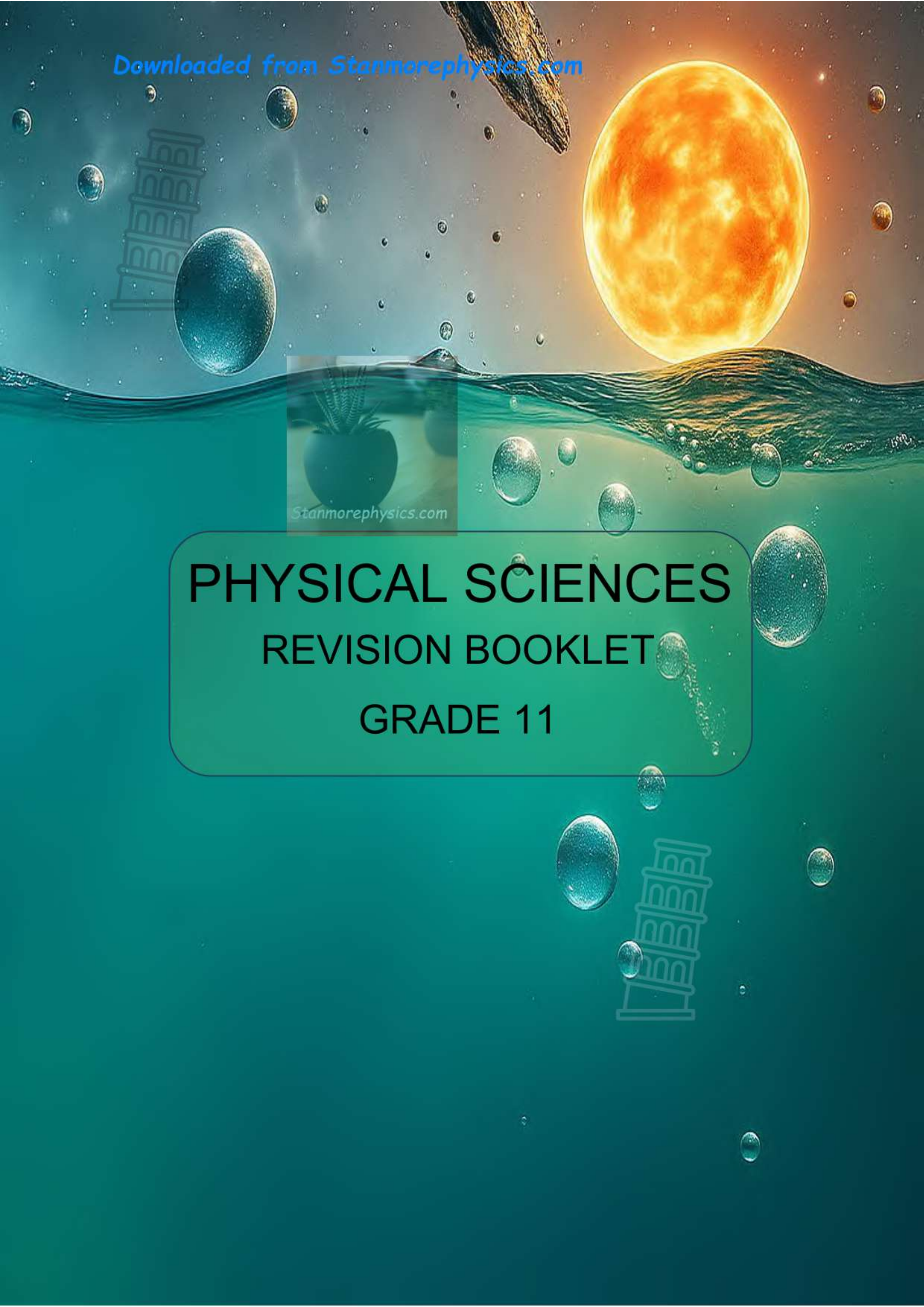


PHYSICAL SCIENCES

REVISION BOOKLET

GRADE 11

Secondary Schools Directorate

education
Department of Education
FREE STATE PROVINCE

TABLE OF CONTENTS

CREDITS

The following question papers were used to compile this book:
Department of Basic Education, *National Senior Certificate Physical Sciences Question Papers*, 2014 – 2022, Pretoria

HOW TO USE THIS DOCUMENT

Dear grade 11 Learner

1. This document was compiled as an extra resource to help you to perform well in physical sciences.

2. Firstly, you must make sure that you study the terms and definitions provided for each topic. Theory always forms part of any test or examination, and you should ensure that you obtain full marks for ALL theory questions. Always be prepared to write a test on terms and definitions as soon as a topic is completed in class. Frequently revise terms and definitions of topics already completed so that you know them by the time you are sitting for a test or an examination.

3. Answer all the questions on a certain topic in your homework book as soon as the topic is completed. Numerical answers are given at the back of this book. Use them to guide you about the correctness of your answers. If you differ from a given answer, you may want to check the correctness of your answer. In the case of vectors, only the magnitude of the answer is given. Interpret the direction in terms of your choice of direction. A separate book with fully worked out answers is available. Your teacher will decide when he/she will hand out that specific booklet.

4. If you have the answer book, DO NOT look at the answers before attempting the questions. First try it yourself. Compare your answers with the given answers. Mark your work with a pencil and do corrections for your incorrect answers. If you do not know how to answer a question, the answers are there to guide you. Acquaint yourself with the way in which a particular type of question should be answered. Answers supplied are from memoranda used to mark the questions in previous years.

5. Your teacher can, for example, give you two of the questions in this document as homework. The following day he/she will just check whether you answered them and whether you marked your answers. The teacher will only discuss those questions in which you do not understand the answers supplied in the document. Therefore, a lot of time will be saved, depending on when you receive the answer booklet.

6. The answers are meant to help you to prepare for your tests and examinations. If you choose to copy answers into your homework book without trying them out yourself, you will be the losing the developmental aspect of trying to solve problems yourself!

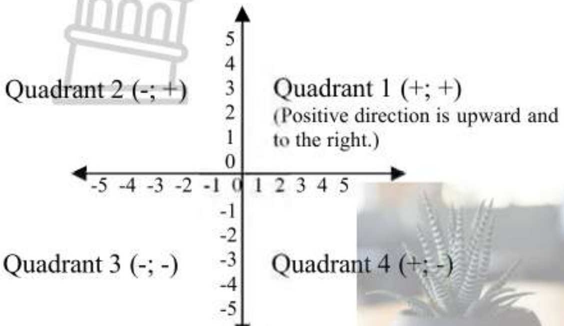
7. Work through all the questions and answers of a particular topic before you sit for an examination, even if you answered the questions before.

8. Any additional resource is only of help when used correctly. Ensure that you make use of all help provided in the correct way to enable you to be successful. All the best and may you perform very well in physical sciences.

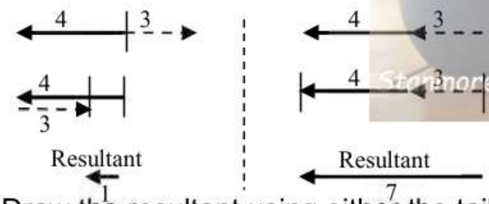
VECTORS IN TWO DIMENSIONS

Resultant of perpendicular vectors

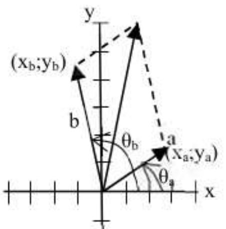
- Draw vectors on the Cartesian plane



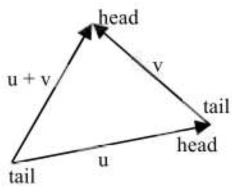
- Add co-linear vectors



- Draw the resultant using either the tail-to-head or tail-to-tail method.

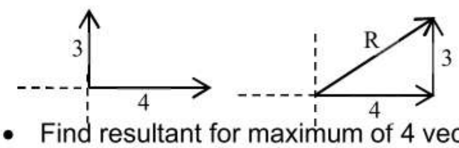


Tail-to-tail method



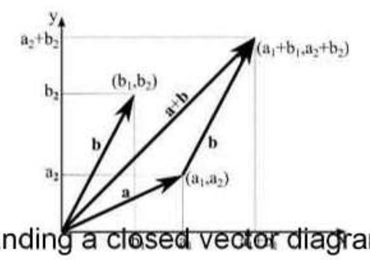
Tail-to-head method

- Calculate resultant using Pythagoras.



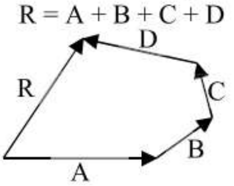
$a^2 + b^2 = c^2$
$4^2 + 3^2 = R^2$
$16 + 9 + R^2$
$R = 5$

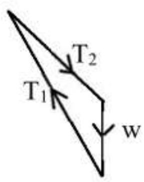
- Find resultant for maximum of 4 vectors using tail-to-head method and by calculation with component method



- Understanding a closed vector diagram.

$R = A + B + C + D$



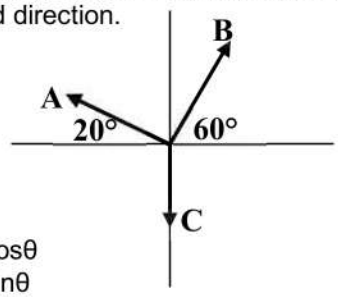


R = 0

- Determine the direction of a resultant vector using trigonometry

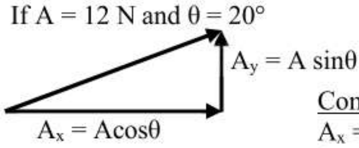
Resolution into components

- Draw vectors on the Cartesian plane showing magnitude and direction.



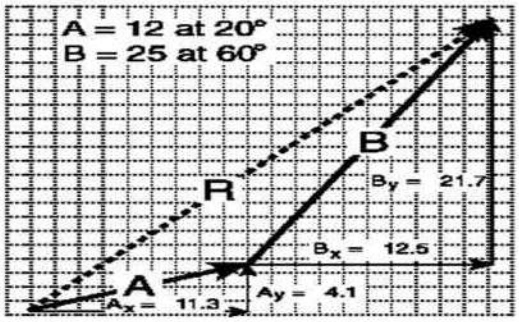
- Use $R_x = R\cos\theta$
- Use $R_y = R\sin\theta$

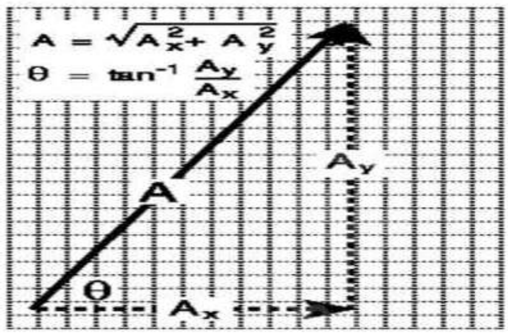
If A = 12 N and θ = 20°



Component calculation
$A_x = 12\cos 20° = 11{,}3$
$A_y = 12\sin 20° = 4{,}1$

Component method: graphically





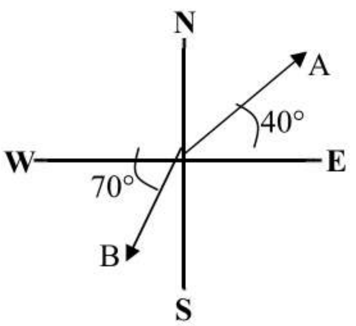
- Use force vectors as examples.

- **Representing vectors:**
  A vector is represented as an arrow where the length of the arrow, drawn to scale, indicates the magnitude and the arrowhead indicates the direction of the vector.

- **Vector addition:**
  Vectors can be added using the:
  ✓ Tail-to-head method
  ✓ Parallelogram method (tail –to-tail method)
  ✓ Component method

- Vector addition must be done for the following situations:
  ✓ Two vectors in the same direction (collinear)
  ✓ Two vectors that are perpendicular to each other (90° angle between the two vectors)
  ✓ Two vectors that acts at an angle smaller or larger than 90° to each other

- **Direction of vectors:**
  The direction of a vector can be indicated by one of the following:
  ✓ Use the points of the compass as reference from which to measure angles



Direction of vector A:
40° north of east or 50° east of north
E 40° N or N 50° E

Direction of vector B:
70° south of west or 20° west of south
W 70° S or S 20° W

✓ Measure angles clockwise from a reference direction, usually north
Direction of vector A: 50°
Direction of vector B: 200°

✓ Use another vector or a fixed point as reference e.g. 30 m at an angle of 20° to the bank of the river

Daily task 1.1: Homework/Classwork

1. Classify the following quantities as scalars or vectors:

1.1 12 km
1.2 1 m south
1.3 2 m·s^{-1}, 45°
1.4 75°, 2 cm
1.5 100 km·h^{-1}, 0°
1.6 3 s
1.7 80 kg
1.8 3 N to the right

2. Represent the following vector quantities with a scale drawing.

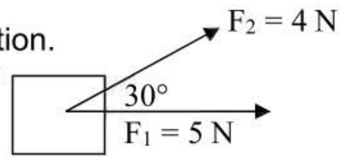
2.1 6 m·s^{-1} north
2.2 16 m east

3. A ship leaves harbour H and sails 6 km north to port A. From here the ship travels 12 km east to port B, before sailing 5,5 km south-west to port C. Determine the ship's resultant displacement using the head-to-tail method.

4. A man walks 40 m east, then 30 m north.

4.1 What was the total distance he walked?
4.2 What is his resultant displacement?

5. A force of F_1 = 5 N is applied to a block in a horizontal direction. A second force, F_2 = 4 N, is applied to the block at an angle of 30° above the horizontal. Determine the resultant force acting on the block using the parallelogram method.



6. A tennis ball is rolled towards a wall which is 10 m away from the ball. After striking the wall, the ball rolls a further 2,5 m along the ground away from the wall. Calculate the ball's resultant displacement.

7. A squash ball is dropped to the floor with an initial velocity of 2,5 m·s^{-1}. It rebounds (comes back up) at a velocity of 0,5 m·s^{-1}. Determine the:

7.1 Change in velocity of the squash ball
7.2 Resultant velocity of the squash ball

8. A man walks 40 m East and then 30 m north. Calculate the man's resultant displacement.

9. A man walks from point A to point B which is 12 km apart on a bearing of 45°. From point B the man walks a further 8 km east to point C. Calculate the resultant displacement.

10. A frog is trying to cross a river. It swims at 3 m·s^{-1} in a northerly direction towards the opposite bank. The water is flowing in a westerly direction at 5 m·s^{-1}. Use appropriate calculations to find the frog's resultant velocity. Include a rough sketch of the situation in your answer.

11. Sandra walks 500 m, northwest to the shop and then 400 m N 30° E. Use appropriate calculations to find her resultant displacement.

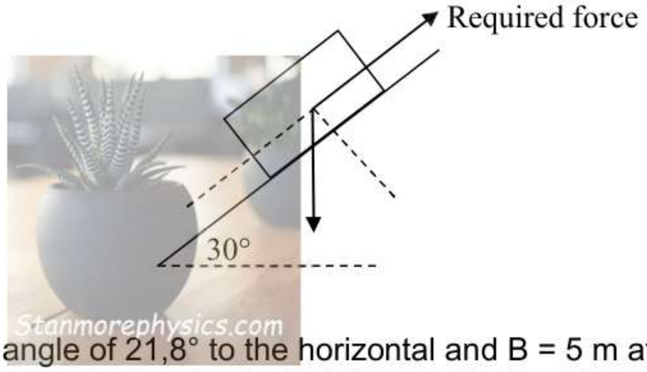
Daily task 1.2: Homework/Classwork

1. A motorist undergoes a displacement of 250 km in a direction 30° north of east.

1.1 Resolve this displacement into components in the directions north (~x N) and east (~x E) by means of a scale drawing.

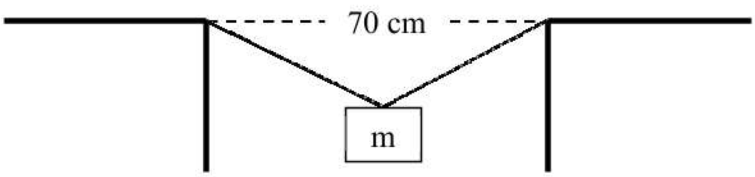
1.2 Now use trigonometry to calculate the magnitudes of the perpendicular components of the original displacement.

2. Determine the force needed to keep a 10 kg block from sliding down a frictionless slope. The slope makes an angle of 30° with the horizontal.



3 A = 5,385 m at an angle of 21,8° to the horizontal and B = 5 m at an angle of 53,13° to the horizontal. Use a scale drawing to find the resultant vector.

4. A rope is tied at two points which are 70 cm apart from each other, on the same horizontal line. The total length of rope is 1 m, and the maximum tension it can withstand in any part is 1 000 N. Find the largest mass, in kg, that can be carried at the midpoint of the rope, without breaking the rope. Include a vector diagram in your answer.



EXPERIMENT 1A: DETERMINE THE RESULTANT OF THREE NON-LINEAR FORCE VECTORS

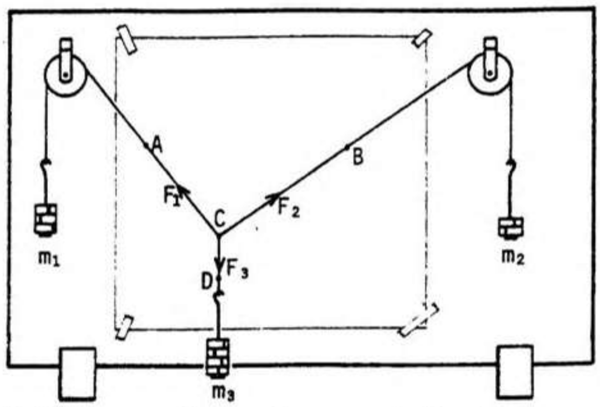
Aim:
To determine the resultant of two non-linear force vectors experimentally.

Investigative question
Formulate an investigative question for this investigation. (2)

Hypothesis
Formulate a hypothesis for this investigation, containing the independent variable, dependent variable as well as a relationship between them. (2)

Apparatus
- Force board
- Three hangers and slotted weights
- Sheet of paper
- Pencil
- Light, non-flexible string or gut

Method
1. Setup the force board with two pulleys attached as shown in the diagram below.



Pass a length of string over the pulleys and attach a hanger to each end of the string. Tie a second piece of string to the first one between the pulleys. Attach a third hanger to this piece of string. Now hang suitable mass pieces (for example, 70g and 80g) to the two hangers over the pulleys. Also attach mass pieces (for example, 100g) to the third hanger so that the knot C comes to rest near the middle of the force board. Pin the sheet of paper behind the knot and in the middle of the force board.
2. Ensure that when knot C is pulled to one side, it returns to its original position.
3. Mark point C on the paper (being careful to avoid a parallax error).
4. Also mark points A, B and D on the paper to show the positions of the strings.
5. By joining the points CA, CB and CD the directions of the forces acting on C are represented.

Results

Determine the total mass of each hanger with its mass pieces. Calculate the magnitudes of the forces F_1, F_2 and F_3 in newton. Record the magnitudes of the three forces:

Magnitude of F_1 = __________ N
Magnitude of F_2 = __________ N
Magnitude of F_3 = __________ N (3)

of **Interpretation of results**

1. Remove the sheet of paper from the board and join points CA, CB and CD.
2. Choose a suitable scale and draw an arrow accurately from C to represent F_1.
3. Draw F_2 with its tail starting at the head of F_1.
4. Now draw a vector from the tail of F_1 to the head of F_2. (6)
5. Consider the magnitude of the closing side determined in step 5 above.

5.1 What is the magnitude of this vector? (1)

5.2 Write down the name given to this vector: (1)

5.3 How does the vector compare with force F_3 (to two significant figures)? (2)

6 On a <u>separate diagram</u>

6.1 Draw vectors F_1 and F_2 as you did above. Draw F_3 with its tail starting at the head of F_2. (6)

6.2 Do you get a closed figure? (1)

6.3 What is the resultant of the three forces (to two significant figures)? (1)

6.4 What is force F_3 called? (1)

7. Explain the following:

7.1 A closed vector diagram. (2)

7.2 Equilibrium of three forces in terms of their resultant. (2)

7.3 Equilibrium in terms of the motion of a body. (2)

7.4 State the triangle rule for three forces in equilibrium (2)

8. List any possible sources of experimental error in this experiment. (5)

9. How do you ensure that the positions of point **C** and the three strings are correctly transferred to the paper? Give a brief explanation. (3)

Conclusion

Write down a conclusion in terms of the **resultant** of the two non-linear force vectors and the **equilibrant** the two force vectors. (2)

[44]

EXPERIMENT 1B: DETERMINATION OF THE WEIGHT OF AN UNKNOWN MASS

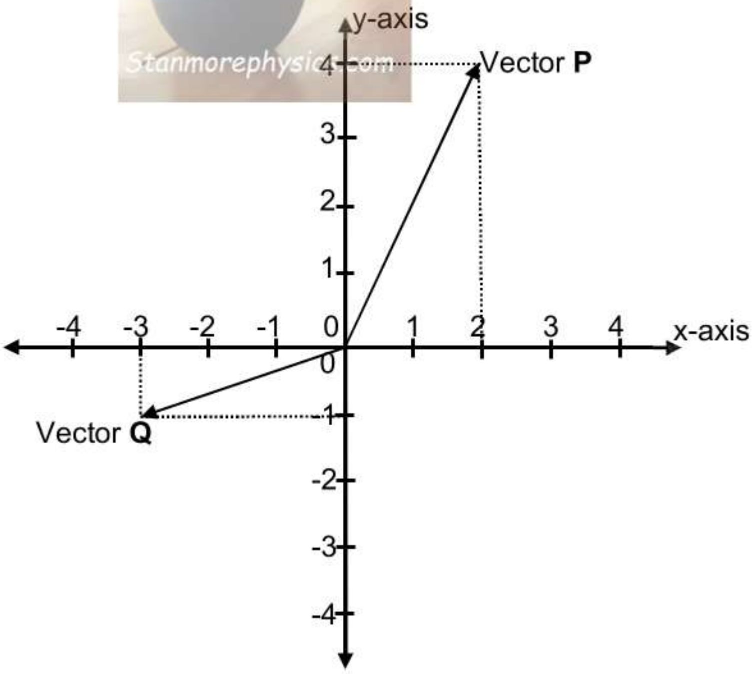
You are supplied with an unknown mass. Using the same apparatus as in experiment 1A and the knowledge obtained:

1. Write down an investigative question for the investigation
2. Formulate a hypothesis for the investigation
3. Design a method to determine the weight of the unknown mass
4. Conduct the investigation and determine the unknown weight.
5. Formulate a conclusion for the investigation. [24]

STRUCTURED QUESTIONS

QUESTION 1 *(Exemplar 2013)*

Force vectors **P** and **Q** were drawn to scale on the Cartesian plane shown below.



1.1 Define the term *resultant of two forces* in words. (2)

1.2 Use a calculation to determine each of the following:

1.2.1 The magnitude of vector **P** in force units (2)

The direction of vector **Q** measured clockwise from the positive y-axis (3)

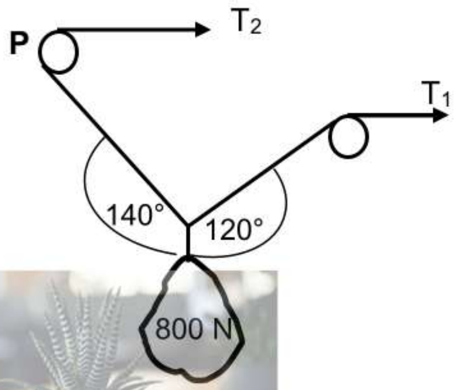
1.3 Use the component method to calculate the magnitude of the resultant (in force units) of vectors **P** and **Q**. (3)

1.4 Calculate the direction (measured clockwise from the positive y-axis) of the resultant of vectors **P** and **Q**. (2)

[12]

QUESTION 2 *(November 2014)*

The diagram below shows a rope and pulley arrangement of a device being used to lift an 800 N object. Assume that the ropes are light and inextensible and also that the pulley is light and frictionless.



Determine the:

2.1 Magnitudes of the tensions $\mathbf{T_1}$ and $\mathbf{T_2}$ (7)

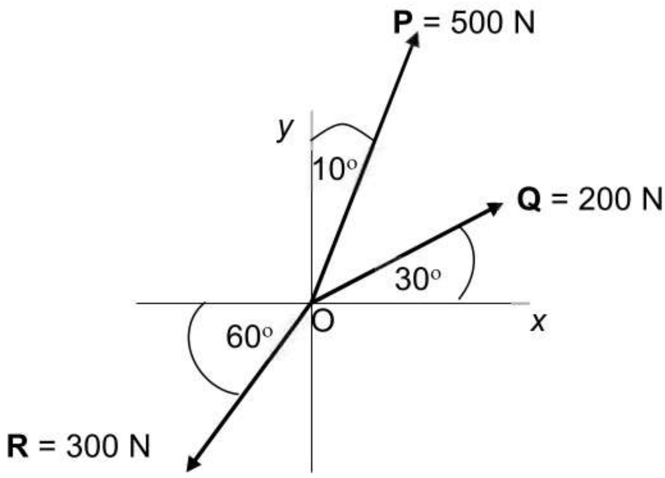
2.2 Magnitude and direction of the reaction force at pulley **P** (4)

[11]

QUESTION 3 *(November 2015)*

Three forces, **P**, **Q** and **R**, of magnitudes 500 N, 200 N and 300 N respectively, act on a point **O** in the directions shown in the diagram below.

The forces are NOT drawn to scale.



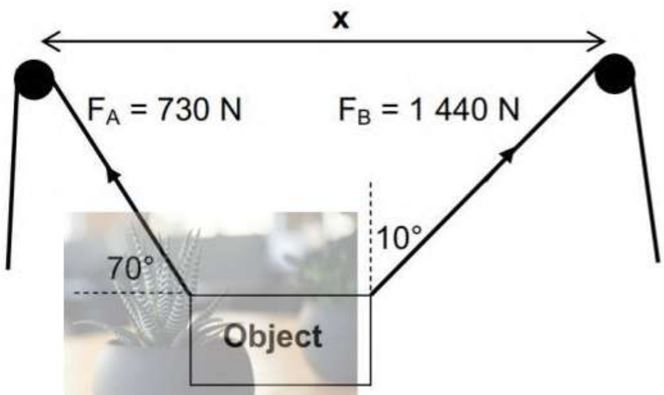
3.1 Refer to the information in the diagram above and give a reason why forces **P**, **Q** and **R** are classified as vectors. (2)

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

[10]

QUESTION 4 *(November 2016)*

A heavy object is lifted using two ropes and two pulleys, as shown in the diagram below. The two pulleys are a distance **x** apart. The force F_A, in rope A, is 730 N andthe force F_B, in rope B, is 1 440 N. Rope A makes an angle of 70° with the horizontal and rope B makes an angle of 10° with the vertical.



4.1 Define the term *resultant vector*. (2)

4.2 Explain why the vector diagram of force F_A, force F_B and the weight will NOT be a closed vector diagram. (2)

4.3 Calculate the:

4.3.1 Vertical component of F_A (2)

4.3.2 Horizontal component of F_A (2)

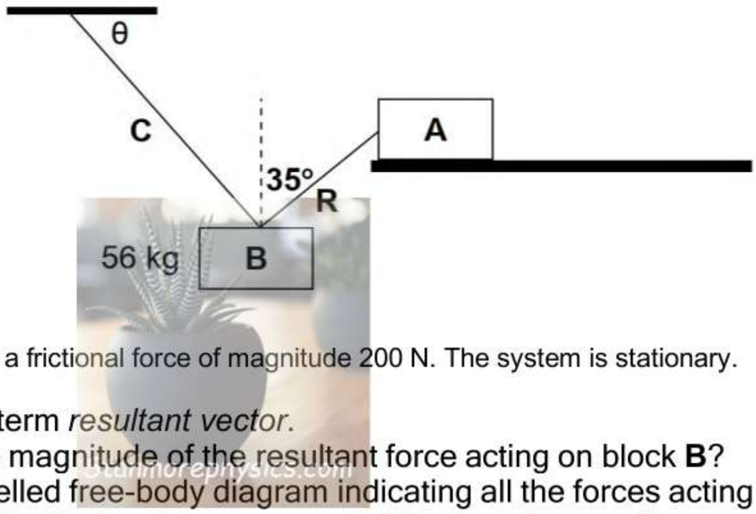
4.4 Calculate the maximum weight that force FA and force FB will be able to lift from the ground. Show ALL calculations. (4)

4.5 Explain why the rope and pulley system will be less effective if the distance x between the pulleys is increased. (2)

[14]

QUESTION 5 *(November 2017)*

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

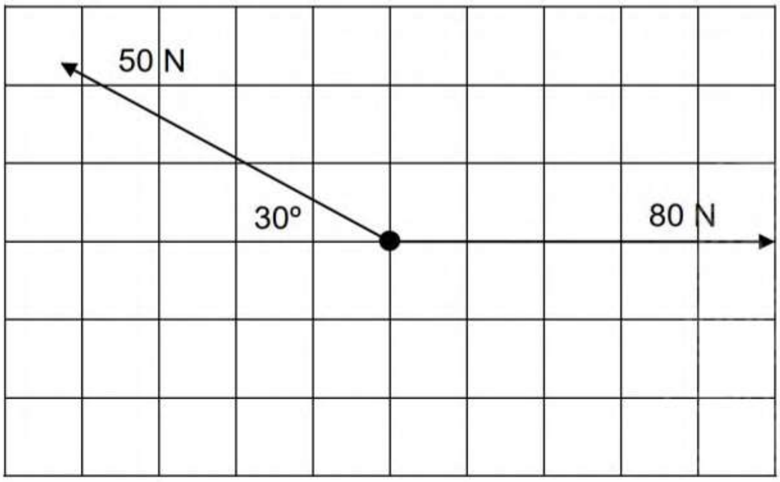


Block **A** experiences a frictional force of magnitude 200 N. The system is stationary.

5.1 Define the term *resultant vector*. (2)
5.2 What is the magnitude of the resultant force acting on block **B**? (1)
5.3 Draw a labelled free-body diagram indicating all the forces acting on block **B**. (3)
5.4 Determine the horizontal component of the force in rope **R**. (1)
5.5 Calculate the vertical component of the force in cable **C**. (4)
5.6 Calculate the angle θ between the cable and the ceiling. (2)
[13]

QUESTION 6 *(November 2018)*

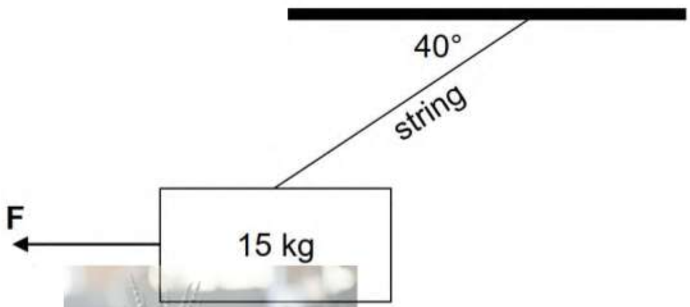
Two forces, of magnitudes 50 N and 80 N, act at a point on a Cartesian plane in the directions shown in the sketch below.



6.1 Give the correct term for the following description: (1)
A single vector having the same effect as two or more vectors together
6.2 Calculate the:
6.2.1 Magnitude of the vertical component of the 50 N (2)
6.2.2 Magnitude of the resultant (net) force (5)
6.2.3 Direction of the resultant (net) force (2)
[10]

QUESTION 7 *(November 2019)*

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



When the angle between the roof and the string is 40°, a closed vector diagram isobtained for all the forces acting on the billboard.

7.1 What deduction can be made when the forces acting on an object forms a closed vector diagram? (2)

7.2 Calculate the weight of the billboard. (2)

7.3 Draw a labelled closed vector diagram of ALL the forces acting on the billboard. Indicate the value of ONE of the angles. (4)

7.4 Calculate the tension in the string. (2)

7.5 The magnitude of force **F** is equal to the magnitude of the horizontal component of the tension in the string.

Give a reason why these two forces are NOT considered to be anaction-reaction pair according to Newton's Third Law. (1)

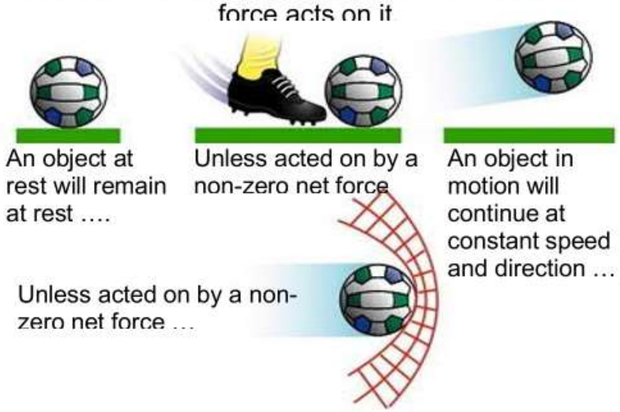
[11]

NEWTON'S LAWS

Newton's Laws of Motion

Newton's First Law

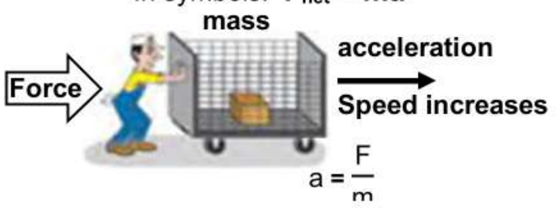
A body will remain in its state of rest or motion at constant velocity unless a non-zero resultant/net force acts on it

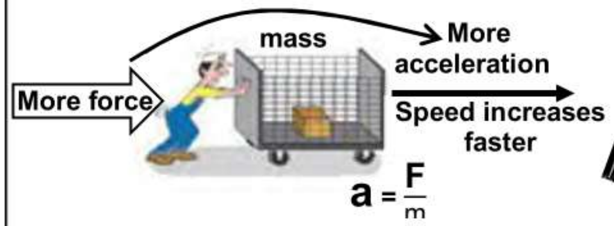


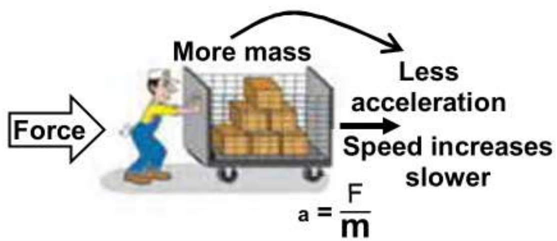
Newton's Second Law

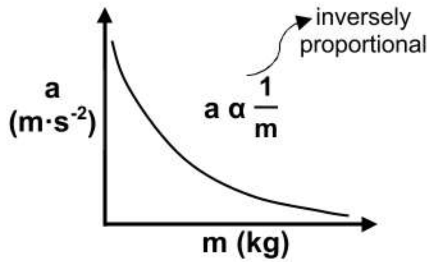
When a **resultant/net force acts on an object**, the **object will accelerate** in the **direction of the force at an acceleration directly proportional to the force and inversely proportional to the mass** of the object.

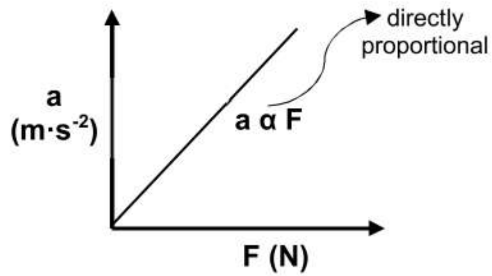
In symbols: $\mathbf{F_{net} = ma}$





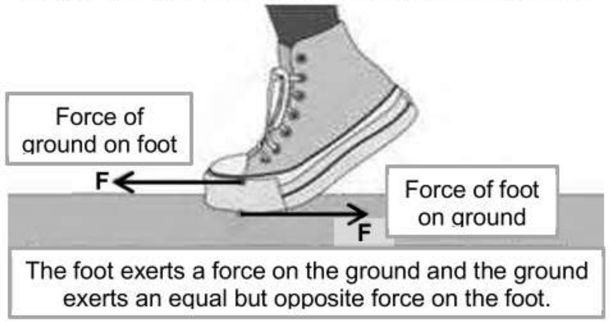






Newton's Third Law

When object **A** exerts a force on object **B**, object **B** SIMULTANEOUSLY exerts a force equal in magnitude but opposite in direction on object **A**.

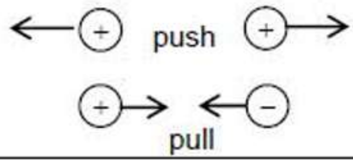
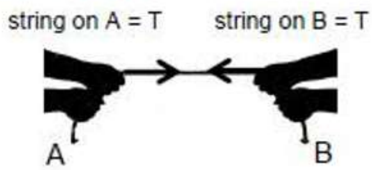
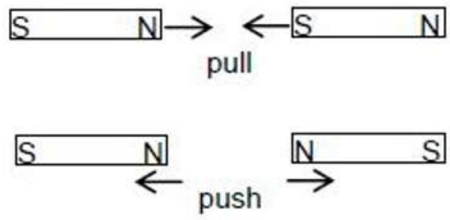


Action-reaction force pairs: The two forces act on

TERMS AND DEFINITIONS	
Acceleration	The rate of change of velocity.
Free-body diagrams	This is a diagram that shows the relative magnitudes and directions of forces acting on a body/particle that has been isolated from its surroundings.
Kinetic frictional force (f_k)	The force acting parallel to a surface and opposes the motion of a MOVING object relative to the surface.
Mass	The amount of matter in a body measured in kilogram (kg).
Maximum static frictional force (f_s^{max})	The static frictional force is a maximum (f_s^{max}) just before the object starts to move across the surface.
Newton's first law of motion	A body will remain in its state of rest or motion at constant velocity unless a non-zero resultant/net force acts on it.
Inertia	The resistance of a body to a change in its state of rest or uniform motion in a straight line. Mass is a measure of an object's inertia.
Newton's second law of motion	When a resultant/net force acts on an object, the object will accelerate in the direction of the force at an acceleration directly proportional to the force and inversely proportional to the mass of the object. In symbols: $F_{net} = ma$
Newton's third law of motion	When object A exerts a force on object B, object B SIMULTANEOUSLY exerts a force equal in magnitude but opposite in direction on object A.
Newton's law of universal gravitation	Every object in the universe attracts every other object with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. In symbols: $F = G\frac{m_1m_2}{r^2}$
Normal force	The force or the component of a force which a surface exerts on an object with which it is in contact, and which is perpendicular to the surface.
Static frictional force (f_s)	The force acting parallel to a surface and opposes the tendency of motion of a STATIONARY object relative to the surface.
Weight	The gravitational force, in newton (N), exerted on an object.
Weightlessness	The sensation experienced when all contact forces are removed i.e. no external objects touch one's body.

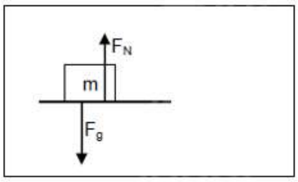
FORCE

- Definition of force: ***pull*** or ***push***.
- Force is a ***vector***.
- Some forces are ***contact*** forces. Others interact over a distance and are called ***non-contact*** forces.

	CONTACT FORCES		NON-CONTACT FORCES
1	***Friction*** (f, f) Definition: ***Friction*** is the force that opposes the motion of an object and which acts parallel to the surface. ◦ works between the object and the surface; ◦ works AGAINST the motion (ALWAYS!), parallel to the surface; ◦ is determined by the coarseness of the surface; ◦ is a PULLING force.	1	***Weight (Fg, W, Fw)*** Definition: ***Weight*** is the gravitational force the earth exerts on any object on or near its surface. ◦ is ALWAYS directed downwards, towards the center of the earth. ◦ is a PULLING force. **F_g = mg** g = 9,8 m·s^{-2} (gravitational acceleration)
2	***Normal (F_N, N)*** Definition: The ***normal force*** is the force or the component of a force which a surface exerts on an object with which it is in contact, and which is perpendicular to the surface. ◦ works between the object and the surface; ◦ works perpendicular to the surface, upwards; ◦ is a PUSHING force.	2	***Coulomb forces*** ◦ works between charged particles; ◦ are PULLING or PUSHING forces. 
3	***Tension*** (in a string ***(T, F_T)*** ◦ is the force of a string on an object; ◦ The tension in the same string has the same magnitude throughout the string. ◦ The direction of the tension is ALWAYS away from the object to which the string is attached. ◦ is a PULLING force.  	3	***Force between magnets*** ◦ works between magnets; ◦ are PULLING or PUSHING forces. 

WEIGHT AND NORMAL

• For an object on a horizontal surface: $F_N = F_g$ (in magnitude).

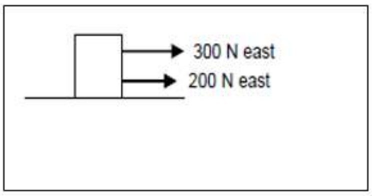


$F_N = F_g$ **With** **F_g = mg**

NET FORCE

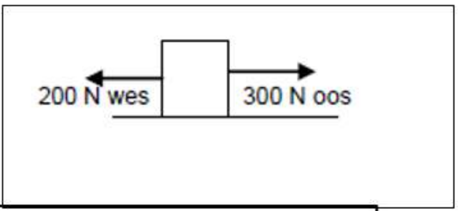
The net force ***(Fnet)*** of all the forces exerted on an object is the ***vector sum*** of all the forces that are exerted on that object. We also refer to the net force as the ***resultant force***.

Net force of forces working in the same direction:
Choose east as positive: Fnet = 300 N east + 200 N east
= 300 + 200 = 500 N east



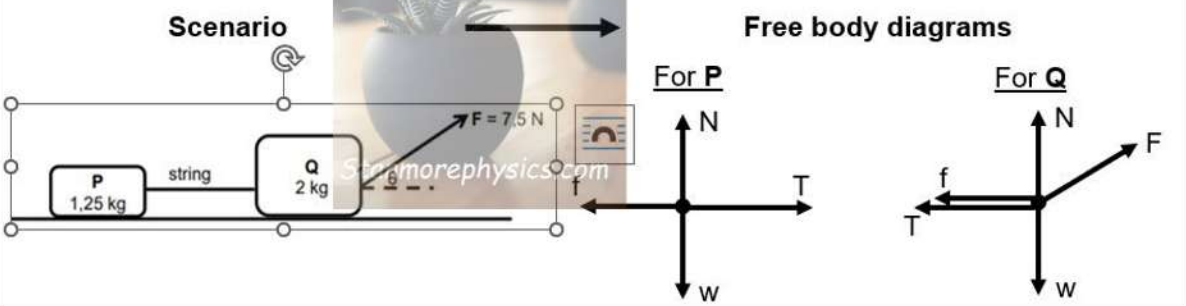
Net force of forces working in opposite directions:
Choose east as positive: Fnet = 300 N east + 200 N west

= 300 + (–200) = 100 N east
The net force is always in the direction of the greatest force.



