SECONDARY SCHOOL IMPROVEMENT PROGRAMME (SSIP) 2022

GAUTENG PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

GRADE 12

SUBJECT: PHYSICAL SCIENCES

LEARNER GUIDE

SESSION 5 TO 11

TERM 1

SESSION 05: ***NEWTON'S LAWS***

APLICATION OF NEWTON'S LAWS

- Define *normal force*, N, as 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.
- Define *frictional force*, f, as the force that opposes the motion of an object and which acts parallel to the surface.
- Define *static frictional force*, f_s, as the force that opposes the tendency of motion of a stationary object relative to a surface.
- Define *kinetic frictional force*, f_k, as the force that opposes the motion of a moving object relative to a surface.

Know that a frictional force:

- Is proportional to the normal force.
- Is independent of the area of contact.
- Is independent of the velocity of motion.

- **Newton's first law:** An object continues in a state of rest or uniform motion (motion with a constant velocity) unless it is acted on by an unbalanced (net or resultant) force.
  - $\vec{F}net = 0\vec{\ }$. OR $\Sigma\vec{F} = 0\vec{\ }$.
- **Newton's second law:** If a resultant force acts on a body, it will cause the body to accelerate in the direction of the resultant force. The acceleration of the body will be directly proportional to the resultant force and inversely proportional to the mass of the body. The mathematical representation is:
  - $\vec{F}net = m\vec{a}$. OR $\Sigma\vec{F} = m\vec{a}$.
- **Newton's third law:** If body A exerts a force on body B, then body B exerts a force of equal magnitude on body A, but in the opposite direction. We can express this.
  - as: $\vec{F}AB = -\vec{F}BA$.
- **Newton's law of universal gravitation**: Every point mass attracts every other point mass by a force directed along the line connecting the two. This force is proportional to the product of the masses and inversely proportional to the square of the distance between them.
- $F = \frac{Gm_1m_2}{r^2}$

Steps to solve problems of Newton's laws:

Step 1: Read the problem as many times as you need.
Step 2: Sketch the problem if it is necessary.
Step 3: Draw a force diagram for the situation.

Step 4: Draw a free-body diagram; you must resolve the forces into component on the Cartesian plane.

Step 5: List all the given information and converted to SI units if it is necessary.
Step 6: Determine which physical principle can solve the problem.
Step 7: Use the principle to solve the question, often by substituting numerical values into an appropriate equation.
Step 8: Check that the question has been answered and that the answer makes sense.

Multiple choice questions

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer.

1.1. Two identical metal spheres, each of mass m and separated by a distance r, exert a gravitational force of magnitude F on each other. The distance between the spheres is now HALVED.

The magnitude of the force the spheres now exerts on each other is:

A ½ F
B F
C 2 F
D 4 F

1.2. Which one of the following physical quantities is a measure of the inertia of a body?

A Mass
B Energy
C Velocity
D Acceleration

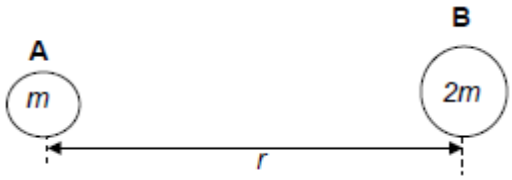
1.3. The magnitude of the gravitational force exerted by one body on another body is *F*. When the distance between the centres of the two bodies is doubled, the magnitude of the gravitational force, in terms of *F*, will now be …

A ¼ F
B ½ F
C 2 F
D 4 F

1.4. Which ONE of the following forces always acts perpendicular to the surface on which a body is placed?

A Normal force
B Frictional force
C Gravitational force
D Tension force

1.5. Two isolated bodies, **A** and **B**, having masses *m* and *2m* respectively, are placed a distance *r* apart.



Consider the following statements regarding the gravitational force exerted by the bodies on each other.

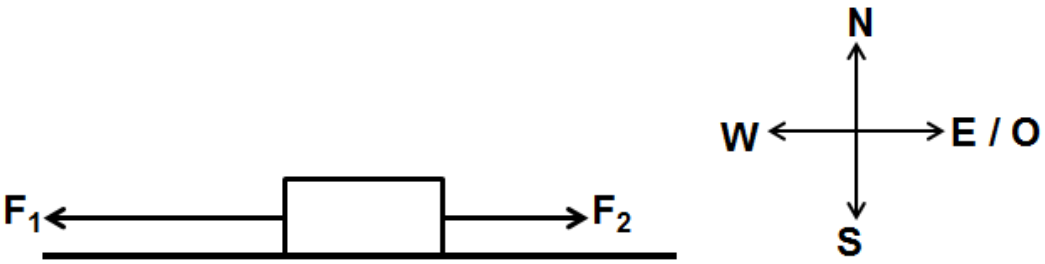
(i) The force exerted by **B** on body **A** is half that exerted by **A** on body **B**.
(ii) The force exerted on the bodies is independent of the masses of the bodies.
(iii) The force exerted on body **A** by **B** is equal but opposite to that exerted on body **B** on **A**.
(iv) The forces will always be attractive.

Which of the statements is/are TRUE?

