boyle's law apparatus, or any useful instrument, for example bicycle pump, to investigate relationship between pressure and volume.
  - Introduce Boyle's law.
- Investigating relationship between pressure and temperature:
  - Use old cans of perfume, carefully heat a can until it explodes, and let learners explain the reason for the explosion.
  - Use calculations to verify the relationship and build the law.

Matter is anything that occupies space and has mass.
Matter is made up of very small particles that are in the constant motion.

The Kinetic Theory of Gases

According to the **KINETIC THEORY OF GASES**,

• gases (like all substances) are *made up of particles* – atoms (He, Ne, Ar …) and molecules (H_2, N_2, H_2O, CO_2 ..)

• the size of these particles is *very small* compared to the distances between the particles.

• the particles are *constantly moving*, in *straight lines*, at *different speeds* (they have kinetic energy: $Ek = ½ mv^2$)

• there are *forces of attraction* between particles – in gases, these tend to be *very weak, and mostly negligible .*

• the *collisions* between the particles and the walls of the container, are *elastic* – they do *not change the kinetic energy of the system.*

• the *temperature* of a gas is a measure of the *average kinetic energy* of the particles

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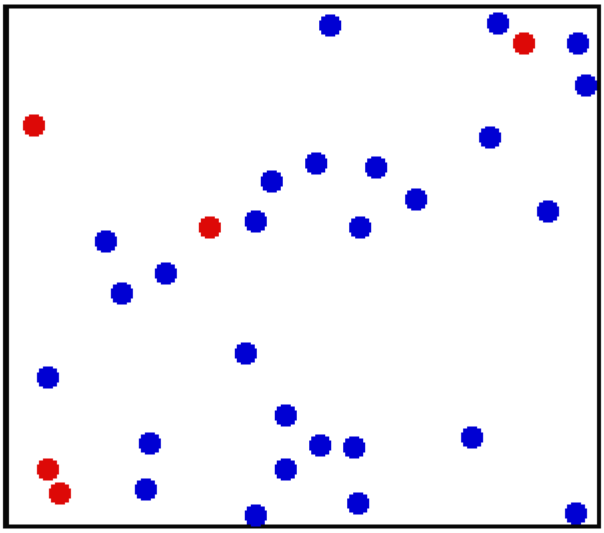
The Motion of Gas Particles / Pressure

All particles – in solids, liquids or gases, are in continuous motion.
In gases, the particles *move large distances* (even very large distances) relative to their size.
In a closed container, gas particles are *bound to collide* with one another as well as with the walls of the container.



<u>EXAMPLES</u>
<u>MCQ</u>

1.1 Which of the following statements regarding the Kinetic Molecular Theory of ideal gases is incorrect.

A: Gas molecules collide elastically.
B: Gas molecules are in random motion.
C: All molecules have the same kinetic energy.
D: Attractive and repulsive forces can be neglected. (2)

<u>Solution</u>

1.1 C, since molecules of gases move at difference speeds.

Do note: the speed of particles may differ significantly. The ***average*** speed of the particles is an indication of the temperature of the gas.
The gas exerts pressure due to the collisions of the particles with the walls of the container.

PRESSURE

- Pressure (p) is a force exerted per unit area – measured in Pascal (Pa: $N \cdot m^{-2}$).
- The pressure of a gas is the *force the gas exerts on the walls* of its container due to the *collision* of the particles with the walls.
- Clearly, *pressure is* ***dependent*** on the number of gas particles (*amount of gas*) in the container. The more gas, the more collisions there are, and the higher the pressure will be.
- The *volume of the container* also plays a significant role. The smaller the container, the greater the number of collisions of particles with the container walls, & hence a greater pressure.

TEMPERATURE

- Temperature (T) is measured in Kelvin (K), the temperature of a substance is a measure of the *average* kinetic energy of the particles. If the temperature of the gas is *increased* / decreased, the average E_k of the gas particles will *increase* / decrease.

VOLUME

- Volume (V) – measured in cubic metre (m^3) or litre (L)
- The gas volume is the size of the space occupied by the gas.
- Gases *always fill the containers they are in*.
- If the *volume* of a container is *increased* (with the number of gas particles remaining constant), the *pressure* exerted by the gas will *decrease*.

Compressibility / Phase Changes

- If *volume is decreased*, the *pressure will increase*.
- A feature of gases that distinguishes them from solids and liquids, is their **COMPRESSIBILITY …**
- Which is a measure of how much a given volume of matter decreases when placed under pressure? Gases are compressible because most of the vol. of a gas is composed of the *empty space* between the gas particles.

PHASE CHANGES

- When the temperature of a gas is decreased, the particles lose E_k and slow down
- *Intermolecular forces* start to play a larger role, and eventually, at a low enough temperature → the gas particles *enter the liquid phase*. The same is true for an increase in pressure. When large enough, the particles are pressed so close to one another.