Drawing of free-body diagrams

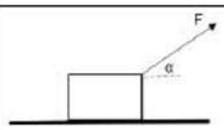
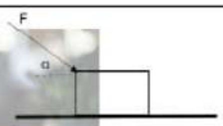
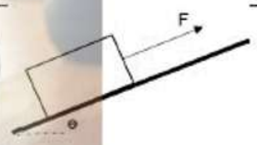
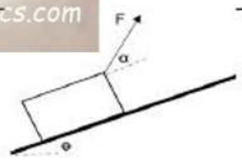
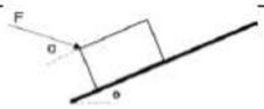
- Draw a dot to represent the object.
- Starting on the dot, draw arrows to represent each force.
- Each arrow's tail must start on the dot; this means the arrowhead must point away from the dot.
- The arrows must represent the direction of the forces.
- Do not draw components of forces in a free-body diagram; draw only the forces!
- Label each force by writing the name or symbol of the force next to the arrow. It is good to use the symbols that are normally used for specific forces, such as "f" for friction, "N" for a normal force, etc. See the memoranda of final papers for more examples.



Normal force (N)

- NEVER include the normal force in the expression of Fnet
- Calculating the normal depends on the surface (horizontal or inclined) and the applied force (parallel to the surface or making an angle with the surface)

Memorise and master how to calculate the Normal force for these scenarios

Surface and force	***Example scenario***	***Formula to calculate Normal force***
Horizontal surface Horizontal force (s)		**N = m.g**
Horizontal surface Force acting at an angle upwards		**N = m.g – Fy** (Fy = F x sin α)
Horizontal surface Force acting at an angle downwards		**N = m.g + Fy** (Fy = F x sin α)
Inclined plane (surface) Force acting parallel to the surface		**N = m.g.cosθ**
Inclined surface Force acting at an angle upwards		**N = m.g.cosθ - Fy** (Fy = F x sin α)
Inclined surface Force acting at an angle downwards		**N = m.g.cosθ + Fy** (Fy = F x sin α)

Friction (f)
- Always include friction, if it is present, in the Fnet expression
- Frictional force always acts opposite to the motion of the object
- If you take the direction of motion as positive,
- then friction will have a negative sign when substituting it in the Fnet expression.
- To calculate the magnitude of frictional force:

If coefficient of friction is given

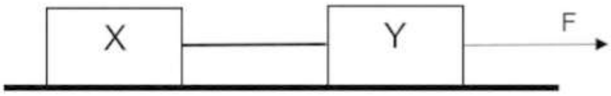
- Use the formula fsmax = μs .N for static friction and
- Use the formula fk = μk.N for kinetic friction

If coefficient of friction is not given

- Make use of the Fnet expression to find friction.

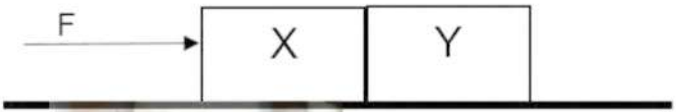
Tension (T)
- Tension is a force developed in (or transmitted through) a rope or string
- There is no specific formula to calculate the tension as it is considered as an applied force.
- You will generally find tension T in the Fnet expression
- The direction of tension goes to the side of the object where the string is attached. So if the string is attached to the left side of the object, the tension pulls it to the left. If the string is attached at the top of the object, the tension goes upwards

e.g.



Note that the string is attached to the right side of X so, the Tension pulls block X to the right. Equally so, the tension pulls block Y to the left.

- If there are two are in contact and one pushes another, then we have an action-reaction pair of forces



Block X experiences a force due to Y (FYonX) pushing it to the left
Block Y experiences a force due to X (FXonY) pushing it to the right
These two forces are equal and act in opposite direction. But they do not cancel each other because they act on different objects.
In calculations, treat them the same way you treated Tension

Applied force (F)

- The applied force must always be included in the Fnet expression
- If the applied force acts at an angle α relative to the surface, then only the component of the force parallel to the surface (Horizontal component), **Fx**, must be included in the Fnet expression.

This component is calculated as **Fx = F cos α**

CALCULATIONS INVOLVING NEWTON'S LAWS

- Draw a free body diagram of ALL forces for each object (Sure case marks)
- Draw a free body diagram showing ONLY forces acting parallel to the motion/surface
- Take the direction of motion as positive
- Write the Fnet expression for each object using vector sum of forces (Fnet = ΣF)
- Write the formula **Fnet = m.a** (a sure case 1 mark)
- Equate the two expressions for Fnet
  Σ F = m.a

If there is only ONE unknown in the equation, solve for it.

If there are two unknowns, **a** and **T**, in both equations then solve the simultaneous equations.

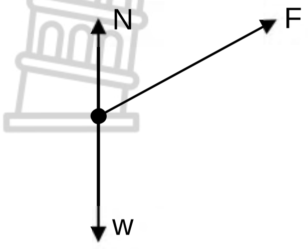
NEWTON'S LAW OF UNIVERSAL GRAVITATION

- Memorise the law
- Use the formula $F = G.m_1.m_2/r^2$
- Other formulae to use under this topic are $g = G.M^2/r^2$ and Fg = m.g

SOLVING FORCE PROBLEMS – NEWTON'S SECOND LAW OF MOTION

PROBLEM 1: *A single object moving on a horizontal plane without friction.*
A 15 kg cement block is pulled to the right across a smooth surface with a force of 100 N, which forms an angle of 14° with the horizontal. Calculate the magnitude of the normal force and the acceleration of the cement block. The effects of friction may be ignored.

SOLUTION
Step 1: Draw a free body diagram.



Step 2: Identify the formula.
Points to consider:

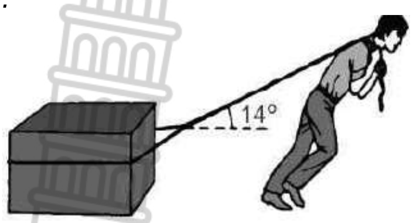
- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- In this case, the applied force acts at an angle and therefore the normal force is not just equal to the weight of the object. The magnitude of the vertical component of the applied force together with the magnitude of the normal force equals the magnitude of the weight i.e. $w = N + F\sin 14°$.
- The forces in the vertical plane i.e. the normal force, weight and the vertical component of the applied force do not affect the horizontal motion. Only one force i.e. the horizontal component of the applied force, influences horizontal motion.

Step 3: Solve
Normal force; upwards positive:
$w + N + F_v = 0$
$mg + N + F\sin 14° = 0$
$-(15)(9,8) + N + 100\sin 14° = 0$ (Use chosen sign convention when substituting.)
$\therefore N = 122,81$ N

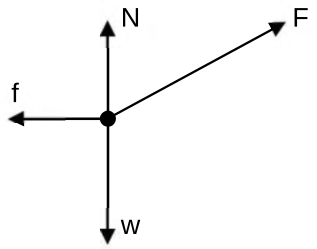
Acceleration:
To the right as positive:
$F_{net} = ma$
$F\cos 14° = ma$
$(100)\cos 14° = 15a \therefore a = 6,47 \text{ m}\cdot\text{s}^{-2}$ $\therefore a = 6,47 \text{ m}\cdot\text{s}^{-2}$ to the right

Step 4: Evaluate/interpret the answer.
The answer is positive – it shows that the acceleration is towards the right.
The normal force is smaller than the weight due to the vertical component of the applied force.

PROBLEM 2: *A single object moving in a horizontal plane with friction.*
A 15 kg cement block is pulled across the floor with a force of 100 N, which forms an angle of 14° with the horizontal. The coefficient of kinetic friction between the block and the floor is 0,4. Calculate the acceleration of the cement block.



SOLUTION
Step 1: Draw a free body diagram.



Step 2: Identify the formula.
Points to consider:

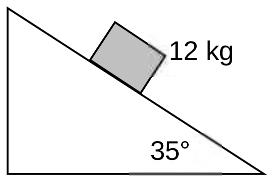
- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- In this case, the applied force acts at an angle and therefore the normal force is not equal to the weight. The magnitude of the vertical component of the applied force together with the magnitude of the normal force equals the magnitude of the weight i.e. $w = N + F\sin14°$.
- The forces in the vertical plane i.e. the normal force, weight and the vertical component of the applied force do not affect the horizontal motion. Only two forces i.e. friction and the horizontal component of the applied force, influence horizontal motion.
- Although the normal force is not asked in this question, it is needed to calculate the frictional force.

Step 3: Solve
To the right as positive:
$F_{net} = ma$
$F_H + f = ma$ (The net force is the vector sum of all the forces acting on the block.)
$F\cos14° + \mu_k N = ma$
$F\cos14° - (0,4)(mg - F\sin14°) = ma$ (Apply chosen sign convention when substituting.)
$100\cos14° - (0,4)[(15)(9,8) - 100\sin14°] = 15a$
$\therefore a = 3,19\ m \cdot s^{-2}$
$\therefore a = 3,19\ m \cdot s^{-2}$ to the right

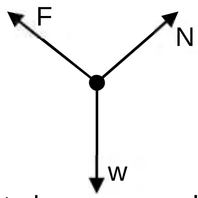
Step 4: Evaluate/interpret the answer.
The answer is positive – it shows that the acceleration is towards the right. The acceleration is smaller than in problem1 due to the presence of a frictional force.

<u>PROBLEM 3:</u> *A single object moving on an inclined plane without friction.*
An inclined surface makes an angle of 35° with the horizontal. Due to an applied force, F, parallel to the surface, the object with mass 12 kg accelerates at 1,5 $m \cdot s^{-2}$. Ignoring all frictional forces, calculate the magnitude and direction of F if the:

3.1 Acceleration is upwards, along the surface
3.2 Acceleration is downward, along the surface



SOLUTION
Step 1: Draw a free body diagram.
3.1 To accelerate upwards, the applied force should act upwards along the inclined plane.



3.2 As above - to have an acceleration smaller than *gsin35°*, the applied force should act upwards along the inclined plane.

Step 2: Identify the formula.
Points to consider:

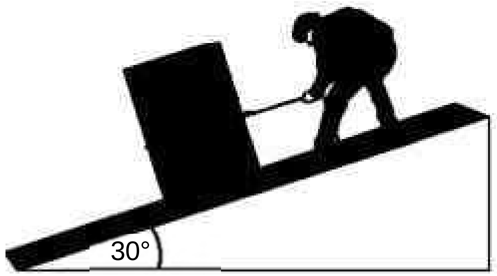
- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- Only the forces or component of forces parallel to the incline will influence motion along the incline i.e. F and mgsin35°.
- In Q3.1, the direction of the acceleration is opposite to that of the component of weight down the incline. In Q3.2 the direction of the acceleration is the same as that of the component of weight down the incline.

Step 3: Solve
Q3.1: Upwards along the incline as positive:
$F_{net} = ma$
$F + w_{//} = ma$ (The net force is the vector sum of all the forces acting on the object.)
$F + mg\sin35° = ma$
$F - (12)(9,8)\sin35° = (12)(1,5)$ (Apply chosen sign convention when substituting.)
$\therefore\ F = 85,45\ N$

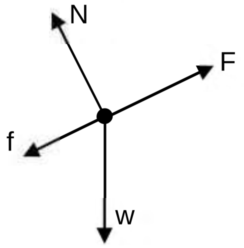
∴ F = 85,45 N upwards along the incline
Q3.2: Upwards along the incline as positive:
$F_{net} = ma$
$F + w_{//} = ma$
$F + mg\sin 35° = ma$
$F - (12)(9,8)\sin 35° = (12)(-1,5)$ (Apply chosen sign convention when substituting.)
∴ F = 49,45 N ∴ F = 49,45 N upwards along the incline

Step 4: Evaluate/interpret the answer
Both answers are positive as expected – it shows that the force in both cases acts upwards parallel to the inclined plane.

PROBLEM 4: *A single object moving on an inclined plane with friction.*
Richard pulls a crate of mass 20 kg with the help of a rope up along an inclined plane as shown. The tension in the rope is 147 N and the coefficient of kinetic friction between the crate and the inclined plane is 0,1. Calculate the acceleration of the block.



SOLUTION
Step 1: Draw a free body diagram.

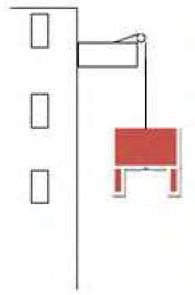


Step 2: Identify the formula.
Points to consider:
- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- The normal force is needed to calculate the frictional force. The magnitude of the normal force is equal to the magnitude of the component of weight perpendicular to the inclined plane i.e. mgcos30°.
- Three forces will influence the motion on the inclined plane i.e. f, F and $w_{//}$.

Step 3: Solve
Upward along the incline as positive:
$F_{net} = ma$
$F + f + w_{//} = ma$ (The net force is the vector sum of all the forces acting on the block.)
$F + \mu_k N + w_{//} = ma$
$F + \mu_k w_{\perp} + w_{//} = ma$
$F + \mu_k mg\cos 30° + mg\sin 30° = ma$
$147 - (0,1)(20)(9,8)\cos 30° – (20)(9,8)\sin 30° = 20a$
∴ $a = 1,60\ m{\cdot}s^{-2}$
∴ $a = 1,60\ m{\cdot}s^{-2}$ upwards along the incline

Step 4: Evaluate the answer.
As expected, the answer is positive i.e. the direction of motion upwards along the incline.

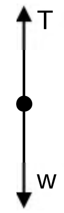
PROBLEM 5: *A single object moving in the vertical plane.*



A company needs to lift a 320 kg piano to the top floor of an apartment building. They use a rope and pulley system to pull the piano up. If the piano has an initial acceleration of 0,45 $m \cdot s^{-2}$, calculate the tension in the rope.

SOLUTION

Step 1: Draw a free body diagram.



Step 2: Identify the formula.

Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- No normal force is included in the free body diagram. The normal force is a force due to the contact between two surfaces; hence a normal force is a contact force. The piano is not resting on any surface – therefore there is no normal force.

Step 3: Solve

Upward as positive:

$F_{net} = ma$

$T + mg = ma$ (The net force is the vector sum of all the forces acting on the piano.)

$T - (320)(9,8) = (320)(0,45)$ (Apply chosen sign convention when substituting.)

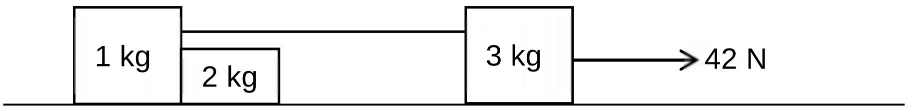
$T = 3\ 280$ N

Step 4: Evaluate the answer.

In this problem, the rope exerts an upwards force on the piano. The force by the rope needs to be large enough to support the weight of the piano (3 136 N) and to give it an upwards acceleration. So tension needs to be greater than 3 136 N.

PROBLEM 6: *Two-bodies joined by a light inextensible string, both on a flat horizontal plane without friction.*

Three blocks of masses 1 kg, 2 kg and 3 kg moves on a horizontal surface under the influence of a force of 42 N as shown. The effect of friction may be ignored.



Calculate the:

6.1 Acceleration of the system

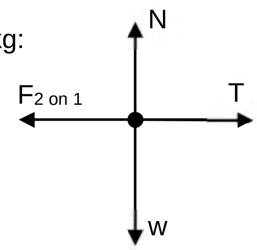
6.2 Tension in rope joining the 1 kg and the 3 kg blocks

6.3 Force exerted by the 1 kg block on the 2 kg block

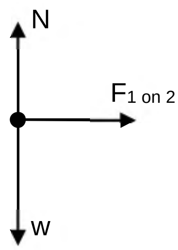
SOLUTION

Step 1: Draw a free body diagram for each block.

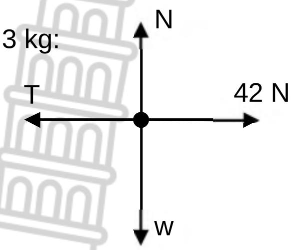
1 kg:



2 kg:



3 kg:



Step 2: Identify the formula.

Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- In the absence of a frictional force, the applied force is the net force acting on the system.
- To find the tension in the rope and the force exerted by the 1 kg block on the 2 kg block, each block should be isolated and Newton's second law should be applied to each block separately.

Step 3: Solve
To the right as positive:

6.1 $F_{net} = ma$
$42 = (2 + 1 + 3)a$
$a = 7\ m{\cdot}s^{-2}$ $\therefore a = 7\ m{\cdot}s^{-2}$ to the right

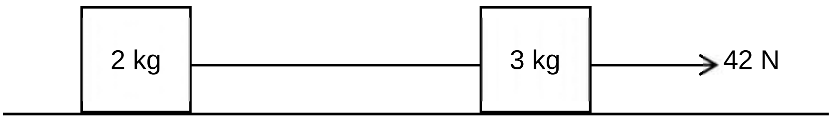
6.2 Consider the free body diagram of the 3 kg block; to the right as positive:
$F_{net} = ma$
$T + F = ma$
$T + 42 = (3)(7)$
$\therefore T = -21$ N $\therefore T = 21$ N to the left

6.3 Consider the free body diagrams of the 1 kg or 2 kg blocks; to the right as positive:
For 2 kg block:
$F_{net} = ma$
$F_{12} = (2)(7) = 14$
$\therefore F_{12} = 14$ N $\therefore F_{12} = 14$ N to the right
OR
For 1 kg block:
$F_{net} = ma$
$T + F_{21} = ma$
$21 + F_{21} = (1)(7)$
$\therefore F_{21} = -14$ N $\therefore F_{12} = 14$ N to the right

Step 4: Evaluate the answer.
The force exerted by the 1 kg block on the 2 kg is to the right (positive sign according to sign convention) whilst the force exerted by the 2 kg block on the 1 kg block is to the left (negative sign according to sign convention). This is in line with Newton's third law of motion.

PROBLEM 7: *Two bodies joined by a light inextensible string, both on a flat horizontal plane with friction.*

Two blocks of masses 2 kg and 3 kg, joined by a light inelastic string, move on a rough horizontal surface under the influence of a force of 42 N as shown. The coefficients of kinetic friction between the surface and the 2 kg and 3 kg blocks are 0,1 and 0,15 respectively.

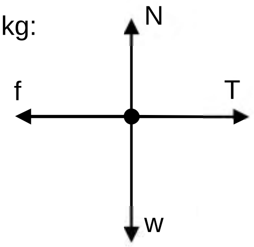


Calculate the tension in the rope joining the two blocks.

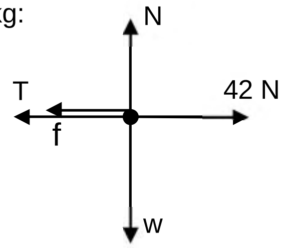
SOLUTION

Step 1: Draw a free body diagram for each block.

2 kg:



3 kg:



Step 2: Identify the formula.
Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- Both objects experience the same acceleration in the same direction.
- Different frictional forces act on the two blocks – therefore the frictional force on each should be calculated separately.
- To find the tension in the rope, each block should be isolated, and Newton's second law should be applied to each block separately. Simultaneous equations must then be used because acceleration is unknown.

Step 3: Solve
Each block is considered separately. An equation with two unknowns is obtained for each block. T is obtained by solving these simultaneous equations.
Important: When using simultaneous equations to solve for the tension in the string joining two objects, it must be remembered that the force that the string exerts on one object is equal, but opposite in direction, to the force

that the string exerts on the other object. Therefore, **when composing the two equations, the tension (T) should be given opposite signs.**

Consider the 2 kg block; to the right as positive:

$F_{net} = ma$

$T + f = ma$ (The net force is the vector sum of all the forces acting on the block.)

$T + \mu_k N = ma$

$T + \mu_k mg = ma$

$T - (0,1)(2)(9,8) = 2a$ (T acts to the right and is given a positive sign when substituting.)

$T – 1,96 = 2a$ ……………(1)

Consider the 3 kg block; to the right as positive:

$F_{net} = ma$

$T + f + F = ma$ (The net force is the vector sum of all the forces acting on the block.)

$T + \mu_k N + F = ma$

$T + \mu_k mg + F = ma$

$- T - (0,15)(3)(9,8) + 42 = 3a$ (T acts to the left and is given a negative sign when substituting.)

$- T + 37,59 = 3a$ …………(2)

Equation (1) + equation (2):

$35,63 = 5a$

$\therefore a = 7,13 \text{ m·s}^{-2}$

$T – 1,96 = 2a$ ……………..(1)

$T – 1,96 = 2(7,13)$

$\therefore T = 16,21 \text{ N}$

OR

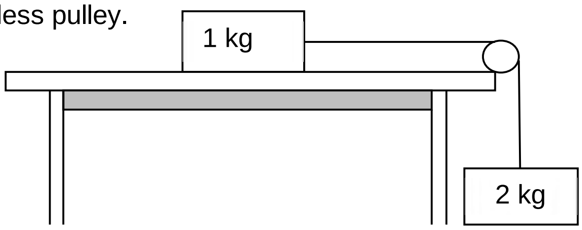
$- T + 37,59 = 3a$ …………(2)

$-T + 37,59 = 3(7,13)$

$\therefore T = 16,21 \text{ N}$

PROBLEM 8: *Two bodies joined by a light, inextensible string, one on a horizontal plane without friction, and a second hanging vertically from a string over a light, frictionless pulley.*

In the diagram below, a 1 kg mass on a smooth horizontal surface is joined to a 2 kg mass by a light, inextensible string running over a frictionless pulley.

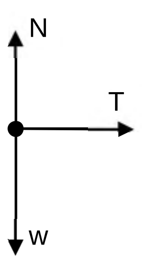


Calculate the tension in the string.

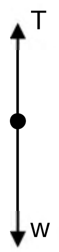
SOLUTION

Step 1: Draw a free body diagram.

1 kg:



2 kg:



Step 2: Identify the formula.

Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- No normal force is included in the free body diagram of the 2 kg mass. The normal force is a force due to the contact between two surfaces; hence a normal force is a contact force. The 2 kg mass is not resting on any surface – therefore there is no normal force.
- The magnitude of the acceleration for both masses have the same value *a*. The directions of the accelerations are not the same. The 1 kg mass moves horizontally to the right and the 2 kg mass moves vertically downward.

Step 3: Solve

The two masses are considered separately. From the two free body diagrams, two equations with two unknowns each are obtained. T is obtained by solving these simultaneous equations.

Important: When using simultaneous equations to solve for the tension in the string joining two objects, it must be remembered that the force that the string exerts on one object is equal, but opposite in direction, to the force that the string exerts on the other object. Therefore, **when composing the two equations, the tension (T) should be given opposite signs.**

1 kg mass; to the right as positive:

$F_{net} = ma$

$T = ma$ (T acts to the right and is given a positive sign when substituting.)

$T = (1)a$

$\therefore T = a$ ……………………(1)

2 kg mass; downward as positive:

$F_{net} = ma$

$T + w = ma$

$-T + (2)(9,8) = 2a$ (T acts upwards and is given a negative sign when substituting.)

$-T + 19,6 = 2a$ …………..(2)

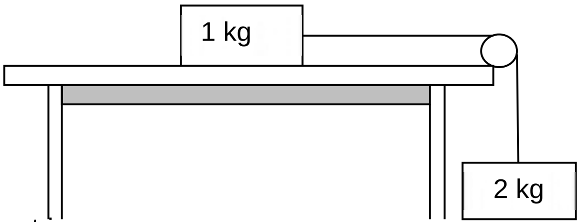
(1) in (2):

$-T + 19,6 = 2T$

$\therefore T = 6,53$ N

PROBLEM 9: *Two-bodies joined by a light inextensible string, one on a horizontal plane with friction, and a second hanging vertically from a string over a light, frictionless pulley.*

In the diagram below, a 1 kg mass on a rough horizontal surface is joined to a 2 kg mass by a light, inextensible string running over a frictionless pulley. The coefficient of kinetic friction between the 1 kg mass and the surface is 0,13.

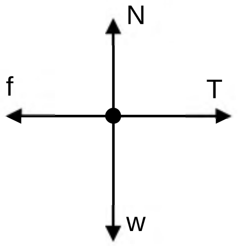


Calculate the tension in the string.

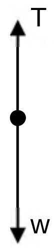
SOLUTION

Step 1: Draw a free body diagram.

1 kg:



2 kg:



Step 2: Identify the formula.

Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- No normal force is included in the free body diagram of the 2 kg mass. The normal force is a force due to the contact between two surfaces; hence a normal force is a contact force. The 2 kg mass is not resting on any surface – therefore there is no normal force.
- The magnitude of the acceleration for both masses have the same value *a*. The directions of the accelerations are not the same. The 1 kg mass moves horizontally to the right and the 2 kg mass moves vertically downward.
- Only the 1 kg object experiences a frictional force. Therefore, two forces act on the 1 kg mass in the horizontal plane. The frictional force is calculated using the formula $f = \mu_k N$.

Step 3: Solve

The two masses are considered separately. From the two free body diagrams, two equations with two unknowns each are obtained. T is obtained by solving these simultaneous equations.

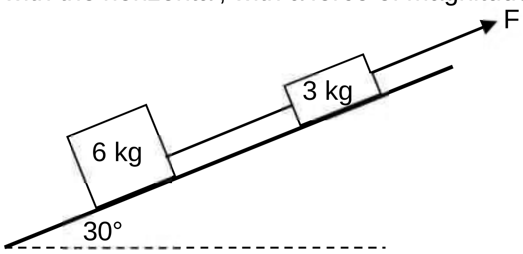
Important: When using simultaneous equations to solve for the tension in the string joining two objects, it must be remembered that the force that the string exerts on one object is equal to but opposite in direction to the force that the string exerts on the other object. Therefore, **when composing the two equations, the tension (T) should be given opposite signs.**

1 kg mass; to the right as positive:
$F_{net} = ma$
$T + f = ma$
$T + \mu_k N = ma$
$T + \mu_k mg = ma$
$T – (0,13)(1)(9,8) = (1)a$ (T acts to the right and is given a positive sign when substituting.)
$\therefore T – 1,27 = a$ ……………………(1)

2 kg mass; downward as positive:
$F_{net} = ma$
$mg + T = ma$
$(2)(9,8) - T = 2a$ (T acts upwards and is given a negative sign when substituting.)
$19,6 - T = 2a$ ……………………..(2)
(1) in (2):
$19,6 - T = 2(T – 1,27)$
$\therefore T = 7,38$ N

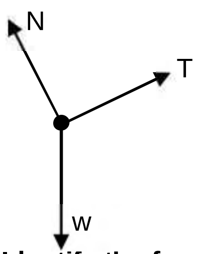
<u>PROBLEM 10:</u> *Two bodies joined by a light inextensible string, both on an inclined plane without friction.*

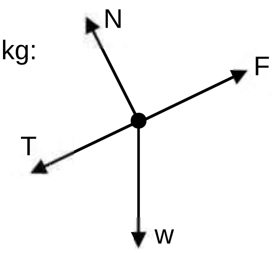
Two objects of mass 6 kg and 3 kg are connected by a light inelastic string. They are pulled up an inclined plane, which makes an angle of 30° with the horizontal, with a force of magnitude F. The effect of friction and the mass of the string may be ignored.



Calculate the:
10.1 Tension in the string if the system accelerates up the inclined plane at 4 $m \cdot s^{-2}$
10.2 Magnitude of F if the system moves up the inclined plane at CONSTANT VELOCITY

<u>SOLUTION</u>
Step 1: Draw a free body diagram.

6 kg:


3 kg:


Step 2: Identify the formula.
Points to consider:

- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- In Q10.1, the two objects experience the same acceleration. The acceleration is given and the only way to calculate the tension in the string is to consider the 6 kg object. The 3 kg object has two unknown forces i.e. F and T, acting on it.
- In Q10.2, the acceleration is zero because the objects move up the incline at constant velocity. The net force acting on the system is zero. Note that the tension in the string in this case is different from the tension in Q10.1 where the acceleration is not zero.
- The force exerted by the string on the 6 kg object is equal in magnitude, but opposite in direction to the force exerted on the 3 kg object. Therefore, when substituting, the sign of T in an equation using the 6 kg object will be opposite to that of T when using the 3 kg object.

Step 3: Solve

10.1

The two objects should be considered separately. Usually, from the two free body diagrams, two equations with two unknowns each are obtained. In this case, the acceleration is known and therefore only the 6 kg object is considered. No simultaneous equations will be used.

6 kg object; upwards along the incline as positive:

$F_{net} = ma$

$T + w_{//} = ma$

$T + mg\sin30° = ma$ (The net force is the vector sum of all the forces acting on the object.)

$T – (6)(9{,}8)\sin30° = 6(4)$ (Apply chosen sign convention when substituting.)

$T – 29{,}4 = 24$

$\therefore T = 53{,}4$ N

10.2

Consider the free body diagram of each object separately.

6 kg object; upwards along the incline as positive:

$F_{net} = ma$

$T + w_{//} = ma$

$T + mg\sin30° = ma$ (The net force is the vector sum of all the forces acting on the object.)

$T – (6)(9{,}8)\sin30° = 0$ (T on 6 kg object is upwards along incline, thus positive sign.)

$T – 29{,}4 = 0$

$\therefore T = 29{,}4$ N

3 kg object; upwards along the incline as positive:

$F_{net} = ma$

$F + w_{//} + T = ma$

$F + mg\sin30° + T = ma$ (The net force is the vector sum of all the forces acting on the object.)

$F – (3)(9{,}8)\sin30° - 29{,}4 = 0$ (T on 3 kg object is downward along incline, thus negative sign.)

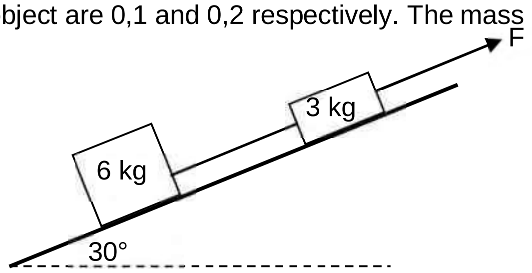
$\therefore F = 44{,}1$ N

Step 4: Evaluate the answer.

An important observation in this problem is that the tension calculated in Q10.1 cannot be substituted when solving Q10.2. The acceleration in Q10.1 differs from that in Q10.2 and therefore the applied force F as well as the tension in the string are different.

PROBLEM 11: *Two bodies joined by a light inextensible string, both on an inclined plane with friction.*

Two objects of mass 6 kg and 3 kg are connected by a light inelastic string. The objects are pulled up an inclined plane which makes an angle of 30° with the horizontal, with a force of magnitude F. The coefficients of kinetic friction for the 3 kg object and 6 kg object are 0,1 and 0,2 respectively. The mass of the string may be ignored.



Calculate the:

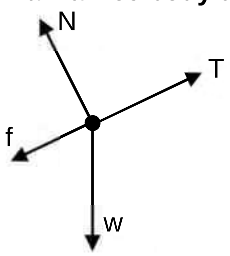
11.1 Tension in the string if the system accelerates up the inclined plane at 4 $m \cdot s^{-2}$

11.2 Magnitude of F if the system moves up the inclined plane at CONSTANT VELOCITY

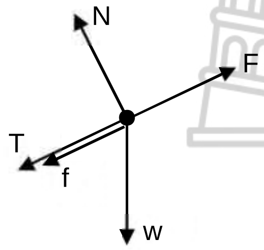
SOLUTION

Step 1: Draw a free body diagram.

6 kg:



3 kg:



Step 2: Identify the formula.

Points to consider:

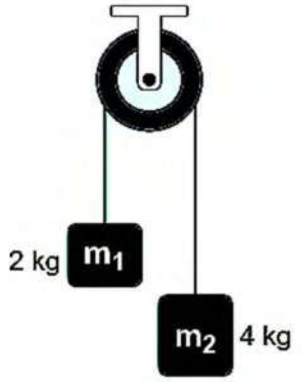
- The key equation for any problem that relates forces and motion is Newton's Second Law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.

- In Q11.1, the two objects experience the same acceleration. The acceleration is given and the only way to calculate the tension in the string is to consider the 6 kg object. The 3 kg object has two unknown forces i.e. F and T, acting on it.
- In Q11.2, the acceleration is zero and the objects move up the incline at constant velocity. The net force acting on the system is zero. Note that the tension in the string in this case will be different from the tension in Q11.1 where the acceleration is not zero.
- The tension in the string exerted on the 6 kg object is equal in magnitude, but opposite in direction to the tension exerted on the 3 kg object. Therefore, when substituting, the sign of T in an equation using the 6 kg object will be opposite to that of T when using the 3 kg object.
- The normal force is needed to calculate the frictional force on each object. The magnitude of the normal force is equal to the magnitude of the component of weight perpendicular to the inclined plane i.e. mgcos30°. The two objects experience different frictional forces and therefore a frictional force for each, using the normal force exerted on each, should be calculated.

Step 3: Solve
11.1
The two objects are considered separately. Usually, from the two free body diagrams, two equations with two unknowns each are obtained. In this case, the acceleration is known and therefore only the 6 kg object is considered. No simultaneous equations will thus be used.
6 kg object; upwards along the incline as positive:
$F_{net} = ma$
$T + f + w_{//} = ma$ (The net force is the vector sum of all the forces acting on the object.)
$T + \mu_k N + mg\sin30° = ma$
$T + \mu_k mg\cos30° + mg\sin30° = ma$
$T – (0,2)(6)(9,8)\cos30° - (6)(9,8)\sin30° = 6(4)$
$\therefore T = 63,58$ N
11.2
Consider the free body diagram of each object separately. Usually, from the two free body diagrams, two equations with two unknowns each are obtained. In this case, the acceleration is known and therefore the 6 kg object is used to calculate T.
6 kg; upwards along the incline as positive:
$F_{net} = ma$
$T + f + w_{//} = ma$
$T + \mu_k N_{6\ kg} + mg\sin30° = ma$
$T + \mu_k mg\cos30° + mg\sin30° = ma$
$T – (0,2)(6)(9,8)\cos30° - (6)(9,8)\sin30° = 0$
$T – 39,58 = 0 \therefore T = 39,58$ N

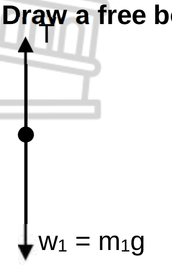
3 kg; upwards along the incline as positive:
$F_{net} = ma$
$F + f + w_{//} + T = ma$
$F + \mu_k N_{3\ kg} + mg\sin30° + T = ma$
$F + \mu_k mg\cos30° + mg\sin30° + T = ma$
$F – (0,1)(3)(9,8)\cos30° - (3)(9,8)\sin30° - 39,58 = 0$
$\therefore F = 56,83$ N
Step 4: Evaluate the answer.
Due to the presence of frictional forces, the tension in Q11.1 is greater than that in Q10.1. Also, due to the presence of frictional forces, the applied force in Q11.2 is greater than that in Q10.2.

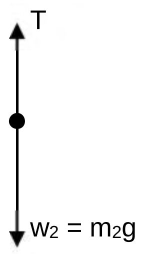
PROBLEM 12: *Two bodies joined by a light inextensible string, both hanging vertically from a string over a frictionless pulley.*



Two blocks, one with a mass of 2 kg and the other with a mass of 4 kg, hang over a frictionless pulley on a thin, light rope.
Calculate the:
12.1 Acceleration of the blocks
12.2 Tension in the rope

SOLUTION
Step 1: Draw a free body diagram.

2 kg:


4 kg:


Step 2: Identify the formula.
Points to consider:

- The key equation for any problem that relates forces and motion is Newton's second law. Regardless of what quantity you are asked to find, begin with the Second Law i.e. $F_{net} = ma$.
- Because the pulley turns easily (is frictionless), the tension in the rope is the same on both sides. Because the rope does not stretch, the magnitude of the acceleration will be the same for both blocks.
- The 2 kg block will accelerate upwards, and the 4 kg block will accelerate downward.
- In problems like this one, it is convenient to consider the direction of motion as positive. The tension in the rope on the two objects will be equal in magnitude but opposite in direction.

Step 3: Solve
12.1 Consider the free body diagram of each object separately.
Important: When using simultaneous equations to solve for the tension in the string joining two objects, it must be remembered that the force that the string exerts on one object is equal to but opposite in direction to the force that the string exerts on the other object. Therefore, **when composing the two equations, the tension (T) should be given opposite signs.**

2 kg object; upwards (direction of motion) positive:
$F_{net} = ma$
$T + w_1 = m_1a$
$T + m_1g = m_1a$
$T - (2)(9,8) = 2a$ (T on 2 kg object is upwards, thus positive sign.)
$T - 19,6 = 2a$
$T = 19,6 + 2a$ ……………….(1)

For the 4 kg object, downward (direction of motion) positive:
$F_{net} = ma$
$w_2 + T = m_2a$
$m_2g + T = m_2a$
$(4)(9,8) - T = 4a$ (T on 4 kg object is upwards, thus negative sign.)
$39,2 - T = 4a$
$-T = -39,2 + 4a$
$T = 39,2 - 4a$ ……………….(2)

Equation (1) into equation (2):
$19,6 + 2a = 39,2 - 4a \therefore a = 3,27 \text{ m·s}^{-2}$
The 2 kg block accelerates at $3,27 \text{ m·s}^{-2}$ upwards.
The 4 kg block accelerates at $3,27 \text{ m·s}^{-2}$ downward.

12.2
From equation (1) for 2 kg object:
$T = 19,6 + 2a$
$= 19,6 + 2(3,27) = 26,14$ N

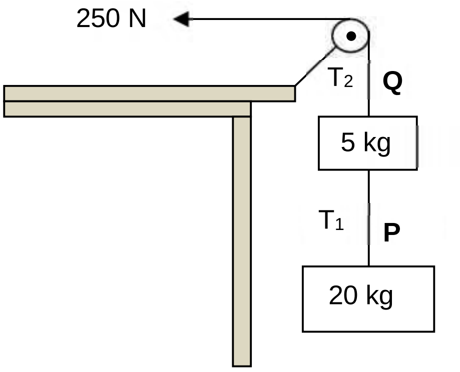
OR

From equation (2) for 4 kg object:
$T = 39,2 - 4a = 39,2 - 4(3,27) = 26,14$ N

STRUCTURED QUESTIONS

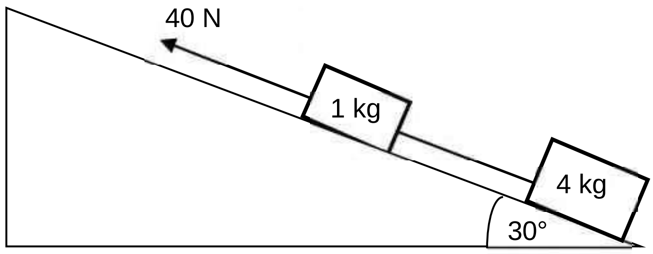
QUESTION 1

Two blocks of masses 20 kg and 5 kg respectively are connected by a light inextensible string, **P**. A second light inextensible string, **Q**, attached to the 5 kg block, runs over a light frictionless pulley.
A constant horizontal force of 250 N pulls the second string as shown in the diagram below. The magnitudes of the tensions in **P** and **Q** are T_1 and T_2 respectively. Ignore the effects of air friction.



1.1 State *Newton's second law of motion* in words. (2)
1.2 Draw a labelled free-body diagram indicating ALL the forces acting on the **5 kg block**. (3)
1.3 Calculate the magnitude of the tension T_1 in string **P**. (6)
1.4 When the 250 N force is replaced by a sharp pull on the string, one of the two strings break. Which ONE of the two strings, **P** or **Q**, will break? (1)
[12]

QUESTION 2

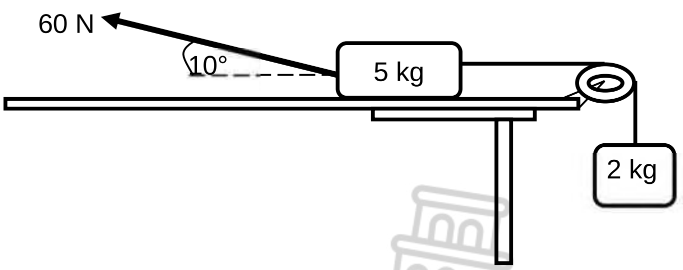


A block of mass 1 kg is connected to another block of mass 4 kg by a light inextensible string. The at 30° to the horizontal, by means of a constant 40 N force parallel to the plane as shown in the diagram below.
The magnitude of the kinetic frictional force between the surface and the 4 kg block is 10 N.
The coefficient of kinetic friction between the 1 kg block and the surface is 0,29.

2.1 State Newton's third law of motion in words. (2)
2.2 Draw a labelled free-body diagram showing ALL the forces acting on the **1 kg block** as it moves up the incline. (5)
2.3 Calculate the magnitude of the:
 2.3.1 Kinetic frictional force between the 1 kg block and the surface (3)
 2.3.2 Tension in the string connecting the two blocks (6)
[16]

QUESTION 3

A 5 kg block, resting on a rough horizontal table, is connected by a light inextensible string passing over a light frictionless pulley to another block of mass 2 kg. The 2 kg block hangs vertically as shown in the diagram below.

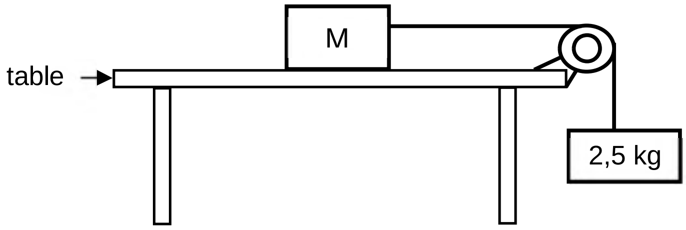


A force of 60 N is applied to the 5 kg block at an angle of 10° to the horizontal, causing the block to accelerate to the left. The coefficient of kinetic friction between the 5 kg block and the surface of the table is 0,5. Ignore the effects of air friction.

3.1 Draw a labelled free-body diagram showing ALL the forces acting on the 5 kg block. (5)
3.2 Calculate the magnitude of the:
 3.2.1 Vertical component of the 60 N force (2)
 3.2.2 Horizontal component of the 60 N force (2)
3.3 State *Newton's Second Law of Motion* in words. (2)
Calculate the magnitude of the:
3.4 Normal force acting on the 5 kg block (2)
3.5 Tension in the string connecting the two blocks (7)
[20]

QUESTION 4

4.1 Two blocks of mass M kg and 2,5 kg respectively are connected by a light, inextensible string. The string runs over a light, frictionless pulley, as shown in the diagram below. The blocks are **stationary**.



4.1.1 State Newton's THIRD law of motion in words. (2)

4.1.2 Calculate the tension in the string. (3)

The coefficient of static friction (μ_s) between the unknown mass M and the surface of the table is 0,2.

4.1.3 Calculate the minimum value of M that will prevent the blocks from moving. (5)

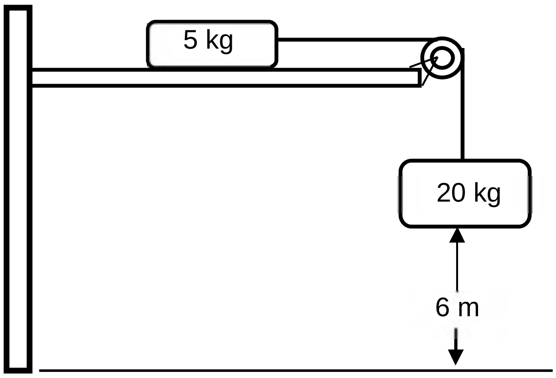
The block of unknown mass M is now replaced with a block of mass 5 kg. The 2,5 kg block now accelerates downwards. The coefficient of kinetic friction (μ_k) between the 5 kg block and the surface of the table is 0,15.