A (i), (ii) and (iv) only
B (ii), (iii) and (iv) only
C (iii) and (iv) only
D (iv) only

1.6. Two forces, $\mathbf{F_1}$ and $\mathbf{F_2}$, are applied on a crate lying on a frictionless, horizontal surface, as shown in the diagram below.

The magnitude of force $\mathbf{F_1}$ is greater than that of force $\mathbf{F_2}$.



The crate will …

A accelerate towards the east.
B accelerates towards the west.
C move at a constant speed towards the east.
D move at a constant speed towards the west.

1.7. A person stands on a bathroom scale that is calibrated in newton, in a stationary elevator. The reading on the bathroom scale is W.

The elevator now moves with a constant upward acceleration of ¼ g, where g is the gravitational acceleration.

What will the reading on the bathroom scale be now?

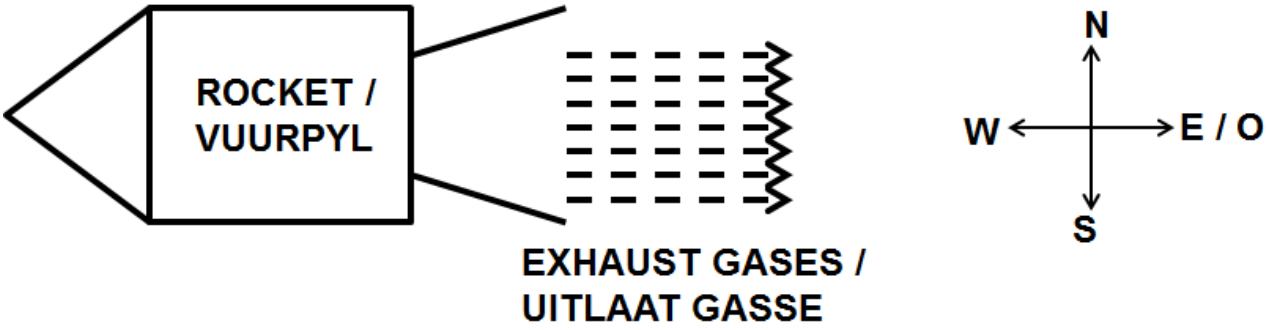
A $\frac{1}{4}$ W

B $\frac{3}{4}$W

C W

D $\frac{5}{4}$W

1.8. The simplified diagram below shows a rocket that has been fired horizontally, accelerating to the west.



Which ONE of the statements below best explains why the rocket accelerates?

A The speed of the exhaust gases is smaller than the speed of the rocket.
B The pressure of the atmosphere at the back of the rocket is less than at the front.
C The air outside the rocket exerts a greater force on the back of the rocket than at the front.
D The rocket pushes the exhaust gases to the east and the exhaust gases push the rocket to the west.

1.9. A net force F which acts on a body of mass m causes an acceleration a. If the same net force F is applied to a body of mass $2\,m$, the acceleration of the body will be …

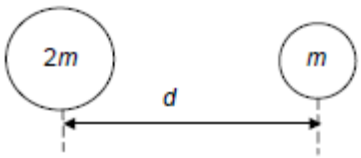
A $\frac{1}{4}a$

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

C $2a$

D $4a$

1.10. Two objects of masses $2m$ and m are arranged as shown in the diagram below.



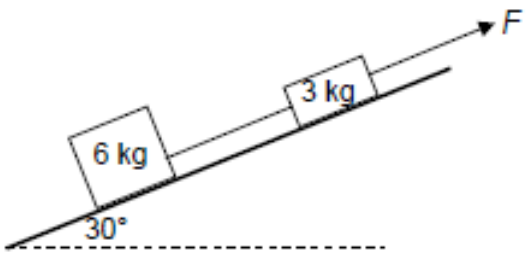
Which ONE of the changes below will produce the GREATEST increase in the gravitational force exerted by the one mass on the other?

A Double the larger mass.

B Halve the smaller mass.
C Double the distance between the masses.
D Halve the distance between the masses.

Question 2

A light inelastic string connects two objects of mass 6 kg and 3 kg respectively. They are pulled up an inclined plane that makes an angle of 30º with the horizontal, with a force of magnitude *F*. Ignore the mass of the string.



The coefficient of kinetic friction for the 3 kg object and the 6 kg object is 0,1 and 0,2 respectively.

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

2.2 How will the coefficient of kinetic friction be affected if the angle between the incline and the horizontal increases? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

2.3 Draw a labelled free-body diagram indicating all the forces acting on the 6 kg object as it moves up the inclined plane. (4)

2.4 Calculate the:

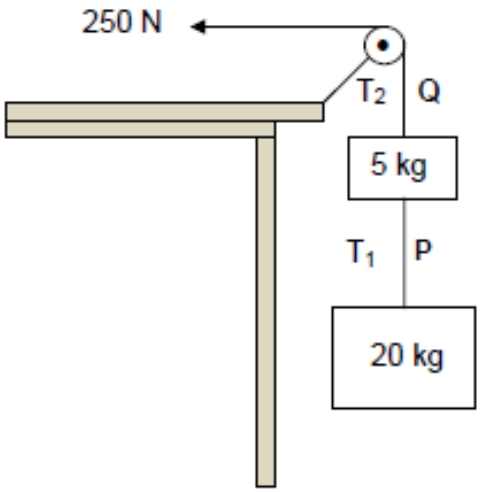
2.4.1 Tension in the string if the system accelerates up the inclined plane at 4 $m \cdot s^{-2}$. 5)