Measurements and Units
PRESSURE …

- Due to collisions between the gas particles and walls of container pressured is expressed as force per unit area ($N \cdot m^{-2}$)
- SI units: *Pascal* (Pa) – other units: kPa (10^3 Pa), atm, mmHg
- standard pressure: 101,3 kPa (equivalent to 1 atm) **TEMPERATURE** is an indication of the average kinetic energy of gas particles, SI units: *kelvin* (K) (*conversion to °C: T°C = TK – 273*)
- Standard temperature (STP): 0°C (273, 15 K – rounded to 273 K) – the temperature at which pure water freezes at sea level
- Absolute zero: O K (-273 K) is the lowest possible temperature **VOLUME** of gases always fill the container they are in

• SI units: *cubic metre* (m^3) – other units: L, mL, cm^3, dm^3

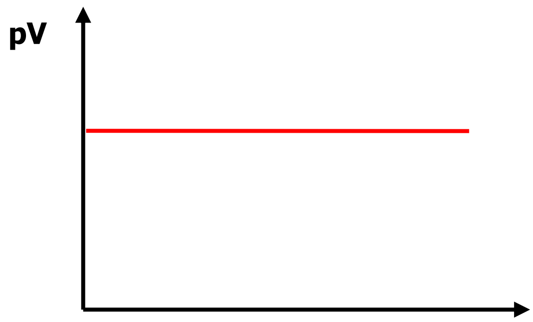
• $1\ m^3 = 10^3\ L = 10^3\ dm^3 = 10^6\ mL = 10^6\ cm^3$

<u>EXAMPLES</u>

1. Name two differences between ideal gases and real gases.

2.. Which real gas behaves most like an ideal gas? Explain your answer.

3. Copy the following pV versus p graph for an ideal gas and complete it by using a dotted line to show the deviation of a real gas. Briefly explain the deviation.

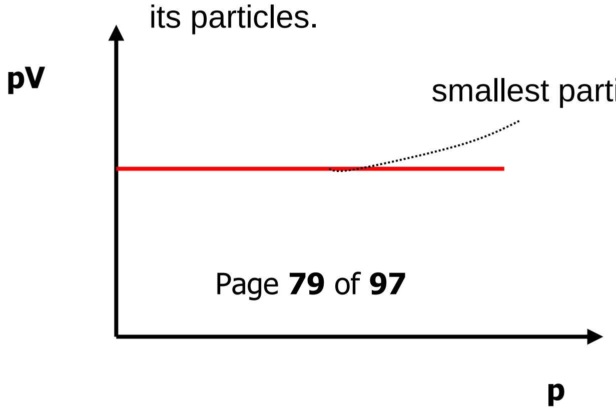


SOLUTIONS

1. The particles of an ideal gas do not have a volume, while the particles of a real g occupy space.
There are no forces of attraction between the particles of an ideal gas, while the real gas has forces of attraction between its particles.

2. Helium gas. It has the smallest particles of all real gases.

3.

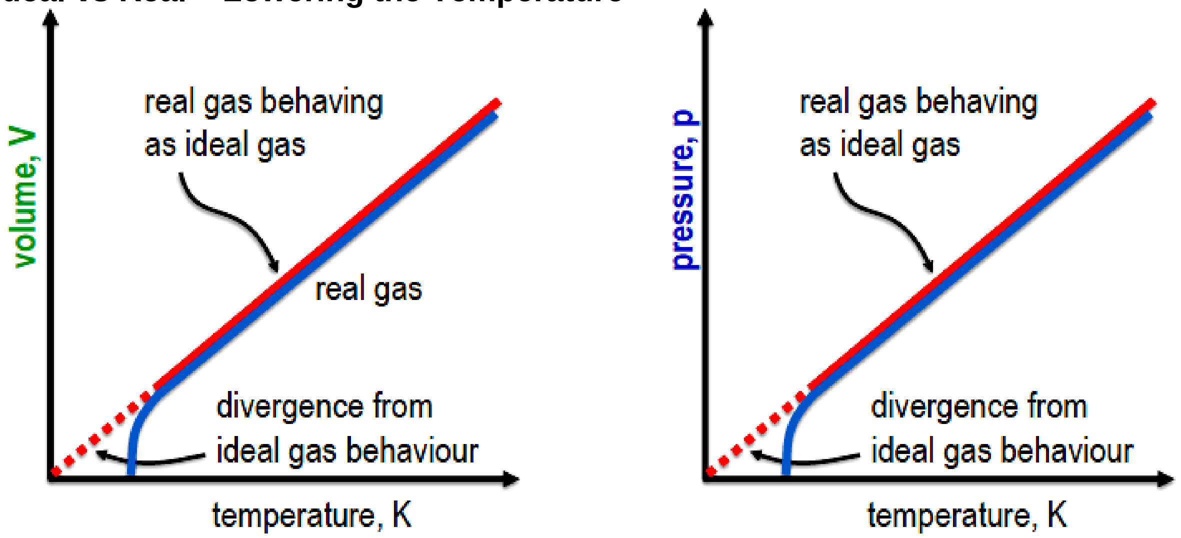


When the pressure increases, pV will increase. The volume of the real gas will not decrease as pressure increases.