4.1.4 Calculate the magnitude of the acceleration of the 5 kg block. (5)

4.2 A small hypothetical planet **X** has a mass of 6,5 x 10^{20} kg and a radius of 550 km.
Calculate the gravitational force (weight) that planet **X** exerts on a 90 kg rock on this planet's surface. (4)
[19]

QUESTION 5

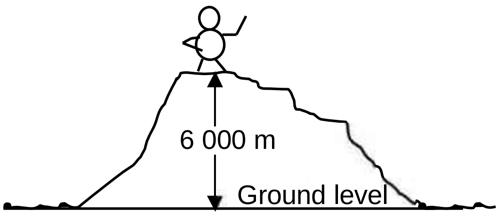
5.1 A 5 kg mass and a 20 kg mass are connected by a light inextensible string which passes over a light frictionless pulley. Initially, the 5 kg mass is held stationary on a horizontal surface, while the 20 kg mass hangs vertically downwards, 6 m above the ground, as shown in the diagram, not drawn to scale. When the *stationary* 5 kg mass is released, the two masses begin to move. The coefficient of kinetic friction, μ_k, between the 5 kg mass and the horizontal surface is 0,4. Ignore the effects of air friction.



5.1.1 Calculate the acceleration of the 20 kg mass. (5)

5.1.2 Calculate the speed of the 20 kg mass as it strikes the ground. (4)

5.1.3 At what minimum distance from the pulley should the 5 kg mass be placed initially, so that the 20 kg mass just strikes the ground? (1)



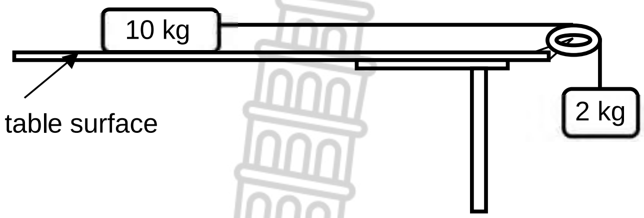
5.2 A person of mass 60 kg climbs to the top of a mountain which is 6 000 m above ground level.

5.2.1 State *Newton's Law of Universal Gravitation* in words. (2)

5.2.2 Calculate the *difference* in the weight of the climber at the top of the mountain and at ground level. (6)
[18]

QUESTION 6

The diagram below shows a 10 kg block lying on a flat, rough, horizontal surface of a table. The block is connected by a light, inextensible string to a 2 kg block hanging over the side of the table. The string runs over a light, frictionless pulley. The blocks are **stationary**.



6.1 State Newton's FIRST law of motion in words. (2)

6.2 Write down the magnitude of the NET force acting on the 10 kg block. (1)

When a 15 N force is applied vertically downwards on the 2 kg block, the 10 kg block accelerates to the right at 1,2 $m{\cdot}s^{-2}$.

6.3 Draw a free-body diagram for the 2 kg block when the 15 N force is applied to it. (3)

6.4 Calculate the coefficient of kinetic friction between the 10 kg block and the surface of the table. (7)

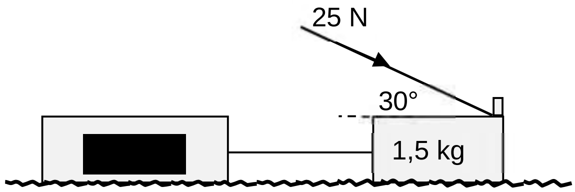
6.5 How does the value, calculated in QUESTION 6.4, compare with the value of the coefficient of STATIC friction for the 10 kg block and the table? Write down only LARGER THAN, SMALLER THAN or EQUAL TO. (1)

6.6 If the 10 kg block had a larger surface area in contact with the surface of the table, how would this affect the coefficient of kinetic friction calculated in QUESTION 6.4? Assume that the rest of the

system remains unchanged. Write down only INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer. (2)
[16]

QUESTION 7

A learner constructs a push toy using two blocks with masses 1,5 kg and 3 kg respectively. The blocks are connected by a massless, inextensible cord. The learner then applies a force of 25 N at an angle of 30° to the 1,5 kg block by means of a light rigid rod, causing the toy to move across a flat, rough, horizontal surface, as shown in the diagram.

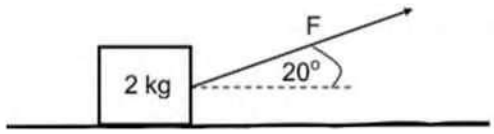


The coefficient of kinetic friction (μ_k) between the surface and each block is 0,15.

7.1 State Newton's Second Law of Motion in words. (2)
7.2 Calculate the magnitude of the kinetic frictional force acting on the 3 kg block. (3)
7.3 Draw a labelled free-body diagram showing ALL the forces acting on the 1,5 kg block. (5)
7.4 Calculate the magnitude of the:
7.4.1 Kinetic frictional force acting on the 1,5 kg block (3)
7.4.2 Tension in the cord connecting the two blocks (5)
[18]

QUESTION 8

8.1 A crate of mass 2 kg is being pulled to the right across a rough horizontal surface by constant force **F**. The force **F** is applied at an angle of 20° to the horizontal, as shown in the diagram.



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

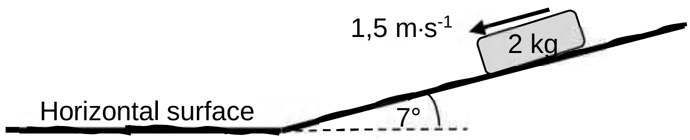
A constant frictional force of 3 N acts between the surface and the crate. The coefficient of kinetic friction between the crate and the surface is 0,2. Calculate the magnitude of the:

8.1.2 Normal force acting on the crate (3)
8.1.3 Force **F** (4)
8.1.4 Acceleration of the crate (3)

8.2 A massive rock from outer space is moving towards the Earth.
8.2.1 State Newton's Law of Universal Gravitation in words. (2)
8.2.2 How does the magnitude of the gravitational force exerted by the Earth on the rock change as the distance between the rock and the Earth becomes smaller? Choose from INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer. (2)
[18]

QUESTION 9

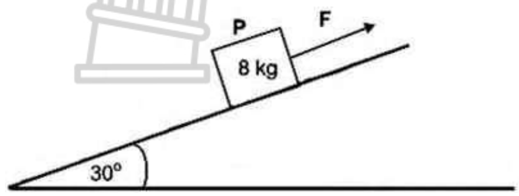
A small object of mass 2 kg is sliding <u>at a constant velocity</u> of 1,5 $m \cdot s^{-1}$ down a rough plane inclined at 7° to the horizontal surface. At the bottom of the plane, the object continues sliding onto a rough horizontal surface and eventually comes to a stop. The coefficient of kinetic friction between the object and both the inclined and the horizontal surfaces is the same.



9.1 Write down the magnitude of the net force acting on the object. (1)
9.2 Draw a labelled free-body diagram for the object while it is on the inclined plane. (3)
9.3 Calculate the:
9.3.1 Magnitude of the frictional force acting on the object while it is sliding down the inclined plane (3)
9.3.2 Coefficient of kinetic friction between the object and the surfaces (3)
9.3.3 Distance the object travels on the horizontal surface before it comes to a stop (5)
[15]

QUESTION 10

10.1 An 8 kg block, **P**, is being pulled by constant force **F** up a rough inclined plane at an angle of 30° to the horizontal, at CONSTANT SPEED. Force **F** is parallel to the inclined plane, as shown in the diagram.



10.1.1 State Newton's First Law in words. (2)
10.1.2 Draw a labelled free-body diagram for block **P**. (4)

The kinetic frictional force between the block and the surface of the inclined plane is 20,37 N.

10.1.3 Calculate the magnitude of force **F**. (5)

Force **F** is now removed and the block ACCELERATES down the plane. The kinetic frictional force remains 20,37 N.

10.1.4 Calculate the magnitude of the acceleration of the block. (4)

10.2 A 200 kg rock lies on the surface of a planet. The acceleration due to gravity on the surface of the planet is 6,0 m·s^{-2}.

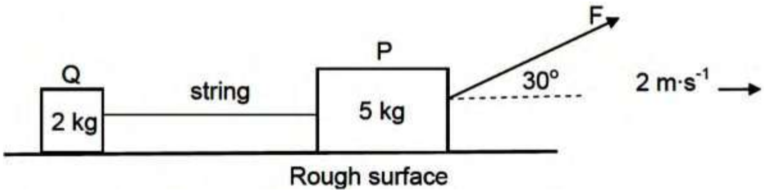
10.2.1 State *Newton's Law of Universal Gravitation* in words. (2)

10.2.2 Calculate the mass of the planet if its radius is 700 km. (4)

[21]

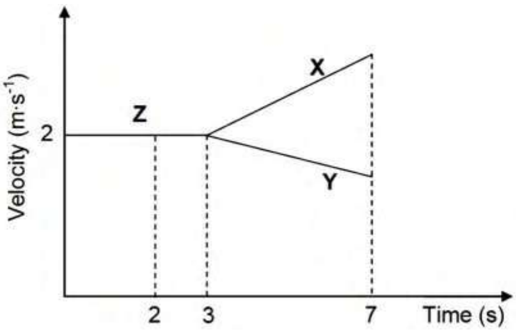
QUESTION 11

Two boxes, **P** and **Q**, resting on a rough horizontal surface, are connected by a light inextensible string. The boxes have masses 5 kg and 2 kg respectively. A constant force **F**, acting at an angle of 30° to the horizontal, is applied to the 5 kg box, as shown. The two boxes now move to the right at a **constant speed** of 2 m·s^{-1}.



11.1 State Newton's First Law of Motion in words. (2)

11.2 Draw a labelled free-body diagram for box **Q**. (4)



Box **P** experiences a constant frictional force of 5 N and box **Q** a constant frictional force of 3 N.

11.3 Calculate the magnitude of force **F**. (6)

The string connecting **P** and **Q** suddenly breaks after 3 s while force **F** is still being applied. Learners draw the velocity-time graph for the motion of **P** and **Q** before and after the string breaks, as shown alongside.

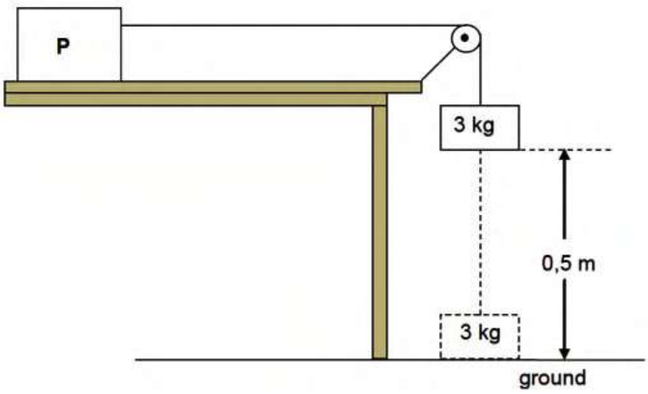
11.4 Write down the time at which the string breaks.

11.5 Which portion (**X**, **Y** or **Z**) of the graph represents the motion of box **Q**, after the string breaks? Use the information in the graph to fully support the answer. (4)

[17]

QUESTION 12

Block **P**, of unknown mass, is placed on a rough horizontal surface. It is connected to a second block of mass 3 kg, by a light inextensible string passing over a light, frictionless pulley, as shown. Initially the system of masses is held stationary with the 3 kg block, 0,5 m above the ground. When the system is released the 3 kg block moves vertically downwards and strikes the ground after 3 s. Ignore the effects of air resistance.



12.1 Define the term *acceleration* in words. (2)

12.2 Calculate the magnitude of the *acceleration* of the 3 kg block using equations of motion. (3)

12.3 Calculate the magnitude of the tension in the string. (3)

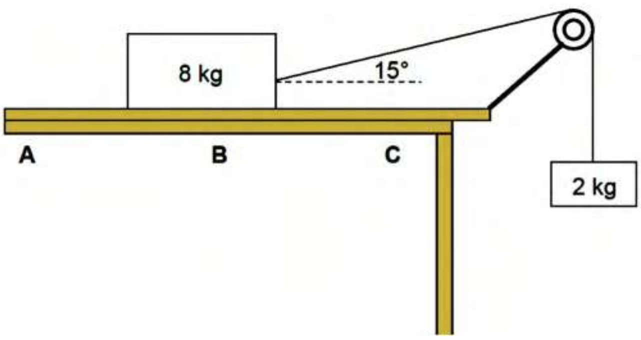
The magnitude of the kinetic frictional force experienced by block **P** is 27 N.

12.4 Draw a labelled free-body diagram for block **P**. (4)

12.5 Calculate the mass of block **P**. (3)

[15]

QUESTION 13



A block, of mass 8 kg, is placed on a rough horizontal surface. The 8 kg block, which is connected to a 2 kg block by means of a light inextensible string passing over a light frictionless pulley, starts sliding from point **A**, as shown.

13.1 State Newton's Second Law in words. (2)

13.2 Draw a labelled free-body diagram for the 8 kg block. (4)

13.3 When the 8 kg block reaches point **B**, the angle between the string and the horizontal is 15° and the acceleration of the system is 1,32 m·s^{-2}.

13.3.1 Give a reason why the system is NOT in equilibrium. (1)

13.3.2 Use the 2 kg mass to calculate the tension in the string. (3)

13.3.3 Calculate the kinetic frictional force between the 8 kg block and the horizontal surface. (4)

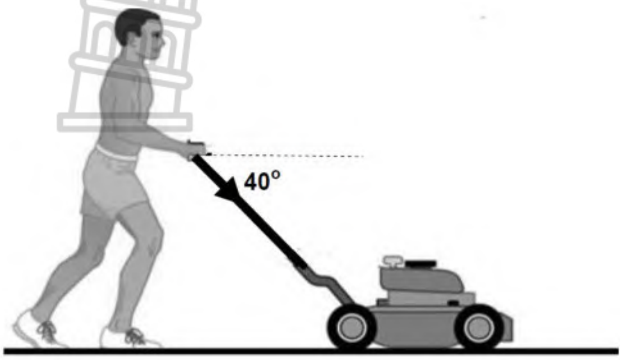
13.4 As the 8 kg block moves from **B** to **C**, the kinetic frictional force between the 8 kg block and the horizontal surface is not constant. Give a reason for this statement. (1)

The horizontal surface on which the 8 kg block is moving, is replaced by another horizontal surface made from a different material.

13.5 Will the kinetic frictional force, calculated in QUESTION 13.3.3 above, change? Choose from: YES or NO. Give a reason for the answer. (2)

[17]

QUESTION 14



14.1 A person pushes a lawn mower of mass 15 kg at a **constant speed** in a straight line over a flat grass surface with a force of 90 N. The force is directed along the handle of the lawn mower. The handle has been set at an angle of 40° to the horizontal. Refer to the diagram.

14.1.1 Draw a labelled free-body diagram for the lawn mower. (4)

14.1.2 Why is it CORRECT to say that the moving lawn mower is in equilibrium? (1)

14.1.3 Calculate the magnitude of the frictional force acting between the lawn mower and the grass. (3)

The lawn mower is now brought to a stop.

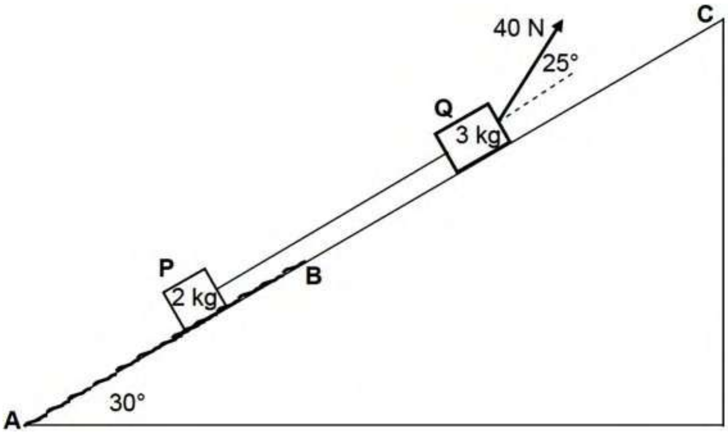
14.1.4 Calculate the magnitude of the constant force that must be applied through the handle in order to accelerate the lawn mower *from rest* to 2 $m \cdot s^{-1}$ in a time of 3 s. Assume that the frictional force between the lawn mower and grass remains the same as in QUESTION 14.1.3. (6)

14.2 Planet **Y** has a radius of 6×10^5 m. A 10 kg mass weighs 20 N on the surface of planet **Y**. Calculate the mass of planet **Y**. (4)

[18]

QUESTION 15

Block **P**, of mass 2 kg, is connected to block **Q**, of mass 3 kg, by a light inextensible string. Both blocks are on a plane inclined at an angle of 30° to the horizontal. Block **Q** is pulled by a constant force of 40 N at an angle of 25° to the incline.



Block **P** moves on a rough section, **AB**, of the incline, while block **Q** moves on a frictionless section, **BC**, of the incline. See diagram.

An average constant frictional force of 2,5 N acts on block **P** as it moves from **A** to **B** up the incline.

15.1 State Newton's Second Law in words. (2)

15.2 Draw a labelled free-body diagram for block **P**. (4)

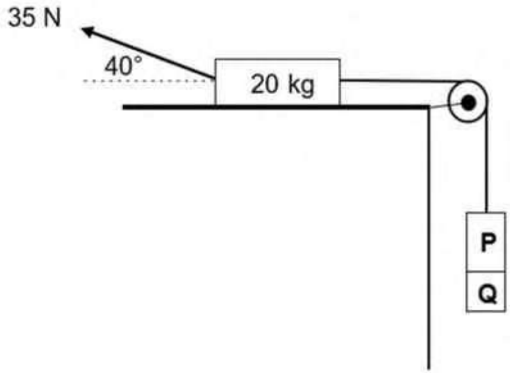
15.3 Calculate the magnitude of the acceleration of block **P** while block **P** is moving on section **AB**. (8)

15.4 If block **P** has now passed point **B**, how will its acceleration compare to that calculated in QUESTION 15.3? Choose from GREATER THAN, SMALLER THAN or EQUAL TO. Give a reason for the answer. (2)

[16]

QUESTION 16

A 20 kg block, resting on a rough horizontal surface, is connected to blocks **P** and **Q** by a light inextensible string moving over a frictionless pulley. Blocks **P** and **Q** are glued together and have a combined mass of *m*. A force of 35 N is now applied to the 20 kg block at an angle of 40° with the horizontal, as shown. The 20 kg block experiences a frictional force of magnitude 5 N as it moves to the RIGHT at a CONSTANT SPEED.



16.1 Define the term *normal force*. (2)

16.2 Draw a labelled free-body diagram of the 20 kg block. (5)

16.3 Calculate the combined mass *m* of the two blocks. (5)

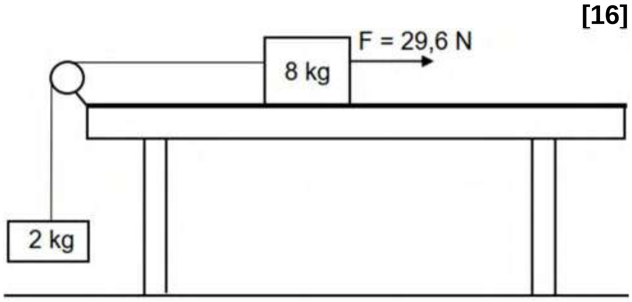
16.4 At a certain stage of the motion, block **Q** breaks off and falls down. How will EACH of the following be affected when this happens?

16.4.1 The tension in the string. Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

16.4.2 The velocity of the 20 kg block. Explain the answer. (3)

[16]

QUESTION 17



An 8-kg block, on a rough horizontal surface, is connected to a 2-kg block by a light inextensible string passing over a frictionless pulley, as shown. The 8-kg block moves at a **constant speed** when pulled by a 29,6 N horizontal force to the right. The frictional force acting on the 8-kg block is 10 N.

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

17.2 Draw a labelled free-body diagram for the 8-kg block. (5)

17.3 Calculate the tension in the string. (3)

The 29,6 N horizontal force is now increased to 50 N.

17.4 Apply Newton's Second Law to EACH block and calculate the:

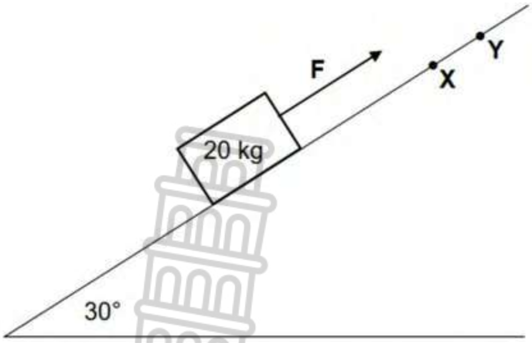
17.4.1 Magnitude of the acceleration of the 8-kg block (5)

17.4.2 Tension in the string (2)

[17]

QUESTION 18

A 20 kg block is placed on a rough surface inclined at 30° to the horizontal. A constant force **F**, acting parallel to the surface, is applied on the block so that the block moves up the incline at a CONSTANT VELOCITY of 2 m·s^{-2}. Refer to the diagram. A constant kinetic frictional force of 18 N acts on the block.



18.1 State *Newton's First Law* in words. (2)

18.2 Draw a labelled free-body diagram for the block. (4)

18.3 Calculate the magnitude of force **F**. (4)

Force **F** is removed when the block reaches point **X** on the surface. The block continues to move up the surface and comes to rest momentarily at point **Y**. Assume that the kinetic frictional force acting on the block remains at 18 N as it moves from point **X** to point **Y**.

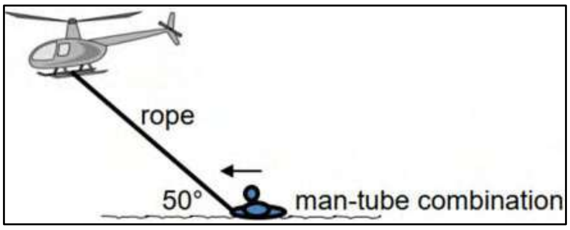
18.4 Write down the net force acting on the block as it moves from **X** to **Y**. (2)

18.5 Calculate the distance between points **X** and **Y**. (4)

[16]

QUESTION 19

A man faces difficulty while swimming in a dam. During the rescue operation, an inflated tube attached to a helicopter by a rope is dropped from the helicopter.



The man, of mass 70 kg, holds onto the inflated tube of mass 4 kg, while the helicopter is flying horizontally at a CONSTANT speed. An average frictional force of 300 N is exerted on the man-tube combination while they are dragged horizontally along the surface of the water by the helicopter. The rope makes an angle of 50° with the surface of the water, as shown in the diagram. Assume that the rope is inextensible and massless, and the water of the dam does not flow.

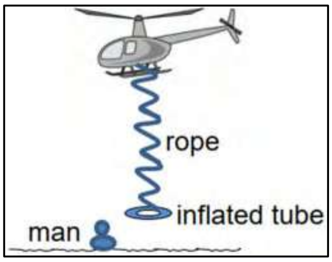
19.1 State Newton's First Law of Motion in words. (2)

19.2 Draw a free-body diagram of the man-tube combination while they are being dragged. (4)

19.3 Calculate the tension in the rope. (4)

19.4 How will the answer to QUESTION 19.3 change if the helicopter ACCELERATES while dragging the man? The frictional force and the angle between the rope and the surface of the water remain the same. Choose from INCREASES, DECREASES or NO CHANGE. Give a reason for the answer. (2)

In another rescue operation, the inflated tube of mass 4 kg is dropped from the stationary helicopter, and it strikes the water at a speed of 16 m·s^{-1}. The tube sinks vertically downwards into the water to a depth of 0,8 m and then rises to the surface. The rope hangs loosely.

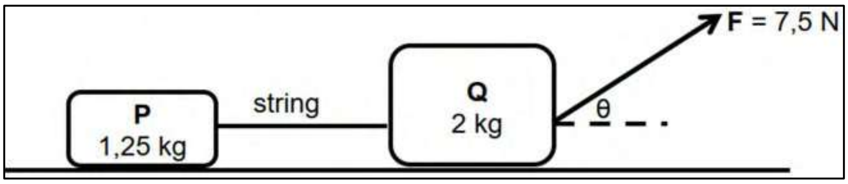


19.5 Calculate the magnitude of the average upward force exerted on the inflated tube while it is sinking. Assume that the average upward force is constant for the motion. (5)

[17]

QUESTION 20

Crate **P** of mass 1,25 kg is connected to another crate, **Q**, of mass 2 kg by a light inextensible string. The two crates are placed on a rough horizontal surface. A constant force *F* of magnitude 7,5 N, acting at angle θ to the horizontal, is applied on crate **Q** as shown in the diagram. The crates accelerate at 0,1 m·s^{-2} to the right. Crate **P** experiences a constant frictional force of 1,8 N and crate **Q** experiences a constant frictional force of 2,2 N.



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

20.2 Draw a labelled free-body diagram for crate **P**. (4)

20.3 Calculate the magnitude of:

20.3.1 The tension in the string (4)

20.3.2 Angle θ (3)

[13]

ELECTROSTATICS

Study of charges at

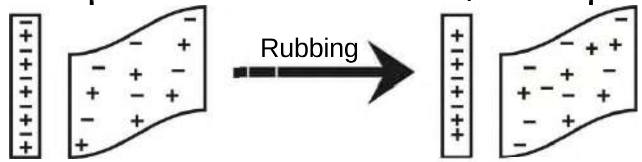
Neutral (uncharged):
Number of protons = number of

Quantisation of charge
All charges are multiples of the smallest charge i.e. the charge on one electron: $1,6 \times 10^{-19}$ C

Conservation of charge
Charge cannot be created or destroyed. It can only be transferred from one object to

Two kinds of charge
Positive: electron deficient
Negative: excess of electrons

Charging of objects
By contact: Electrons transferred from one object to



Electric field
Region in space where an electric charge experiences a force. Represented with field lines.

Definition of electric field: $E = \frac{F}{q}$

Electrostatic force
Like charges repel
Unlike charges attract

Coulomb's law

$F \propto Q_1Q_2$ and $F \propto \frac{1}{r^2}$

$\therefore F = \frac{kQ_1Q_2}{r^2}$ $k = 9 \times 10^9$ N·m²·C⁻

Electric potential

Electric potential energy

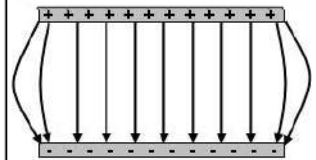
$U = \frac{kQ_1Q_2}{r}$

Electric field between two parallel plates: $E = \frac{V}{d}$

Parallel-plate capacitor
Stores charge

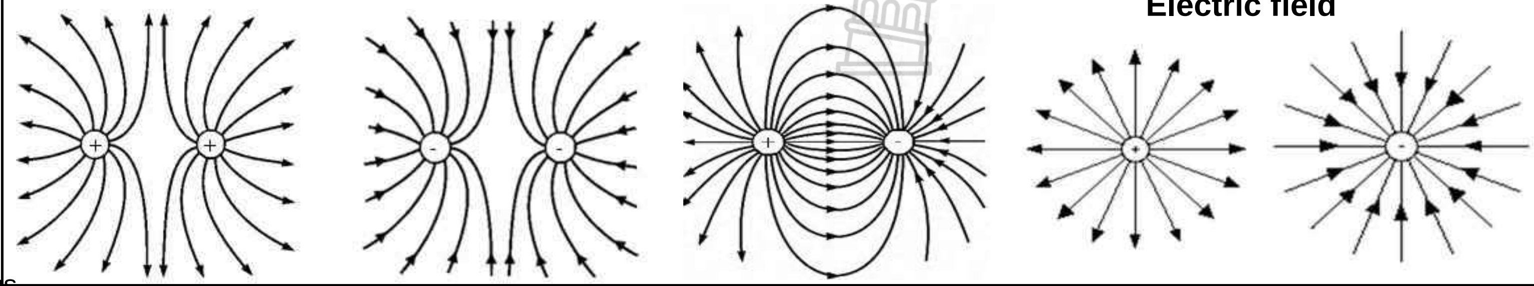
$C = \frac{Q}{V}$; $C = \frac{\varepsilon_0 A}{d}$

Electric field



Electric field at a certain distance from a point charge: $E = \frac{kQ}{r^2}$

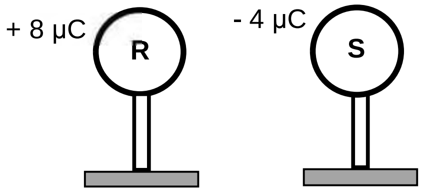
Electric field



STRUCTURED QUESTIONS

QUESTION 1

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



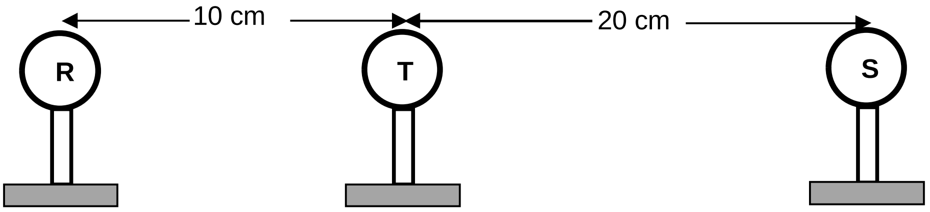
1.1 Explain why the spheres were placed on wooden stands. (1)

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

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

1.3 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.



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

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

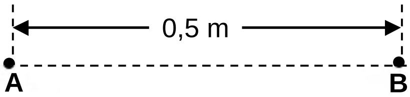
1.6 Define the *electric field at a point*. (2)

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

[19]

QUESTION 2

Two identical negatively charged spheres, **A** and **B**, having charges of the **same magnitude**, are placed 0,5 m apart in vacuum. The magnitude of the electrostatic force that one sphere exerts on the other is $1,44 \times 10^{-1}$ N.



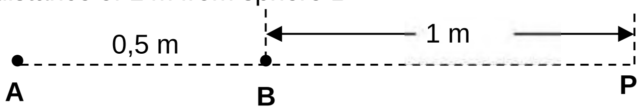
2.1 State *Coulomb's law* in words. (2)

2.2 Calculate the:

2.2.1 Magnitude of the charge on each sphere (4)

2.2.2 Excess number of electrons on sphere **B** (3)

2.3 **P** is a point at a distance of 1 m from sphere **B**.



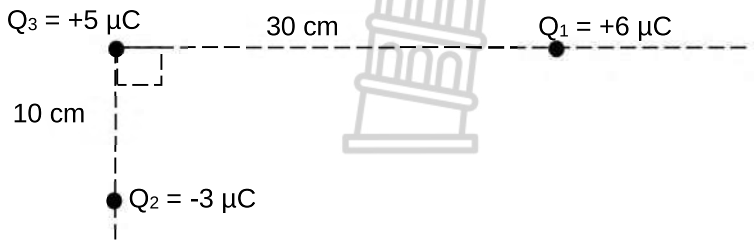
2.3.1 What is the direction of the net electric field at point **P**? (1)

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

[18]

QUESTION 3

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



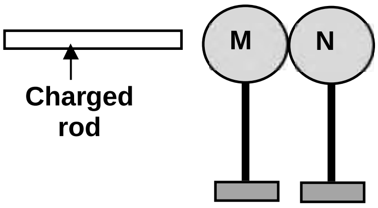
3.1 State *Coulomb's law* in words. (2)

3.2 Calculate the net force acting <u>on charge **Q_3**</u> due to the presence of **Q_1** and **Q_2**. (7)

[9]

QUESTION 4

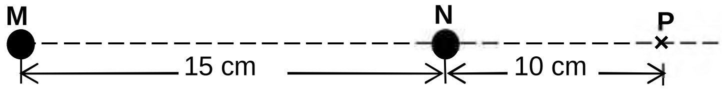
Two identical neutral spheres, **M** and **N**, are placed on insulating stands. They are brought into contact and a charged rod is brought near sphere **M**. When the spheres are separated it is found that 5 x 10^6 electrons were transferred from sphere **M** to sphere **N**.



4.1 What is the net charge on sphere **N** after separation? (3)

4.2 Write down the net charge on sphere **M** after separation. (2)

The charged spheres, **M** and **N**, are now arranged along a straight line, in space, such that the distance
between their centres is 15 cm. A point **P** lies 10 cm to the right of **N** as shown in the diagram below.

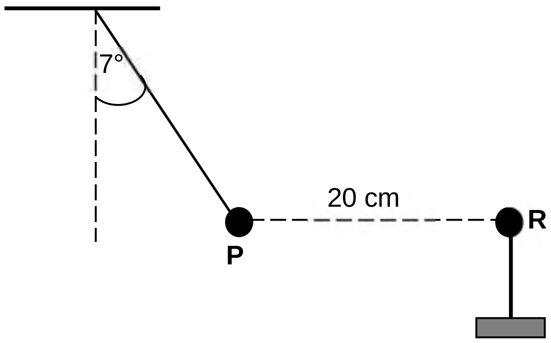


4.3 Define the *electric field* at a point. (2)

4.4 Calculate the net electric field at point **P** due to **M** and **N**. (6)

[13]

QUESTION 5



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.

5.1 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. The system is in equilibrium and the angle between the string and the vertical is 7°.

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

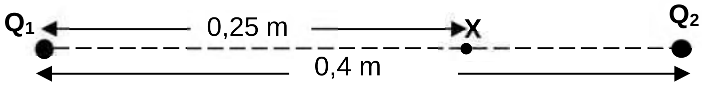
5.3 State Coulomb's law in words. (2)

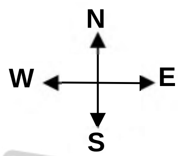
5.4 Calculate the magnitude of the tension in the string. (5)

[13]

QUESTION 6

Two charged particles, $\mathbf{Q_1}$ and $\mathbf{Q_2}$, are placed 0,4 m apart along a straight line. The charge on $\mathbf{Q_1}$ is + 2 x 10^{-5} C, and the charge on $\mathbf{Q_2}$ is – 8 x 10^{-6} C. Point **X** is 0,25 m **east** of $\mathbf{Q_1}$, as shown in the diagram below.





Calculate the:

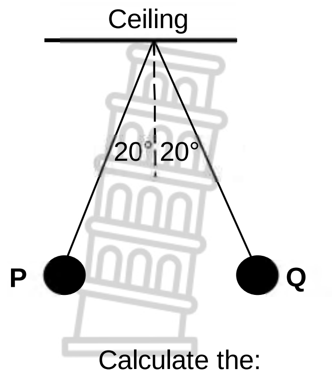
6.1 Net electric field at point **X** due to the two charges (6)

6.2 Electrostatic force that a – 2 x 10^{-9} C charge will experience at point **X** (4)\

The – 2 x 10^{-9} C charge is replaced with a charge of – 4 x 10^{-9} C at point **X**.

6.3 Without any further calculation, determine the magnitude of the force that the – 4 x 10^{-9} C charge will experience at point **X**. (1)

[11]



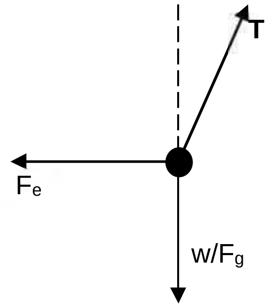
QUESTION 7

Two identical spherical balls, **P** and **Q**, each of mass 100 g, are suspended at the same point from a ceiling by means of identical light, inextensible insulating strings. Each ball carries a charge of +250 nC. The balls come to rest in the positions shown in the diagram.

7.1 In the diagram, the angles between each string and the vertical are the same. Give a reason why the angles are the same. (1)

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

7.3 The free-body diagram, not drawn to scale, of the forces acting on ball **P** is shown below.



Calculate the:

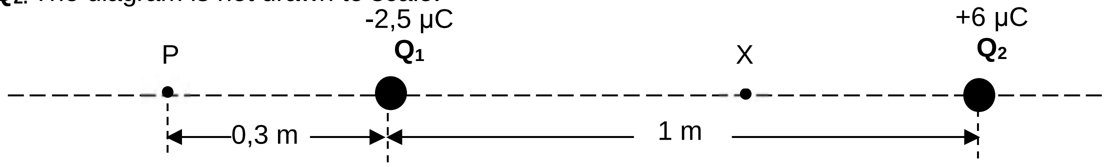
7.3.1 Magnitude of the tension (**T**) in the string (3)

7.3.2 Distance between balls **P** and **Q** (5)

[11]

QUESTION 8

A sphere $\mathbf{Q_1}$, with a charge of -2,5 μC, is placed 1 m away from a second sphere $\mathbf{Q_2}$, with a charge +6 μC. The spheres lie along a straight line, as shown in the diagram below. Point **P** is located a distance of 0,3 m to the left of sphere $\mathbf{Q_1}$, while point **X** is located between $\mathbf{Q_1}$ and $\mathbf{Q_2}$. The diagram is not drawn to scale.



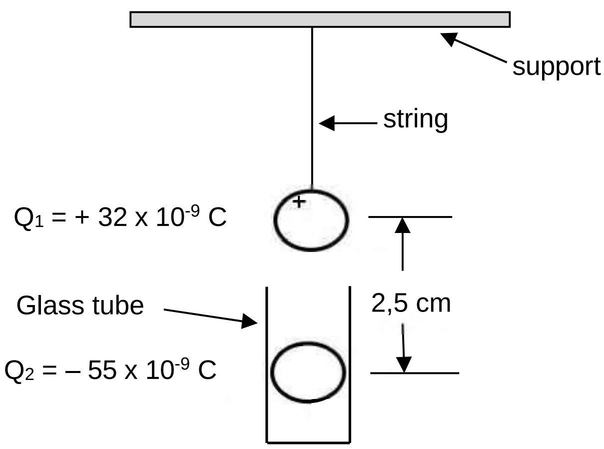
8.1 Show, with the aid of a VECTOR DIAGRAM, why the net electric field at point **X** cannot be zero. (4)

8.2 Calculate the net electric field at point **P**, due to the two charged spheres $\mathbf{Q_1}$ and $\mathbf{Q_2}$. (6)

[10]

QUESTION 9

A small sphere, Q_1, with a charge of + 32 x 10^{-9} C, is suspended from a light string secured to a support.



A second, identical sphere, Q_2, with a charge of – 55 x 10^{-9} C, is placed in a narrow, cylindrical glass tube vertically below Q_1. Each sphere has a mass of 7 g. Both spheres come to equilibrium when Q_2 is 2,5 cm from Q_1, as shown in the diagram. Ignore the effects of air friction.

9.1 Calculate the number of electrons that were removed from Q_1 to give it a charge of + 32 x 10^{-9} C. Assume that the sphere was neutral before being charged. (3)

9.2 Draw a labelled free-body diagram showing all the forces acting on sphere Q_1. (3)

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

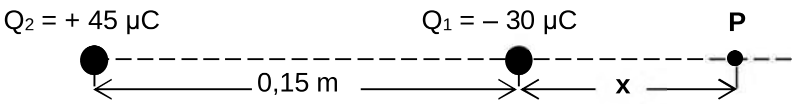
[11]

QUESTION 10

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

10.2 Draw the electric field pattern for two identical positively charged spheres placed close to each other. (3)

10.3 A – 30 μC point charge, Q_1, is placed at a distance of 0,15 m from a + 45 μC point charge, Q_2, in space, as shown in the diagram below. The net electric field at point **P**, which is on the same line as the two charges, is zero.

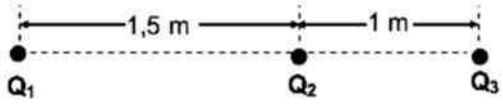


Calculate **x**, the distance of point **P** from charge Q_1. (5)

[10]

QUESTION 11

In the diagram below, Q_1, Q_2 and Q_3 are three stationary point charges placed along a straight line. The distance between Q_1 and Q_2 is 1,5 m and that between Q_2 and Q_3 is 1 m, as shown in the diagram.



11.1 State Coulomb's law in words. (2)

11.2 The magnitude of charges Q_1 and Q_2 are unknown. The charge on Q_1 is positive. The charge on Q_3 is $+2 \times 10^{-6}$ C and it experiences a net electrostatic force of 0,3 N to the left.

11.2.1 Write down the sign (POSITIVE or NEGATIVE) of charge Q_2. (2)

Charge Q_2 is now removed. The magnitude of the electrostatic force experienced by charge Q_3 due to Q_1 now becomes 0,012 N.

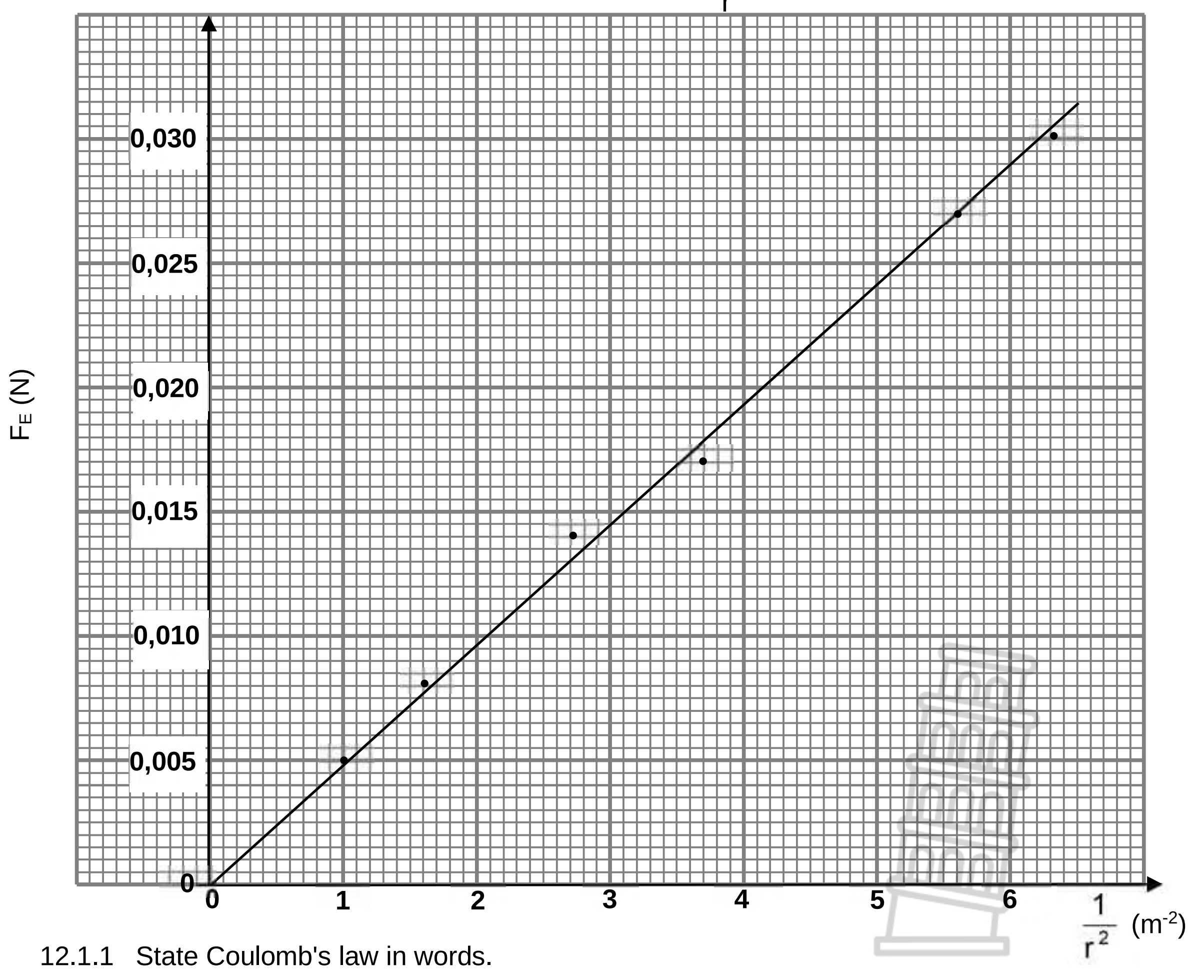
11.2.2 Calculate the magnitudes of the unknown charges Q_1 and Q_2. (7)

[11]

QUESTION 12

12.1 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.