2.4.2 Magnitude of *F* if the system moves up the inclined plane at CONSTANT VELOCITY. (6)

2.5 How would the tension in the string, calculated in QUESTION 2.4.1, be affected if the system accelerates up a FRICTIONLESS inclined plane at 4 $m \cdot s^{-2}$? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)
[19]

Question 3

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 5 kg block, runs over a light frictionless pulley. A constant force of 250 N pulls the second string as shown in the diagram below. The magnitudes of the tensions in **P** and **Q** are $\mathbf{T_1}$ and $\mathbf{T_2}$ respectively. Ignore the effects of air friction.



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

3.2. Draw a labelled free-body diagram indicating ALL the forces acting on the **5 kg block**.

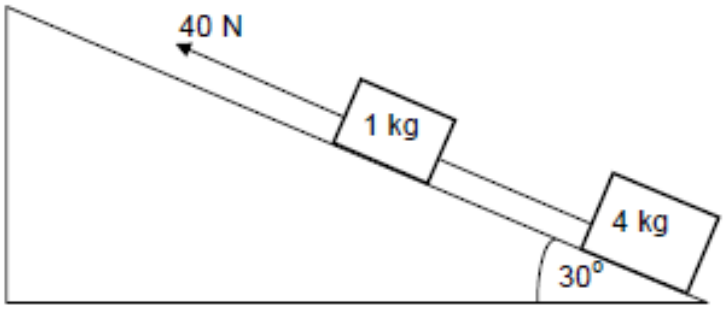
3.3. Calculate the magnitude of the tension $\mathbf{T_1}$ in string **P**. (6)

3.4. 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 4

A block of mass 1 kg is connected to another block of mass 4 kg by a light inextensible string. The system is pulled up a rough plane inclined at 30º 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.

1.1. State Newton's third law in words. (2)

1.2. Draw a labelled free-body diagram showing ALL forces acting on the **1 kg block** as it moves up the incline. (5)

1.3. Calculate the magnitude of the:

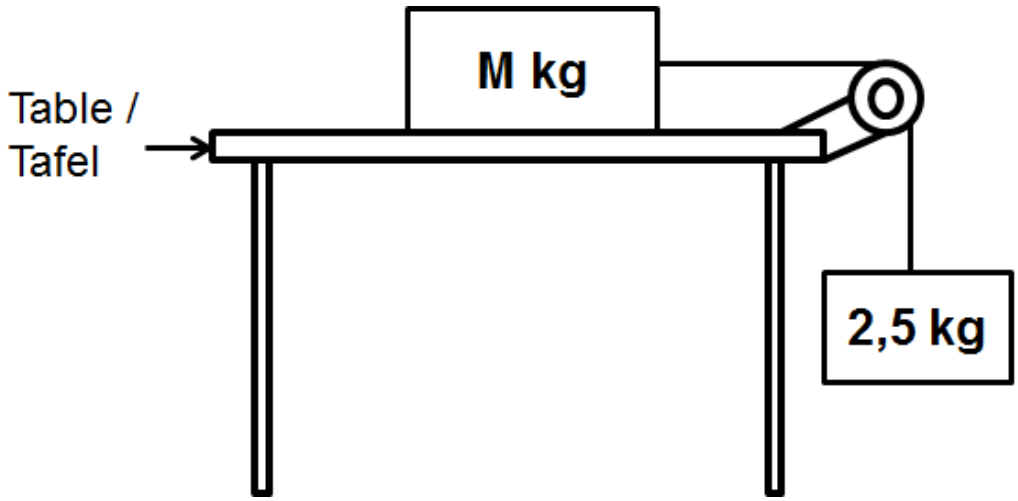
1.3.1. Kinetic frictional force between the **1 kg block** and the surface. (3)

1.3.2. Tension in the string connecting the two blocks. (6)

Question 5

1.1. 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**.



1.1.1. State Newton's THIRD law in words. (2)

1.1.2. 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.

1.1.3. 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.

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

1.2. A small hypothetical planet X has a mass of $6{,}5 \times 10^{20}$ 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]

Session 06

Momentum and Impulse

Momentum

- Define *momentum* as the product of an object's mass and its velocity.
- Describe the *linear momentum* of an object as a vector quantity with the same direction as the velocity of the object.
- Calculate the momentum of a moving object using p = mv.
- Describe the *vector nature of momentum* and illustrate it with some simple examples.
- Draw vector diagrams to illustrate the relationship between the initial momentum, the final momentum and the change in momentum for each of the above examples.