Ideal Gases

- An Ideal gas is a gas:
  - That has identical particles of zero volume.
  - With no intermolecular forces between particles.
  - In which all collisions of molecules with themselves or the walls of the container are perfectly elastic.
- **REAL GASES**
  - (gases that do exist) can behave (more or less) like ideal gases under certain circumstances, when the pressure is very low and when temperatures are relatively high [not near absolute zero, 0 K (–273°C)]
  - Ideal gases and data related to them, may be used to predict how real gases will behave, as long as we stay within the parameters detailed above (i.e. low pressure, high temp.)

Ideal vs Real – Lowering the Temperature



At very low temperatures (near absolute zero), the particles hardly move, the intermolecular forces exert a large effect, and the particle size becomes important. At these very low temperatures, real gases do not behave like ideal gases.

<u>**EXAMPLES**</u>

1 Under which conditions do real gases behave like ideal gases?

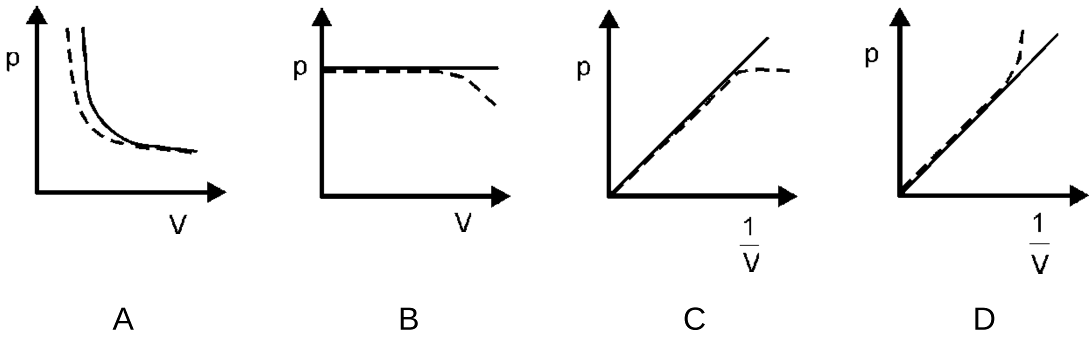
A low temperature and low pressure

B high temperature and high pressure

C low temperature and high pressure

D high temperature and low pressure (2)

2. The following graphs represent possible relationships between pressure and volume for an ideal gas (solid line) and oxygen (dashed line). Which graph correctly illustrates the deviation of the oxygen gas from that of an ideal gas? (Hint: Assume that the real gas did NOT liquefy and that the temperature remained constant when the data was obtained.)

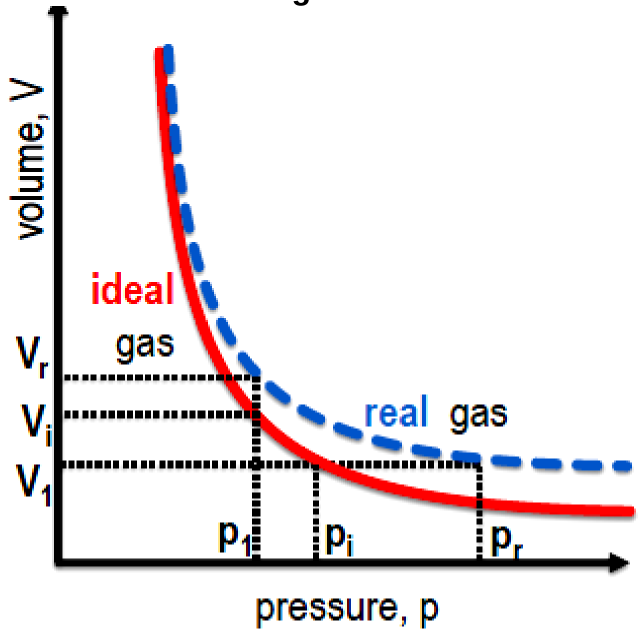


(2)

SOLUTIONS

1. D (At the low pressure and high temperature ordinary gases behaviour like ideal gases).
2.

Real vs Ideal – At High Pressure



- As the pressure on an ideal gas increases, its volume decreases.
- When the *pressure* is very *high*, the volume of the particles becomes significant.
- With *less space*, collisions also become more frequent thus real gases behave differently.
- At low overall volume, says V_1, the size of the gas particles becomes a factor, and thus the pressure in a real gas (p_r) is higher than in an ideal gas (p_i).
- At a high pressure, says p_1, the volume of a real gas (V_r) will be higher than for an ideal gas (V_i).
  ❖Note this divergence increases as the pressure increases.