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



12.1.1 State Coulomb's law in words. (2)

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

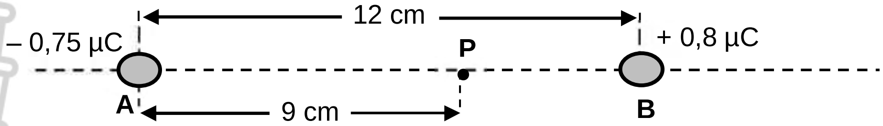
12.1.3 What relationship between the electrostatic force F_E and the square of the distance, r^2, between the charged spheres can be deduced from the graph? (1)

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

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

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

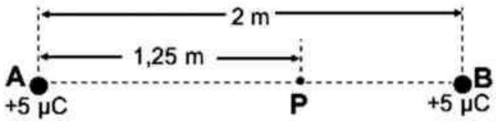
Sphere **A** is placed 12 cm away from another charged sphere, B, along a straight line in a vacuum, as shown below. Sphere **B** carries a charge of +0,8 μC. Point **P** is located 9 cm to the right of sphere **A**.



12.2.2 Calculate the magnitude of the net electric field at point P. (5)
[17]

QUESTION 13

Two small identical spheres, **A** and **B**, each carrying a charge of +5 μC, are placed 2 m apart. Point **P** is in the electric field due to the charged spheres and is located 1,25 m from sphere **A**. Study the diagram.



13.1 Describe the term *electric field*. (2)
13.2 Draw the resultant electric field pattern due to the two charged spheres. (3)
13.3 Calculate the magnitude of the net electric field at point **P**. (5)
[10]

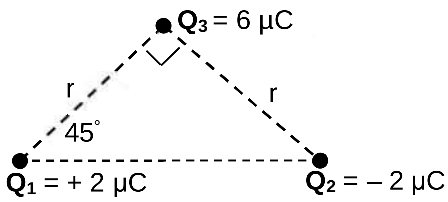
QUESTION 14

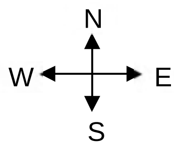
14.1 A metal sphere **A**, suspended from a wooden beam by means of a non-conducting string, has a charge of +6 μC.

14.1.1 Were electrons ADDED TO or REMOVED FROM the sphere to obtain this charge? Assume that the sphere was initially neutral. (1)

14.1.2 Calculate the number of electrons added to or removed from the sphere. (3)

14.2 Point charges Q_1, Q_2 and Q_3 are arranged at the corners of a right-angled triangle, as shown in the diagram. The charges on Q_1 and Q_2 are + 2 μC and – 2 μC respectively and the magnitude of the charge on Q_3 is 6 μC. The distance between Q_1 and Q_3 is r. The distance between Q_2 and Q_3 is also r. The charge Q_3 experiences a resultant electrostatic force of 0,12 N to the west.





14.2.1 Without calculation, identify the sign (positive or negative) on the charge Q_3. (1)

14.2.2 Draw a vector diagram to show the electrostatic forces acting on Q_3 due to charges Q_1 and Q_2 respectively. (2)

14.2.3 Write down an expression, in terms of ***r***, for the horizontal component of the electrostatic force exerted on Q_3 by Q_1. (3)

14.2.4 Calculate the distance r. (4)

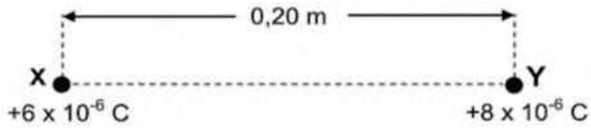
14.3 The magnitude of the electric field is 100 $N{\cdot}C^{-1}$ at a point which is 0,6 m away from a point charge **Q**.

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

14.3.2 Calculate the distance from point charge **Q** at which the magnitude of the electric field is 50 $N{\cdot}C^{-1}$. (5)
[21]

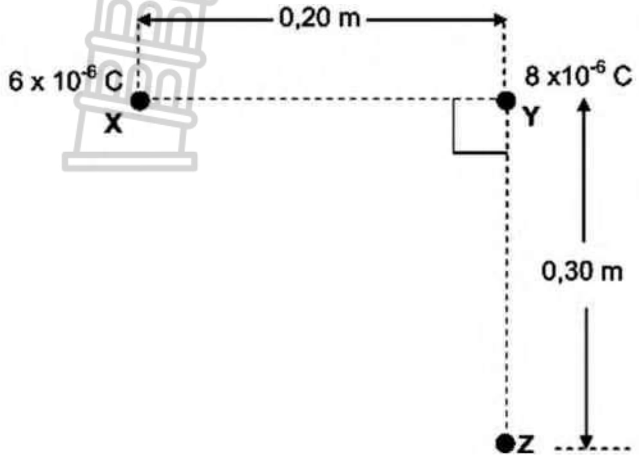
QUESTION 15

Two small spheres, **X** and **Y**, carrying charges of $+6 \times 10^{-6}$ C and $+8 \times 10^{-6}$ C respectively, are placed 0,20 m apart in air.



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

15.2 Calculate the magnitude of the electrostatic force experienced by charged sphere **X**. (4)



A third sphere, **Z**, of unknown negative charge, is now placed at a distance of 0,30 m below sphere **Y**, in such a way that the line joining the charged spheres **X** and **Y** is perpendicular to the line joining the charged spheres **Y** and **Z**, as shown in the diagram alongside.

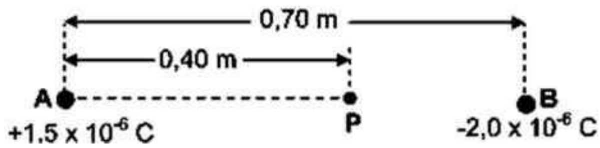
15.3 Draw a vector diagram showing the directions of the electrostatic forces and the net force experienced by charged sphere **Y** due to the presence of charged spheres **X** and **Z** respectively. (3)

15.4 The magnitude of the net electrostatic force experienced by charged sphere **Y** is 15,20 N. Calculate the charge on sphere **Z**. (4)

[13]

QUESTION 16

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



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

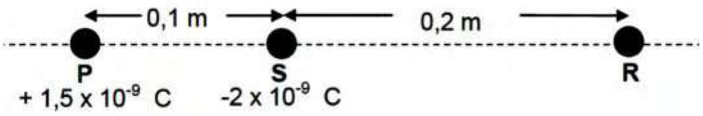
16.2 Calculate the magnitude of the net electric field at point **P**. (4)

16.3 A point charge of magnitude $3,0 \times 10^{-9}$ C is now placed at point **P**. Calculate the magnitude of the electrostatic force experienced by this charge. (3)

[9]

QUESTION 17

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



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

17.2 Draw a labelled force diagram showing the electrostatic forces acting on **R** due to **P** and **S**. (2)

17.3 Calculate the magnitude of the charge on **R**, if it experiences a net electrostatic force of $1,27 \times 10^{-6}$ N to the left. Take forces directed to the right as positive. (7)

[11]

QUESTION 18

P is a point 0,5 m from charged sphere **A**. The electric field at **P** is 3×10^{7} N·C^{-1} directed towards **A**. Refer to the diagram.

18.1 Draw the electric field pattern due to charged sphere **A**. Indicate the sign of the charge on the sphere in your diagram. (2)

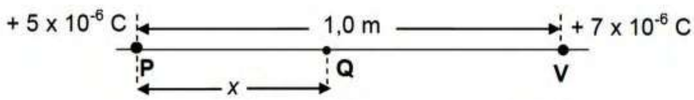
18.2 Calculate the magnitude of the charge on sphere **A**. (3)

18.3 Another charged sphere, **B**, having an excess of 10^{5} electrons, is now placed at point **P**. Calculate the electrostatic force experienced by sphere **B**. (6)

[11]

QUESTION 19

A particle, **P**, with a charge of $+ 5 \times 10^{-6}$ C, is located 1,0 m along a straight line from particle **V**, with a charge of $+7 \times 10^{-6}$ C. Refer to the diagram.



A third charged particle, **Q**, at a point ***x*** metres away from **P**, as shown above, experiences a net electrostatic force of zero newton.

19.1 How do the electrostatic forces experienced by **Q** due to the charges on **P** and **V** respectively, compare with each other? (2)

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

19.3 Calculate the distance **x**. (5)
[9]

QUESTION 20

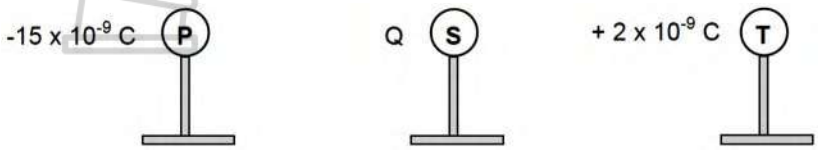
A small metal sphere **Y** carries a charge of + 6 x 10^{-6} C.

20.1 Draw the electric field pattern associated with sphere **Y**. (2)

20.2 If 8 x 10^{13} electrons are now transferred to sphere **Y**, calculate the electric field at a point 0,5 m from the sphere. (7)
[9]

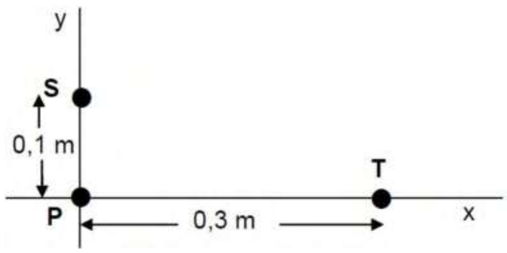
QUESTION 21

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



21.1 Determine the value of charge **Q**. (2)

21.2 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 x 10^{-9} C, are now placed at points on the *x*-axis and the *y*-axis, as shown in the diagram, with sphere **P** at the origin.

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

21.4 Calculate the magnitude of the net electrostatic force acting on sphere **P**. (5)

21.5 Calculate the magnitude of the net electric field at the origin due to charges **S** and **T**. (3)

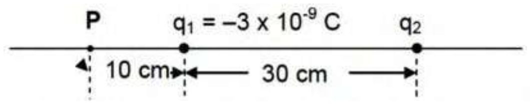
21.6 ONE of the charged spheres, **P** and **T**, experienced a very small increase in mass after it was charged initially.

21.6.1 Which sphere, **P** or **T**, experienced this very small increase in mass? (1)

21.6.2 Calculate the increase in mass by the sphere in QUESTION 21.6.1. (3)
[19]

QUESTION 22

Two point charges, q_1 and q_2, are placed 30 cm apart along a straight line. Charge q_1 = –3 x 10^{-9} C. Point **P** is 10 cm to the left of q_1, as shown in the diagram below. The **net** electrostatic field at point **P** is **zero.**



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

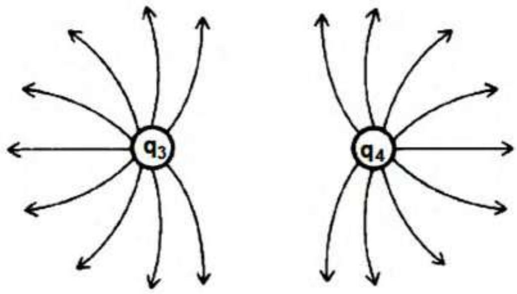
22.2 State, giving reasons, whether point charge q_2 is POSITIVE or NEGATIVE. (3)

22.3 Calculate the magnitude of charge q_2. (4)

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

22.5 Calculate the magnitude of the electrostatic force exerted by charge q_1 on charge q_2. (3)

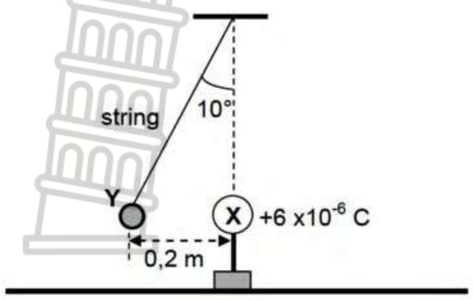
22.6 The two charges are now brought into contact with each other and are then separated. A learner draws the electric field pattern for the new charges q_3 and q_4 after contact, as shown below.



22.7 Is the diagram CORRECT? Give a reason for the answer. (2)
[16]

QUESTION 23

23.1 A small sphere, **Y**, carrying an unknown charge, is suspended at the end of a light inextensible string which is attached to a fixed point. Another sphere, **X**, carrying a charge of +6 x10-6 C, on an insulated stand is brought close to sphere **Y**.



Sphere **Y** experiences an electrostatic force and comes to rest 0,2 m away from sphere **X**, with the string at an angle of 10° with the vertical, as shown in the diagram.

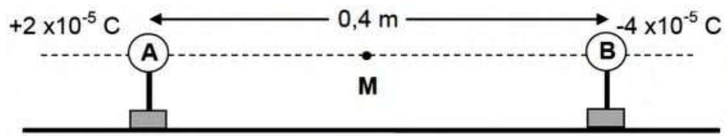
23.1.1 What is the nature of the charge on sphere **Y**? Choose from POSITIVE or NEGATIVE. (1)

23.1.2 Calculate the magnitude of the charge on sphere **Y** if the magnitude of the electrostatic force acting on it is 3,05 N. (3)

23.1.3 Draw a labelled free-body diagram for sphere **Y**. (3)

23.1.4 Calculate the magnitude of the tension in the string. (3)

23.2 Two small charged spheres, **A** and **B**, on insulated stands, with charges +2 x10^{-5} C and -4 x10^{-5} C respectively, are placed 0,4 m apart, as shown in the diagram below. **M** is the midpoint between spheres **A** and **B**.



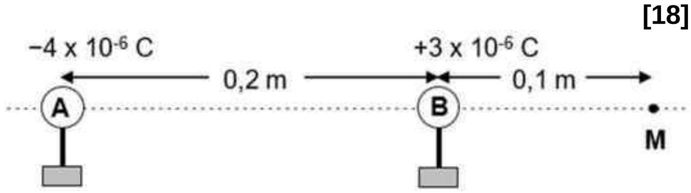
23.2.1 Define the term *electric field at a point*. (2)

23.2.2 Calculate the net electric field at point **M**. (6)

[18]

QUESTION 24

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



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

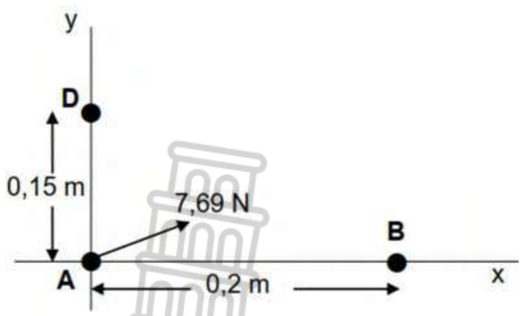
24.1 Calculate the number of electrons in excess on sphere **A**. (3)

24.2 Calculate the magnitude of the electrostatic force exerted by sphere **A** on sphere **B**. (3)

24.3 Describe the term *electric field*. (2)

24.4 Calculate the magnitude of the net electric field at point **M**. (5)

Charged spheres **A** and **B** and another charged sphere **D** are now arranged along a rectangular system of axes, as shown in the diagram. The net electrostatic force experienced by sphere **A** is 7,69 N in the direction as shown in the diagram.



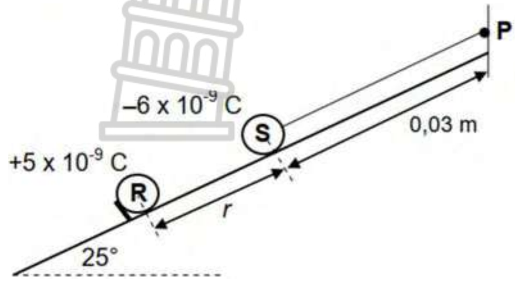
24.5 Is the charge on sphere **D** POSITIVE or NEGATIVE? (1)

24.6 Calculate the magnitude of the charge on sphere **D**. (3)

[17]

QUESTION 25

Two charged spheres, **R** and **S**, are both stationary on a smooth, insulated surface inclined at an angle of 25° to the horizontal. Sphere **S**, of mass 0,01 kg and carrying a charge of –6 x 10^{-9} C, is connected to a 0,03 m long, light inextensible string attached to point **P** at the top of the incline. Sphere **R**, carrying a charge of +5 x 10^{-9} C, is held such that the distance between the centres of the spheres is *r*, as shown in the diagram. Ignore the effects of friction. Sphere **R** exerts an electrostatic force of magnitude 1,2 x 10^{-3} N on sphere **S**.



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

25.2 Calculate the distance *r* between the spheres. (3)

25.3 Draw a labelled free-body diagram for sphere **S**. (4)

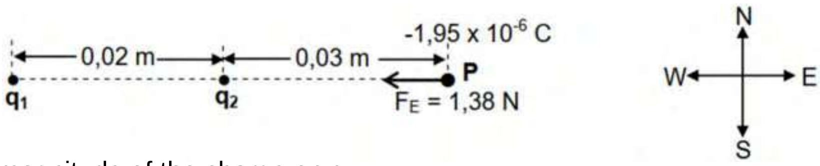
25.4 Calculate the:

25.4.1 Tension in the string (4)
25.4.2 Net electric field at point **P** (5)
[18]

QUESTION 26

26.1 A small neutral sphere acquires a charge of $-1,95 \times 10^{-6}$ C.
26.1.1 Were electrons ADDED TO or REMOVED FROM the sphere? (1)
26.1.2 Calculate the number of electrons which were added or removed. (3)
26.1.3 Define the term electric field at a point. (2)
26.1.4 Calculate the magnitude of the electric field at a point 0,5 m from the centre of the charged sphere. (3)

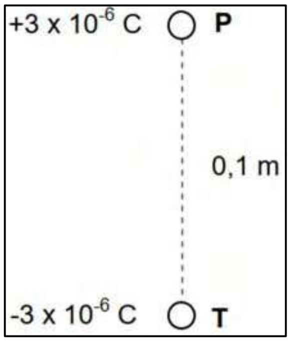
26.2 Two point charges, $\mathbf{q_1}$ and $\mathbf{q_2}$, are fixed 0,02 m apart. The magnitude of charges $\mathbf{q_1}$ and $\mathbf{q_2}$ is the same and $\mathbf{q_1}$ is NEGATIVELY charged. The small charged sphere with the charge of $-1,95 \times 10^{-6}$ C is placed at point **P**, 0,03 m east of charge $\mathbf{q_2}$, as shown in the diagram below. The sphere at point **P** experiences a net electrostatic force of 1,38 N west.



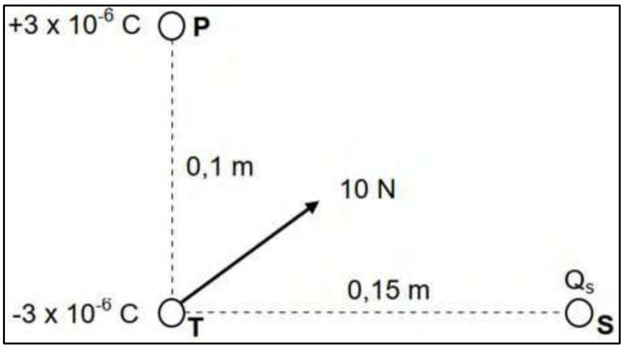
Calculate the magnitude of the charge on $\mathbf{q_2}$. (5)
[14]

QUESTION 27

27.1 Two small, identical spheres, **P** and **T**, are placed a distance of 0,1 m apart, as shown in the diagram on the right. **P** carries a charge of $+3 \times 10^{-6}$ C and **T** carries a charge of -3×10^{-6} C.



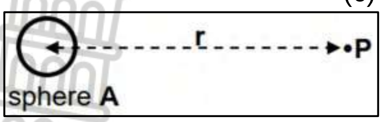
27.1.1 State *Coulomb's law* in words. (2)
27.1.2 Draw the resultant electric field pattern due to the charges on **P** and **T**. (3)

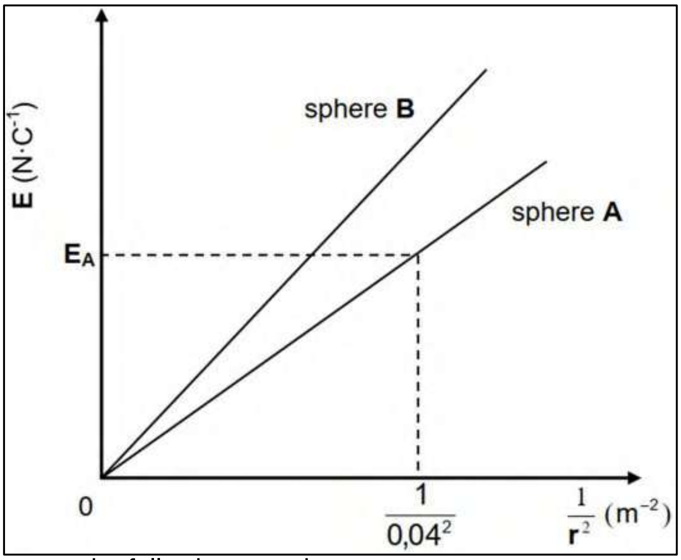


A third charged sphere **S** of unknown charge Q_s is placed a distance of 0,15 m from sphere **T** such that the three charged spheres are at the vertices of a right-angled triangle. The net electrostatic force on sphere **T** due to the other two charged spheres has a magnitude of 10 N, as shown in the diagram on the left.

27.1.3 Is charge Q_s POSITIVE or NEGATIVE? (1)
27.1.4 Calculate the number of electrons added to or removed from sphere **S** to give it a charge of Q_s. (6)

27.2 **P** is a variable point in the electric field of charged sphere **A** and *r* is the distance between point **P** and the centre of sphere **A**. See the diagram on the right. A learner determines the magnitude of the electric field (*E*) at point **P** for different values of *r*. Sphere **A** is then replaced by another sphere, **B**, of a different charge. Another set of results are obtained. The graphs below are obtained from the results for sphere **A** and sphere **B**. $\mathbf{E_A}$ is the magnitude of the electric field at a distance of 0,04 m from the centre of charged sphere **A**.





Use the graphs to answer the following questions.

27.2.1 State the proportionality between the magnitude of electric field E at a point and $\frac{1}{r^2}$. (1)

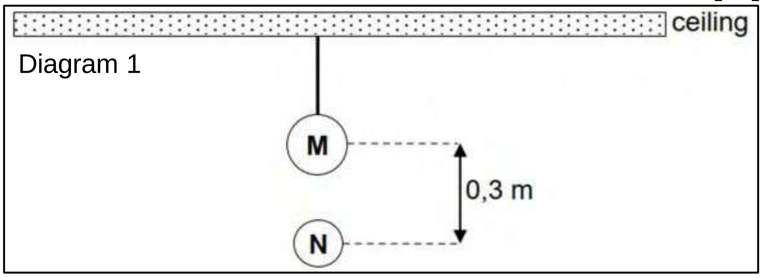
27.2.2 Calculate E_A if the numerical value of the gradient of the graph for sphere **A** is 680. (4)

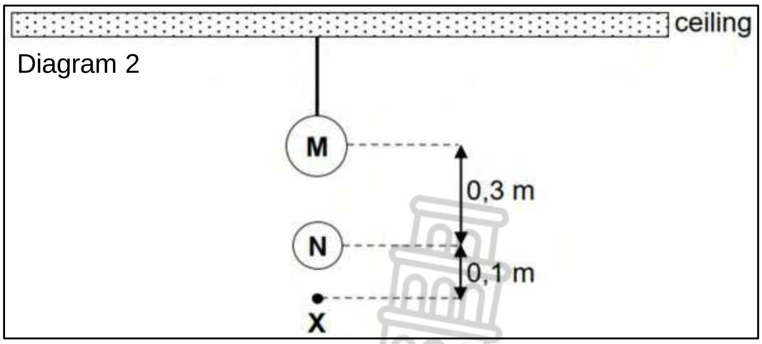
27.2.3 How does the magnitude of the charge on sphere **B** compare to the magnitude of the charge on sphere **A**? Choose from GREATER THAN, SMALLER THAN or EQUAL TO. Give a reason for the answer. (3)

[20]

QUESTION 28

A charged sphere **M** is suspended from a ceiling by a light inextensible, insulated string. Another charged sphere **N**, of mass $2,04 \times 10^{-3}$ kg and carrying a charge of $+8,6 \times 10^{-8}$ C, hangs STATIONARY vertically below sphere **M**. The centres of the spheres are 0,3 m apart, as shown in diagram 1.





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

28.2 State whether the charge on sphere **M** is POSITIVE or NEGATIVE. (1)

28.3 Draw a labelled free-body diagram for sphere **N**. (2)

28.4 Calculate the magnitude of the charge on sphere **M**. (5)

28.5 How does the electrostatic force that sphere **M** exerts on sphere **N** compare to that exerted by sphere **N** on sphere **M** with respect to:

28.5.1 Magnitude (1)

28.5.2 Direction (1)

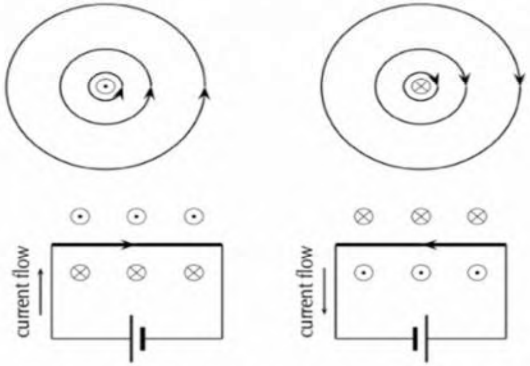
28.6 Point **X** is 0,1 m vertically below the centre of sphere **N**, as shown in diagram 2. Calculate the net electric field at point **X**. (5)

[17]

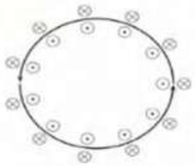
ELECTROMAGNETISM

Electromagnetism is the study of the properties and relationship between *electric currents* and *magnetism*.

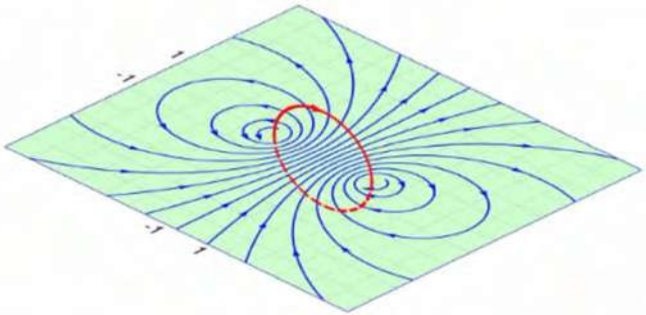
Magnetic field around a current carrying conductor



Magnetic field around a current carrying loop



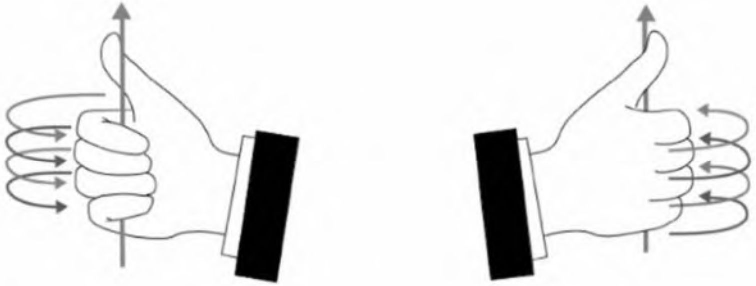
The directions of the magnetic field around a loop of current carrying conductor with the current flowing in a counter-clockwise direction is shown.

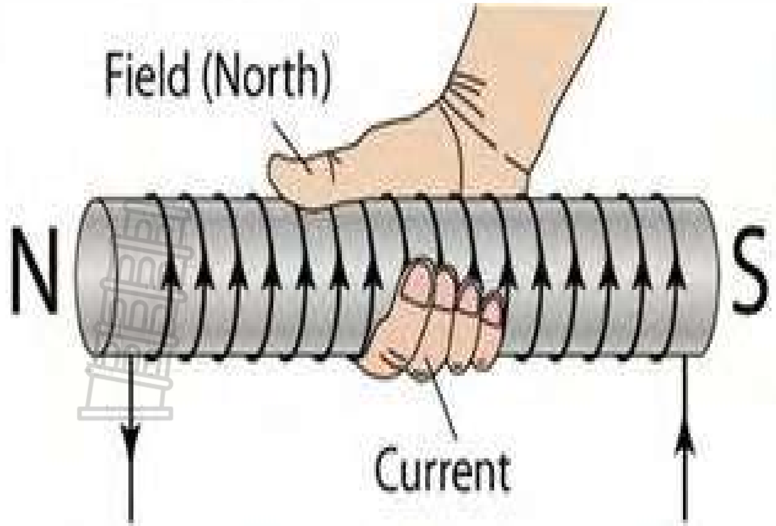


"Dot (.) Sign Is Used To Represent The Magnetic Field Outward The Plane Whereas Cross (X) Sign Represent The Inward Direction of The Field."

The Right Hand Rule

The Right Hand Rule says that the magnetic field lines produced by a current-carrying wire will be oriented in the same direction as the curled fingers of a person's right hand (in the "hitchhiking" position), with the thumb pointing in the direction of the current flow.





Magnetic flux (ϕ)

The magnetic flux through a surface is the product of the component of the magnetic field normal to the surface and the surface area:

$$\phi = B \cdot A \cos\theta$$

Where:
θ = the angle between the magnetic field, $\boldsymbol{B}$, and the normal to the loop of area $\boldsymbol{A}$.
A = the area of the loop.
B = the magnetic field.

Electromagnetic induction

Electromagnetic induction occurs when a changing magnetic field induces a voltage in a current-carrying conductor.
The magnitude of the induced emf is given by Faraday's law of electromagnetic induction:

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

where ϕ = $\boldsymbol{B \cdot A}$ and $\boldsymbol{B}$ is the strength on magnetic field. $\boldsymbol{N}$ is the number of circuit loops. A magnetic field is measured in units of tesla (T). The minus sign indicates direction and that the induced *emf* (ε) tends to oppose the change in magnetic flux ($\Delta\phi$). The minus sign can be ignored when calculating the magnitudes.

TERMS AND DEFINITIONS	
Faraday's law of electromagnetic induction	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.
The Magnetic flux	The magnetic flux through a surface is the product of the component of the magnetic field normal to the surface and the surface area.

STRUCTURED QUESTIONS

QUESTION 1 *(Exemplar 2013)*

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)

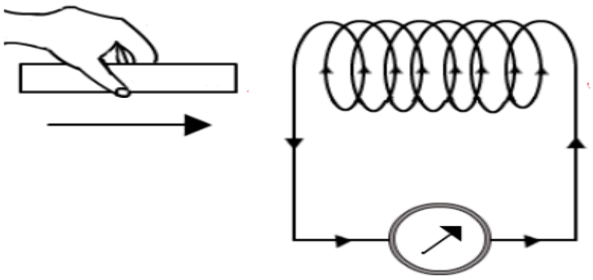
1.2.2 Radius of the coil (4)

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)

[11]

QUESTION 2 (*November 2014)*

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



2.1 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)

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

2.3 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.

10.4 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:

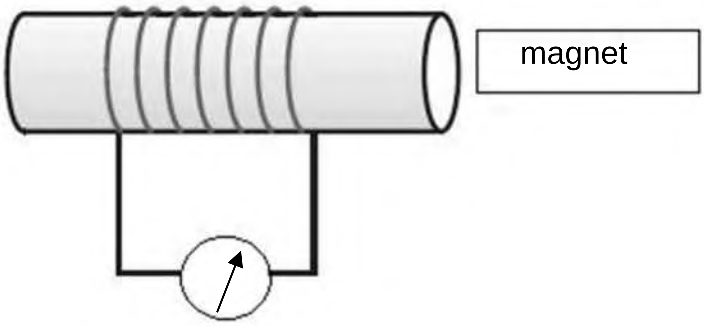
2.5 Magnitude of the emf induced in the coil (5)

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

[15]

QUESTION 3 (*November 2015)*

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



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

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

3.2 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.

3.2.1 Calculate the magnetic flux linkage. (3)

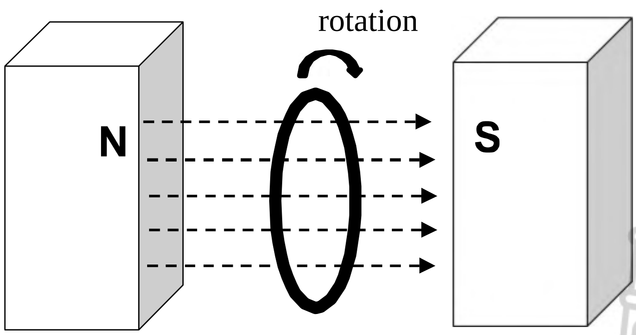
In order to produce an emf of 9 V, the area of the coil, with its axis coinciding with the direction of a magnetic field, is halved from 0,6 m^2 to 0,3 m^2 in 2 minutes.

3.2.2 Calculate the number of turns in the coil. (4)

[11]

QUESTION 4 (*November 2016)*

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



4.1 Calculate the magnetic flux through the coil at the position indicated on the diagram, where the coil is perpendicular to the field. (3)

4.2 If the coil rotates clockwise through 25°, and the potential difference induced is 2,8 V, Calculate the time in which this rotation took place. (4)

4.3 Which law can be used toexplainthe phenomenon described inQUESTION 4.2? Name and state the law. (2)

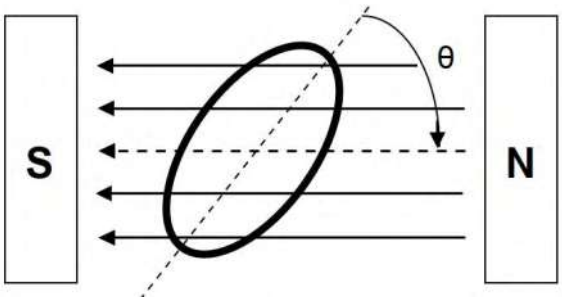
4.4 If the circular coil is replaced with a square coil with a side lengthof 0,04 m, and the same movement is made in the same amountof time, will the induced emf be the same as, larger than or smaller than the circular coil? Write down only THE SAME AS, LARGER THAN or SMALLER THAN. (1)

4.5 Explain the answer to QUESTION 4.4 (2)

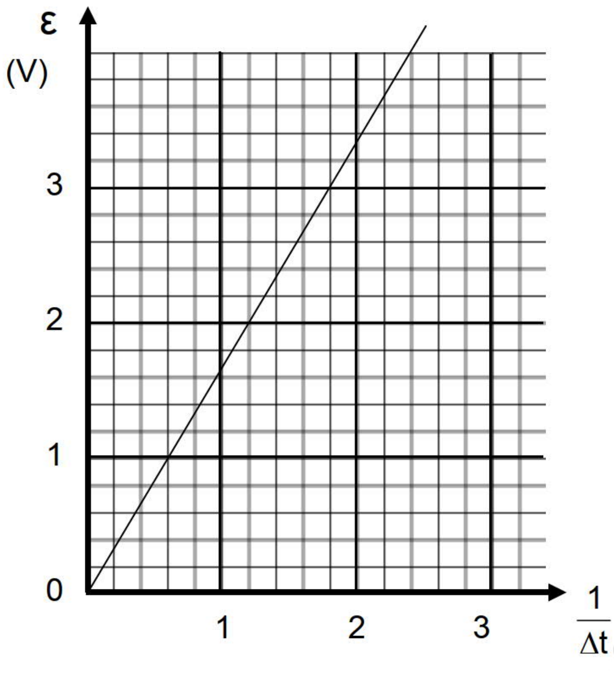
[12]

QUESTION 5 (*November 2017*)

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



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



5.1 State *Faraday's law* in words. (2)

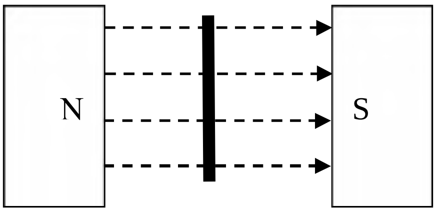
5.2 Use the information in the graph to calculate the change in magnetic flux. (5)

5.3 The coil rotates through an angle θ to a position where the magnetic flux becomes zero. Calculate angle θ. (4)

[11]

QUESTION 6 (*November 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 45ºin 0,08 s.



An emf of 7 V is induced in the coil.

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

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

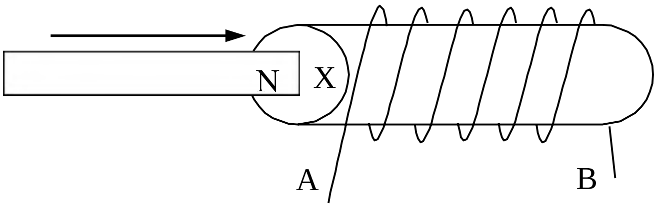
6.3 Calculate the magnitude of the magnetic field. (4)

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

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

6.5 Explain the answer to QUESTION 6.4. (1)

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



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

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

[13]

QUESTION 7 (November 2019)

A coil with 200 windings and a surface area of 2,8 × 10^{-3} m is rotated at constant speedin a constant magnetic field of 2,5 T. An emf of 3,5 V is induced in the coil.

7.1 Consider the following statement: 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.

Name the law represented by the above statement. (1)

7.2 Calculate the:

7.2.1 Change in magnetic flux if the angle of the coil relative to the magnetic field changes from 0° to 90° (3)

7.2.2 Time it takes the coil to rotate from 0° to 90° (3)

7.3 By what factor will the induced emf change if a coil with 100 windings is used under the same conditions? Give a reason for the answer. (2)

[9]

ELECTRIC CIRCUITS

TERMS AND DEFINITIONS	
Ohm's law	The potential difference across a conductor is directly proportional to the current in the conductor at constant temperature. In symbols: $R = \frac{V}{I}$ The units: $\Omega = V \cdot A^{-1}$
Emf	Maximum energy provided / amount of work done by a battery per coulomb/unit charge passing through it. (It is the potential difference across the ends of a battery when there is NO current in the circuit.)
Terminal potential difference	The energy transferred to or the work done per coulomb of charge passing through the battery when the battery delivers a current. (It is the potential difference across the terminals of a battery when there IS a current in the circuit.)
Ohmic conductors	A conductor that obeys Ohm's law, i.e., the ratio of potential difference to current remains constant. (Resistance of the conductor remains constant.)
Non-ohmic conductors	A conductor that does NOT obey Ohm's law, i.e., the ratio of potential difference to current does NOT remain constant. (Resistance of the conductor increases as the current increases, e.g. a bulb.)
Potential difference	Potential difference is the amount of work done (or energy transferred) per coulomb of charge. It is measured in volt (V). In symbols: $V = \frac{W}{Q}$ The units: $V = J \cdot C^{-1}$
Current	Current is the rate of flow of charge. It is measured in ampere (A). In symbols: $I = \frac{Q}{\Delta t}$ The units: $A = C \cdot s^{-1}$
Resistance	Resistance is the opposition to the flow of charge (electric current). It is measured in ohm (Ω) and can be calculated by using the ratio of potential difference (V) to current (I). In symbols: $R = \frac{V}{I}$ The units: $\Omega = V \cdot A^{-1}$
Resistors in series	The total resistance of resistors in series is given by: $R_T = R_1 + R_2 + \cdots$ OR $R_S = R_1 + R_2 + \cdots$
Resistors in parallel	The effective resistance (do NOT use the word "total") of resistors in parallel is given by: $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$
Internal resistance	The resistance within a battery that causes a drop in the potential difference across the battery when there is a current in the circuit.
Power	Power is the rate at which work is done or rate at which energy is transferred. It is measured in watt (W). In symbols: $P = \frac{W}{\Delta t}$ The units: $W = J \cdot s^{-1}$
	Other formulae for power: $P = VI$ $P = I^2R$ $P = \frac{V^2}{R}$
kilowatt hour (kWh) (This is an energy unit related to the formula $W = P\Delta t$.)	It is the use of 1 kilowatt of electricity for 1 hour.
Other energy formulae (electric circuits)	$W = VQ$ $W = I^2R\Delta t$ $W = VI\Delta t$ $W = \frac{V^2\Delta t}{R}$

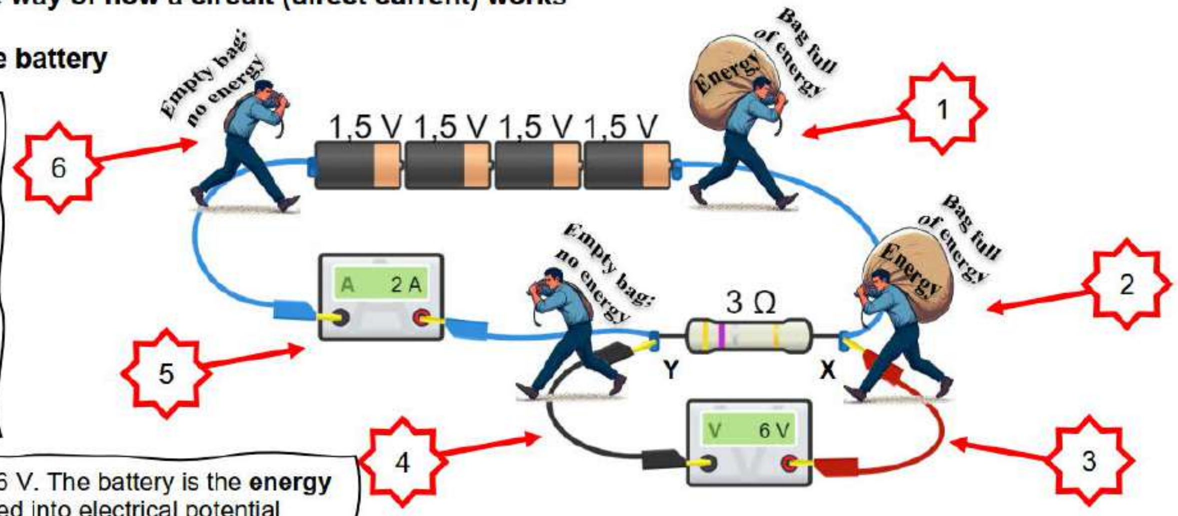
A simple way of how a circuit (direct current) works

Example 1: <u>One</u> resistor is <u>connected in series</u> with the battery

Read this first to understand the idea of the picture.

In this example, **one coulomb of charge** is represented by the **picture of the man**. He carries a bag initially filled with **energy**. The **same man** is represented at **different positions** in the circuit. **Only ONE coulomb is represented here, but there are millions of charges behind and in front of this one doing the same things described in this example.**

Follow the numbers below and study what happens in the circuit.



Each cell's emf is 1,5 V. For four cells (the battery), the emf is 6 V. The battery is the **energy factory**. Chemical potential energy of the chemicals is converted into electrical potential energy and the **charges are transporting the energy** to the resistor in the circuit.

1 **One coulomb** of charge leaves the battery with the **maximum amount of energy** (a full bag of energy). In this case it is six joule per coulomb (6 J·C^{-1}) because the emf of the battery is 6 V which is equal to 6 J·C^{-1} according to $V = \frac{W}{Q}$.