Newton's second law of motion in terms of momentum

- State Newton's second law of motion in terms of momentum: The resultant/net force acting on an object is equal to the rate of change of momentum of the object in the direction of the resultant/net force.
- Express Newton's second law of motion in symbols: $F_{net} = \frac{\Delta p}{\Delta t}$

- Calculate the change in momentum when a resultant/net force acts on an object and its velocity:

  - Increases in the direction of motion, e.g. 2nd stage rocket engine fires
  - Decreases, e.g. brakes are applied
  - Reverses its direction of motion, e.g. a soccer ball kicked back in the direction it came from

Impulse

- Define *impulse* as the product of the resultant/net force acting on an object and the time the resultant/net force acts on the object.
- Deduce the impulse-momentum theorem: $F_{net}\Delta t = m\Delta v$.
- Use the impulse-momentum theorem to calculate the force exerted, the time for which the force is applied and the change in momentum for a variety of situations involving the motion of an object in one dimension.
- Explain how the concept of impulse applies to safety considerations in everyday life, e.g. airbags, seatbelts and arrestor beds.

Conservation of momentum and elastic and inelastic collisions

- Explain what is meant by *a closed/an isolated system* (in Physics), i.e. a system on which the resultant/net external force is zero.

- A closed/an isolated system exclude external forces that originate outside the colliding bodies, e.g. friction. Only internal forces, e.g. contact forces between the colliding objects, are considered.

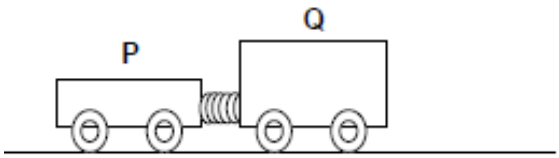
- State the principle of conservation of linear momentum: The total linear momentum of a closed system remains constant (is conserved).
- Apply the conservation of momentum to the collision of two objects moving in one dimension (along a straight line) with the aid of an appropriate sign convention.

- Distinguish between *elastic collisions* and *inelastic collisions* by calculation.

Question 1
Multiple choice questions

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer.

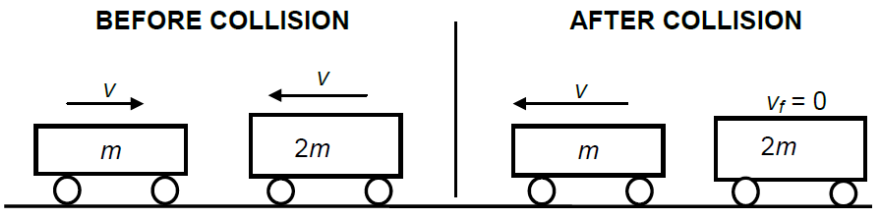
1.1. Two trolleys, P and Q, of mass *m* and *2m* respectively are at rest on a frictionless horizontal surface. The trolleys have a compressed spring between them.



The spring is released and the trolleys move apart. Which ONE of the following statements is TRUE?

A **P** and **Q** have equal kinetic energies.
B The speed of **P** is less than the speed of **Q**.
C The sum of the kinetic energies of **P** and **Q** is zero.
D The sum of the final momentum of **P** and **Q** ia zero.

1.2. An object of mass *m* moving at constant velocity *v* collides head-on with an object of mass *2m* moving in the opposite direction at velocity *v* in the opposite direction and the larger mass is brought to rest. Refer to the diagram below.



Ignore the effects of friction.

Which ONE of the following is CORRECT?

	MOMENTUM	MECHANICAL ENERGY
A	Conserved	Conserved
B	Not Conserved	Conserved
C	Conserved	Not Conserved
D	Not Conserved	Not Conserved

1.3. Two bodies undergo an INELASTIC collision in the absence of friction. Which ONE of the following combinations of momentum and kinetic energy of the system is CORRECT?

	MOMENTUM	KINETIC ENERGY
A	Not Conserved	Conserved
B	Conserved	Not Conserved

C	Not Conserved	Not Conserved
D	Conserved	Conserved

1.4. Airbags in modern cars provide more safety during an accident.
The statements below are made by a learner to explain how airbags can ensure better safety in a collision.

(i) The time of impact increases.
(ii) The impact force decreases.
(iii) The Impulse increases.

A (i) only
B (ii) only
C (ii) and (iii) only
D (i) and (ii) only

[4 × 2 = 8]

Questions 2-6 is possible examples of question 4 from final exam papers on Momentum and Impulse.

Question 2

Two boys, each of mass *m*, are standing at the back of a flatbed trolley of mass *4m*. The trolley is as at rest on a frictionless horizontal surface.

The boys jump of simultaneously at one end of the trolley with a horizontal velocity of $2 m \cdot s^{-1}$. The trolley moves in the opposite direction.

2.1. Write down the *principle of conservation of linear momentum* in words. (2)

2.2. Calculate the final velocity of the trolley. (5)

2.3. The two boys jump of the trolley one at a time. How will the velocity of the trolley compare to that calculated in QUESTION 2.2? Write down only GREATER THAN, SMALLER THAN or EQUAL TO. (1)

[8]

Question 3

Dancers have to learn many skills, including how to land correctly. A dancer of mass 50 kg leaps into the air and lands feet first on the ground. She lands on the ground with a velocity of $5 m \cdot s^{-1}$. As she lands, she bends her knees and comes to a complete stop in 0,2 seconds.