Gas Laws: Boyle

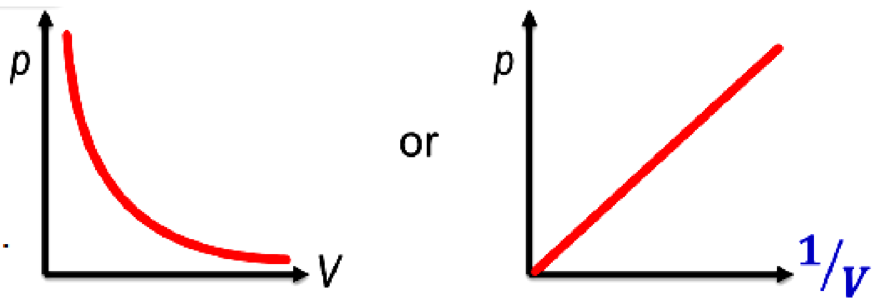
A number of laws apply to ideal gases …

• **BOYLE'S LAW**: the pressure of an enclosed gas is inversely proportional to the volume it occupies at *constant temperature*.

$p_1V_1 = p_2V_2$

represented graphically:

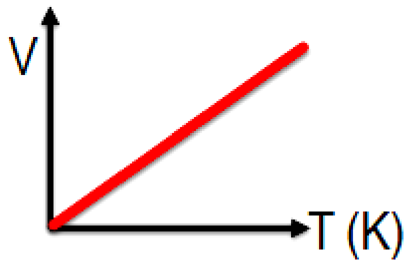
(with T constant).



decreased volume → increased # gas particles per unit volume → increased number of gas particles near any area of wall / each other → increased number of collisions per second per area of wall → increased force due to larger number of collisions per area of wall → increased pressure

Gas Laws: Charles & Gay-Lussac

CHARLES' LAW: the volume of an enclosed gas is directly proportional to its, Kelvin temperature provided the pressure is kept constant.



V $\propto T$

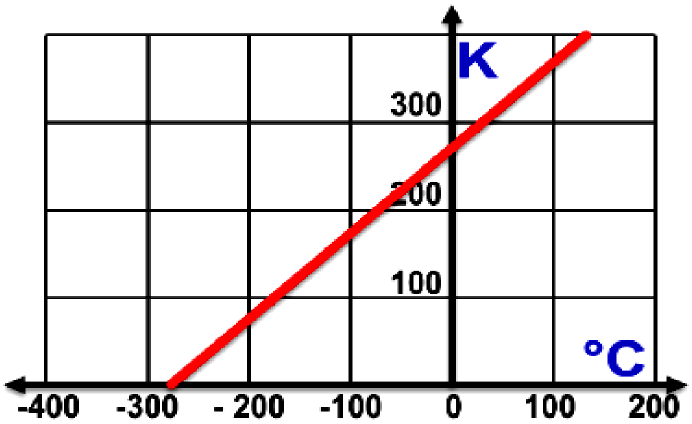
- *Increased temperature → increased rate of collisions and increased force of collisions*

- *Increase in pressure until the internal pressure (due to force of gas particles) equals the external pressure decreased volume .*

❖A third gas law is that of **GAY-LUSSAC**: The pressure of an enclosed gas, at *constant volume*, is directly proportional to its kelvin temperature i.e $p \propto T$

❖*Gay-Lussac:*
  - *Increased temperature, increased average velocity of particles and increased average force per collision and increased rate of collisions.*
  - *Increased total force, with constant area also increased force per area, and thus increased pressure.*

Note: When dealing with the gas laws, temperature ***always*** refers to ***temperature in kelvin***, not in °C or any other measure.
Conversion:
TK = T°C + 273,
or T°C = TK – 273



The General Gas Equation

- The three relationships discussed all apply only when considering the same amount of a gas.
- Use the general gas equation,
  $\frac{p1v1}{T1} = \frac{p2V2}{T2}$
  and the ideal gas equation: pV= nRT *to* solve problems.
- **Remember**, for pressure and volume any unit may be used*, as long as the use is consistent. For temperature, the Kelvin scale must be used.*