2 This coulomb of charge arrives at the resistor with 6 J of energy (assume the conductor offers no resistance; hence, it uses no energy). There is only **one resistor** in the circuit. Therefore, **all the energy** is transferred to this resistor.

3 The voltmeter measures the amount of energy in joule per coulomb at **X** **before** the energy is transferred to the resistor. Therefore, it measures 6 J·C^{-1} at **X**.

4 The voltmeter measures the amount of energy in joule per coulomb at **Y** **after** the energy has been transferred to the resistor. Therefore, it measures 0 J·C^{-1} at **Y**.

3&4 The voltmeter reading is equal to the **difference** between the readings at **X** and **Y**.

∴ Voltmeter reading = reading at **X** - reading at **Y**
= 6 J·C^{-1} - 0 J·C^{-1} = 6 J·C^{-1} = 6 V

Note a few things about the voltmeter and its reading:

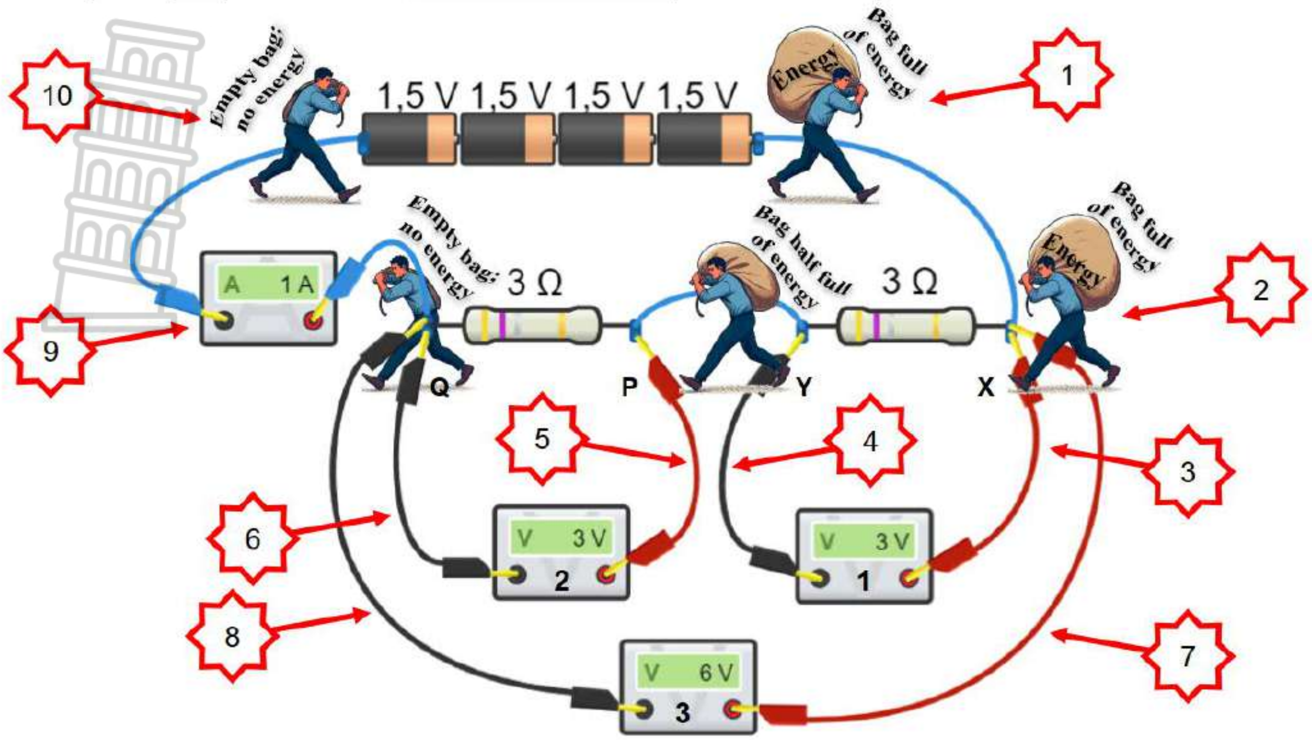
- The reading represents the energy per coulomb of charge transferred to the resistor that is **connected between its wires**.
- The voltmeter **measures the energy per coulomb of charge, also called potential difference, at TWO points**. Therefore, the **voltmeter** must be connected in **parallel** with the resistor. To prevent the charges from flowing through the voltmeter, the latter is manufactured with a **very high resistance**.
- **There is no change in the charges** itself. It is **only the energy that is transferred** to the resistor.

5 The **charges flow THROUGH** the ammeter. Therefore, the **ammeter** must have a very **low resistance** and it is connected in **series** with the resistor. The **current, which is measured at ONE point**, is then given by $I = \frac{Q}{\Delta t}$. If two coulomb of charge flows through the ammeter in one second, the current is:

$I = \frac{Q}{\Delta t} = \frac{2}{1} = 2\ C \cdot s^{-1} = 2\ A.$

6 The coulomb of charge returns to the battery where the bag is again filled with energy and the process is repeated for this coulomb of charge until the battery is flat.

Example 2: Two resistors are connected in series with the battery



1 **One coulomb** of charge leaves the battery with the **maximum amount of energy**. In this case it is 6 J·C^{-1} because the emf of the battery is 6 V.

2 This coulomb of charge arrives at the first resistor with 6 J of energy. If there are **more than one resistor in series**, the charges must **transfer energy to EACH of the resistors**. The amount of energy transferred depends on each resistor's resistance. In this example, the resistances are the same; hence, each one gets half of the energy.

3 Voltmeter 1 measures 6 J·C^{-1} at **X before** the energy is transferred to the resistor. Half of this energy is transferred to the first resistor. Hence, there is 3 J·C^{-1} of energy left.

4 Voltmeter 1 measures 3 J·C^{-1} at **Y after** the energy was transferred.
The reading on voltmeter 1 = reading at **X** - reading at **Y** = 6 J·C^{-1} - 3 J·C^{-1} = 3 J·C^{-1} = 3 V

5 The coulomb of charge flows further and reaches the second resistor where the remaining energy is transferred to the resistor. Voltmeter 2 measure 3 J·C^{-1} at **P before** the energy is transferred to the resistor. It is the same reading as at **Y** because no energy is transferred to the conductors.

6 Voltmeter 2 measures 0 J·C^{-1} at **Q after** the energy was transferred.
The reading on voltmeter 2 = reading at **P** - reading at **Q** = 3 J·C^{-1} - 0 J·C^{-1} = 3 J·C^{-1} = 3 V

7 Voltmeter 3 is connected **across BOTH resistors.** It therefore measures the amount of energy at **X** and **Q**. At **X** it measures 6 J·C^{-1}. All the energy is transferred to both resistors.

8 Voltmeter 3 measures 0 J·C^{-1} at **Q after** the energy was transferred.
The reading on voltmeter 3 = reading at **X** - reading at **Q** = 6 J·C^{-1} - 0 J·C^{-1} = 6 J·C^{-1} = 6 V
Note that the reading on voltmeter 3 is equal to the sum of the readings on voltmeters 1 and 2.

9 The charges flow **through** the ammeter. If one coulomb of charge flows through the ammeter in one second, the current is:
$I = \frac{Q}{\Delta t} = \frac{1}{1} = 1\,C \cdot s^{-1} = 1\,A.$

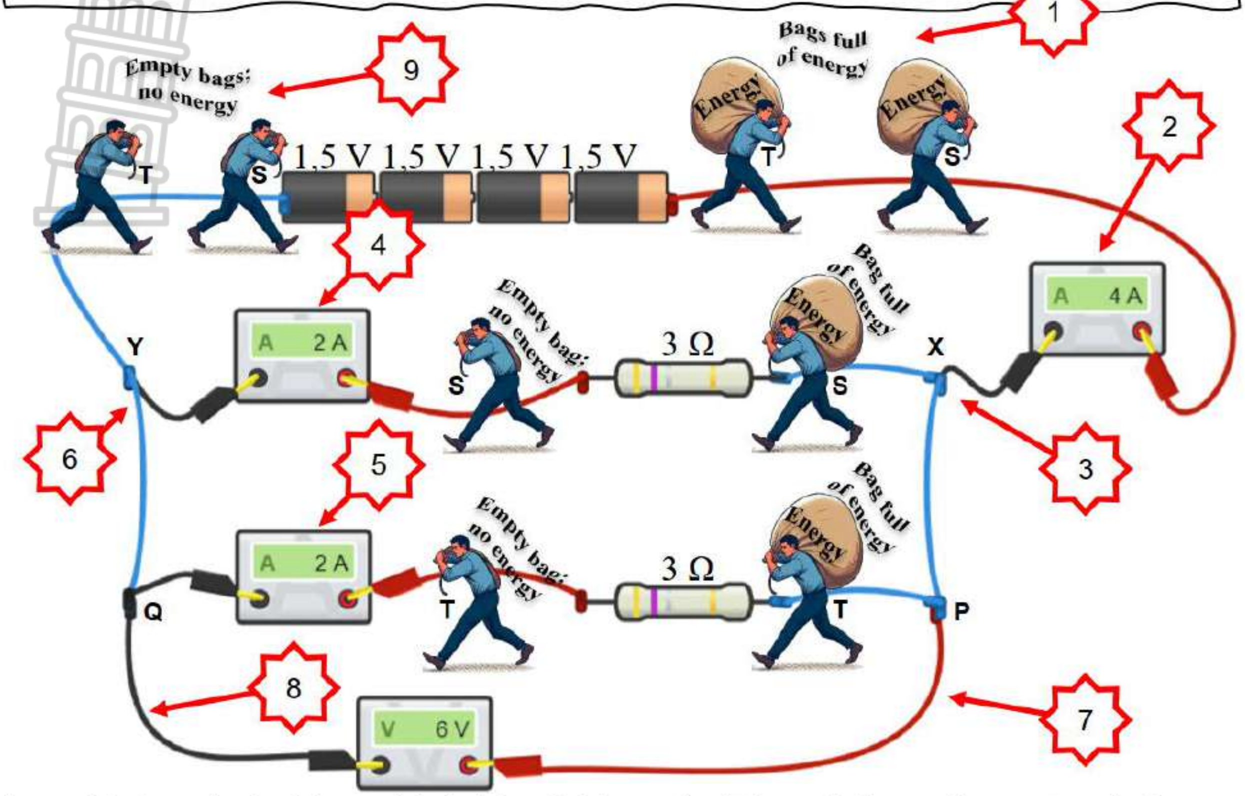
10 The coulomb of charge returns to the battery where the bag is again filled with energy and the process is then repeated for this coulomb of charge until the battery is flat.

Note once again that:

- Each voltmeter measures the **potential difference at TWO points**.
- The voltmeter reading represents the energy per coulomb of charge transferred to the resistor that is **connected between its wires**. This is important. **The reading on any voltmeter is only applicable to the resistor(s) connected between its wires while charges are flowing**.
- All three **voltmeters** are connected in **parallel** with the resistors.
- **There is no change in the charges** itself. It is **only the energy that is transferred** to the resistor.
- The charges flow **through** the ammeter and the latter measures the current **at the point where it is connected**.

Example 3: Two resistors are connected in parallel with the battery

In this example, we look at **two coulomb of charge**, **each one** represented by the **picture of the man**. **Only TWO are represented here, but there are millions of charges behind and in front of those doing the same thing**.



1 **Each coulomb** of charge, labelled **S** and **T**, leaves the battery with the **maximum amount of energy**. In each case it is 6 $J\cdot C^{-1}$ because the emf of the battery is 6 V.

2 Both coulombs of charge flow **through** this ammeter because it is the **only path** for them to follow. This is what is called the **main current** of the circuit. If, for example, four coulomb of charge flows through this ammeter in one second, the **main current** is: $I = \frac{Q}{\Delta t} = \frac{4}{1} = 4\ C\cdot s^{-1} = 4\ A$.

3 At point **X**, the main current splits into **two branch currents**. One branch is represented by **XY** and the other branch by **XPQY**. Some of the coulombs of charge (labelled **S**) flow through branch **XY** and the others (labelled T) flow through branch **XPQY**. **The ratio in which the main current splits into two branch currents depend on the ratio of the resistors in the branches. In this example** the **resistances** are **equal**; hence the main current splits into **two equal branch currents**.

4 This ammeter measures the current in branch **XY** only. Hence, it measures 2 A if the main current is 4 A with equal branch resistances.

5 This ammeter measures 2 A, which is the current in branch **XPQY**.

2,4&5 **Very important: The sum of the two branch currents is equal to the main current**.

6 At point **Y**, the two branch currents combine again to form the main current.

Note that the voltmeter is connected across both resistors because they are connected in parallel.

7 The wire of the voltmeter is connected at **P**, but the reading on the voltmeter is also valid for **X** because there is just another wire between **P** and **X**. The coulomb of charge labelled **S** arrives at the resistor in branch **XY** with 6 J of energy. Hence, the voltmeter measures 6 $J\cdot C^{-1}$ at **X before** the energy is transferred to the resistor.

8 The voltmeter measures 0 $J\cdot C^{-1}$ at **Y after** the energy was transferred to the single resistor in branch **XY**.

7 The coulomb of charge labelled **T** arrives at the resistor in branch **XPQY** with 6 J of energy. Hence, the voltmeter also measures 6 $J\cdot C^{-1}$ at **P before** the energy is transferred to the resistor.

8 For branch **XPQY**, the voltmeter measures 0 $J\cdot C^{-1}$ at **Q after** the energy was transferred to the single resistor in branch **XPQY**.

The reading on the voltmeter = reading at **P** (or **X**) - reading at **Q** (or **Y**)

= 6 $J\cdot C^{-1}$ - 0 $J\cdot C^{-1}$ = 6 $J\cdot C^{-1}$ = 6 V

Very important: The reading on the voltmeter is the same for both resistors.

9 The two coulombs of charge return to the battery where new energy is obtained from the battery and the process is then repeated until the battery is flat.

Let's confirm the readings on the ammeters and voltmeters in the three examples and make some important conclusions about the use of formulae.

Example 1

Known data is: emf = 6 V; external resistor = 3 Ω; internal resistance = 0 Ω

To calculate the reading on the ammeter, which is the total (main) current in the circuit:

$$R_{total} = \frac{V_{emf}}{I_{total}}$$
$$3 = \frac{6}{I_{total}}$$
$$I_{total} = 2\ A$$

The three variables deal with the **same situation**. The **total** resistance, the **total** current and the **emf**, which is the "maximum" potential difference.

To calculate the reading on the voltmeter, which is the potential difference across the specific resistor:

$$R = \frac{V}{I_{total}}$$
$$3 = \frac{V}{2}$$
$$V = 6\ V$$

Once again, the three variables deal with the **same situation**. The **specific** resistance, the current in **that** resistor and the potential difference across the **specific** resistor.

Example 2

Known data is: emf = 6 V; each external resistor = 3 Ω and they are connected in series; internal resistance = 0 Ω

To calculate the reading on the ammeter, which is the total (main) current in the circuit:

$$R_T = R_1 + R_2$$
$$= 3 + 3$$
$$= 6\ \Omega$$

$$R_T = \frac{V_{emf}}{I_{total}}$$
$$6 = \frac{6}{I_{total}}$$
$$I_{total} = 1\ A$$

The three variables in $R = \frac{V}{I}$ deal with the **same situation**. The **total** resistance, the **total** current and the **emf**.

To calculate the reading on voltmeter 1, which is the potential difference across **one** of the resistors:

$$R = \frac{V_1}{I_{total}}$$
$$3 = \frac{V_1}{1}$$
$$V_1 = 3\ V$$

The three variables deal with the **same situation**. The **specific** resistance, the current in **that** resistor and the potential difference across the **specific** resistor.

To calculate the reading on voltmeter 2, which is the potential difference across **one** of the resistors:

$$R = \frac{V_2}{I_{total}}$$
$$3 = \frac{V_2}{1}$$
$$V_2 = 3\ V$$

The three variables deal with the **same situation**. The **specific** resistance, the current in **that** resistor and the potential difference across the **specific** resistor.

To calculate the reading on voltmeter 3, which is the potential difference across **both** resistors:

$$R_T = \frac{V_3}{I_{total}}$$
$$6 = \frac{V_3}{1}$$
$$V_3 = 6\ V$$

The three variables deal with the **same situation**. The **total** resistance is used, the current in **both** resistors and the potential difference across **both** resistors.

Example 3

Known data is: emf = 6 V; each external resistor = 3 Ω and they are connected in parallel; internal resistance = 0 Ω

To calculate the reading on the ammeter that measures the **main** current in the circuit:

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$= \frac{1}{3} + \frac{1}{3}$$
$$R_P = 1{,}5\ \Omega$$

$$R_P = \frac{V_{emf}}{I_{total}}$$
$$1{,}5 = \frac{6}{I_{total}}$$
$$I_{total} = 4\ A$$

The three variables in $R = \frac{V}{I}$ deal with the **same situation**. The **effective** resistance, the **total** current and the **emf**.

To calculate the reading on the voltmeter, which is the potential difference across each resistor: (*)

$$R_P = \frac{V}{I_{total}}$$
$$1{,}5 = \frac{V}{4}$$
$$V = 6\ V$$

The three variables deal with the **same situation**. The **effective** resistance, the **total** current in both resistors and the potential difference across **one or both** resistors.

To calculate the reading on the ammeter in branch **XY**, which is **one** of the branch currents:

$$R = \frac{V}{I_{XY}}$$
$$3 = \frac{6}{I_{XY}}$$
$$I_{XY} = 2\ A$$

The three variables deal with the **same situation**. The **specific** resistance, the current in **that** resistor and the potential difference across the **specific** resistor.

To calculate the reading on the ammeter in branch **XPQY**, which is the **other** branch current:

$$R = \frac{V}{I_{XPQY}}$$
$$3 = \frac{6}{I_{XPQY}}$$
$$I_{XPQY} = 2\ A$$

The three variables deal with the **same situation**. The **specific** resistance, the current in **that** resistor and the potential difference across the **specific** resistor.

(*) In this solution, the voltmeter reading was calculated by using the main current, followed by the calculation of the two branch currents by using the voltmeter reading. If a branch current is available, it can also be used to calculate the voltmeter reading.

The most important conclusion to make from these examples is that you must always ensure that **variables** in an equation **address the same situation!**

That is true for any equation!

A few notes about internal resistance

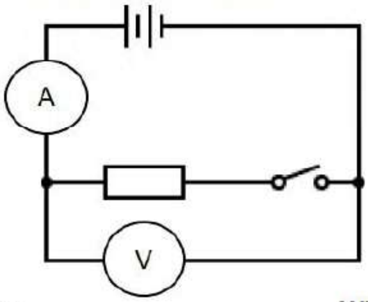
Questions usually indicate whether the cell or battery has internal resistance and therefore it is important to know how to deal with internal resistance if it must be taken into consideration.

The following are important aspects of internal resistance:

- Cells consists of chemicals and other materials and in real life it resists the flow of charge (the current) like an ordinary resistor. This resistance of a cell (or battery) is called "internal resistance".
- **Cells are connected in series with the external resistors**. Hence, the internal resistance must be seen as **connected in series** with the external resistors, irrespective if the external resistors are connected in series or parallel.

Voltmeter readings with or without internal resistance

Consider the following circuit and study the summary below to see how a voltmeter reading differs when internal resistance is present or not.



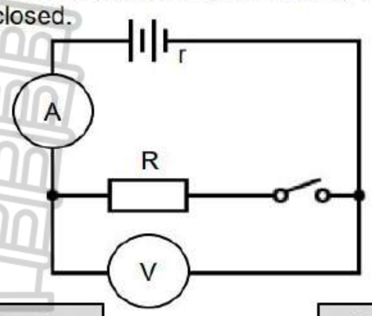
No internal resistance

Switch open	Switch closed
Ammeter reading is zero.	Ammeter measures the current. In this case the main current.
Voltmeter measures the emf.	The voltmeter measures the potential difference across the resistor, and it is **the SAME as** the emf.

With internal resistance

Switch open	Switch closed
Ammeter reading is zero.	Ammeter measures the current. In this case the main current.
Voltmeter measures the emf.	The voltmeter measures the potential difference across the resistor, and it is **LESS THAN** the emf.

A mind experiment may further clarify the situation of internal resistance. Consider the circuit below. The battery has an internal resistance represented by *r*. Ammeter and voltmeter readings are taken; first with the switch open and then closed.



	Switch open	Switch closed
Ammeter reading (A)	0	0,3
Voltmeter reading (V)	3	2,7

Switch open

- Voltmeter measures emf.
- Reading can be **SEEN** on the voltmeter.
- Reading is 3 V.
- 3 V = 3 J·C^{-1} Each coulomb of charge receives 3 J of energy from the battery.

Switch closed

- Voltmeter measures potential difference across external resistor.
- Reading can be **SEEN** on the voltmeter.
- Reading is 2,7 V.
- 2,7 V = 2,7 J·C^{-1} Each coulomb of charge transfers 2,7 J of energy to the external resistor.

What happened to the 0,3 J·C^{-1}, which is the **DIFFERENCE** between 3 J·C^{-1} and 2,7 J·C^{-1}?

This 0,3 J·C^{-1} is the amount of energy used by the battery due to its internal resistance.

This number **CANNOT BE SEEN** on any voltmeter. It must be **CALCULATED**.

This number has a few names:

- Potential difference across the battery or cell;
- Potential drop across the battery or cell; or
- Lost volts (a term one tends to avoid).

Look at the following applications of the formula $R = \frac{V}{I}$ to see how it should be used correctly.

To calculate the external resistance *R*:

$$R = \frac{V}{I_{total}}$$
$$R = \frac{2,7}{0,3}$$
$$= 9\ \Omega$$

The three variables deal with the **same situation**. The **external** resistor, the current in **that** resistor and the potential difference across **that** resistor.

To calculate the total resistance R_T:

$$R_T = \frac{V_{emf}}{I_{total}}$$
$$= \frac{3}{0,3}$$
$$= 10\ \Omega$$

The three variables deal with the **same situation**. The **total** resistance (*R*+*r*), the current in **those** resistors and the **emf**.

To calculate the internal resistance *r*: (**)

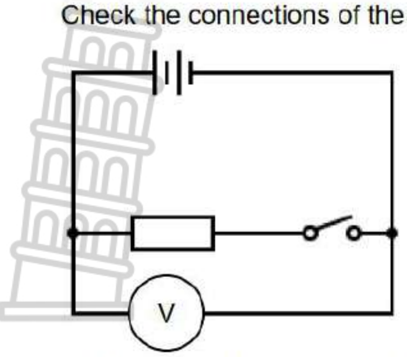
$$r = \frac{V_{cell}}{I_{total}}$$
$$= \frac{3 - 2,7}{0,3}$$
$$= 1\ \Omega$$

The three variables deal with the **same situation**. The **internal** resistance, the current **in the battery** and the potential drop across **the battery**.

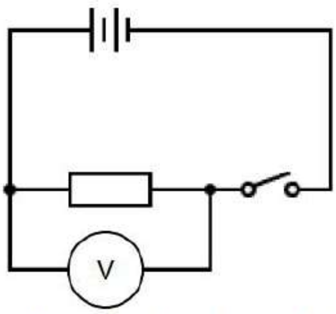
(**) The internal resistance is also the total resistance minus the external resistance, because $R_T = R + r$.

General useful hints about electric circuits

1. Check the connections of the voltmeters when emf is considered.



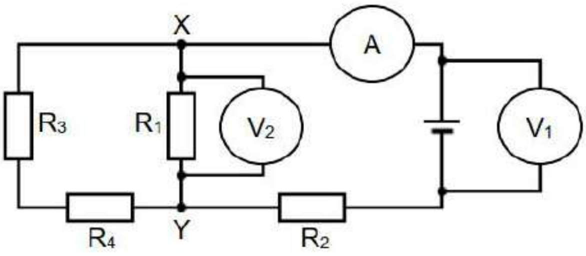
This voltmeter measures the emf. The switch is open and both wires are in contact with the battery.



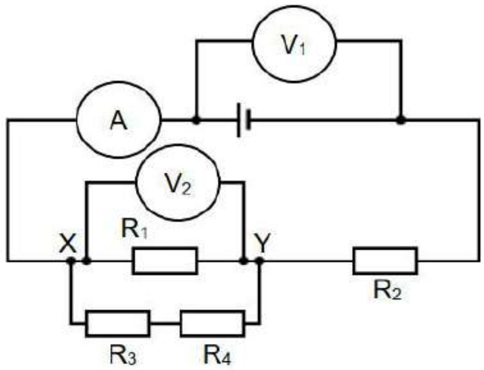
This voltmeter **does not** measure the emf although the switch is open. One of the wires is not in contact with the battery.

2. From examples 1 to 3 above you must remember that a voltmeter measures potential difference acros the resistor(s) between its wires when there is a current in that resistor / those resistors.

3. Simplify a circuit diagram if it is complicated.



Circuit 1



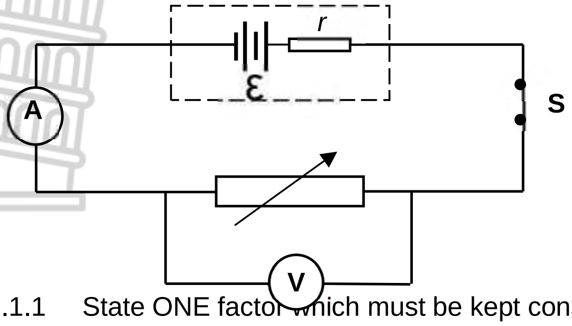
Circuit 2

Circuit 1 can be simplified to look like circuit 2 where all the resistors are put on one side of the circuit diagram. One way of doing it is as follows:

- Do the voltmeters after the battery, wires, resistors, ammeters and switches have been connected
- Follow the direction of the conventional current from the positive terminal of the cell.
- The ammeter is reached first, and it measures the main current.
- The main current splits into two branch currents at **X** and combine again at **Y**.
- In one of the branches resistors $\mathbf{R_3}$ and $\mathbf{R_4}$ are connected in series.
- Resistor $\mathbf{R_1}$ is in the other branch, and $\mathbf{R_1}$ is connected in parallel with $\mathbf{R_3}$ and $\mathbf{R_4}$.
- From **Y** back to the negative terminal of the cell one has the main current again.
- Resistor $\mathbf{R_2}$ is between **Y** and the cell. In circuit 2 it is easy to see that $\mathbf{R_2}$ is connected in series wi the parallel combination of resistors.
- Finally, consider the position of the voltmeters:
  - One of the wires of $\mathbf{V_1}$ is connected between the positive terminal of the cell and the ammeter The other wire is connected between the negative terminal and $\mathbf{R_2}$. Looking at circuit 2 it is ea to see that $\mathbf{V_1}$ is actually connected across all four resistors. When no current exists, it measu the emf, and with current in the circuit, it measures the potential difference across all four external resistors (terminal potential difference).
  - One of the wires of $\mathbf{V_2}$ is connected between **X** and $\mathbf{R_1}$. The other wire is connected between I and **Y**. Looking at circuit 2 it is easy to see that $\mathbf{V_2}$ is connected across the parallel set of resistors. It therefore measures the potential difference across $\mathbf{R_1}$, but also the potential difference across $\mathbf{R_3}$ and $\mathbf{R_4}$. It has nothing to do with $\mathbf{R_2}$.

QUESTION 1

1.1 A group of learners conduct an experiment to determine the emf (ε) and internal resistance (*r*) of a battery. They connect a battery to a rheostat (variable resistor), a low-resistance ammeter and a high-resistance voltmeter as shown in the diagram below. The data obtained from the experiment is displayed in the table below.



READING ON VOLTMETER (V)	READING ON AMMETER (A)
2	0,58
3	0,46
4	0,36
5	0,24
6	0,14

1.1.1 State ONE factor which must be kept constant during the experiment. (1)

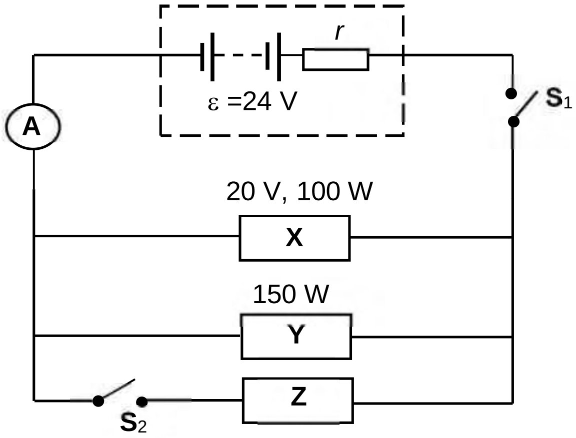
1.1.2 Using the information in the table above, plot the points and draw the line of best fit on a graph paper. (3)

Use the graph drawn in QUESTION 1.1.2 to determine the following:

1.1.3 Emf (ε) of the battery (1)

1.1.4 Internal resistance of the battery, WITHOUT USING ANY FORM OF THE EQUATION $\varepsilon = I(R + r)$ (3)

1.2 Three electrical devices, **X**, **Y** and **Z**, are connected to a 24 V battery with internal resistance *r* as shown in the circuit diagram. The power rating of each of the devices **X** and **Y** are indicated in the diagram.



With switch **S_1** closed and **S_2** open, the devices function as rated. Calculate the:

1.2.1 Current in **X** (3)

1.2.2 Resistance of **Y** (3)

1.2.3 Internal resistance of the battery (5)

Now switch **S_2** is also closed.

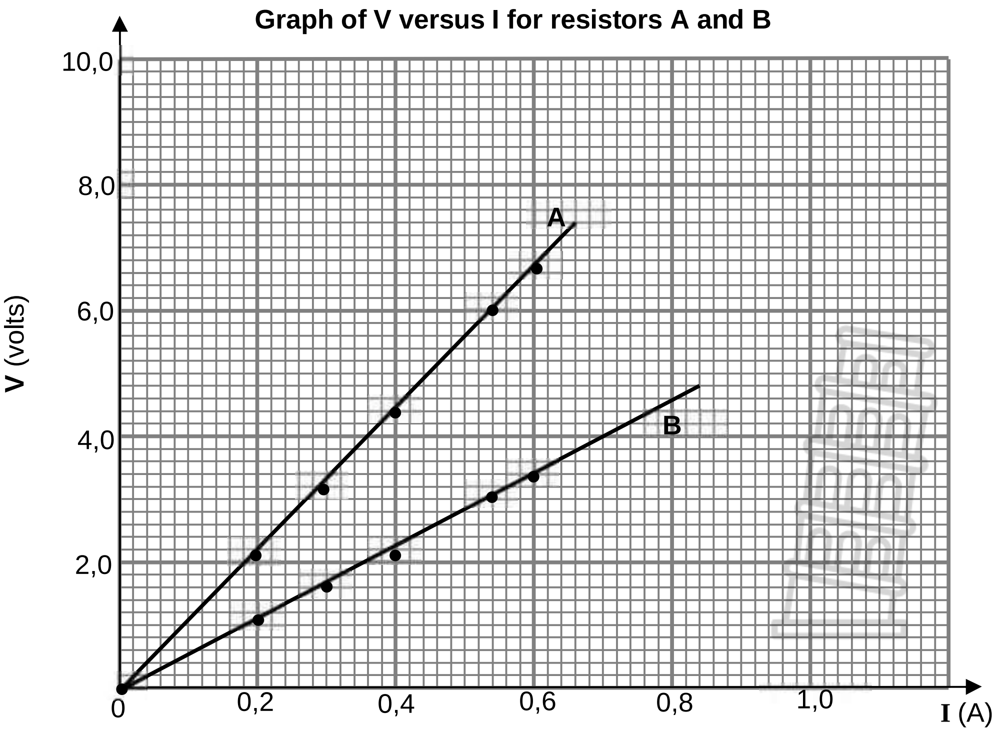
1.2.4 Identify device **Z** which, when placed in the position shown, can still enable **X** and **Y** to operate as rated. Assume that the resistances of all the devices remain unchanged. (1)

1.2.5 Explain how you arrived at the answer to QUESTION 1.2.4. (2)

[22]

QUESTION 2

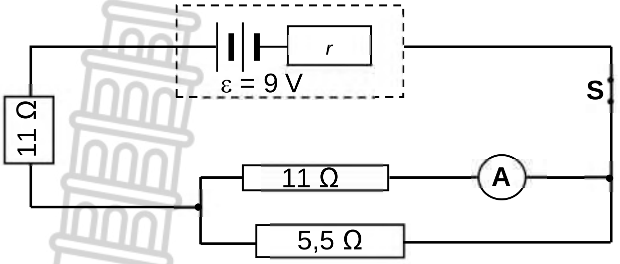
2.1 Learners want to construct an electric heater using one of two wires, **A** and **B**, of different resistances. They conduct experiments and draw the graphs as shown.



2.1.1 Apart from temperature, write down TWO other factors that the learners should consider to ensure a fair test when choosing which wire to use. (2)

2.1.2 Assuming all other factors are kept constant, state which ONE of the two wires will be the most suitable to use in the heater. Use suitable calculations to show clearly how you arrive at the answer. (8)

2.2 In the circuit below the reading on ammeter **A** is 0,2 A. The battery has an emf of 9 V and internal resistance *r*.



2.2.1 Calculate the current through the 5,5 Ω resistor. (3)

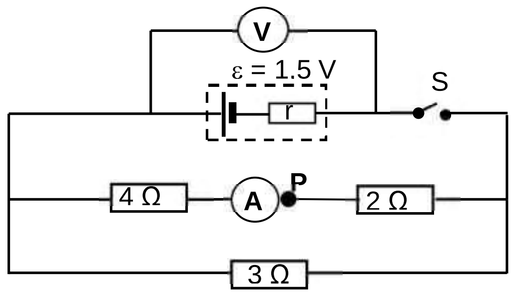
2.2.2 Calculate the internal resistance of the battery. (7)

2.2.3 Will the ammeter reading INCREASE, DECREASE or REMAIN THE SAME if the 5,5 Ω resistor is removed? Give a reason for the answer. (2)

[22]

QUESTION 3

A cell of unknown internal resistance, *r*, has emf (ε) of 1,5 V. It is connected in a circuit to three resistors, a high-resistance voltmeter, a low-resistance ammeter and a switch **S** as shown. When switch **S** is closed, the voltmeter reads 1,36 V.



3.1 Which terminal of the ammeter is represented by point **P**? Write down POSITIVE or NEGATIVE. (1)

3.2 Calculate the ammeter reading. (3)

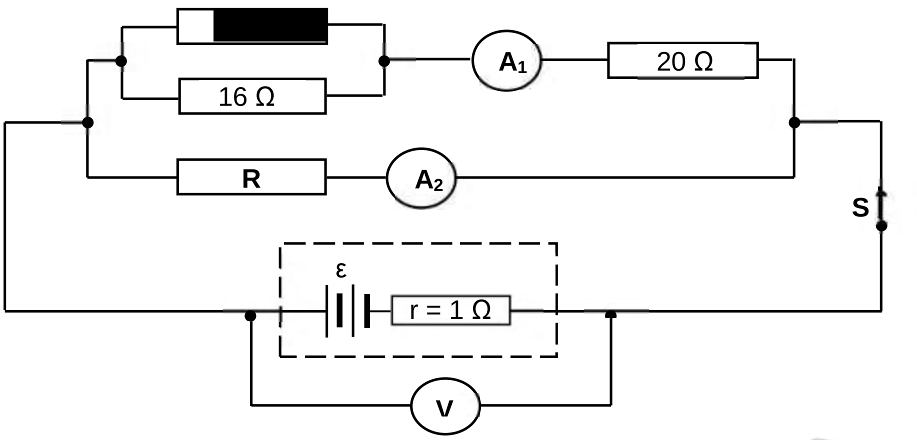
3.3 Determine the internal resistance of the cell. (7)

3.4 An additional resistor **X** is connected parallel to the 3 Ω resistor in the circuit. Will the reading on the ammeter INCREASE, DECREASE or REMAIN UNCHANGED? Give a reason for the answer. (4)

[15]

QUESTION 4

A battery with an internal resistance of 1 Ω and an unknown emf (ε) is connected in a circuit, as shown below. A high-resistance voltmeter (V) is connected across the battery. **A₁** and **A₂** represent ammeters of negligible resistance.



With switch **S** closed, the current passing through the 8 Ω resistor is 0,5 A.

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

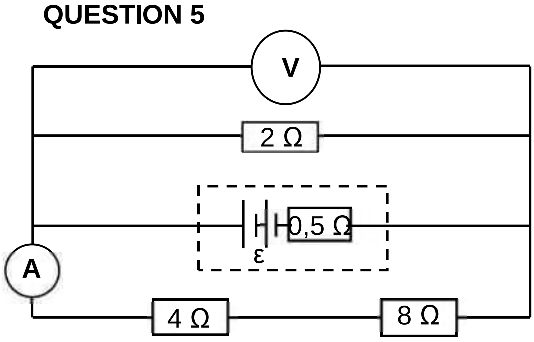
4.2 Calculate the reading on ammeter $\mathbf{A_1}$. (4)

4.3 If device **R** delivers power of 12 W, calculate the reading on ammeter A_2. (5)

4.4 Calculate the reading on the voltmeter when switch **S** is open. (3)

[14]

QUESTION 5



A battery of an unknown emf and an internal resistance of 0,5 Ω is connected to three resistors, a high-resistance voltmeter and an ammeter of negligible resistance, as shown. The reading on the ammeter is 0,2 A.

5.1 Calculate the:

5.1.1 Reading on the voltmeter (3)

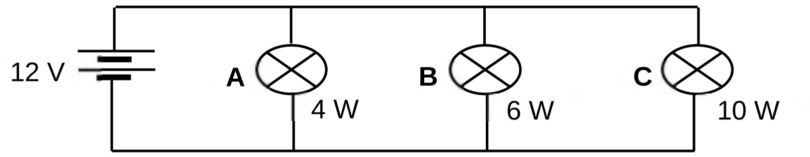
5.1.2 Total current supplied by the battery (4)

5.1.3 Emf of the battery (5)

5.2 How would the voltmeter reading change if the 2 Ω resistor is removed? Write down INCREASE, DECREASE or REMAIN THE SAME. Explain the answer. (3)
[15]

QUESTION 6

6.1 In the diagram below, three light bulbs, **A**, **B** and **C**, are connected in parallel to a 12 V source of negligible internal resistance. The bulbs are rated at 4 W, 6 W and 10 W respectively and are all at their maximum brightness.



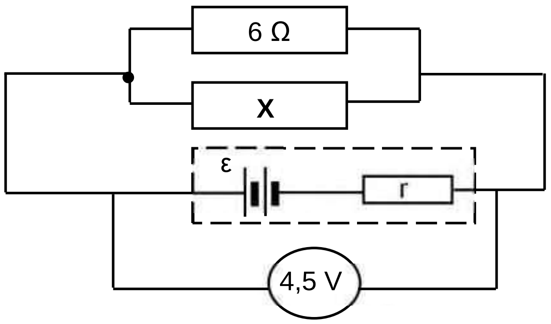
6.1.1 Calculate the resistance of the 4 W bulb. (3)

6.1.2 How will the equivalent resistance of the circuit change if the 6 W bulb burns out? Write down only INCREASES, DECREASES or NO CHANGE. (1)

6.1.3 How will the power dissipated by the 10 W bulb change if the 6 W bulb burns out? Write down only INCREASES, DECREASES or NO CHANGE. Give a reason for the answer. (2)

6.2 A learner connects a high-resistance voltmeter across a battery. The voltmeter reads 6 V. She then connects a 6 Ω resistor across the battery. The voltmeter now reads 5 V.

6.2.1 Calculate the internal resistance of the battery. (4)



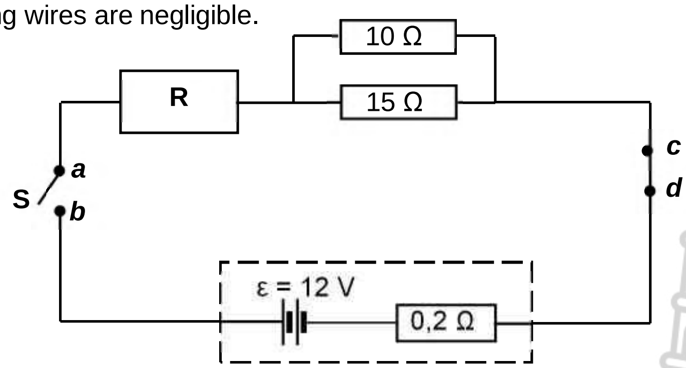
The learner now builds the circuit alongside, using the same 6 V battery and the 6 Ω resistor. She connects an unknown resistor **X** in parallel with the 6 Ω resistor. The voltmeter now reads 4,5 V.

6.2.2 Define the term *emf of a cell*. (2)

6.2.3 Calculate the resistance of **X** when the voltmeter reads 4,5 V. (5)
[17]

QUESTION 7

7.1 In the circuit below the battery has an emf (ε) of 12 V and an internal resistance of 0,2 Ω. The resistances of the connecting wires are negligible.



7.1.1 Define the term *emf of a battery*. (2)

7.1.2 Switch **S** is open. A high-resistance voltmeter is connected across points **a** and **b**. What will the reading on the voltmeter be? (1)

7.1.3 Switch **S** is now closed. The same voltmeter is now connected across points **c** and **d**. What will the reading on the voltmeter be? (1)

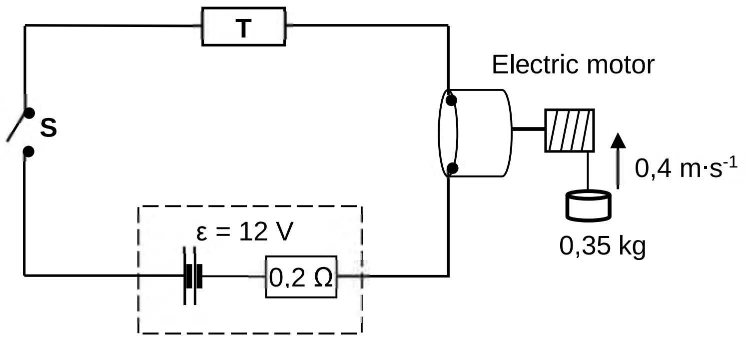
When switch **S** is closed, the potential difference across the terminals of the battery is 11,7 V. Calculate the:

7.1.4 Current in the battery (3)

7.1.5 Effective resistance of the parallel branch (2)

7.1.6 Resistance of resistor **R** (4)

7.2 A battery with an emf of 12 V and an internal resistance of 0,2 Ω are connected in series to a very small electric motor and a resistor, **T**, of unknown resistance, as shown in the circuit below. The motor is rated **X** watts, 3 volts, and operates at optimal conditions. When switch **S** is closed, the motor lifts a 0,35 kg mass vertically upwards at a constant speed of 0,4 m·s^{-1}. Assume that there is no energy conversion into heat and sound.