3.1 Calculate the momentum with which the dancer reaches the ground. (3)

3.2 Define the term *Impulse* of a force. (2)

3.3 Calculate the magnitude of the net force acting on the dancer as she lands. (3)

Assume that the dancer performs the same jump as before but lands without bending her knees.

3.4 Will the force now be GREATER THAN, SMALLER THAN or EQUAL TO the force calculated in QUESTION 3.3? (1)

3.5 Give a reason for the answer to QUESTION 3.4. (3)

[12]

Question 4

A bullet of mass 20 g is fired from a stationary rifle of mass 3 kg. Assume that the bullet moves horizontally. Immediately after firing, the rifle recoils (moves back) with a velocity of 1,4 $m \cdot s^{-1}$.

4.1 Calculate the speed at which the bullet leaves the rifle. (4)

The bullet strikes a stationary 5 kg wooden block **fixed** to a flat, horizontal table. The bullet is brought to rest after travelling a distance of 0,4 m **into the block**. Refer to the diagram below.

4.2 Calculate the magnitude of the average force exerted by the block on the bullet. (5)

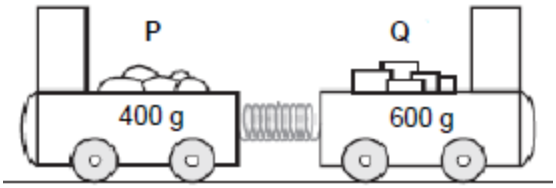
4.3 How does the magnitude of the force calculated in QUESTION 4.2 compare to the magnitude of the force exerted by the bullet on the block? Write down only LARGER THAN, SMALLER THAN or THE SAME.

(1)

[10]

Question 5

The diagram below shows two trolleys, P and Q, held together by means of a compressed spring on a flat, frictionless horizontal track. The masses of P and Q are $400\ g$ and $600\ g$ respectively.



When the trolleys are released, it takes $0{,}3\ s$ for for the spring to unwind to its natural length. Trolley Q then moves to the right at $4\ m \cdot s^{-1}$.

5.1 State the *principle of conservation of linear momentum* in words. (2)

5.2 Calculate the:

5.2.1 Velocity of trolley P after the trolleys is released. (4)

5.2.2 Magnitude of average force exerted by the spring on trolley Q. (4)

5.3 Is this an elastic collision? Only answer YES or NO. (1)

[11]

Session 07

Vertical Projectile Motion in One Dimension (1D)

- Explain what is meant by a *projectile*, i.e. an object upon which the only force acting is the force of gravity.
- Use equations of motion to determine the position, velocity and displacement of a projectile at any given time.
- Sketch position versus time (x vs. t), velocity versus time (v vs. t) and acceleration versus time (a vs. t) graphs for:
  - A free-falling object
  - An object thrown vertically upwards.
  - An object thrown vertically downwards.
  - Bouncing objects (restricted to balls)
- For a given x vs. t, v vs. t or a vs. t graph, determine:
  - Position
  - Displacement
  - Velocity or acceleration at any time t
- For a given x vs. t, v vs. t or a vs. t graph, describe the motion of the object: o Bouncing.
  - Thrown vertically upwards.
  - Thrown vertically downward.

Question 1
Multiple choice questions

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer.

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1.1. A ball is thrown vertically upwards. Which ONE of the following physical quantities has a non-zero value at the instant the ball changes direction?

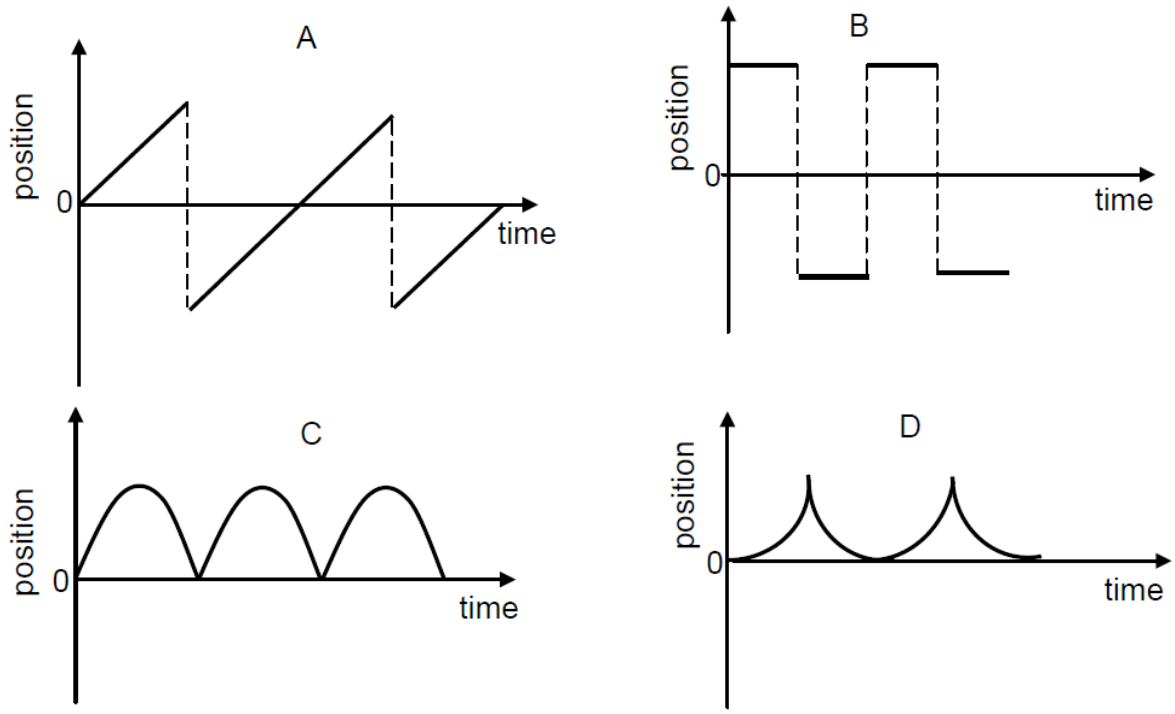
A Acceleration
B Kinetic energy
C Momentum
D Velocity