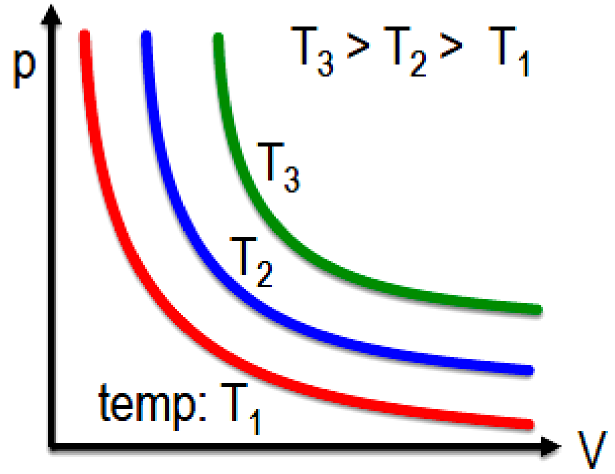
Ideal Gas Equation

$p\,V = n\,RT$

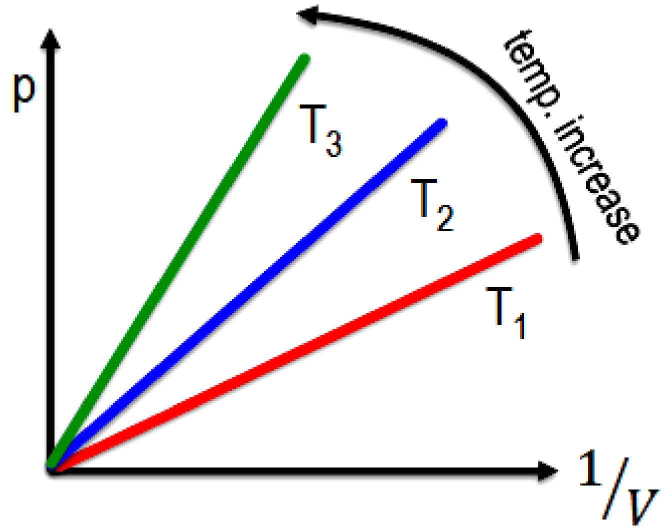
p (pressure) – *pascal* (**Pa**); ***V*** (volume) – *cubic metres* (**m³**) ***n*** (no. of mole) – in *moles* (**mol**), ***T*** (temp.) – kelvin (**K**), and ***R*** is the universal gas constant, units $J{\cdot}K^{-1}{\cdot}mol^{-1}$

Some Thoughts

According to Boyle's law, the pressure of a gas is inversely proportional to its volume, provided the temperature and number of gas particles remains constant. As shown in the graph below:



When amount of gas is held constant, but temperature increases, what would the graph look like? Something similar happens for the plot of p vs 1/V ….



MC QUESTIONS
There are four possible options for each answer in the following questions. Each question has only ONE correct answer. Choose the correct answer and write only A, B, C or D next to the question number.

1.1 The temperature of a gas is defined as …

A the heat of the gas

B the product of the pressure and volume of the gas

C a measure of the average speed of the molecules of the gas

D a measure of the average kinetic energy of the molecules of the gas (2)

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

A The volume occupied by the ideal gas is equal to the total volume of all the individual molecules.

B The collisions between the molecules are perfectly elastic.

C There are no forces of attraction between the molecules.

D The product of the pressure and the volume of the ideal gas is constant at constant temperature. (2)

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

	Temperature	Pressure
A.	Low	Low
B.	Moderate	High
C.	Low	High
D.	Moderate	Low

(2)

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

A ⅛ ***p***
B ¼ ***p***
C 4***p***
D 8***p***

1.5.A fixed mass of oxygen gas is sealed in a syringe at a certain temperature and pressure. The gas has a volume V. If both the pressure and the Kelvin temperature are now doubled, the volume of the gas will be ...

A V

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

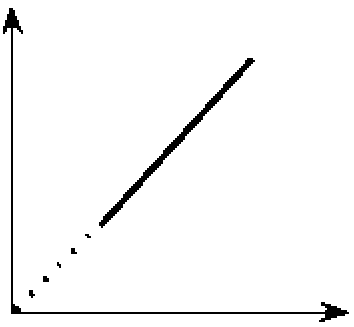
C 2V

D 4V

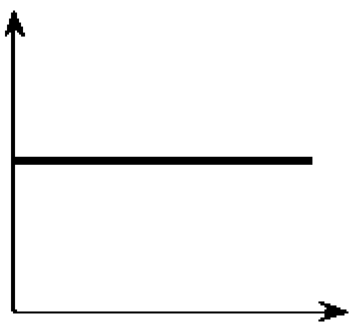
1.6 The relationship between p, V and T, for 1 mol of an enclosed gas was investigated and the results are plotted below. In which ONE of the graphs does the gradient of the line represent the universal gas constant (R)?