7.2.1 Calculate the value of **X**. (3)

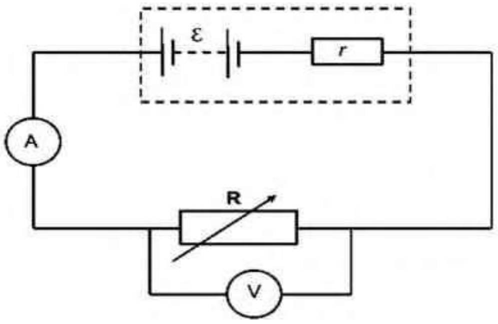
7.2.2 Calculate the resistance of resistor **T**. (5)

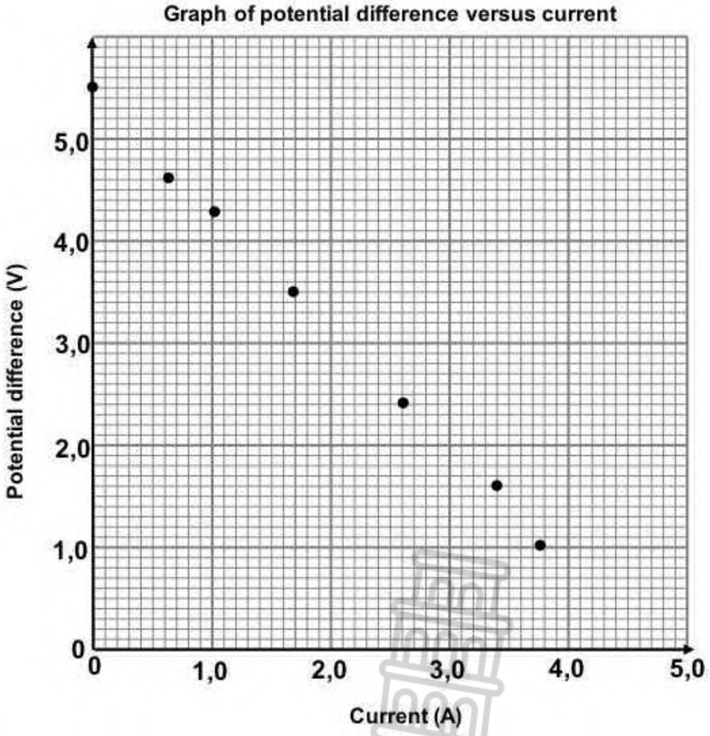
[21]

QUESTION 8

8.1 The emf and internal resistance of a certain battery were determined experimentally. The circuit used for the experiment is shown in the diagram below.

8.1.1 State Ohm's law in words. (2)





The data obtained from the experiment is plotted on the graph sheet alongside.

8.1.2 Draw the line of best fit through the plotted points. Ensure that the line cuts both axes. (2)

Use information in the graph to answer QUESTIONS 8.1.3 and 8.1.4.

8.1.3 Write down the value of the emf (ε) of the battery. (1)

8.1.4 Determine the internal resistance of the battery. (3)

8.2 The circuit diagram shows a battery with an emf (ε) of 60 V and an unknown internal resistance r, connected to three resistors. A voltmeter connected across the 8 Ω resistor reads 21,84 V.

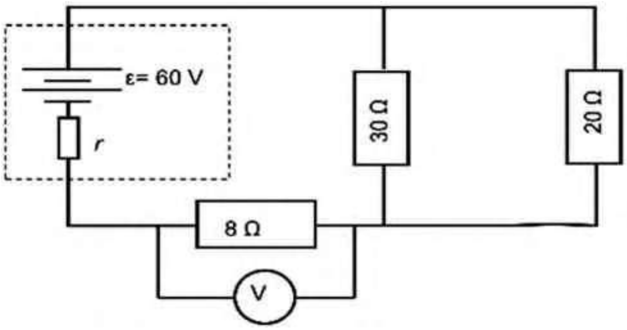
Calculate the:

8.2.1 Current in the 8 Ω resistor (3)

8.2.2 Equivalent resistance of the resistors in parallel (2)

8.2.3 Internal resistance r of the battery .... (4)

8.2.4 Heat dissipated in the external circuit in 0,2 seconds (3)

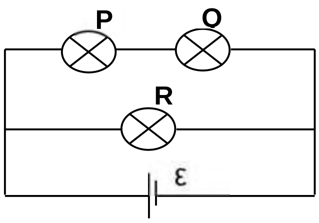


[20]

QUESTION 9

9.1 In **Circuit 1**, three identical light bulbs, **P**, **Q** and **R**, with the same resistance, are connected to a battery with emf ε and negligible internal resistance.

Circuit 1

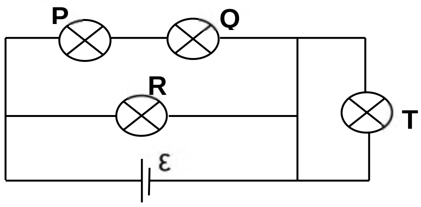


9.1.1 How does the brightness of bulb **P** compare with that of bulb **Q**? Give a reason. (2)

9.1.2 How does the brightness of bulb **P** compare with that of bulb **R**? Give a reason. (2)

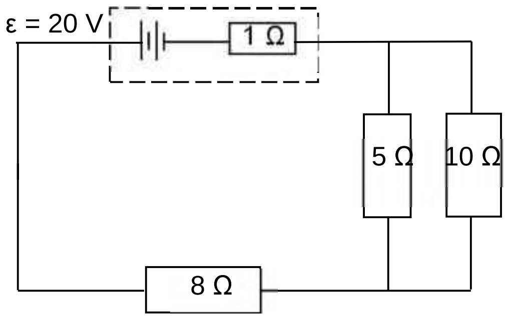
A fourth, identical bulb **T**, with the same resistance as the other three, is connected to the circuit by means of an ordinary wire of negligible resistance, as shown in **Circuit 2**.

Circuit 2



9.1.3 How does the brightness of bulb **T** compare with that of bulb **R**? Give a reason for the answer. (2)

9.2 A battery with an emf of 20 V and an internal resistance of 1 Ω is connected to three resistors, as shown in the circuit alongside.



Calculate the:

9.2.1 Current in the 8 Ω resistor (6)

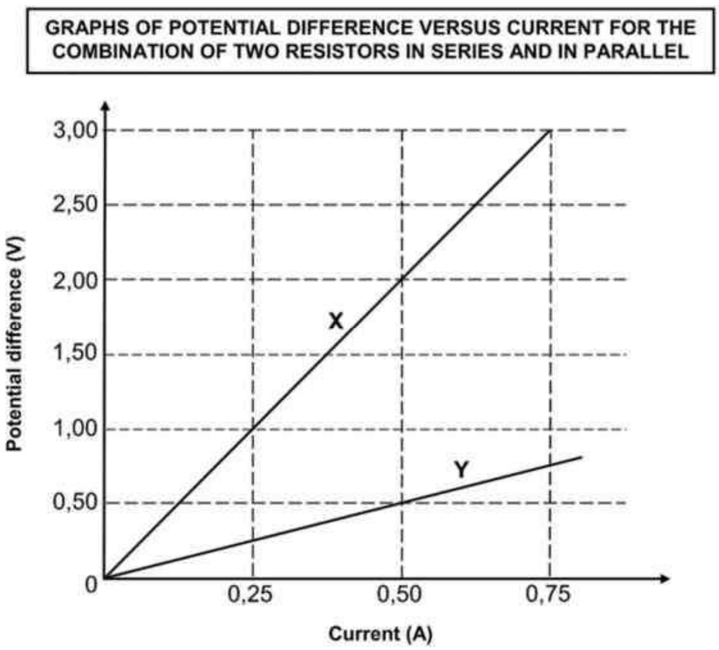
9.2.2 Potential difference across the 5 Ω resistor (4)

9.2.3 Total power supplied by the battery (3)

[19]

QUESTION 10

10.1 Learners investigated the relationship between potential difference (V) and current (I) for the combination of two resistors, R_1 and R_2.



In one experiment, resistors R_1 and R_2 were connected in parallel.

In a second experiment, resistors R_1 and R_2 were connected in series.

The learners then plotted graph **X**, the results of one of the experiments, and graph **Y**, the results of the other experiment, as shown.

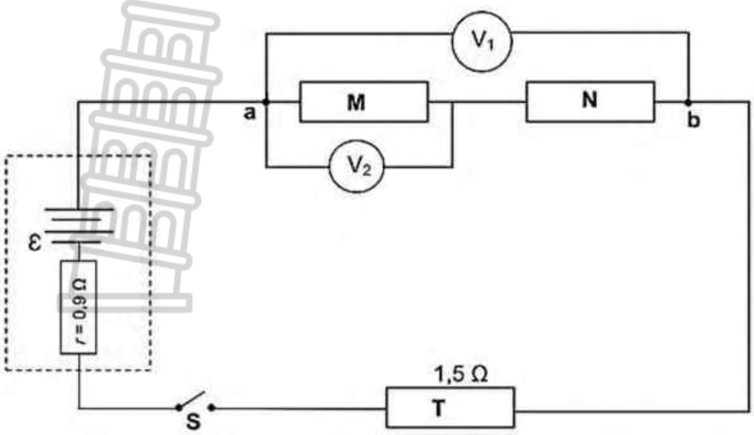
10.1.1 State Ohm's law in words. (2)

10.1.2 What physical quantity does the gradient (slope) of the V-I graph represent? (1)

10.1.3 Calculate the gradient (slope) of graph **X**. (2)

10.1.4 Determine the resistance of resistor **R_1**. (4)

10.2 The circuit below consists of three resistors, **M**, **N** and **T**, a battery with emf Ɛ and an internal resistance of 0,9 Ω. The effective resistance between points **a** and **b** in the circuit is 6 Ω. The resistance of resistor **T** is 1,5 Ω. When switch **S** is closed, a high-resistance voltmeter, V_1, across **a** and **b** reads 5 V.



Calculate the

10.2.1 Current delivered by the battery (3)

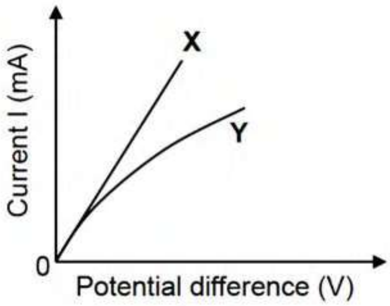
10.2.2 Emf (Ɛ) of the battery (4)

V_2 reads 2,5 V when the switch is closed.

10.2.3 Write down the resistance of **N**. (No calculations required.) Give a reason for the answer. (2)

[18]

QUESTION 11

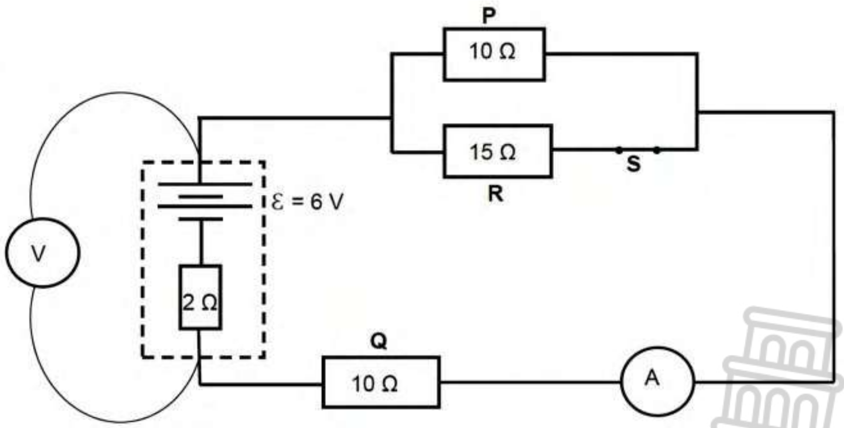


11.1 The two graphs alongside show the relationship between current and potential difference for two different conductors, **X** and **Y**.

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

11.1.2 Which ONE of the two conductors, **X** or **Y**, is ohmic? Refer to the graph and give a reason for the answer. (2)

11.2 In the diagram below, a battery with an emf of 6 V and an internal resistance of 2 Ω, is connected to three resistors **P**, **Q** and **R**. A voltmeter **V** is connected across the battery. The ammeter **A** has a negligible resistance.



11.2.1 Calculate the ammeter reading when switch **S** is closed. (5)

The switch **S** is now open.

11.2.2 Will the ammeter reading in QUESTION 11.2.1 INCREASE, DECREASE or REMAIN THE SAME? Give a reason for the answer. (2)

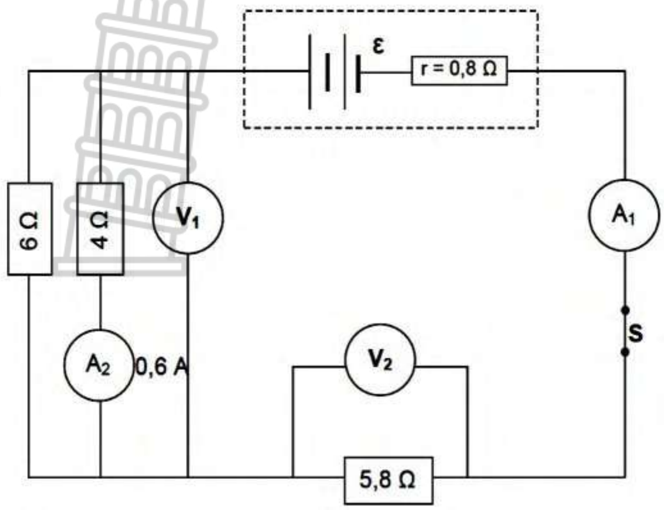
11.2.3 How will the voltmeter reading now compare with the voltmeter reading when the switch is closed? Choose from INCREASE, DECREASE or REMAIN THE SAME. (1)

11.2.4 Explain the answer to QUESTION 11.2.3. (3)

[15]

QUESTION 12

12.1 In the circuit diagram below the battery has an unknown emf (ε) and an internal resistance (r) of 0,8 Ω.

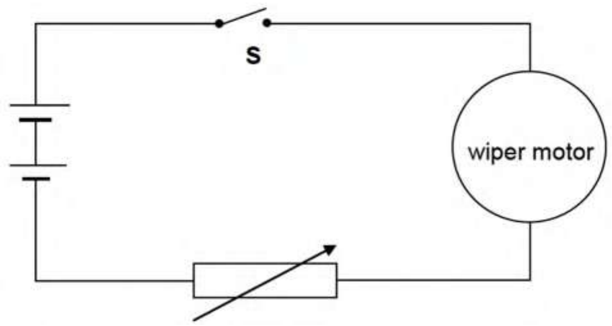


12.1.1 State *Ohm's law* in words. (2)

The reading on ammeter **A_2** is 0,6 A when switch **S** is closed. Calculate the:

12.1.2 Reading on voltmeter **V_1** (3)
12.1.3 Current through the 6 Ω resistor (2)
12.1.4 Reading on voltmeter **V_2** (2)
12.1.5 Emf (ε) of the battery (3)
12.1.6 Energy dissipated as heat inside the battery if the current flows in the circuit for 15 s (3)

12.2 A simplified circuit diagram for the windscreen wiper of a car consists of a variable resistor and a wiper motor connected to a 12 volt battery. When switch **S** is closed, the potential difference across the variable resistor is 2,8 V and the current passing through it is 0,7 A.



12.2.1 Calculate the resistance of the variable resistor. (2)

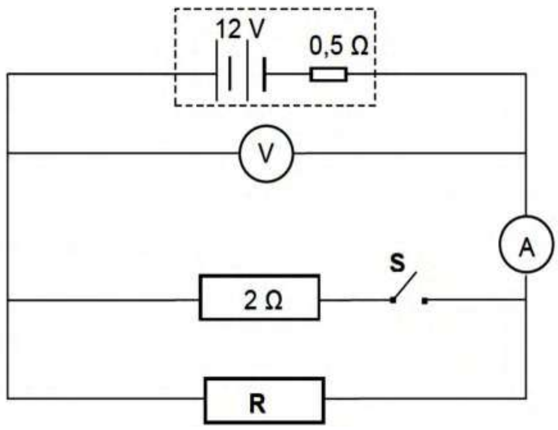
The resistance of the variable resistor is now decreased.

12.2.2 State whether the speed at which the wiper turns will INCREASE, DECREASE or REMAIN THE SAME. Give a reason for the answer. (3)

[20]

QUESTION 13

The battery in the circuit diagram below has an emf of 12 V and an internal resistance of 0,5 Ω. Resistor **R** has an unknown resistance.



13.1 What is the meaning of the following statement?
The emf of the battery is 12 V. (2)

The reading on the ammeter is 2 A when switch **S** is OPEN.
Calculate the:

13.2 Reading on the voltmeter (3)
13.3 Resistance of resistor **R** (2)

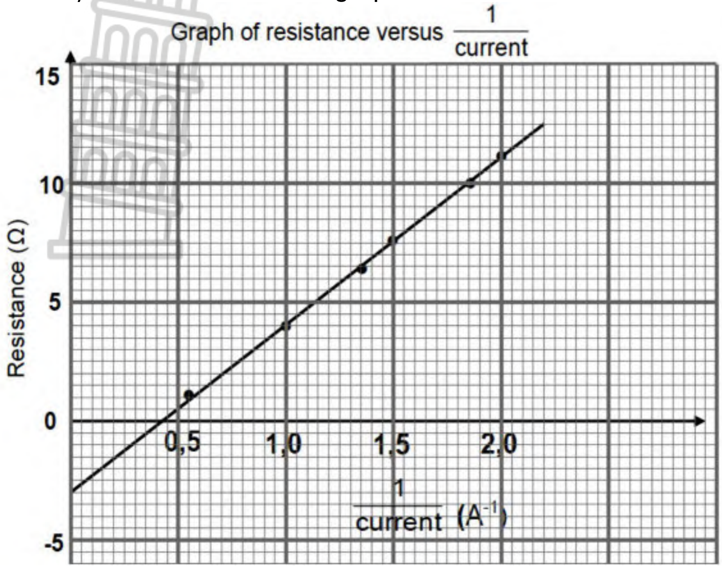
Switch **S** is now CLOSED.

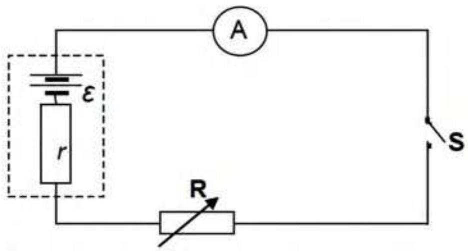
13.4 How does this change affect the reading on the voltmeter? Choose from: INCREASES, DECREASES or REMAINS THE SAME. Explain the answer. (4)

[11]

QUESTION 14

Learners perform an experiment to determine the emf (ε) and the internal resistance (*r*) of a battery using the circuit below. The learners use their recorded readings of current and resistance, together with the equation R = "ε" /"I" – r, to obtain the graph below.





14.1 Which variable has to be kept constant in the experiment? (1)

Refer to the graph.

14.2 Write down the value of the internal resistance of the cell. (2)

14.3 Calculate the emf of the battery. (3)

[6]

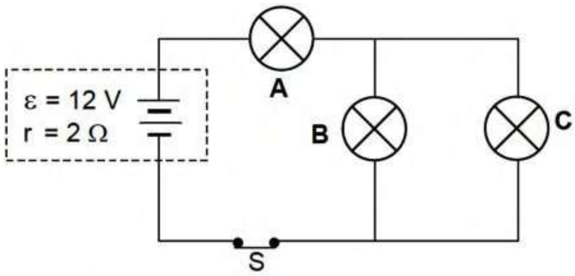
QUESTION 15

15.1 Three identical light bulbs, **A**, **B** and **C**, are each rated at 6 W, 12 V.

15.1.1 Define the term *power*. (2)

15.1.2 Calculate the resistance of EACH bulb when used as rated. (3)

The light bulbs are connected in a circuit with a battery having an emf (ε) of 12 V and internal resistance (*r*) of 2 Ω. Refer to the diagram.
Assume that the resistance of each light bulb is the same as that calculated in QUESTION 15.1.2.
Switch **S** is closed.

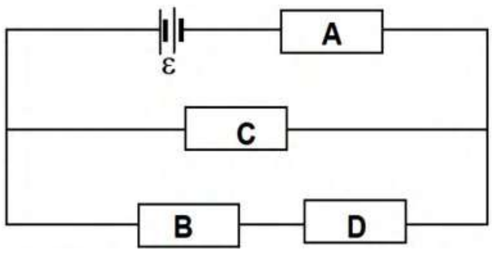


15.1.3 Calculate the total current in the circuit. (5)

15.1.4 Calculate the potential difference across light bulb **C**. (3)

15.1.5 Explain why light bulb **C** in the circuit will NOT burn at its maximum brightness. (3)

15.2 Resistors **A**, **B**, **C** and **D** are connected to a battery having emf (ε) and negligible internal resistance, as shown in the diagram below.



15.2.1 Give a reason why the current in resistor **A** is greater than that in resistor **C**. (2)

15.2.2 Resistor **C** is removed. How will the current in resistor **B** compare to the current in **A**? Give a reason for the answer. (2)

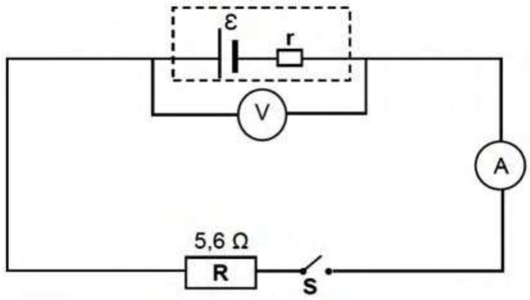
[20]

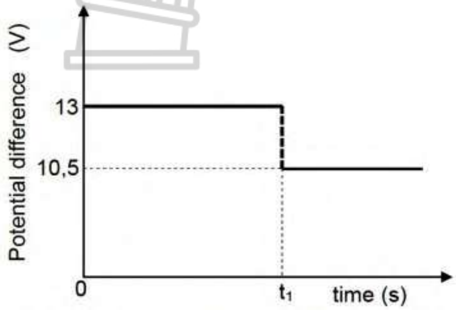
QUESTION 16

In the circuit diagram, resistor **R,** with a resistance of 5,6 Ω, is connected, together with a switch, an ammeter and a high-resistance voltmeter, to a battery with an unknown internal resistance, **r**.

The resistance of the connecting wires and the ammeter may be ignored.

The graph below shows the potential difference across the terminals of the battery as a function of time. At time t_1, switch **S** is closed.





16.1 Define the term *emf of a battery*. (2)

16.2 Write down the value of the emf of the battery. (1)

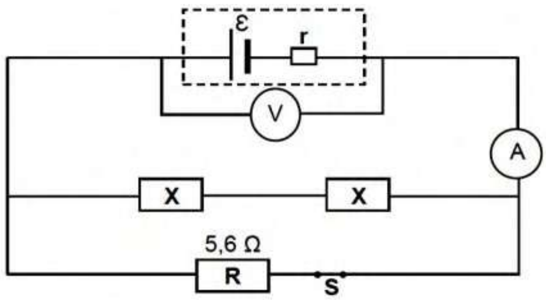
16.3 When switch **S** is CLOSED, calculate the:

16.3.1 Current through resistor **R** (3)

16.3.2 Power dissipated in resistor **R** (3)

16.3.3 Internal resistance, r, of the battery (3)

16.4 Two IDENTICAL resistors, each with resistance **X**, are now connected in the same circuit with switch **S** closed, as shown below.



The ammeter reading now increases to 4 A.

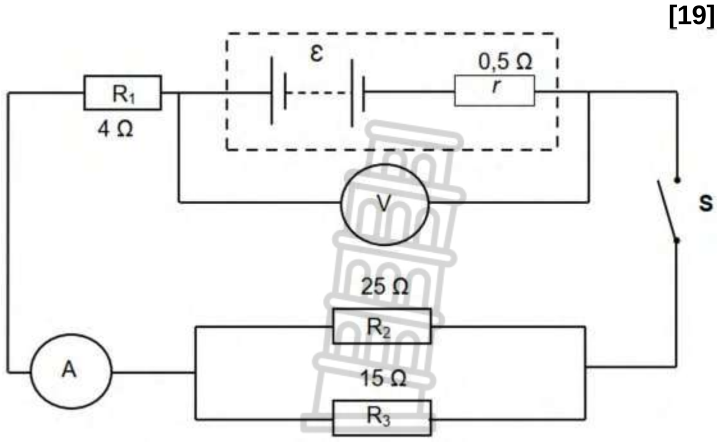
16.4.1 How would the voltmeter reading change? Choose from INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer by referring to $V_{\text{internal resistance}}$. (2)

16.4.2 Calculate resistance **X**. (5)

[19]

QUESTION 17

A battery with an internal resistance of 0,5 Ω and an unknown emf (ε) is connected to three resistors, a high resistance voltmeter and an ammeter of negligible resistance, as shown in the circuit diagram. The resistance of the connecting wires must be ignored.



17.1 Define the term *emf* of a battery. (2)

The reading on the voltmeter DECREASES by 1,5 V when switch **S** is closed.

17.2 Give a reason why the voltmeter reading decreases. (2)

17.3 Calculate the following when switch **S** is closed:

17.3.1 Reading on the ammeter (3)

17.3.2 Total external resistance of the circuit (4)

17.3.3 Emf of the battery (3)

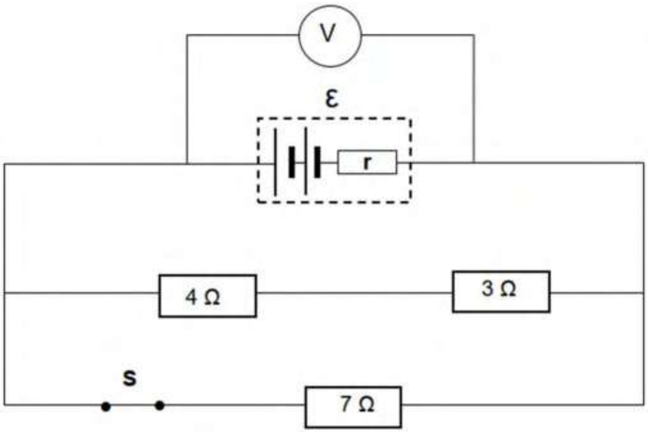
17.4 A learner makes the following statement: *The current through resistor R_3 is larger than the current through resistor R_2.* Is this statement CORRECT? Choose from YES or NO. Explain the answer. (3)

17.5 The 4 Ω resistor is now removed from the circuit. How will this affect the emf of the battery? Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

[18]

QUESTION 18

Three resistors are connected to a battery with an unknown emf and unknown internal resistance **r**, as shown. Ignore the resistance of the connecting wires.



18.1 In the definition of the emf of a battery given below, (a) and (b) represent missing words or phrases.

The emf of the battery is the maximum (a) … supplied by a battery per (b) …. passing through it.

Write down (a) and (b) in your ANSWER BOOK and next to each the missing word or phrase. (2)

With switch **S** CLOSED, the voltmeter reads 2,63 V.

18.2 Calculate the equivalent external resistance of the circuit. (4)

Switch **S** is now OPENED and the voltmeter reads 2,8 V.

18.3 Calculate:

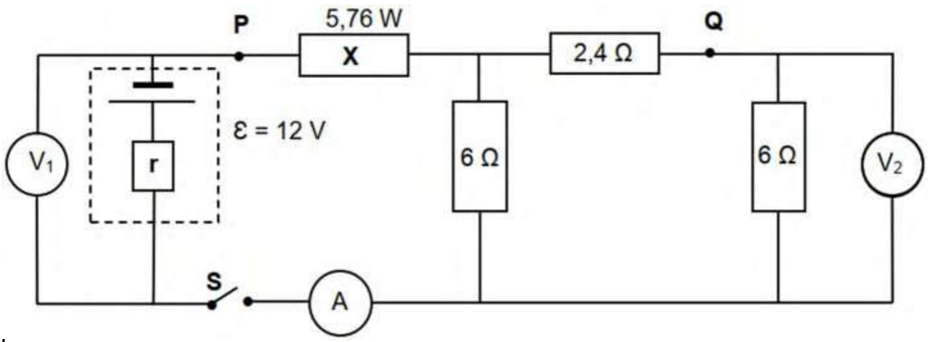
18.3.1 The internal resistance of the battery (8)

18.3.2 The emf of the battery (2)

[16]

QUESTION 19

The battery in the circuit shown below has an emf of 12 V and an unknown internal resistance **r**. The resistance of the connecting wires and the ammeter is negligible.



Switch **S** is OPEN.

19.1 Write down the reading on:

19.1.1 Voltmeter V_1 (1)

19.1.2 Voltmeter V_2 (1)

Switch **S** is now CLOSED. The reading on the ammeter is 1,2 A and the power dissipated in resistor **X** is 5,76 W.

19.2 Define the term *power*. (2)

Calculate the:

19.3 Resistance of resistor **X** (3)

19.4 Total EXTERNAL resistance of the circuit (3)

19.5 Reading on voltmeter V_2 (5)

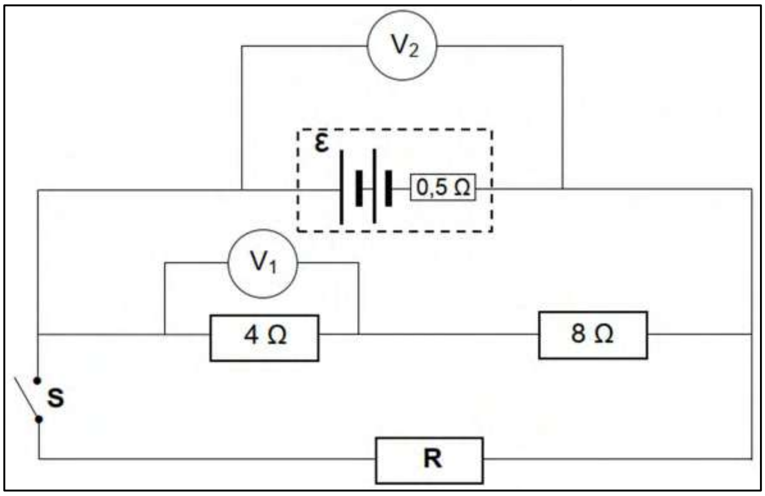
A length of wire of negligible resistance is used to connect point **P** to point **Q** in the circuit.

19.6 How will the reading on voltmeter V_1 be affected? Choose from INCREASES, DECREASES or NO EFFECT. Explain the answer. (4)

[19]

QUESTION 20

In the circuit below a battery of UNKNOWN emf and an internal resistance of 0,5 Ω is connected to two resistors of 4 Ω and 8 Ω each, and a resistor **R** of unknown resistance. Ignore the resistance of the connecting wires.



20.1 The three external resistors are ohmic conductors. Explain the meaning of the term *ohmic conductor*. (2)

20.2 When switch **S** is OPEN, voltmeter $\mathbf{V_1}$ reads 3,2 V. Calculate the:

20.2.1 Current through the battery (3)

20.2.2 Emf of the battery (4)

20.3 When switch **S** is CLOSED, voltmeter $\mathbf{V_2}$ reads 8,8 V.

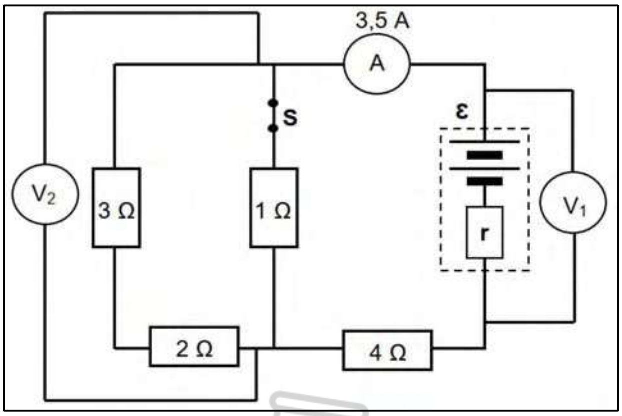
20.3.1 Calculate the resistance of resistor **R**. (5)

20.3.2 The battery becomes heated when voltmeter $\mathbf{V_2}$ is replaced by a connecting wire. Explain this observation. (3)

[17]

QUESTION 21 [N2022 Q8]

The circuit diagram shows four resistors connected to a battery of emf Ɛ and internal resistance *r*. The resistances of the ammeter and the connecting wires are negligible, while the voltmeters have very high resistances. Switch **S** is CLOSED.



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

21.2 The reading on the ammeter is 3,5 A.

21.2.1 Calculate the total external resistance of the circuit. (4)

21.2.2 Calculate the reading on voltmeter $\mathbf{V_1}$. (3)

21.2.3 How does the reading on voltmeter $\mathbf{V_2}$ compare to the reading on voltmeter $\mathbf{V_1}$? Choose from SMALLER THAN, EQUAL TO or GREATER THAN. (1)

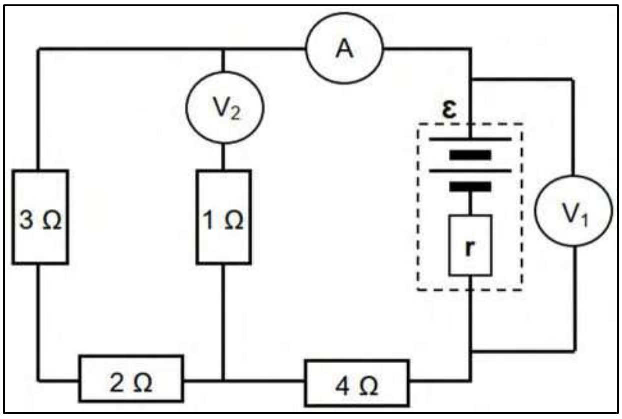
21.3 A learner concludes that the emf of the battery is equal to the reading on voltmeter $\mathbf{V_1}$.

21.3.1 Define the term *emf*. (2)

21.3.2 Is the learner's conclusion CORRECT? Choose from YES or NO. (1)

21.3.3 Give a reason for the answer to QUESTION 21.3.2. (1)

Switch **S** is now removed and replaced by voltmeter $\mathbf{V_2}$, as shown in the circuit diagram on the right.



21.4 How will EACH of the following change? (Choose from INCREASES, DECREASES or REMAINS THE SAME.)

21.4.1 The power dissipated by the 4 Ω resistor (1)

21.4.2 The reading on voltmeter $\mathbf{V_1}$ (1)

21.5 Explain the answer to QUESTION 21.4.2. (4)

[20]

ATOMIC COMBINATIONS

CHEMICAL BONDING

- IONIC BONDING
  Transfer of electrons from one atom to another, typically between metals and non-metals.
- COVALENT BONDING
  Atoms share electron pairs to attain stable electron configurations. This typically occurs between non-metal atoms.
- **METALLIC BONDING**
  In metals, atoms release some of their electrons, forming a "sea of electrons" that

Molecular Shapes and the VSEPR Theory

The shape of a molecule is determined by the repulsion between electron pairs around the central atom.

Molecular shapes:

- Linear (e.g., CO_2)
- Trigonal Planar (e.g., BF_3)
- Tetrahedral (e.g., CH_4)
- Bent or Angular (e.g., H_2O)
- Trigonal Pyramidal (e.g., NH_3)

ATOMIC COMBINATIONS

Electronegativity and Bond Polarity

Electronegativity:

- When the electronegativity difference between two atoms is large, the bond is ionic.
- When the difference is moderate, the bond is polar covalent, with partial positive and negative charges.
- If the difference is small or zero, the bond is non-polar covalent.

Bond Polarity:

- Polar bonds have uneven electron sharing, causing dipoles

Intermolecular Forces

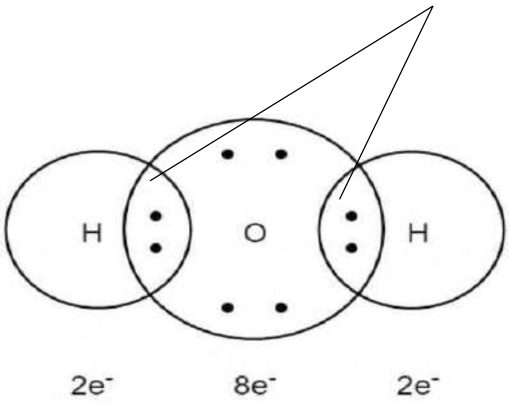
- **London Dispersion:**
  Forces: Weak forces due to temporary dipoles in non-polar molecules.
- **Dipole-Dipole Interactions:**
  Occur between polar molecules where the positive end of one molecule is attracted to the negative end of another.
- **Hydrogen Bonding:**
  A strong type of dipole-dipole interaction occurring when hydrogen is bonded to highly electronegative atoms like N, O, or F

ATOMIC COMBINATIONS

- **Covalent Compounds**: Lower melting and boiling points, poor electrical conductors, may or may not dissolve in water.

- **Metallic Compounds**: Good electrical and thermal conductors, malleable, ductile, generally high melting points.

Lewis Structures (Electron Dot Diagrams)
Lewis structures represent molecules showing the valence electrons of atoms. Covalent bonds are depicted as shared pairs of dots or lines between atoms.
Example: For a molecule like H_2O, oxygen forms TWO bonds with two hydrogen atoms.



Valency

Valency is the combining power of an atom, indicating how many electrons an atom needs to lose, gain, or share to achieve a stable electron configuration.
For example, oxygen has a valency of 2 (it needs to gain 2 electrons to fill its outer shell).

RULES FOR BOND FORMATION.

IONIC BOND

Ionic bonds form when electrons are transferred from one atom to another.

Involves: Metals and non-metals.

- **Metals** (usually from Groups 1, 2, or 3 of the periodic table) lose electrons to form positive ions (cations).
- **Non-metals** (usually from Groups 15, 16, or 17) gain electrons to form negative ions (anions).

- **Bond Strength**: Strong electrostatic attraction between oppositely charged ions.
- **Example**: Sodium (Na) donates an electron to Chlorine (Cl), forming Na^+ and Cl^-, which combine to form NaCl (table salt).

Atomic combinations:

DEFINITIONS

- Define a **chemical bond** as **a mutual attraction between two atoms resulting from the simultaneous attraction between their nuclei and the outer electrons.** (NOTE: The energy of the combined atoms is lower than that of the individual atoms resulting in higher stability.)
- Define a **covalent bond** as the sharing of electrons between two atoms to form a molecule.

Molecule: A group of two or more atoms covalently bonded and that function as a unit**.**

Describe rules for bond formation:

- Different atoms, each with an unpaired valence electron can share these electrons to form a chemical bond e.g. two H atoms form a H_2 molecule by sharing an electron pair.
- Different atoms with **paired valence electrons**, called **lone pairs**, cannot share these four electrons and cannot form a chemical bond e.g. no bond forms between two **He** atoms.
- Different atoms, with unpaired valence electrons, can share these electrons and form a chemical bond for each electron pair shared. The two atoms can form multiple bonds between them. If two pairs of electrons are shared, a double bond is formed e.g. between two O atoms to form O_2.
- Atoms with an empty valence shell can share a lone pair of electrons from another atom to form a coordinate covalent or dative covalent bond e.g. in NH_4^+ the lone pair of nitrogen is shared with H^+ and in H_3O^+ the lone pair of oxygen is shared with H^+.
- Define a **bonding pair** as **a pair of electrons that is shared between two atoms in a covalent bond.**
- Define a **lone pair** as **a pair of electrons in the valence shell of an atom that is not shared with another atom.**
- Describe the formation of the dative covalent (or coordinate covalent) bond by means of electron diagrams using NH_4^+ and H_3O+ as examples.
- Define **electronegativity** as **a measure of the tendency of an atom in a molecule to attract bonding electrons.**
- Describe a **non-polar covalent bond** as **a bond in which the electron density is shared equally between the two atoms.** An example is the bond between two H atoms.
- Describe a **polar covalent bond** as **a bond in which the electron density is shared unequally between the two atoms.** An example is the bond between an **H** atom and a Cℓ atom.

State the major principles used in the VSEPR:

- Molecular shape is determined by the repulsions between electron pairs present in the valence shell of the central atom.
- The number of electron pairs around the central atom can be determined by writing the Lewis structure for the molecule.
- The shape of the molecule depends on the number of bonding electron groups (or atoms bonded to the central atom) and the number of lone pairs on the central atom.
- **A** is used to represent the central atom and **X** is used to represent terminal atoms.
- There are five ideal shapes found when there are NO lone pairs on the central atom, ONLY bond pairs.
- Define **electronegativity** as **a measure of the tendency of an atom in a molecule to attract bonding electrons.**
- Describe a **non-polar covalent bond** as **a bond in which the electron density is shared equally between the two atoms.** An example is the bond between two H atoms.

- Describe a **polar covalent bond** as **a bond in which the electron density is shared unequally between the two atoms.** An example is the bond between an H atom and a Cℓ atom.
- Define **bond energy** of a compound as **the energy needed to break one mole of its molecules into separate atoms.**
- Define **bond length** as **the average distance between the nuclei of two bonded atoms.**

COVALENT BONDS

Covalent bonds form when atoms share electrons.

Involves: Non-metals only.

- Each atom contributes one or more electrons to be shared in the bond.
- The shared electrons allow each atom to achieve a stable electron configuration (usually achieving a full outer shell, like noble gases).

Types:

- **Single bond**: One pair of electrons is shared (e.g., H_2).
- **Double bond**: Two pairs of electrons are shared (e.g., O_2).
- **Triple bond**: Three pairs of electrons are shared (e.g., N_2).

Example: Two oxygen atoms share two pairs of electrons to form an O_2 molecule.

METALLIC BONDS

Metallic bonds occur when atoms in a metal release some of their electrons into a "sea of electrons."

Involves: Metals only.

- The electrons are free to move throughout the entire metal structure.
- The positively charged metal ions are held together by their attraction to the sea of delocalized electrons.

Properties: This gives metals their characteristic properties such as conductivity, malleability, and ductility.

Example: Copper (Cu) atoms are held together in a metallic bond.

STRUCTURED QUESTIONS

QUESTION 1 *(November Exemplar)*

Ammonia (NH_3) is an important gas used in the preparation of fertilisers. An ammonia molecule is formed when electrons are shared between three hydrogen atoms and a nitrogen atom.

1.1 Name the type of chemical bond formed between a hydrogen and a nitrogen atom. (1)

1.2 How many valence electrons does a nitrogen atom have? (1)

1.3 Write down a Lewis structure for the ammonia molecule. (2)

1.4 For the ammonia molecule, write down the:

- 1.4.1 Number of electron pairs surrounding the central atom (1)
- 1.4.2 Number of atoms surrounding the central atom (1)
- 1.4.3 Name used to describe the molecular shape (1)

Ammonia dissolves readily in water to form ammonium ions, NH_4^+(aq). An ammonium ion is formed when an ammonia molecule shares a lone pair of electrons with a hydrogen ion.

1.5 Name the type of bond formed between an ammonia molecule and a hydrogen ion. (1)

1.6 Represent the formation of an ammonium ion with the aid of Lewis structures. (4)

1.7 For the ammonium ion, write down the:

- 1.7.1 Number of atoms surrounding the central atom (1)
- 1.7.2 Name used to describe the molecular shape (1)

The nitrogen atom can also bond with itself to form the nitrogen molecule.