1.2. An object is thrown vertically upwards. Which ONE of the following regarding the object's velocity and acceleration at the highest point of its motion is CORRECT? Ignore the effects of friction.

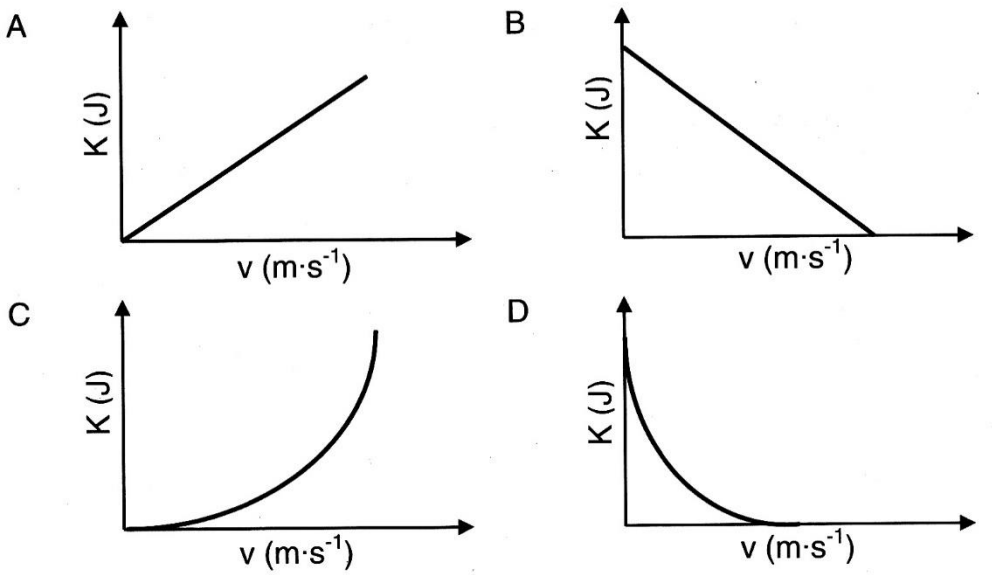
	VELOCITY	ACCELERATION
A	Zero	Zero
B	Zero	Upwards
C	Maximum	Zero
D	Zero	Downwards

1.3. A ball is released from a height above the floor. The ball falls vertically and bounces off the floor a number of times. Ignore the effects of friction and assume that the collision of the ball with the floor is elastic. Take the point of release of the ball as the reference point and downward direction as positive.

Which ONE of the following is a CORRECT representation of the position-time graph for the motion of the ball?



1.4. Which ONE of the graphs below correctly represents the relationship between the kinetic energy (K) of a free-falling object and its speed (v)?



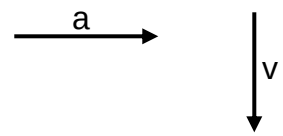
1.5. The statements below describe the motion of objects.

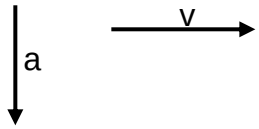
(i) A feather falls from a certain height inside a vacuum tube.
(ii) A box slides along a smooth horizontal surface at constant speed.
(iii) A steel ball falls through air in the absence of air friction.

Which of the following describes UNIFORMLY ACCELERATED motion CORRECTLY?

A (i) and (ii) only
B (i) and (iii) only
C (ii) and (iii) only
D (i), (ii) and (iii)

1.6 Which ONE of the diagrams BEST represents the acceleration (**a**), and velocity (**v**) for an object moving **upwards** in the absence of air resistance?

A


B


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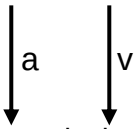

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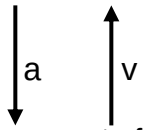
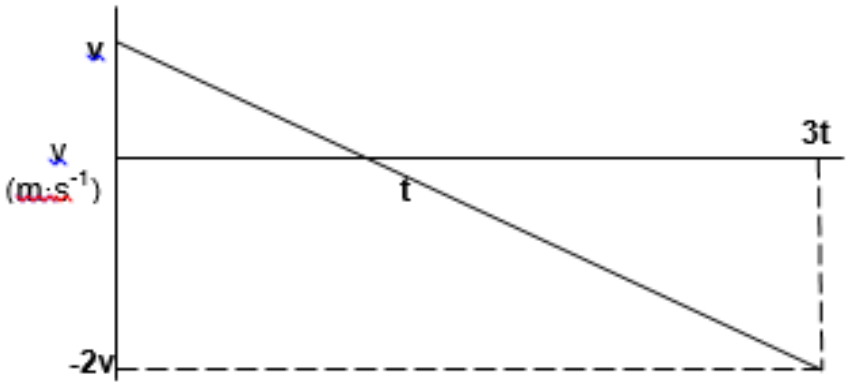


1.7 The velocity versus-time graph below represents the movement of an object that is initially projected vertically upward. Ignore the effects of friction.