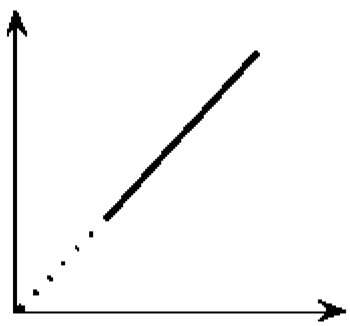
A

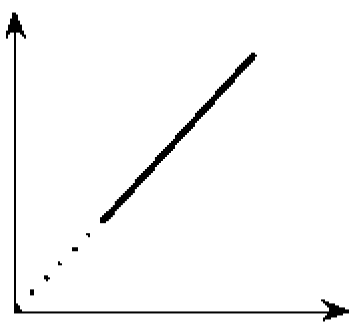
pV



V

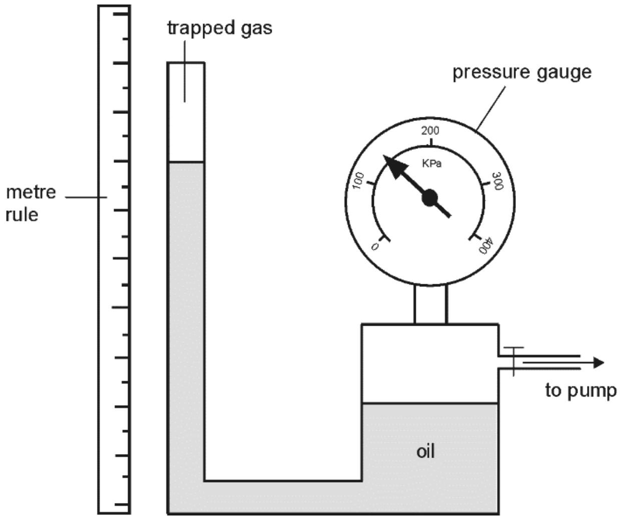






LONG QUESTIONS
QUESTION 1

Mrs Kgopa demonstrates an experiment about gases to her Grade 11 class. The following diagram represents the apparatus she used. She attaches a bicycle pump to the apparatus. She then increases the pressure on the liquid when she applies pressure to the bicycle pump.



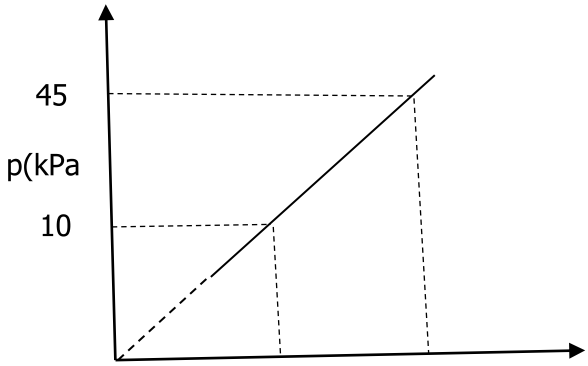
1.1 Write an investigative question for Mrs Kgopa's experiment. (2)
1.2 Identify the independent variable in this experiment. (1)
1.3 After each increase in pressure, explain why Mrs Kgopa should leave the apparatus alone for a few seconds before she measures the volume of the gas.(2)
1.4 Copy the following table. Calculate the values of $\frac{1}{V}$ to complete the table.

p (kPa)	*V* (cm³)	$\frac{1}{V}$ (cm⁻³)
105,0	30	
126,0	25	
157,5	20	
210,0	15	

(4)

1.5 Draw a graph of $\frac{1}{V}$ versus *p*. (4)
1.6 State a conclusion to the experiment. (2)

QUESTION 2
The graph below indicate the relationship between the pressure(p) and the reciprocal of volume (1/v) of the enclosed mass of Helium(He)gas at 25°C.Aassume that Helium behaves as an ideal gas.



2.1 Give the name and state $\frac{1}{50}$ rds the Law $\frac{1}{V}$ illustrated by the graph. (3)
2.2 Calculate the volume of t gas at a pre e of 450 kPa (4)
2.3 Use the graph the mass of Helium that was used. (5)
2.4 Copy the graph in your answer book. Label this graph A on the same set of axes draw the graph that will be obtained if:
2.4.1 The experiment is conducted at 35°C (Label this graph B) (2)
2.4.2 The real such ammonia is used instead of Helium (2)
2.5 Explain fully why the shape of the graph is different in question 2.4.2. (3)
[19]

QUESTION 3

3. A group of learner investigate the relationship between the volume, temperature and pressure of a fixed amount of Helium gas in the closed balloon.

3.1 When the pressure is 102 kPa, temperature is 29°C and volume is 31,8cm^3, the balloon is than released to high altitude. Calculate the temperature inside the ballon at this higher altitude when pressure drops to 75kPa and volume changes as 34,5cm^3. (5)

3.2 Explain in terms of the kinetic molecular theory, the effect that a decrease in the temperature of a gas will have on its pressure at constant volume. (2)

3.3 Helium gas can behave as an ideal gas

3.3.1. Define an ideal gas (2)

3.3.2. List Three properties of an ideal gas (3)

3.3.3. List two conditions when a real gas behaves like an ideal gas. (2)

3.4. Write down the magnitude of the molar gas volume at STP. (2)

[16]

QUESTION 4

Carbon dioxide (CO2) gas is produced as a result of the reaction between calcium carbonate and hydrochloric acid. The gas that is produced is collected in a 20 dm3 container. The pressure of the gas is 105 kPa at a temperature of 200C. What mass of carbon dioxide was produced?

SOLUTIONS: QUANTITATIVE ASPECTS OF CHEMICAL CHANGE

Activities on Particle Formula

1.1 0,25	1.2 40	1.3 0,0005	1.4 0,6
2.1 $1,204 \times 10^{23}$	2.2 $3,01 \times 10^{24}$	2.3 $6,02 \times 10^{25}$	2.4 $2,408 \times 10^{24}$
3.1 $4,8 \times 10^{23}$	3.2 6×10^{24}	3.3 $3,6 \times 10^{26}$	3.4 $2,4 \times 10^{24}$