1.8 Which ONE of the following bonds will be the strongest?

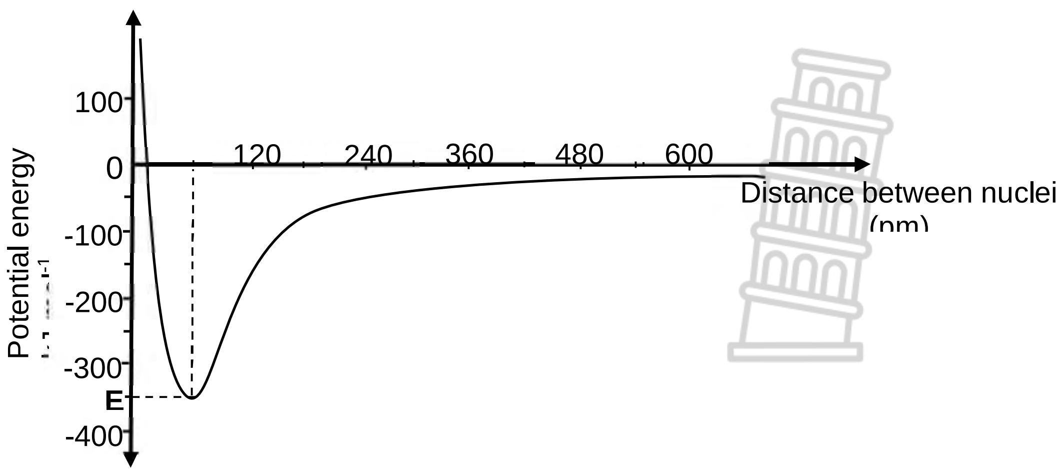
I: Bond between a nitrogen atom and a hydrogen atom
OR
II: Bond between a nitrogen atom and a nitrogen atom

Write down **I** or **II**. Give a reason for the answer. (2)

[16]

QUESTION 2 (*November 2014)*

The graph below shows the change in energy that takes place when a hydrogen (H) atom approaches a bromine (Br) atom.



2.1 Define the term *bond length*. (2)

2.2 From the graph, write down the:

- 2.2.1 Bond length, in pm, of the H-Br bond (2)
- 2.2.2 Energy, in $kJ\cdot mol^{-1}$, needed to break the H-Br bond (2)

2.2.3 Name of the potential energy represented by **E** (1)

2.3 How will the bond length of an H-F bond compare to that of the H-Br bond?

Write down EQUAL TO, SHORTER THAN or LONGER THAN. Give a reason for the answer. (2)

[9]

QUESTION 3 *(November 2014)*

Both aluminium fluoride ($A\ell F_3$) and phosphorous trifluoride (PF_3) contain fluorine. Aluminium fluoride is a colourless solid used in the production of aluminium, whilst phosphorous trifluoride is a poisonous, colourless gas.

3.1 Explain the difference between a *covalent bond* and an *ionic bond*. (2)

3.2 Name the type of chemical bond between particles in:

3.2.1 $A\ell F_3$ (1)

3.2.2 PF_3 (1)

3.3 Draw the Lewis structures for:

3.3.1 $A\ell F_3$ (3)

3.3.2 PF_3 (2)

3.4 Write down the molecular shape of PF_3. (1)

3.5 The melting point of $A\ell F_3$ is 1 291 °C and that of PF_3 is -151 °C.

Fully explain this difference in melting point. (4)

[14]

QUESTION 4 *(November 2015)*

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

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

4.2 ONE of the above molecules has lone pairs of electrons on the central atom. Draw the Lewis diagram for this molecule. (2)

4.3 H_3O^+ is formed when H_2O forms a dative covalent bond with an H^+ ion.

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

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

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

4.4.1 Define the term *electronegativity.* (2)

4.4.2 Calculate the difference in electronegativity between:

(a) C and O in CO_2 (1)

(b) H and O in H_2O (1)

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

[17]

QUESTION 5 *(November 2016)*

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

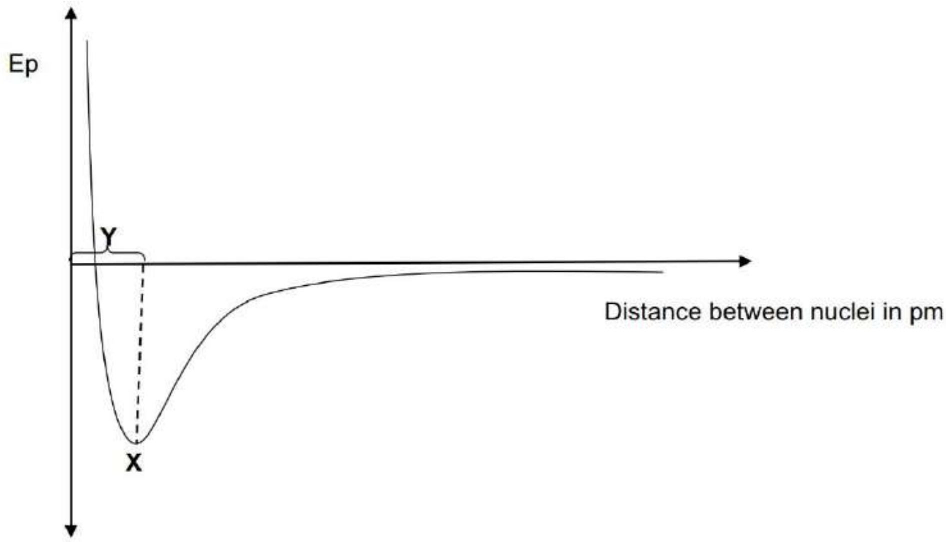
5.1 Define the term *electronegativity.* (2)

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

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

5.4 A polar bond does not always lead to a polar molecule.
Explain the statement by referring to OF_2 and CO_2 molecules. In your explanation, include the polarity of the bonds and the shape of the molecules. (4)

5.5 The diagram below shows the energy change that takes place when twoatoms move towards each other.



5.5.1 What does **X** and **Y** represent? (2)

5.5.2 Define the concept represented by **X**. (2)

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

[17]

QUESTION 6 *(November 2017)*

Consider the following two reactions of methane (CH_4):

Reaction 1: $CH_4 (g) + HCl (g) \rightarrow CH_3Cl (g) + H_2 (g)$

Reaction 2: $CH_4 (g) + 2O_2 (g) \rightarrow CO_2 (g) + 2H_2O (g)$

6.1 Define the term *covalent bond*. (2)

6.2 Draw Lewis structures for:

6.2.1 CH_3Cl (2)

6.2.2 CO_2 (2)

6.3 How many lone-pair electrons are on the central atom in the CO_2 molecule? (1)

6.4 Identify ONE of the substances in Reaction 2 that can form a dative covalent bond when reacting with an acid. (1)

6.5 Write down the shape of the:

6.5.1 H_2O molecule (1)

6.5.2 CO_2 molecule (1)

6.6 Although the molecules of CH_4 and CH_3Cl have the same shape, CH_4 is non-polar, while CH_3Cl is polar. Give a reason for the difference in molecular polarity. (1)
[11]

QUESTION 7 *(November 2018)*

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

7.1 Define the term *chemical bond.* (2)

7.2 Draw Lewis structures for:

7.2.1 HCN (2)

7.2.2 H_2O (2)

7.3 What is the shape of the HCN molecule? (1)

7.4 Calculate the electronegativity difference for the CN bond. (1)

7.5 What is polarity of the HCN molecule? Write only POLAR or NON-POLAR. (1)

The table below indicates the values of the bond length and bond energy of the different bonds in HCN.

BOND	BOND LENGTH (nm)	BOND ENERGY ($kJ\cdot mol^{-1}$)
CH	0,109	413
CN	0,116	890

7.6 Explain why the bond energy of the CN bond is more than the bond energy of the CH bond. (2)

7.7 Explain the difference between the *bond length of the CH bond* and the *bond length of the CN bond*. (2)

7.8 Will HCN be soluble in water? Write only YES or NO. (1)

7.9 Explain the answer to QUESTION 2.8 by referring to the polarity and intermolecular forces of the compounds. (3)
[17]

QUESTION 8 *(November 2019)*

8.1 Ammonia $NH_3(g)$ and hypochlorous acid $HOCℓ(ℓ)$ are both examples of covalent compounds.

8.1.1 Define the term *bonding pair*. (2)

8.1.2 Draw Lewis structures for the following molecules:

(a) NH_3 (2)

(b) HOCℓ (2)

8.1.3 Write down the:

(a) Number of bonding pairs in NH_3 (1)

(b) Number of lone pairs on the oxygen atom in HOCℓ (1)

(c) Shape of an ammonia molecule (1)

8.1.4 Which bond, N-H or O-H, is more polar? Give a reason for the answer. (2)

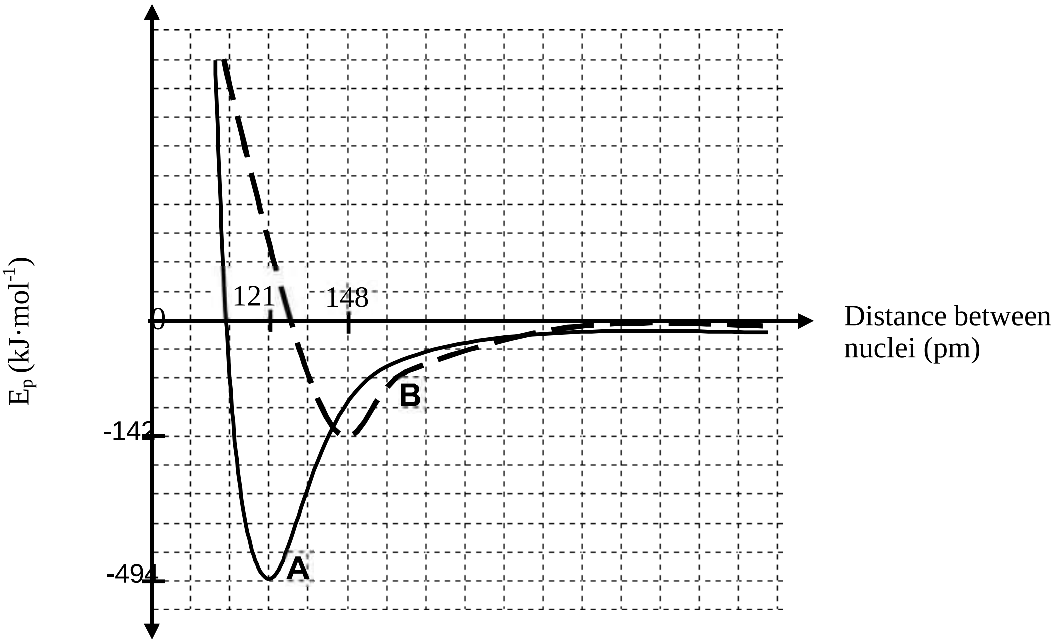
8.1.5 Write down the type of intermolecular forces present in BOTH ammonia and hypochlorous acid. (1)

8.1.6 When ammonia dissolves in water, the ammonium ion (NH_4^+) is formed.

What type of bond forms between the ammonia molecule and the hydrogen ion? (1)

8.2 The graph of potential energy versus distance between the nuclei of two Oxygen atoms during bond formation is shown below.

Graph of potential energy versus distance between nuclei



8.2.1 Define the term *bond energy*. (2)

8.2.2 Which curve, **A** or **B**, represents the formation of the double bond (O=O) between oxygen atoms? Briefly explain the answer. (3)

8.2.3 Write down the bond length of the bond represented by curve **B**. (1)

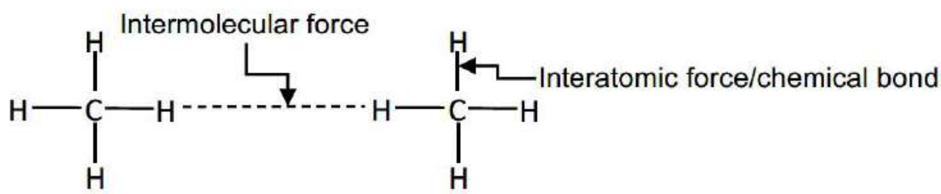
[19]

INTERMOLECULAR FORCES

TERMS AND DEFINITIONS	
Boiling point	The temperature at which the vapour pressure of a substance equals atmospheric pressure.
Melting point	The temperature at which the solid and liquid phases of a substance are at equilibrium.
Vapour pressure	The pressure exerted by a vapour at equilibrium with its liquid in a closed system.
Solubility	The property of a solid, liquid, or gaseous chemical substance (solute) to dissolve in a solid, liquid, or gaseous solvent to form a homogeneous solution

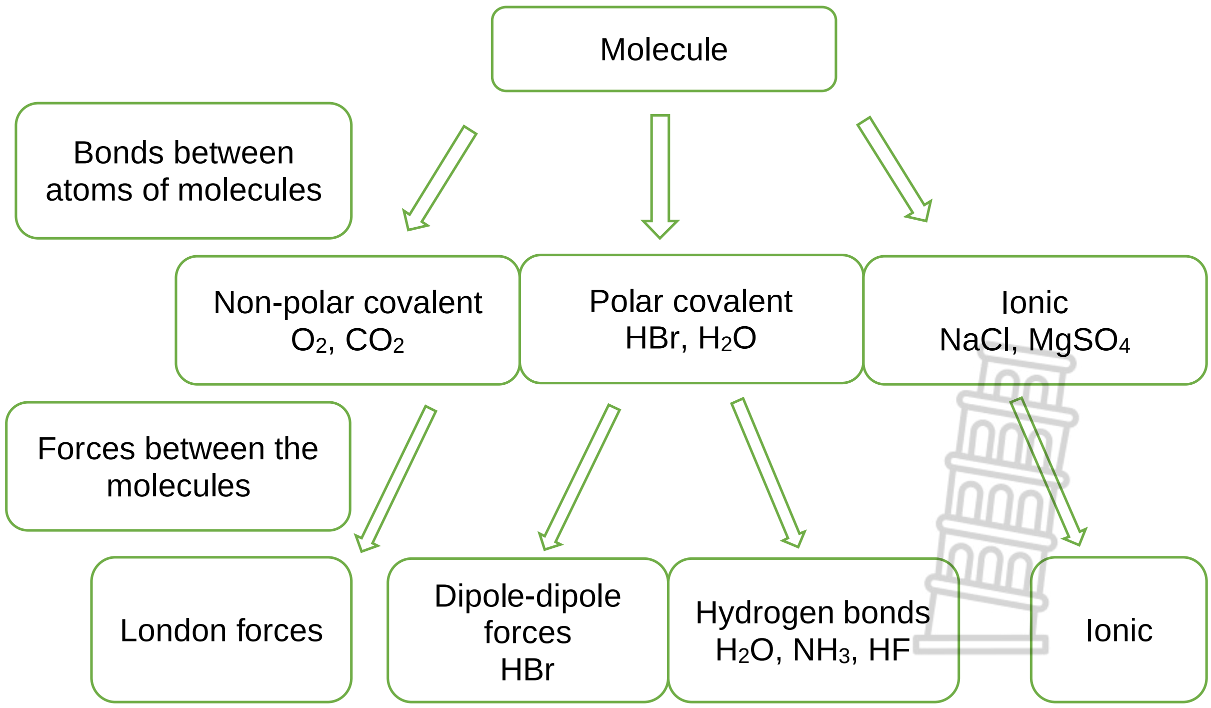
Understanding **bonds** and **intermolecular forces:**

Example:



Bonds: between atoms. This is the force that holds atoms together within a molecule - intramolecular force. Covalent bons are such an example.

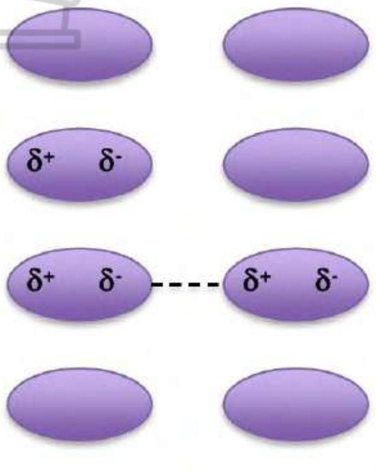
Intermolecular forces: This is the force that holds molecules together. The strength of intermolecular forces will influence properties like boiling-, melting points and vapour pressure.



INTERMOLECULAR FORCES

London forces

Sometimes called induced dipole forces or just dispersion forces. Temporary dipole attractions between non-polar molecules that form due to shifting electrons.
This is the only type of force between non-polar molecules.
Bigger molecules or atoms usually have stronger dispersion forces. (More electrons)



1) Two nonpolar molecules with no attractive forces between them.
2) As electrons shift within one of the molecules, a temporary dipole may appear.
3) An adjacent molecule will be attracted to the molecule with the temporary dipole and a new dipole within the second molecule will be induced. This creates the London dispersion force.
4) The electrons move back, and the temporary dipoles disappear. This makes the London forces a weak force, it is only temporary.

Dipole-Dipole Forces

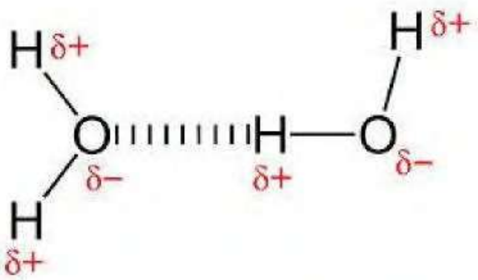
A permanent dipole force exists between polar molecules. Attractions form between the partially positive and partially negative ends of adjacent polar molecules. The opposite dipoles align themselves to create attractive forces.

Dipole forces are usually stronger than London forces since the dipoles are permanent.

Only polar molecules can form dipole-dipole forces.

Hydrogen Bonds

An especially strong dipole force exists between molecules containing H-F, H-O or H-N bonds. (These bonds are highly polar due to the large electronegativity difference.)

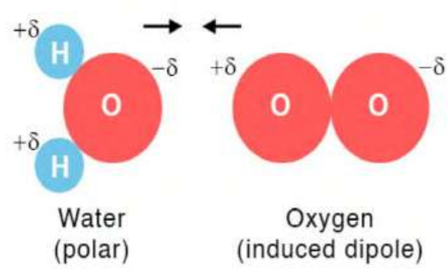


A very strong type of intermolecular force between specific polar molecules.

> Take note: Hydrogen bond also occur between organic molecules: CH_3OH, CH_3CH_2OH etc. because of the H-O strong dipole.

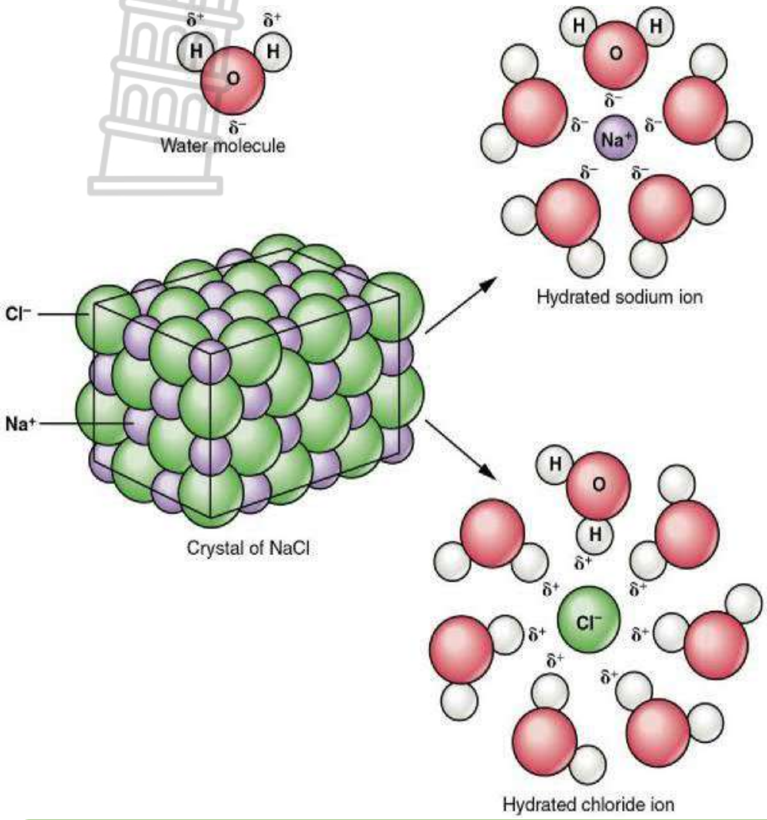
Dipole-induced dipole forces

Forces between polar and non-polar molecules



Ion-Dipole Forces

When an ionic compound such as NaCl dissolves in water, the water molecules arrange their oppositely charged dipole to be attracted to the fully charged ion, creating a very strong attractive force called an ion-dipole force.



The partial negative charge on the water molecule is attracted to the fully charged positive sodium ion (Na^+).

The partial positive charge on the water molecule is attracted to the fully charged negative chloride ion (Cl^-).

Boiling point
The stronger the intermolecular forces, the higher the boiling point.

Melting point:
The stronger the intermolecular forces, the higher the melting point.

Vapour pressure
The stronger the intermolecular forces, the lower the vapour pressure.

STRUCTURED QUESTIONS

QUESTION 1 *(November Exemplar 2013)*

The table below shows the boiling points of the hydrides of group IV (compounds in which hydrogen is bonded to elements from group IV in the periodic table).

BOILING POINTS OF HYDRIDES FROM GROUP IV

HYDRIDES OF GROUP IV	RELATIVE MOLECULAR MASS	BOILING POINT (°C)
CH_4	16	–164
SiH_4	32	–112
GeH_4	77	–89
SnH_4	123	–52

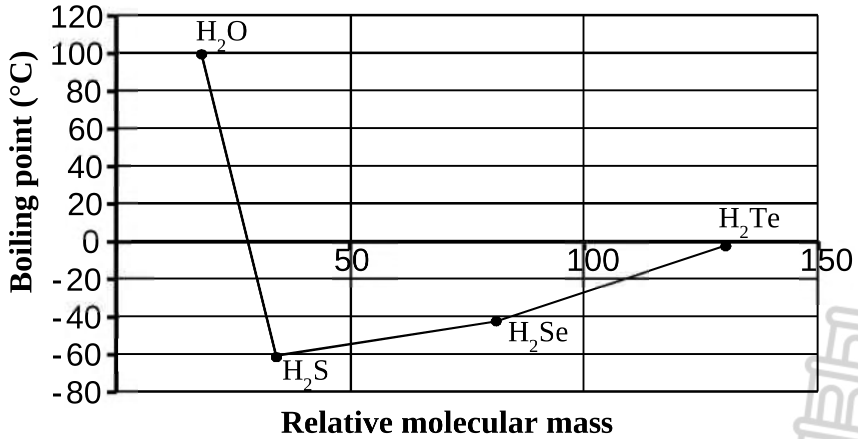
1.1 What is the phase (solid, liquid or gas) of the hydrides above at 25 °C? (1)

1.2 Name the type of Van der Waals forces between molecules of the hydrides in the table above. (1)

1.3 Explain the trend in boiling points observed for the hydrides in the above table. In your explanation, refer to molecular size, intermolecular forces and the energy needed. (3)

The graph below shows the boiling points of the hydrides of group VI in the periodic table versus their relative molecular masses.

GRAPH OF BOILING POINT VERSUS RELATIVE MOLECULAR MASS



1.4 From the graph above, deduce and then write down the NAME of the hydride:

1.4.1 With the weakest intermolecular forces (1)

1.4.2 With hydrogen bonds between molecules (1)

1.4.3 That requires the most energy to undergo a phase change (1)

1.5 Refer to intermolecular forces and energy and give a reason why one of the hydrides of group VI deviates from the trend in boiling point observed for the others. (2)

[10]

QUESTION 2 *(November 2014)*

The boiling points of four compounds of hydrogen, represented by the letters **P**, **Q**, **R** and **S**, are given in the table below.

	Formula	Boiling point (°C)
P	CH_4	-164
Q	NH_3	-33
R	H_2O	100
S	SiH_4	-112

2.1 Define the term *boiling point*. (2)

2.2 Fully explain the difference in boiling points between compound **P** and:

2.2.1 Compound **Q** (3)

2.2.2 Compound **S** (3)

2.3 Explain why the boiling points of compounds **Q** and **R** differ by referring to ELECTRONEGATIVITY and DEGREE OF POLARITY. (2)

2.4 Write down the letter from the table that represents the following:

2.4.1 ONE polar compound (1)

2.4.2 ONE non-polar compound (1)

[12]

QUESTION 3 **(***November 2015)*

3.1 The boiling point of compounds **A** to **E** are given in the table below.

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

3.1.1 Define the term *boiling point.* (2)

3.1.2 Calculate the molecular mass of compound **D**. (1)

3.1.3 In what phase is compound **B** at 25 °C? (1)

3.1.4 Name the type of intermolecular force present in compound **A**. (1)

3.1.5 Explain why the boiling point increases from compound **A** to **E**. (3)

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

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

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

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

3.2.2 Name the type of intermolecular force found between NH_3 molecules. (1)

3.2.3 Explain the following statement:

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

[15]

QUESTION 4 *(November 2016)*

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

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

4.1 Define the term *boiling point.* (2)

4.2 Formulate an investigative question for this experiment. (2)

4.3 In which compound in the table above will the strongest intermolecular forces occur? Give a reason for the answer. (2)

4.4 The learners now use 40 mℓ of each of the compounds above in the experiment. Will it affect the boiling points? Choose YES or NO. Give a reason for the answer. (2)

4.5 Methylated spirits is highly flammable. State TWO safety precautions that should be taken when using methylated spirits in the laboratory. (2)

4.6 Which compound in the table above will have the highest rate of evaporation? Give reason for the answer. (2)

4.7 Sunflower oil is a non-polar compound with induced dipole forces between themolecules, while water is a polar molecule with hydrogen bonds between its molecules. Explain why the boiling point of sunflower oil is higher than the boiling point of water. (2)

[14]

QUESTION 5 *(November 2017)*

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

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

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

5.2 Explain why the boiling point of iodine is higher than that of bromine. Refer to the intermolecular forces present in EACH substance in the explanation. (3)

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

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

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

5.5 Give a reason for the answer to QUESTION 5.4 by referring to the relative strength of the intermolecular forces and boiling points. (2)

[13]

QUESTION 6 *(November 2018)*

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

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

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

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

6.1 Refer to the intermolecular forces and explain the difference in boiling point between NH_3 and N_2. (3)

6.2 Write down the FORMULA of the substance in the table that will have the lowest melting point. (1)

6.3 Explain why H_2 will evaporate faster than N_2. Refer to the type and relative strength of the intermolecular forces. (3)

6.4 Write down the FORMULA of the substance in the table that will have the highest vapour pressure. Explain your answer. (3)

[10]

QUESTION 7 *(November 2019)*

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

	SUBSTANCES	**MELTING POINT (°C)**	**BOILING POINT (°C)**
A	HF	- 83,11	19,54
B	HCℓ	- 114,2	- 81,7
C	CS_2	- 111	46,0
D	CO_2	- 56,6	- 78,5

7.1 Define the term *melting point*. (2)

7.2 Explain the difference in melting points of HF and HCℓ by referring to the TYPE of intermolecular forces. (4)

7.3 Which ONE of the substances (**A**, **B**, **C** or **D**) above is a liquid at 25 °C? (1)

7.4 Explain why CS_2 has a higher boiling point than CO_2. (3)

7.5 Which ONE of the substances (**A**, **B**, **C** or **D**) above has the highest vapour pressure? Give a reason for the answer by referring to the data in the table. (2)

[12]

QUANTITATIVE ASPECTS OF CHEMICAL CHANGE

MOLE CONCEPT

Mole(mol)

Avogadro's Law (Gases)

Calculating Molar mass e.g.
$Mr(H_2O) = 2 + 16$
$= 18\ g.mol^{-1}$

Molar gas Volume (V_m)

At STP $V_m = 22,4\ dm^{-3}$

Avogadro, s Number (N_A) $= 6,02 \times 10^{23}\ mol^{-1}$

CALCULATING THE NUMBER OF MOLES

Balanced Chemical Equation
$Mg + 2HC\ell \rightarrow MgC\ell_2 + H_2$

Reactants mole

Solid Mass: $n = \frac{m}{M}$

Solutions: $c = \frac{n}{V}$, $c = \frac{n}{MV}$

Gases: $c = \frac{n}{V_m}$

Reactants mole

Solid Mass: $n = \frac{m}{M}$

Solutions: $c = \frac{n}{V}$, $c = \frac{n}{MV}$

Gases: $c = \frac{n}{V_m}$

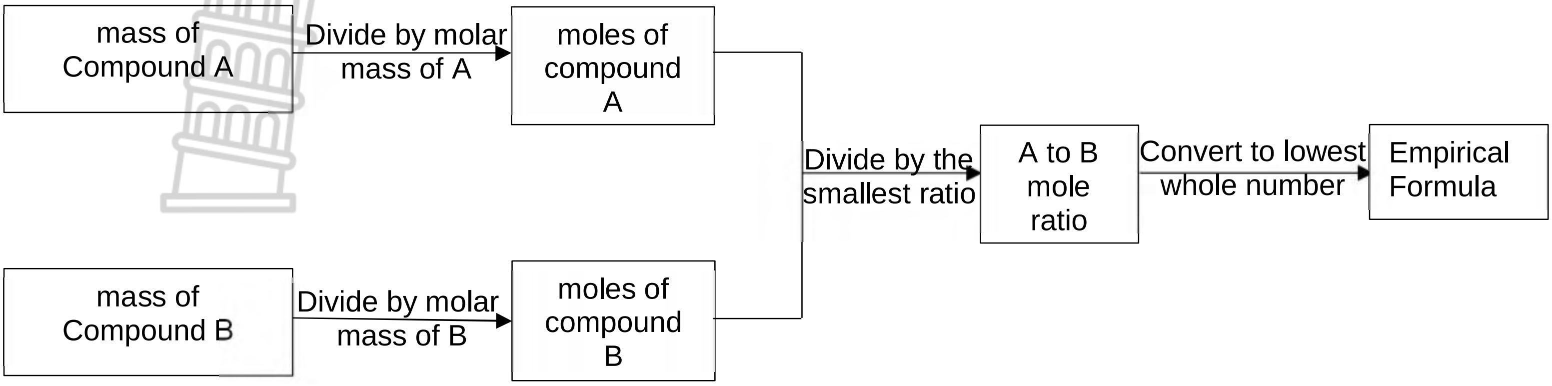
CALCULATING THE PERCENTAGE YIELD

Actual Yield: Number of moles/mass of products obtained from the chemical reaction

Theoretical Yield: Number of moles/mass of reactants obtained from the balanced chemical reaction

Percentage Yield: $\frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$

CALCULATING THE EMPIRICAL FORMULA



TERMS AND DEFINITIONS	
Mole	One mole of a substance is the amount of substance having the same number of particles as there are atoms in 12 g carbon-12.
Molar gas volume at STP	The volume of one mole of a gas. (1 mole of any gas occupies 22,4 dm^3 at 0 °C (273 K) and 1 atmosphere (101,3 kPa).
Molar mass	The mass of one mole of a substance. Symbol: M Unit: $g \cdot mol^{-1}$
Avogadro's Law	Under the same conditions of temperature and pressure, the same number of moles of all gases occupy the same volume.
Concentration	The amount of solute per litre/cubic decimeter of solution. In symbols: $c = \frac{n}{V}$ Unit: $mol \cdot dm^{-3}$
Empirical formula	The simplest positive whole number ratios of toms in a molecule.
Percentage yield	Yield is the amount of product obtained from a reaction. $\text{percentage yield} = \frac{\text{actual mass obtained}}{\text{calculated mass}} \times 100$
Percentage purity	$\text{percentage purity} = \frac{\text{mass of pure chemical}}{\text{total mass of sample}} \times 100$
Percentage composition	The percentage of each of the components in a substance. $\text{Percentage of component} = \frac{\text{mass contribute d by component}}{\text{mass of all components}} \times 100$
Limiting reagents	The substance that is totally consumed when the chemical reaction is complete.

STRUCTURED QUESTIONS

QUESTION 1 *(November Exemplar 2013)*

The airbags in motor vehicles contain the compound sodium azide (NaN_3). When a car crashes into an object, the compound decomposes and the nitrogen inflates the airbag. The balanced equation for the reaction is as follows:

$$NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$

In one such decomposition, 2,53 x 10^8 molecules of nitrogen are generated.
Calculate the:

1.1 Number of moles of $NaN_3(s)$ that decomposed (4)

1.2 Volume of $N_2(g)$ produced
Assume that the reaction occurs at standard pressure. (3)

[7]

QUESTION 2 *(November Exemplar 2013)*

Aluminium sulphate is used as a coagulant in water purification. It reacts with sodium hydroxide to form aluminium hydroxide which drags the impurities as it settles.

The balanced equation for the reaction is:

$$A\ell_2(SO_4)_3(aq) + 6NaOH(aq) \rightarrow 2A\ell(OH)_3(s) + 3Na_2SO_4(aq)$$

A chemist at a water purification plant adds 700 g of $A\ell_2(SO_4)_3$ to a sample of water.

2.1 Calculate the maximum mass of $A\ell(OH)_3$ that can be produced from this mass of $A\ell_2(SO_4)_3$. (5)

The chemist now dissolves 0,85 mol of Na_2SO_4 in 250 cm^3 of distilled water. He then tops it up with enough distilled water to make a 1 litre solution.

2.2 Define, in words, the term *concentration of a solution*. (2)

2.3 Calculate the concentration of this Na_2SO_4 solution. (3)

[10]

QUESTION 3 *(November Exemplar 2013)*

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

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

A chemist reacts 14 g of compound **X** with 10 g of compound **Y**.

3.1 Define the term *limiting reactant* in a chemical reaction. (2)

3.2 Perform the necessary calculations to determine which one of compound **X** or compound **Y** is the limiting reactant. (5)

The actual mass of aspirin obtained is 11,5 g.

3.3 Calculate the percentage yield of the aspirin. (5)

[12]

QUESTION 4 *(November 2014)*

4.1 Define the term *molar mass* of a substance. (1)
4.2 Calculate the number of moles of water in 100 g of water. (3)
4.3 Methyl benzoate is a compound used in the manufacture of perfumes. It is found that a 5,325 g sample of methyl benzoate contains 3,758 g of carbon, 0,316 g of hydrogen and 1,251 g of oxygen.
4.3.1 Define the term *empirical formula*. (2)
4.3.2 Determine the empirical formula of methyl benzoate. (7)
4.3.3 If the molar mass of methyl benzoate is 136 $g\cdot mol^{-1}$, what is its molecular formula? (2)
[15]

QUESTION 5 *(November 2014)*

5.1 Define the term *limiting reactant*. (2)
52 Iron (Fe) reacts with sulphur (S) to form iron sulphide (FeS) according to the following balanced equation:

$$Fe(s) + S(s) \rightarrow FeS$$

5.2.1 Calculate which of the two substances will be used up completely if 20 g of Fe and 10 g of S are mixed and heated. (5)
5.2.2 How many grams of the other substance are in excess? (2)
5.3 Magnesium burns in air to form magnesium oxide according to the following balanced equation:

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

If the percentage yield of this reaction is only 80%, calculate the mass of magnesium that needs to be burned to produce 30 g of magnesium oxide. (6)
[15]

QUESTION 6 *(November 2015)*

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

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

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

A certain antacid contains 1,8 g of $H_3C_6H_5O_7$ and 3,36 g of $NaHCO_3$. The antacid is issolved in 100 cm^3 distilled water in a beaker.

6.2 Define *1 mole of a substance.* (2)
6.3 Calculate the number of moles of $NaHCO_3$ in the antacid. (3)
6.4 Determine, using calculations, which substance is the limiting reagent. (4)
6.5 Calculate the mass of the reactant in excess. (3)
6.6 Calculate the mass decrease of the beaker contents on completion of the reaction. (3)
[16]

QUESTION 7 *(November 2015)*

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

$$Na_2S_2O_3(s) + 2HCℓ(aq) \rightarrow 2NaCℓ(aq) + S(s) + SO_2(g) + H_2O(ℓ)$$

7.1.1 Define the term *concentration of a solution.* (2)
7.1.2 Calculate the number of moles of HCℓ(aq) added to the sodium thiosulphate. (3)
7.1.3 Calculate the volume of SO_2(g) that will be formed if the reaction takes place at STP. (3)

7.2 Menthol, the substance we can smell in mentholated cough drops, is composed of carbon (C), hydrogen (H) and oxygen (O).

During combustion of a 9,984 g sample of menthol, it is found that 28,160 g of CO_2(g) and 11,520 g of H_2O(g) is produced.

7.2.1 Calculate the mass of carbon (C) in the CO_2. (4)
7.2.2 Use relevant calculations to determine the empirical formula of menthol. (7)
7.2.3 The molar mass of menthol is 156 g·mol^{-1}. Determine the molecular formula of menthol. (2)

[21]

QUESTION 8 *(November 2016)*

8.1 Define the term *concentration.* (2)
8.2 Eight (8) grams of $Na_2S_2O_3$ is dissolved in water to prepare 500 cm^3 of solution. Calculate the concentration of the $Na_2S_2O_3$ solution. (3)
8.3 A 10 g sample of a compound contains 2,66 g of potassium, 3,54 g ofchromium and 3,81 g of oxygen.

8.3.1 Define the term *empirical formula*. (2)
8.3.2 Determine the empirical formula of this compound. (7)

[14]

QUESTION 9 *(November 2016)*

Learners made a mini volcano in a science laboratory by adding sodium bicarbonate to ethanoic acid. They added 100 mℓ of a 0,2 mol·dm^{-3} ethanoic acid solution to 10 g of $NaHCO_3$ to start the reaction of the volcano.
The balanced equation for this reaction is:

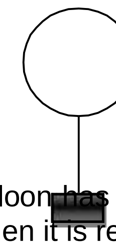
$$CH_3COOH(aq) + NaHCO_3(s) \rightarrow CH_3COONa(aq) + H_2O(ℓ) + CO_2(g)$$

9.1 Define the term *limiting reagent.* (2)
9.2 Determine the limiting reagent in this reaction. (6)
9.3 Calculate the mass of the other substance in excess. (3)
9.4 Calculate the volume of CO_2 produced at STP. (4)

[15]

QUESTION 10 *(November 2017)*

Weather balloons are sent into space to gather data. The balloons usually burst at a pressure of 27 640 Pa and a volume of 36,3 m^3. The data collector then falls back to Earth.



The gas in a certain weather balloon has an initial volume of 12,6 m^3 and pressure of 105 000 Pa at a temperature of 25 °C when it is released into space.

Calculate the:

10.1 Temperature of the gas, in °C, in the balloon when it bursts (4)

10.2 Initial amount of gas (in moles) in the balloon (4)

[8]

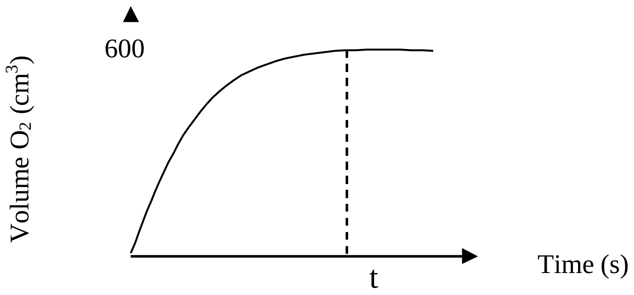
QUESTION 11 *(November 2017)*

11.1 The decomposition of hydrogen peroxide in the presence of a catalyst at standard pressure and room temperature is given by the unbalanced chemical equation below.

$$H_2O_2(aq) \rightarrow H_2O(\ell) + O_2(g)$$

The oxygen gas is collected and the volume is recorded over a period of time.The reaction is completed at time **t**.

The results are plotted on a graph of volume O_2 versus time, as shown below.



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

11.1.1 Balance the equation. (2)

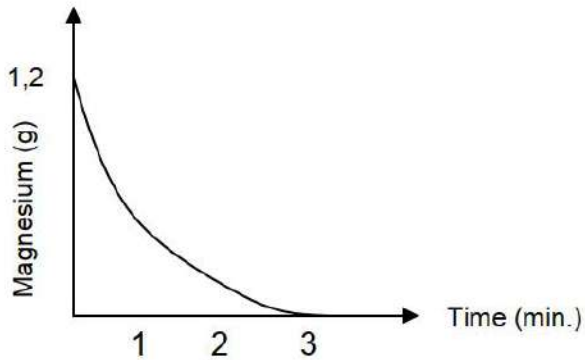
11.1.2 How would a catalyst affect the reaction? (2)

11.1.3 Use the information on the graph to calculate the mass of hydrogen peroxide that decomposed. (6)

11.2 In an experiment, a learner adds 500 cm^3 hydrochloric acid (HCℓ), with a concentration of 0,36 mol·dm^{-3}, to 1,2 g of magnesium in a test tube. She records the change in the mass of magnesium as the reaction proceeds at regular intervals. The balanced chemical equation for the reaction is:

$$Mg(s) + 2HC\ell(aq) \rightarrow MgC\ell_2(aq) + H_2(g)$$

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



11.2.1 Identify the limiting agent in this reaction. Give a reason for the answer. (2)

11.2.2 Calculate the number of moles of **unreacted** hydrochloric acid in the test tube after 3 minutes. (7)

[19]

QUESTION 12 *(November 2018)*

12.1 In an experiment, a learner added 1,5 g of sodium carbonate (Na_2CO_3) to hydrochloric acid (HCℓ). A volume of 306 cm^3 of carbon dioxide gas was formed and collected under standard pressure at room temperature. Take the molar gas volume at room temperature (V_m) as 24,45 dm^3.

The unbalanced equation for the reaction is:

$$Na_2CO_3(s) + HC\ell(aq) \rightarrow NaC\ell(aq) + H_2O(\ell) + CO_2(g)$$

12.1.1 Define the term *one mole of a substance*. (2)

12.1.2 Balance the equation for the reaction. (2)

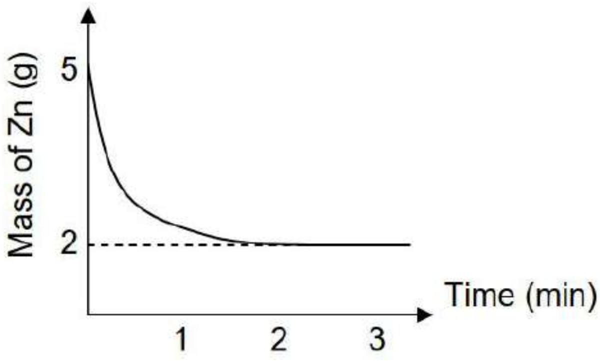
12.1.3 Calculate the mass of sodium carbonate that reacted. (7)

12.1.4 Calculate the percentage of sodium carbonate in excess. (2)

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

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

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



12.2.1 Name the substance that is the limiting reagent. (1)

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

[19]

QUESTION 13 *(November 2019)*

13.1 Potassium permanganate, $KMnO_4$, burns with a bright flame when a fewdrops of glycerine are added to it.

The incomplete equation for the reaction is:

$$14KMnO_4 + \text{glycerine} \rightarrow 7K_2CO_3 + 7Mn_2O_3 + xCO_2 + 16H_2O$$

13.1.1 Define the term *molar mass*. (2)

13.1.2 The composition of glycerine is as follows:

39,13% carbon; 8,7% hydrogen; 52,17% oxygen

Determine the EMPIRICAL formula of glycerine. Show ALLcalculations. (6)

13.1.3 Write down the value of x in the equation above if the MOLECULAR formula of glycerine is $C_3H_8O_3$. (1)

13.1.4 Calculate the mass of Mn_2O_3 that can be prepared if 18 g of $KMnO_4$ reacts with excess glycerine. (4)

13.2 The balanced equation for the reaction of sodium chloride, NaCℓ, withsulphuric acid, H_2SO_4, is as follows:

$$2NaC\ell(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2HC\ell(g)$$

During a reaction, 1,5 g of an impure sample of sodium chloride reacts with100 cm^3 sulphuric acid of concentration 0,1 $mol{\cdot}dm^{-3}$ at room temperature.