The maximum height that the object reaches above the projection point is given by…

A $\frac{1}{2}$**vt**
B Zero
C -2**vt**
D $\frac{2}{3}$**vt**

1.8 A ball is thrown vertically upwards. Which ONE of the following quantities will be zero when it reaches maximum height?

A Acceleration

B Kinetic energy

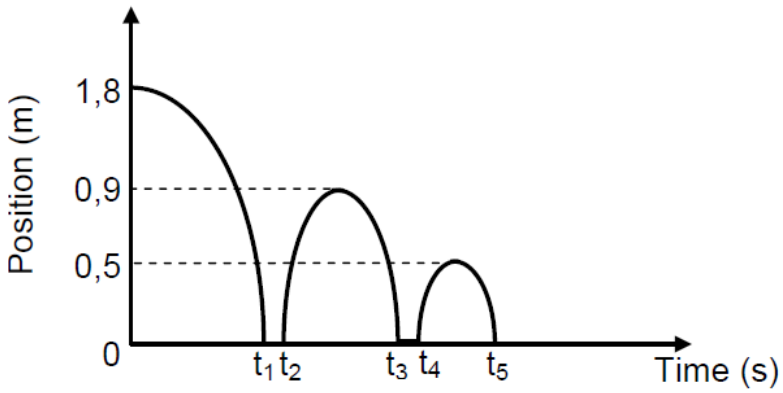
C Gravitational potential energy

D Gravitational force

STRUCTURED QUESTIONS (VPM)

Question 2

A ball of mass 0,5 kg is projected vertically downwards towards the ground from a height of 1,8 m at a velocity of 2 $m \cdot s^{-1}$. The position-time graph for the motion of the ball is shown below.



2.1. What is the maximum vertical height reached by the ball after the second bounce?(1)

Calculate the:

2.2. Magnitude of the time t_1 indicated on the graph. (5)

2.3. Velocity with which the ball rebounds from the ground during the first bounce. (4)

The ball is in contact with the ground for 0,2 s during the first bounce.

2.4. Calculate the magnitude of the force exerted by the ground on the ball during the first bounce if the ball strikes the ground at 6,27 $m \cdot s^{-1}$. (4)

2.5. Draw a velocity-time graph for the motion of the ball from the time that it is projected to the time when it rebounds to a height of 0.9 m.

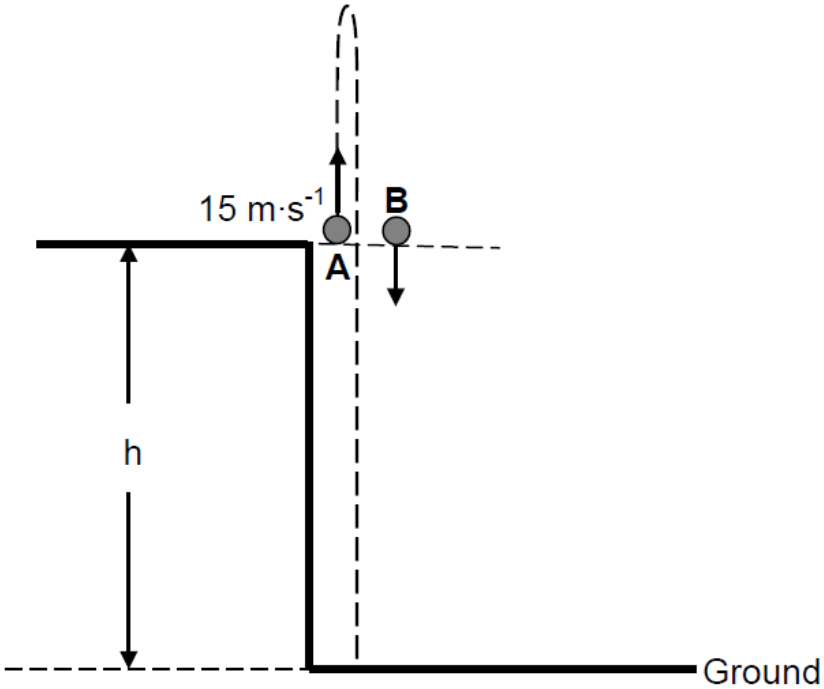
Clearly show the following on your graph:

- The time when the ball hits the ground.
- The velocity of the ball when it hits the ground.
- The velocity of the ball when it rebounds from the ground (3)

Question 3

A ball, A, is thrown vertically upward from a height, h, with a speed of 15 $m \cdot s^{-1}$. AT THE SAME INSTANT, a second identical ball, B, is dropped from the same height as ball A as shown in the diagram below.