Molar mass and moles

1.1 5 mol	1.2 0,2 mol	1.3 2,5 mol	1.4 0,05mol
2.1 21,2g	2.2 440g	2.3 0,8g	2.4 170g
3.1 $1,204 \times 10^{24}$	3.2 $3,01 \times 10^{22}$	3.3 $1,505 \times 10^{24}$	3.4 $4,53 \times 10^{22}$

Molar Gas Volumes

1.1 2,5	1.2 0,05	1.3 2	1.4 30
2.1 $44,8dm^3$	2.2 $2,24dm^3$	2.3 $44,8dm^3$	2.4 $15,68dm^3$

Moles Calculations

1.1 5	1.2 0,1	1.3 0,2	1.4 0,1	1.5 0,5
1.6 2,5	1.7 0,03	1.8 40	1.9 0,5	1.10 10
1.11 0,25	1.12 20	1.13 0,05	1.14 5	1.15 4

2.1 74g	2.2 175,5g	2.3 3190g	2.4 440g	2.5 0,85g
2.6 3,8g	2.7 11,5g	2.8 160g	2.9 13,6g	2.10 60g

3.1 134,4dm^3	3.2 8,96dm^3	3.3 224dm^3	3.4 11,2dm^3	3.5 4,48dm^3
3.6 11,2dm^3	3.7 336dm^3	3.8 5600dm^3	3.9 44,8dm^3	3.10 4,48dm^3

A (molecules)

4.1 $6,01 \times 10^{22}$	4.2 $1,505 \times 10^{25}$	4.3 $3,01 \times 10^{24}$	4.4 $3,01 \times 10^{24}$	4.5 $1,204 \times 10^{25}$
4.6 $1,806 \times 10^{24}$	4.7 $3,01 \times 10^{22}$	4.8 $1,204 \times 10^{26}$	4.9 $6,02 \times 10^{22}$	4.10 $3,01 \times 10^{23}$

B (molecules)

4.1 $3,01 \times 10^{23}$	4.2 $3,01 \times 10^{25}$	4.3 $6,02 \times 10^{24}$	4.4 $9,03 \times 10^{24}$	4.5 $4,816 \times 10^{25}$
4.6 $5,418 \times 10^{24}$	4.7 $2,107 \times 10^{23}$	4.8 $2,408 \times 10^{26}$	4.9 $1,204 \times 10^{23}$	4.10 $1,204 \times 10^{24}$

Stoichiometry Calculations

1.1 10 mol	1.2 180g	1.3 8g	1.4 5,6dm^3	1.5 89,6 dm^3

2.1 0,8 mol	2.2 17,92dm^3	2.3 54g	2.4 8,96dm^3	2.5 136g	2.6 391g NH_3 excess

3.1 1 mol	3.2 22,4dm^3	3.3 14,4g	3.4 134,4dm^3	3.5 156g	3.6 1,8g H_2O in excess

4.1 6 mol	4.2 204g	4.3 2,24dm^3	4.4 24g	4.5 4,48dm^3	4.6 0,448dm^3 SO_2 in excess

5.1 8 mol	5.2 56g	5.3 11,2dm^3	5.4 3,4g	5.5 6,72dm^3	5.6 3,5g	5.7 2g H_2 in excess

Concentrations Calculations

1.	0,6g	2.	0,1mol.dm^{-3}
3.	0,1mol.dm^{-3}	4.	0,2mol.dm^{-3}
5.	2,72g	6.	0,625dm^{3}
7.2	0,08mol.dm^{-3}	7.3	0,16mol.dm^{-3}
8.	0,3mol.dm^{-3}	9.	2mol.dm^{-3}
10.	0,22mol.dm^{-3}	11.	0,08dm^{3}
12.	0,0625mol.dm^{-3}		

Empirical Formula and Molecular Formula

1. a Cu = 33,87 % ; N = 12,80 % ; O = 8,53 %
   b C = 49,48 % ; H = 5,15 % ; N = 28,87 % ; O = 16,49 %
2. 51,21 %
3. NH_4NO_3