13.2.1 Define the term *concentration*. (2)

13.2.2 Calculate the number of moles of sulphuric acid used in the reaction above. (3)

On completion of the reaction it is found that 460 cm^3 of HCℓ gas has formed.

13.2.3 Calculate the percentage purity of the sodium chloride. Use 24,45 dm^3 as the molar gas volume (V_m) at room temperature. (6)

[24]

GAS LAWS

TERMS AND DEFINITIONS	
State Boyle's law	The pressure of an enclosed gas is inversely proportional to the volume it occupies at constant temperature. In symbols: $p \propto \frac{1}{V}$, therefore pV = k thus $p_1V_1 = p_2V_2$, T = constant
Temperature of a gas	Temperature of a gas directly proportional to the average kinetic energy of the molecules of the gas. In symbols: $T \propto E_{k\,avg}$
Gas pressure	The pressure exerted by a gas is due to the collision of the molecules with each other and the walls of the container. Gas pressure is influenced by temperature and amount of gas particles

Kinetic theory of gases

- Molecules are in constant motion and collide with each other and the walls of the container.
- There are forces of attraction between molecules.
- Molecules in a gas move at different speeds.

Gasses → Ideal Gasses; Gasses → Real Gasses

Ideal Gasses

Has identical particles of zero volume

No intermolecular forces between particles

All collisions of the molecules with themselves or the walls of the container are perfectly elastic.

Real Gasses

Particles has volume and differ from ideal gasses at high pressure

Intermolecular forces become evident at low temperatures

MULTIPLE CHOICE QUESTIONS

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

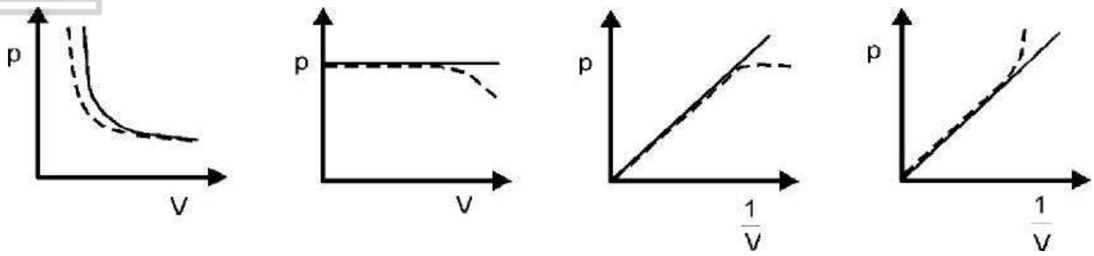
A Gas molecules collide elastically
B Gas molecules are in random motion.
C All molecules have the same kinetic energy.
D Attractive and repulsive forces can be neglected. (2)

1.2 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

1.3 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?

1.4



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

1.5 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)

The behavior 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	High	High
C	Low	High
D	High	Low

1.7 The volume of a fixed mass of a gas is reduced without a change in temperature. The gas pressure increases because ...

A the gas particles are now moving faster.

B the gas particles have increased in number.

C there is a greater distance separating the gas particles.

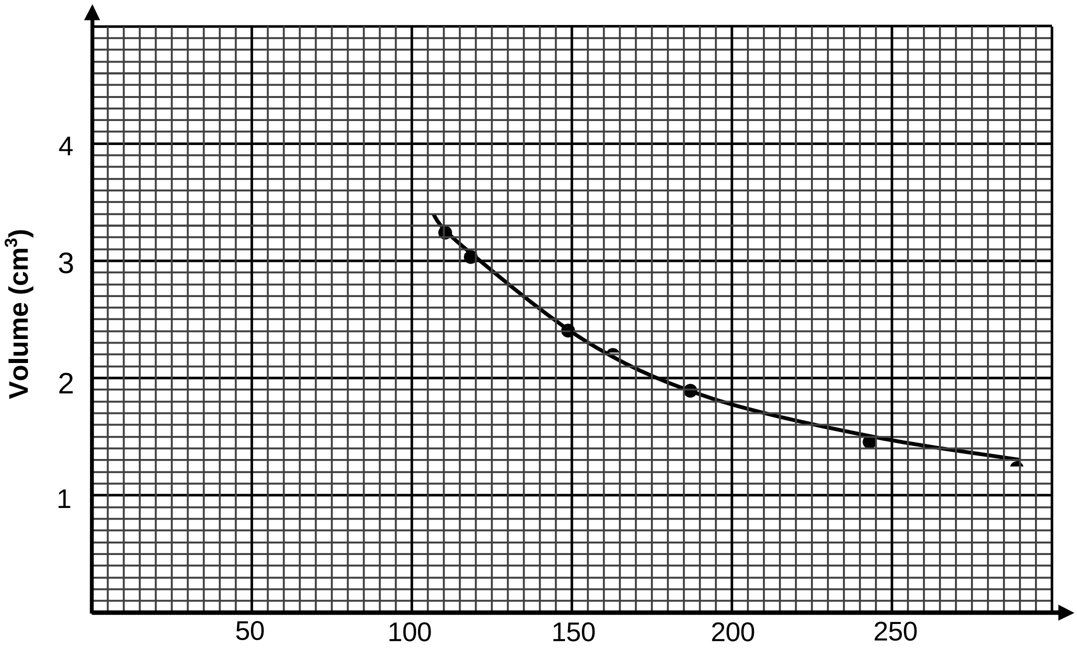
D a greater number of collisions per unit time now occurs against the container walls. (2)

STRUCTURED QUESTIONS

QUESTION 2 *(November Exemplar)*

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

GRAPH OF VOLUME VERSUS PRESSURE



2.1 Write down:

2.1.1 A mathematical expression, in symbols, for the relationship between the variables shown in the graph (1)

2.1.2 The name of the gas law investigated (1)

2.1.3 Explain the relationship in QUESTION 4.1.1 in terms of the kinetic theory of gases. (2)

2.2 Write down TWO variables that must be kept constant during this investigation and briefly describe how this is done. (4)

2.3 From the graph, write down the volume of oxygen, in cm^3, when the pressure is 120 kPa. (2)

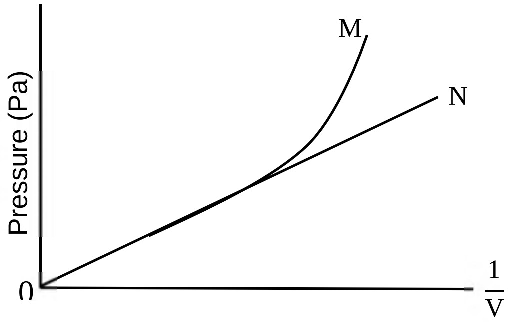
2.4 Calculate the pressure, in kPa, exerted on the gas when it is compressed to 5 cm^3. (4)

2.5 Write down TWO conditions under which oxygen gas will deviate from ideal gas behaviour. (2)

[16]

QUESTION 3 (FS Nov 2022)

The graph on the right shows the behaviour of an ideal gas and a real gas at different pressures.



3.1 Write down THREE properties of an ideal gas. (3)

3.2 Under what conditions will a real gas behave LIKE an ideal gas? (2)

3.3 Which graph, **M** or **N**, represents a REAL gas? (1)

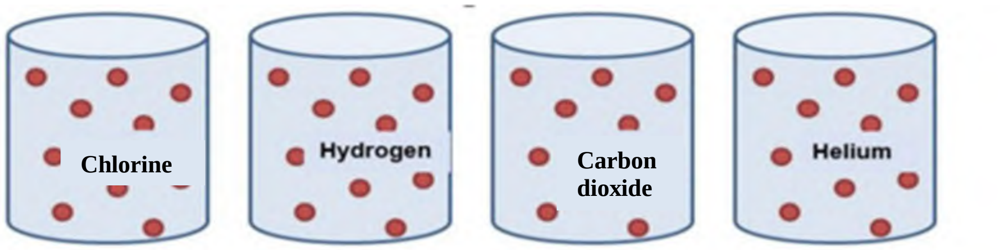
3.4 Fully explain your answer to QUESTION 3.3 by referring to pressure only. (3)

3.5 What conclusion can be drawn about the relationship between pressure and volume for the IDEAL gas? GIVE YOUR ANSWER WITH THE HELP OF SYMBOLS. (2)
[11]

QUESTION 4 (FS Nov 2023)

4.1 Explain what is meant by the term *temperature* of a gas. (2)

4.2 Four samples of gases were given to grade 11 learners to investigate the behaviour of real gasses and ideal gasses.



4.2.1 Study the table below that compares the real gases and ideal gases. Use the attached DIGRAM SHEET 4.2.1 to complete the comparison by choosing ONE of the suggested options for both real and ideal gas.

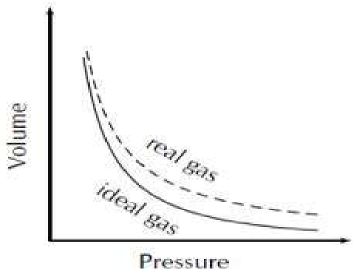
	Property	Real gas	Ideal gas
a)	Speed of particles	Same/ Different	Same/ Different
b)	Intermolecular forces.	Present but weak/ not present	Present but weak/ not present
c)	Type of collision with the walls of the container	Elastic / Inelastic	Elastic / Inelastic

(3)

4.2.2 Write down the NAMES or FORMULAE of TWO gases, from the collected samples, that behave closely to the ideal gas. (2)

4.2.3 Apart from the gases you identified in QUESTION 4.2.2 above, the other two gases tend to liquify at low temperatures. Briefly explain why the gases liquify by referring to the FORCES OF ATTRACTION between the molecules and NUMBER OF COLLISIONS between the molecules. (2)

4.3 Learners analysed the behaviour of gases and sketched the graph of volume versus pressure of the hydrogen and oxygen sample of gases to present their findings. The solid line on the graph represents the ideal gas while the broken line represents the real gas as shown below



4.3.1 Write down the dependent variable in this investigation. (1)
4.3.2 Fully explain why the real gas deviates from the ideal gas (3)
13]

QUESTION 5 (FS Nov 23)

Grade 11 learners were investigating the relationship between pressure and volume of an enclosed DIATOMIC gas at 25 °C. They recorded the volume of the gas for the different pressures in the table below.

PRESSURE (kPa)	**VOLUME (cm^3)**	$\frac{1}{V}$ **(cm^{-3})**
40	43	0,02
80	27	0,04
100	22	**a**
120	**b**	**0,06**

5.1 Write down the NAME of the gas law they were investigating. (2)
Answer QUESTIONS 5.2 and 5.3 on the attached ANSWER SHEET.
5.2 From the table, calculate the values of:
5.2.1 **a** (1)
5.2.2 **b** (1)

5.3 Use the table above and draw a graph of pressure versus $\frac{1}{V}$ on the attached answer sheet. (4)

5.4 Use dotted lines on the graph drawn to determine the volume of the gas at 68 kPa. . (3)
[11]

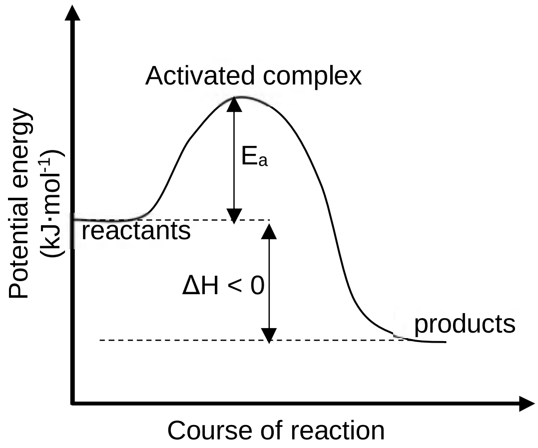
ENERGY AND CHEMICAL CHANGE

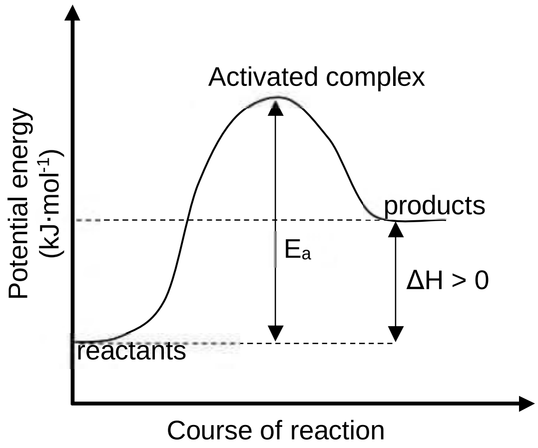
ENERGY IN CHEMICAL REACTIONS

HEAT OF REACTION (ΔH): The energy absorbed or released in a chemical reaction.

EXOTHERMIC REACTIONS
Reactions that release energy.

ENDOTHERMIC REACTIONS
Reactions that absorb energy.

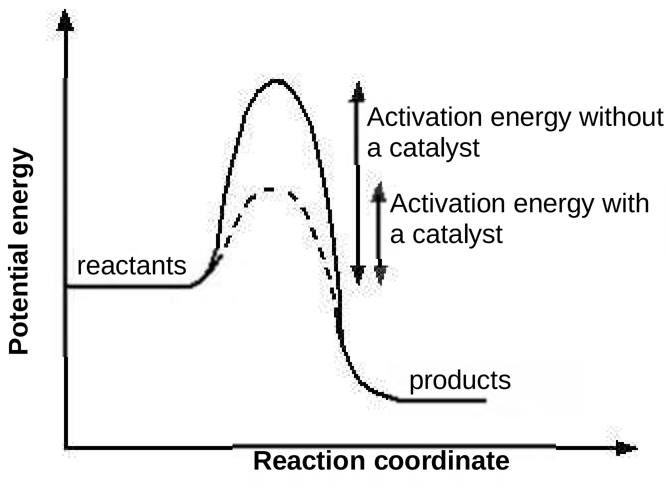




Activation energy
The minimum energy needed for a reaction to take place.

Activated complex
The unstable transition state from reactants to products.

EFFECT OF A CATALYST



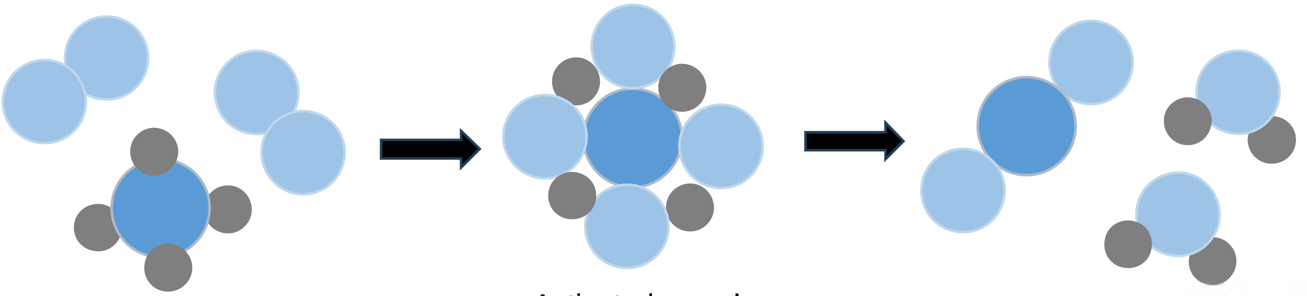
Catalyst
Increases reaction rate witout undergoing a permanent change.

Mechanism of catalyst:
Increase reaction rate by lowering the total activation energy

TERMS AND DEFINITIONS	
Heat of reaction (ΔH)	The energy absorbed or released in a chemical reaction.
Exothermic reactions	Reactions that release energy. (ΔH < 0)
Endothermic reactions	Reactions that absorb energy. (ΔH > 0)
Activation energy	The minimum energy needed for a reaction to take place.
Activated complex	The unstable transition state from reactants to products.
Catalyst	A substance that increases the rate of a chemical reaction without itself undergoing a permanent change. (A catalyst increases the rate of a reaction by providing an alternative path of lower activation energy. It therefore decreases the net/total activation energy.)

When existing bonds are broken and new are formed, there is a change in the potential energy of the system. The activated complex occurs when the system is at the maximum potential energy.

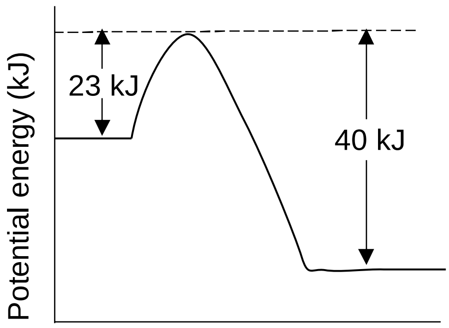
EXAMPLE: $CH_4(g)$ + $2O_2(g)$ → $CO_2(g)$ + $2H_2O(g)$



WORKED EXAMPLES

EXAMPLE 1

The diagram below shows the energy profile of a given reaction.



a. Is the reaction endothermic or exothermic?
Answer: Exothermic reaction.

1.2 What is the value of the activation energy for the reaction?
Answer: 23 kJ

1.3 Calculate the heat of the reaction (ΔH) in kJ for the reaction.
Answer: $\Delta H = -27\ kJ\cdot mol^{-1}$

EXAMPLE 2 QUESTION 4 (November 2016)
Methane is used as an alternative fuel. The combustion of methane releases carbon dioxide and water. The balanced equation for this reaction is:

$CH_4(g) + O_2(g) \rightarrow CO_2(g) + 2H_2O(g) + 891\ kJ.mol^{-1}$

The activation energy for this reaction is 172 kJ.mol-1.

2.1 Is this reaction ENDOTHERMIC or EXOTHERMIC? Give a reason for the answer. (2)
Answer: Exothermic. Energy is released or energy is a product
2.2 Explain why all chemical reactions need activation energy. (2)
Answer: Energy is needed to break the bond between atoms/ions in molecules

STRUCTURED QUESTIONS

QUESTION 1 *(November Exemplar 2013)*

Consider the reaction represented by the equation below.

$$CO_2(g) + 2H_2O(\ell) \rightarrow CH_4(g) + 2O_2(g)$$

During the reaction the temperature of the reaction mixture decreases.

1.1 Define the term *enthalpy change*. (2)
1.2 Does the enthalpy change (ΔH) for this reaction have a positive or negative value? Explain the answer by referring to the energy involved. (2)
1.3 Sketch a labelled potential energy graph for this reaction. On the graph, show the position of the reactants, products, ΔH and activation energy. (6)
[10]

QUESTION 2 *(November 2014)*

Hydrogen gas and oxygen gas react to form water according to the following balanced equation:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g) + 241,8\ kJ \cdot mol^{-1}$$

The activation energy (E_A) for this reaction is 1 370 $kJ \cdot mol^{-1}$.
2.1 Define the term *activation energy*. (2)
2.2 Sketch a potential energy versus reaction coordinate graph for the above reaction. Clearly label the axes and indicate the following on the graph:

- ΔH
- E_A for the forward reaction
- Reactants (**R**) and products (**P**)
- Activated complex (**X**) (5)

2.3 Write down the value of the:
1.3.1 Heat of reaction (1)
1.3.2 Activation energy for the following reaction:

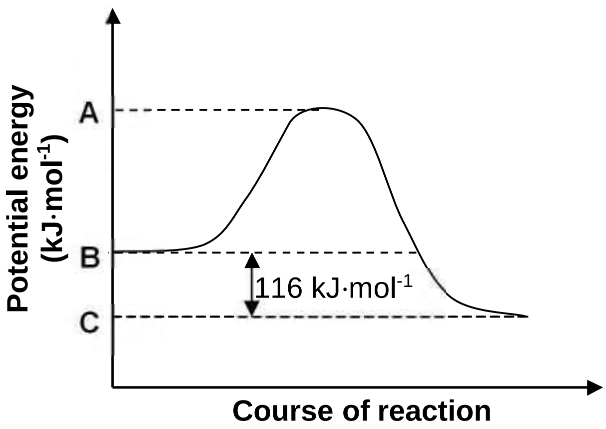
$$2H_2O(g) \rightarrow 2H_2(g) + O_2(g)$$ (2)
[10]

QUESTION 3 (*November 2015)*

A barium hydroxide solution, $Ba(OH)_2(aq)$, reacts with a nitric acid solution, $HNO_3(aq)$, according to the following balanced equation:

$$Ba(OH)_2(aq) + 2HNO_3(aq) \rightarrow Ba(NO_3)_2(aq) + 2H_2O(\ell)$$

The potential energy graph below shows the change in potential energy for this reaction.



3.1 Is this reaction ENDOTHERMIC or EXOTHERMIC? Give a reason for the answer. (2)

3.2 Use energy values **A**, **B** and **C** indicated on the graph and write down an expression for each of the following:

3.2.1 The energy of the activated complex (1)

3.2.2 The activation energy for the forward reaction (1)

3.2.3 ΔH for the reverse reaction (1)

3.3 Calculate the amount of energy released during the reaction if 0,18 moles of $Ba(OH)_2(aq)$ reacts completely with the acid. (3)

[8]

QUESTION 4 *(November 2016)*

Methane is used as an alternative fuel. The combustion of methane releases carbondioxide and water. The balanced equation for this reaction is:

$$CH_4(g) + O_2(g) \rightarrow CO_2(g) + 2H_2O(g) + 891\ kJ \cdot mol^{-1}$$

The activation energy for this reaction is $172\ kJ \cdot mol^{-1}$.

4.1 Is this reaction ENDOTHERMIC or EXOTHERMIC? Give a reason for the answer. (2)

4.2 Explain why all chemical reactions need activation energy. (2)

4.3 Why is this reaction not considered to be environmentally friendly? (2)

[6]

QUESTION 5 *(November 2017)*

The equation for the combustion of butane gas is given below.

butane(g) + $13O_2$(g) → $8CO_2$(g) + $10H_2O$(g) $\Delta H < 0$

5.1 Define the term *activation energy.* (2)

5.2 Is the combustion reaction of butane *exothermic* or *endothermic*? Give a reason for the answer. (2)

5.3 Draw a sketch graph of potential energy versus course of reaction for the reaction above.

Clearly indicate the following on the graph:

- Activation energy
- Heat of reaction (ΔH)
- Reactants and products (3)

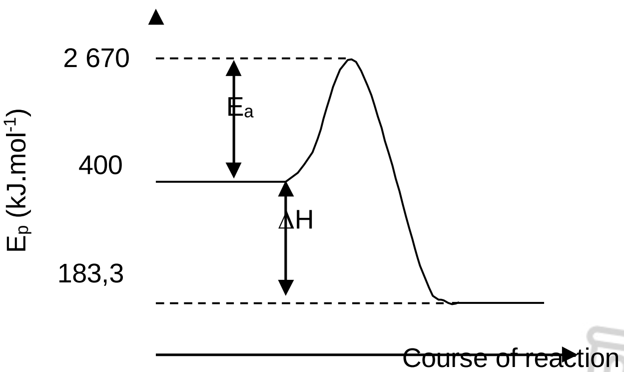
5.4 Determine the empirical formula of butane gas if it consists of 82,76% carbon and 17,24% hydrogen. (4)

[11]

QUESTION 6 *(November 2018)*

The following reaction between ammonia and oxygen takes place in a closed systemat constant pressure and temperature:

$4NH_3$(g) + $5O_2$(g) → 4NO(g) + $6H_2O$(g)



6.1 Define the term *activation energy.* (2)

6.2 Give a reason why this reaction is exothermic. (1)

6.3 Calculate the heat of reaction. (3)

6.4 Redraw the graph and indicate with a dotted line the effect of a catalyst on the activation energy. (2)

6.5 State *Avogadro's law* in words. (2)

6.6 If 6 dm^3 of NH_3 and 9 dm^3 of O_2 are used, calculate the TOTAL VOLUME ofthe gases at the end of the reaction. (4)

6.7 The reaction above is the first step in the manufacturing of an acid. This acid contains 1,59% hydrogen, 22,2% nitrogen and 76,2% oxygen. Determine theempirical formula of the acid. (4)

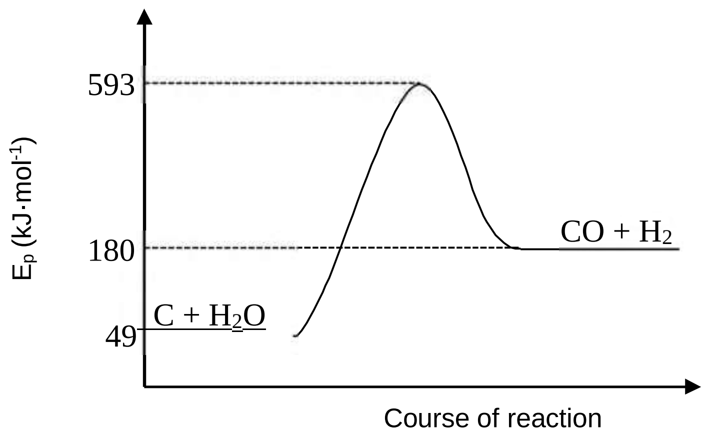
[18]

QUESTION 7 *(November 2019)*

The balanced equation for the reaction of carbon with steam is as follows:

$$C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$$

The graph below, NOT drawn to scale, represents the change in potential energy of the substances during the reaction.



7.1 Define the term *heat of reaction*. (2)

7.2 Is the reaction ENDOTHERMIC or EXOTHERMIC? Give a reason for the answer. (2)

7.3 Use the information on the graph and write down the value of the:

7.3.1 Activation energy (2)

7.3.2 Heat of reaction (2)

[8]

ACIDS AND BASES REACTIONS

QUESTION 1 *(November Exemplar 2014)*

Acids and bases can be defined in terms of the following two theories:

I: Arrhenius theory
II: Lowry-Brönsted theory

1.1 According to the Arrhenius theory, sodium hydroxide is classified as a base.

Write down the chemical formula of the ion responsible for the basic properties of sodium hydroxide. (1)

1.2 Consider the reaction represented by the incomplete equation below:

$$HNO_3(aq) + OH^-(aq) \rightleftharpoons \_\_\_\_\_ + \_\_\_\_\_$$

1.2.1 Use your knowledge of the Lowry-Brönsted theory to write a balanced equation for this reaction. (3)

1.2.2 Write down the formulae of ONE conjugate acid-base pair in this reaction. (2)

1.3 In a reaction, 40 cm^3 of nitric acid neutralises 25 cm^3 of a 0,05 $mol\cdot dm^{-3}$ solution of barium hydroxide according to the following balanced equation:

$$2HNO_3(aq) + Ba(OH)_2(aq) \rightarrow Ba(NO_3)_2(aq) + 2H_2O(\ell)$$

Calculate the:

1.3.1 Number of moles of base that reacted (2)

1.3.2 Number of moles of acid that reacted (1)

1.3.3 Concentration of the acid (2)

[11]

QUESTION 2 *(November 2014)*

2.1 Limestone, or sometimes ash, is used in pit latrines (long drops) to neutralise acidic waste.

Limestone reacts with hydrochloric acid according to the following UNBALANCED equation:

$$CaCO_3(s) + HC\ell(aq) \rightarrow CaC\ell_2(aq) + H_2O(\ell) + CO_2(g)$$

2.1.1 Define an *acid* in terms of the Arrhenius theory. (2)

2.1.2 Is ash acidic or basic? (1)

2.1.3 Rewrite the above equation into your ANSWER BOOK and then balance the equation. (1)

2.2 Sulphuric acid reacts with water in two steps as represented by the equations below.

Equation **I**: $H_2SO_4(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + HSO_4^-(aq)$

Equation **II**: $HSO_4^-(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + SO_4^{2-}(aq)$

2.2.1 Define the term *ampholyte*. (2)

2.2.2 Write down the FORMULA of a species that acts as ampholyte in the above reactions. (1)

2.2.3 Write down the NAME of the conjugate base of the hydrogen sulphate ion. (1)

2.3 A standard sodium carbonate solution is prepared in a 250 cm^3 volumetric flask.

During a titration, 20 cm^3 of a 0,1 $mol\cdot dm^{-3}$ nitric acid solution neutralises 25 cm^3 of the above standard solution according to the following balanced equation:

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

2.3.1 Write down the NAME of the salt formed in the above reaction. (1)

2.3.2 Calculate the mass of sodium carbonate used to prepare the standard solution in the volumetric flask. (5)

[14]

QUESTION 3 *(November 2015)*

When sulphuric acid reacts with water, it ionises in two steps, as shown in the two balanced equations below.

I: $H_2SO_4(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + HSO_4^-(aq)$

II: $HSO_4^-(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + SO_4^{2-}(aq)$

3.1 Define an *acid* in terms of the Lowry-Brønsted theory. (2)

3.2 Write down the FORMULA of:

3.2.1 The conjugate base of $HSO_4^-(aq)$ (1)

3.2.2 The conjugate acid of $HSO_4^-(aq)$ (1)

3.2.3 A substance that acts as ampholyte in these reactions (1)

3.3 A few drops of bromothymol blue indicator are added to a potassium hydroxide solution in a beaker. A dilute sulphuric acid solution is now gradually added to this solution until the colour of the indicator changes.
Write down the:

3.3.1 Type of reaction that takes place
(Write down only REDOX, PRECIPITATION or NEUTRALISATION.) (1)

3.3.2 Balanced equation for the reaction that takes place (3)

3.3.3 Colour change of the indicator (2)

3.3.4 NAME of the salt formed in this reaction (1)

[12]

QUESTION 4 *(November 2016)*

4.1 Define an *acid* in terms of the Lowry-Brønsted theory. (2)

4.2 Consider the following acid-base reaction:

$$H_2PO_4^- + NH_3 \rightarrow HPO_4^{2-} + NH_4^+$$

4.2.1 Identify the conjugate acid-base pairs in the above reaction. (4)

4.2.2 Define the term *ampholyte*. (1)

4.2.3 Choose an ampholyte in the above reaction. (2)

4.3 Ten grams (10 g) of an impure sample of sodium carbonate is added to 100 cm^3 of a 0,2 $mol.dm^{-3}$ solution of hydrochloric acid. The acid is in excess.

The equation for the reaction is:

$$Na_2CO_3 + HC\ell \rightarrow NaC\ell + H_2O + CO_2$$

4.3.1 Balance the equation above. (1)

4.3.2 Calculate the number of moles of hydrochloric acid. (3)

The excess acid neutralises 20 cm^3 of a solution of 0,1 $mol.dm^{-3}$ ofmagnesium hydroxide.

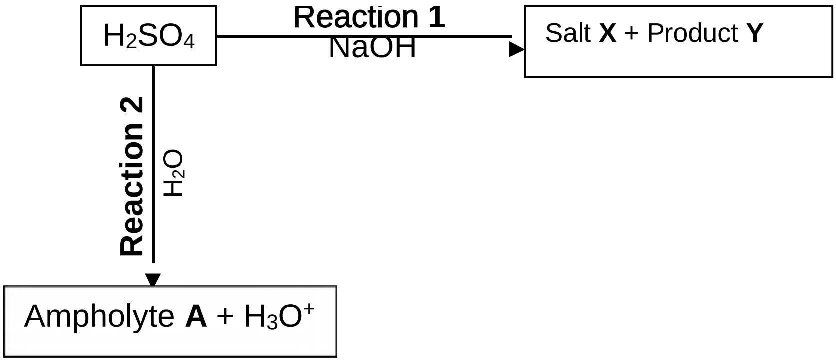
$$2HC\ell(aq) + Mg(OH)_2(aq) \rightarrow MgC\ell_2(aq) + H_2O(\ell)$$

4.3.3 Calculate the percentage purity of the sodium carbonate solution. (8)

[21]

QUESTION 5 *(November 2017)*

5.1 Two reactions of sulphuric acid are shown in the diagram below.



5.1.1	Define a *Lowry-Brønsted base*.	(2)
5.1.2	Write down a balanced equation for Reaction **1**.	(3)
5.1.3	Write down the NAME of the salt represented by **X**.	(2)
5.1.4	Write down the FORMULA of ampholyte **A**.	(2)
5.1.5	Write down the formulae of the TWO conjugate acid-base pairs in Reaction **2**.	(4)

5.2 A solution of sodium hydroxide (NaOH) is prepared by dissolving 6 g solidNaOH in 500 cm^3 water.

This solution reacts completely with 10 g impure ammonium chloride ($NH_4C\ell$)according to the equation below.

$$NaOH(aq) + NH_4C\ell(s) \rightarrow NaC\ell(aq) + H_2O(\ell) + NH_3(aq)$$

5.2.1	Calculate the concentration of the NaOH solution.	(4)
5.2.2	Calculate the percentage **impurities** in the $NH_4C\ell$	(6)

[23]

QUESTION 6 *(November 2018)*

Ammonia can readily dissolve in water according to the equation below:

$$NH_3(g) + H_2O(\ell) \rightarrow NH_4^+(aq) + OH(aq)$$

6.1	Explain why a hydroxide ion is regarded as a Lowry-Brønsted base.	(2)
6.2	Identify the type of bond responsible for the formation of the ammonium ion in the above equation.	(1)
6.3	Write a balanced equation to show how the ampholyte in the above equation will act as a base when it reacts with hydrochloric acid ($HC\ell$).	(2)

5 dm^3 of nitric acid (HNO_3), with a concentration of 0,75 $mol{\cdot}dm^{-3}$, is spilled accidentally in a small pond of water. The acid and water has a total volume of1 000 dm^3. To neutralise the acid, calcium hydroxide is added to the water.

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

6.4	Define the term *concentration*.	(2)
6.5	Calculate the concentration of the acid AFTER it was spilled in the pond.	(4)

6.6 Use calculations to determine if 120 g of calcium hydroxide will be sufficient to react completely with ALL the acid in the pond. (6)
[17]

QUESTION 7 *(November 2019)*

7.1 Consider the balanced equations for the reaction of water with nitric acid and ammonia below:

Reaction 1: $HNO_3(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + NO_3^-(aq)$

Reaction 2: $NH_3(g) + H_2O(\ell) \rightarrow NH_4^+(aq) + OH^-(aq)$

7.1.1 Define an *acid* in terms of the Lowry-Brønsted theory. (2)

7.1.2 Write down the FORMULA of ONE conjugate acid-base pair in **Reaction 1**. (2)

7.1.3 Is the solution formed in **Reaction 1** ACIDIC or BASIC (ALKALINE)? Give a reason for the answer. (2)

7.1.4 Define the term *ampholyte*. (2)

7.1.5 Write down the FORMULA of a substance that acts as an ampholyte in the reactions above. (1)

7.1.6 Explain the answer by referring to the role of this substance in **Reaction 1** and **Reaction 2**. (2)

100 cm^3 of HNO_3 of a concentration of 0,2 $mol{\cdot}dm^{-3}$ is diluted to 0,16 $mol{\cdot}dm^{-3}$.

7.1.7 Calculate the volume of water that must be added to the 0,2 $mol{\cdot}dm^{-3}$ HNO_3. (4)

7.2 Zinc oxide, ZnO, is insoluble in water and can be harmful to the environment.Nitric acid can be used to neutralize zinc oxide.

The incomplete equation for the reaction is:

$$ZnO(s) + 2HNO_3(aq) \rightarrow \text{salt } \mathbf{X}(aq) + H_2O(\ell)$$

7.2.1 Calculate the mass of zinc oxide that can be neutralized by 80 cm^3 of nitric acid with a concentration of 0,16 $mol{\cdot}dm^{-3}$. (5)

7.2.2 Write the NAME and FORMULA of salt **X** that forms during this reaction. (2)
[22]

REDOX REACTIONS

REDuction and Oxidation reaction

Losing and gaining of electrons: electron transfer.

Meaning of oxidation number: is a number assigned to an atom in a molecule or ion that represents the number of electrons lost or gained by that atom in a chemical compound. It indicates the degree of oxidation(loss of electrons) or reduction (gain of electrons of an atom in a chemical reaction

OXIDATION NUMBER RULES

1. The oxidation number for an atom in its elemental form is always 0.
2. The oxidation number of a mono-atomic ion equals to the charge of a mono-atomic ion.
3. The oxidation number of all group 1 metals in a compound equal to +1 and group 2 metals in a compound +2.
4. Hydrogen atom has 2 possible oxidation numbers +1 when bonded to non-metals and -1 when bonded to metals.
5. Oxygen atom has 2 possible oxidation numbers -1 in peroxides and -2 in all other compounds.
6. The sum of the oxidation number of all atoms (or ions) in a neutral compound equal to 0.
7. The sum of the oxidation numbers of all atoms in a polyatomic ion equal to charge on the polyatomic ion.

ASSIGNING OXIDATION NUMBER

1. **H_2O**: H = +1, O = -2
2. **CH_4**: C = -4, H = +1
3. **CO_2**: C = +4, O = -2
4. **H_2O_2**: H = +1, O = -1 (peroxide)
5. **HOCl**: H = +1, O = -2, Cl = +1

Electron transfer reactions

TERMS AND DEFINITIONS	
Redox reaction	A reaction in which an electron transfer takes place.
Oxidation	A loss of electrons. /An increase in oxidation number.
Reduction	A gain of electrons. /A decrease in oxidation number.
Oxidising agent	A substance that is reduced/gains electrons/whose oxidation number decreases.
Reducing agent	A substance that is oxidised/loses electrons/whose oxidation number increases.
Overall redox reaction	The reaction obtained by combining two half-reactions.
Overall cell reaction	The reaction obtained by combining two half-reactions.
Positive value of the standard emf	The reaction is spontaneous under standard conditions.

STRUCTURED QUESTIONS

QUESTION 1 *(November Exemplar)*

Redox reactions can be explained in terms of electron transfer as well as oxidation numbers. The unbalanced equations **A**, **B** and **C** below represent three redox reactions.

A: $Zn(s) + HC\ell(aq) \rightarrow ZnC\ell_2(aq) + H_2(g)$

B: $NiO(s) + CO(g) \rightarrow Ni(s) + CO_2(g)$

C: $Cu(s) + HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + NO(g) + H_2O(\ell)$

1.1 Define o*xidation* in terms of electron transfer. (2)

1.2 Write down the formula of the substance which is:

1.2.1 Oxidised in reaction **A** (1)

11.2.2 The reducing agent in reaction **B**
Explain the answer in terms of oxidation numbers. (3)

11.3 For reaction **C**, write down the balanced equation using the ion-electron method. Show the oxidation and reduction half-reactions during the balancing. (5)

[11]

QUESTION 2 *(November 2014)*

Nitric acid and copper reacts according to the following unbalanced equation:

$$HNO_3(aq) + Cu(s) \rightarrow Cu(NO_3)_2(aq) + NO_2(g) + H_2O(\ell)$$

2.1 Define *reduction* in terms of oxidation numbers. (2)

2.2 For this reaction, write down the FORMULA of the:

2.2.1 Substance that is oxidised (1)

2.2.2 Reducing agent
Allocate oxidation numbers to the relevant species and then explain the answer. (3)

2.2.3 Oxidising agent
Explain the answer in terms of electron transfer. (2)

2.3 Balance the equation using the ion-electron method. Show the oxidation and reduction half-reactions during the balancing. (5)

[13]

QUESTION 3 (*November 2015)*

3.1 Oxidation numbers make it easier to determine whether an element or a substance is oxidised or reduced during a chemical reaction.

3.1.1 Define the term *oxidation* with reference to oxidation numbers. (2)

3.1.2 Calculate the oxidation number of chromium in $Cr_2O_7^{2-}$. (1)

3.1.3 Calculate the oxidation number of oxygen in H_2O_2. (1)

3.2 Consider the UNBALANCED equation below:

$$Fe^{2+}(aq) + C\ell_2(g) \rightarrow Fe^{3+}(aq) + C\ell^-$$

3.2.1 Define the term *reducing agent* with reference to electron transfer. (2)

From the above equation, write down the:

3.2.2 FORMULA of the reducing agent (1)

3.2.3 FORMULA of the oxidising agent (1)

3.2.4 Reduction half-reaction (2)
3.2.5 Oxidation half-reaction (2)
3.2.6 Balanced net redox reaction (2)
[14]

QUESTION 4 *(November 2016)*

A silver Christmas tree can be made by placing copper wire, shaped in the form ofa tree, into a silver nitrate solution. The unbalanced equation for the reaction is:

$$Cu(s) + AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + Ag(s)$$

4.1 Define the term *oxidation* in terms of oxidation number. (2)
4.2 Write down the following for the reaction above:

4.2.1 Formula of the reducing agent (2)
4.2.2 Name of the oxidising agent (2)
4.2.3 Oxidation half-reaction (2)
4.2.4 Balanced net ionic equation using the ion-electron method (4)
4.3 Use oxidation numbers to explain your choice of oxidising agent in QUESTION 4.2.2. (2)
[14]

QUESTION 5 *(NOVEMBER 2017)*

The reaction between dichromate ions ($Cr_2O_7^{-2}$) and iron(II) ions (Fe^{2+}) in an acidic medium is given below.

$$Cr_2O_7^{-2}(aq) + Fe^{2+}(aq) + H^+(aq) \rightarrow Cr^{3+}(aq) + Fe^{3+}(aq) + H_2O(\ell)$$

5.1 Determine the oxidation number of CHROMIUM in $Cr_2O_7^{-2}$(aq). (2)
5.2 Define *reduction* in terms of electron transfer. (2)
5.3 Write down the FORMULA of the substance that undergoes oxidation. Explain the answer in terms of oxidation numbers. (2)
5.4 Write down the FORMULA of the oxidising agent. (2)
5.5 Write down the reduction half-reaction. (2)
5.6 Write down the net balanced ionic equation for the reaction, using the ion-electron method. (3)
[13]

QUESTION 6 *(November 2018)*

The reaction between permanganate ions (MnO_4^-) and hydrogen sulphide (H_2S) is given below.

$$MnO_4^-(aq) + H^+(aq) + H_2S(g) \rightarrow Mn^{2+}(aq) + S(s) + H_2O(\ell)$$

6.1 Define *reduction* in terms of oxidation numbers. (2)
6.2 Determine the oxidation number of manganese in the permanganate ion. (1)
6.3 Write down the FORMULA of the substance that undergoes oxidation. (1)
6.4 Explain the answer to QUESTION 9.3 in terms of oxidation numbers. (2)
6.5 Write down the FORMULA for the oxidising agent. (1)
6.6 Write down the oxidation half-reaction. (2)
6.7 Use the ion-electron method and write down the balanced net ionic equation. (3)
[12]

QUESTION 7 *(November 2019)*

The unbalanced equations for two redox reactions, in which SO_2 is involved, areshown below.

Reaction 1: $SO_2(g) + H_2S(g) \rightarrow S(s) + H_2O(\ell)$

Reaction 2: $SO_2(g) + KMnO_4(s) + H_2O(\ell) \rightarrow MnSO_4(aq) + K_2SO_4(aq) + H_2SO_4(aq)$

7.1 Explain what is meant by the term *redox reaction*. (2)

7.2 Write down the oxidation number of Mn in:

7.2.1 $KMnO_4$ (1)

7.2.2 $MnSO_4$ (1)

7.3 Is Mn in **Reaction 2** OXIDISED or REDUCED? Give a reason for the answer. (2)

7.4 In which reaction, **Reaction 1** or **Reaction 2**, does SO_2 act as an oxidising agent? Give a reason for the answer. (2)

7.5 Write down the oxidation half-reaction in **Reaction 1**. (2)

7.6 Use the Table of Standard Reduction Potentials and write down the balancednet ionic equation for **Reaction 1**. Show the half-reactions and how you arrived at the final equation. (4)

[14]