4.1 CaO_2H_2

4.2 $AgNO_3$

4.3 $BaCl_2.2H_2O$

5. E.F = BH_3 M.F = B_2H_6
6. C_2H_3

7.1 n 0,005 moles

7.2 n = 0,011moles

Eastern Cape 2016 NOV

5.1.2 CH_2

5.1.3 C_2H_4

5.2.1 26.25g

Eastern Cape 2012 NOV

5.1 Nicotine

5.2 harmful

5.3 Cancer

5.4 C_5H_7N

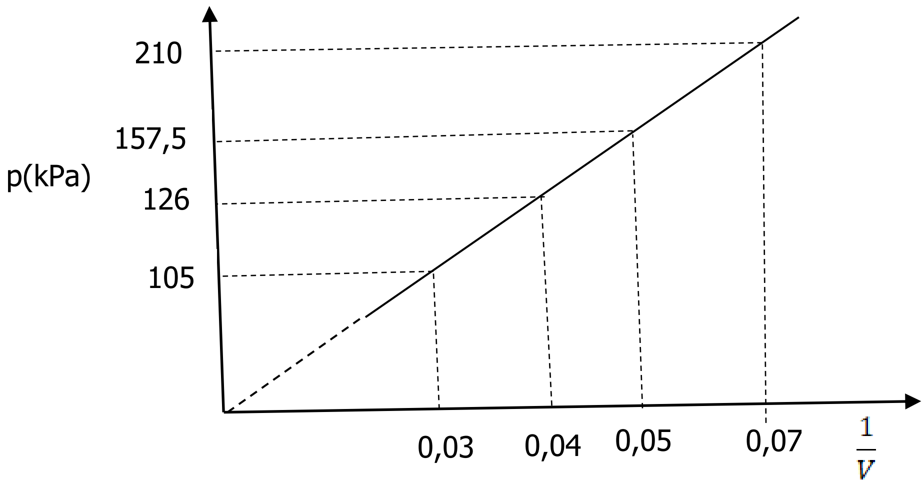
GP JUNE 2016

SOLUTIONS: GASES
MC ANSWERS
QUESTION 1

1.1 D √√
1.2 D √√
1.3 C √√
1.4 D √√
1.5 A √√
1.6 B √√

LONG QUESTIONS
QUESTION 1

1.1 What is the relationship between pressure and volume?√√ (2)
1.2. Pressure√ (1)
1.3. Allow temperature to stabilise as the control variable.√√ (2)
1.4. (i) 0.03 √
(ii) 0.04 √
(iii) 0.05 √
(iv) 0.07 √
1.5.



1.6. Volume is inversely proportional to the pressure provided the temperature remains constant.√√ (2)

QUESTION 2

2.1 Boyle's Law.✓

The pressure exerted by an enclosed gas is inversely proportional to the volume ✓

it occupies at constant temperature.✓ (3)

2.2 p_1V_1 = p_2V_2✓

105x50✓ = 450✓ Xv_2

V_2 = 11.67dm^3✓ (4)

2.3 Gradient = Pv

= 450 –105

1 _1 ✓

11,67 50

= 5251. 957J

Pv = nrt✓5251.957

=n x8.31 x298✓

n = 2.121 /2.12 mol n

=m/M

2.121 = m/4 ✓

Pv = nrt ✓

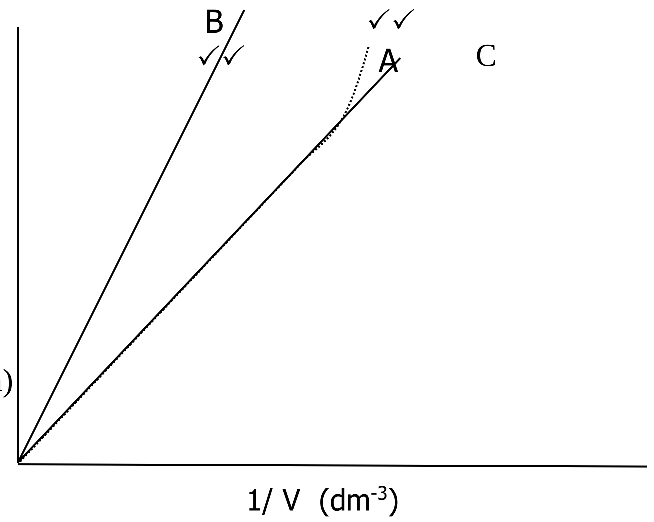
450 x 10^3x 11.67x10^{-3} ✓= n x 8.31 x298✓

n = 2.121 mol

m = 8.484/ 8.483 /8.48g✓ (5)

2.2.1

2.2.2



(4)

2.5 At high pressure the gas particles are closer together. ✓The forces of attraction

Between the particles become significant and increase. ✓ <u>The gas begins to liquefy Resulting in an increase in volume.</u> ✓ (3)

[19]

QUESTION 3

3.1. $\frac{P1V1}{T1} = \frac{P2V2}{T2}$ ✓

$\frac{102\ X31.8}{302}\sqrt{}= \frac{75X34.5}{T2}$ ✓

T_2 = 240,91k✓✓ (5)

3.2. Decrease in temperature decrease the rate of collision and decrease the force of collision hence decrease the pressure. ✓ ✓ (2)

3.3.1. An Ideal gas is a theoretical gas which obeys the gas laws under all conditions of temperature and pressure. ✓ ✓ (2)

3.3.2. (a) are identical in all ways✓

(b) Occupy no volume✓

(c) Exert no force on each other except during a collision. ✓

(d) In all collision of the molecules with themselves or the walls of the container, are perfectly elastic. ✓ (Any three)

3.3. At a low pressure and high temperature ✓✓

3.4. 22.4 dm^3 ✓✓

QUESTION 4
DATA
p = 105 kPa
V = 20 dm3
T = 20◦C

p = 105 × 1 000 = 105 000 Pa
T = 20 + 273 = 293 K
V =20÷1000 = 0.02m3

pV = nRT
105000 X 0,02 = n x 8.31 x 293
n = 0.86 mol
n = m/M
0.86 = m/44
m = 37.84g