Both balls undergo free fall and eventually hit the ground.



3.1 Explain the term *free fall*. (2)

3.2 Calculate the time it takes for ball A to return to its starting point. (4)

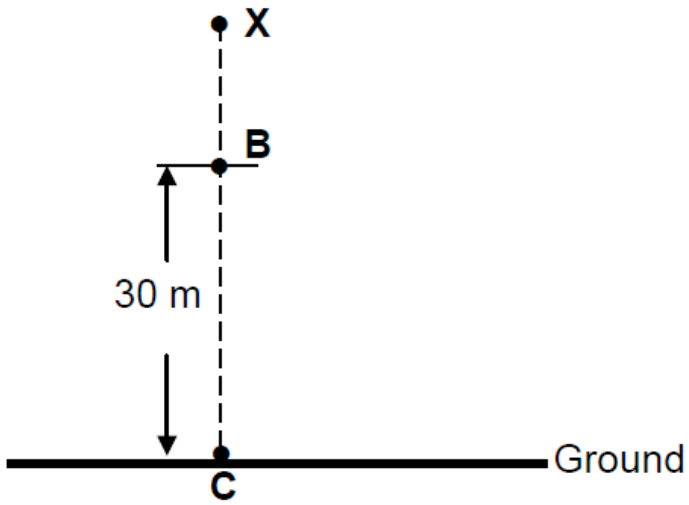
3.3 Calculate the distance between ball A and ball B when ball A is at its maximum height. (7)

3.4 Sketch a velocity-time graph for the motion of ball A from the time it is projected until it hits the ground.
Clearly show the following on your graph:

- The initial velocity
- The time it takes to reach its maximum height
- The time it takes to return to its starting point (4)

Question 4

An object is released from rest from a point X, above the ground as shown in the diagram below. It travels the last 30 m (BC) in 1,5 s before hitting the ground. Ignore the effects of air friction.



4.1 Name the type of motion described above. (1)

4.2 Calculate the:

4.2.1 Magnitude of the velocity of the object at point B. (4)

4.2.2 Height of point X above the ground. (5)

After hitting the ground, the object bounces once and then comes to rest on the ground.

4.3 Sketch an acceleration time graph for the entire motion of the object. (3)

[13]

Question 5

Ball **A** is projected vertically upwards at a velocity of 16 $m \cdot s^{-1}$ from the ground. Ignore the effects of air resistance. **Use the ground as zero reference.**

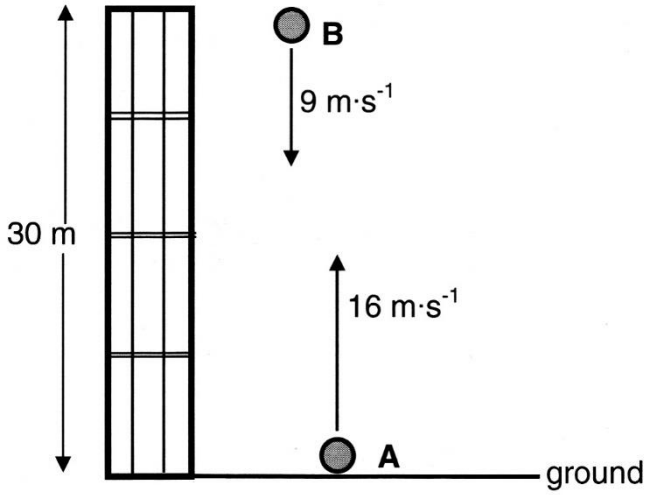
5.1 Calculate the time taken by ball **A** to return to the ground. (4)

5.2 Sketch a velocity-time graph for ball **A**.

Show the following on the graph:

(a) Initial velocity of ball **A**
(b) Time taken to reach the highest point of the motion
(c) Time taken to return to the ground (3)

ONE SECOND after ball **A** is projected upwards, a second ball, **B**, is thrown vertically downwards at a velocity of 9 $m \cdot s^{-1}$ from a balcony 30 m above the ground. Refer to the diagram below.



5.3 Calculate how high above the ground ball **A** will be at the instant the two balls pass each other. (6)

[13]

Question 6

A man throws ball **A** downwards with a speed of $2\ m \cdot s^{-1}$ from the edge of a window, $45\ m$ above a dam of water. One second later he throws a second ball, ball **B**, downwards and observes that both balls strike the surface of the water in the dam at the same time. Ignore air friction.

6.1 Calculate the:

6.1.1 Speed with which ball **A** hits the surface of the water. (3)

6.1.2 Time it takes for ball **B** to hit the surface of the water. (3)

6.1.3 Initial velocity of ball **B**. (5)

6.2 On the same set of axes, sketch a velocity versus time graph for the motion of balls **A** and **B**. Clearly indicate the following on your graph:

- Initial velocities of both balls **A** and **B**.
- The time of release of ball **B**.
- The time taken by both balls to hit the surface of the water. (5)

[16]

SESSION 08

Electrostatics

Coulomb's law

- State Coulomb's law: The magnitude of the electrostatic force exerted by one point charge (Q_1) on another point charge (Q_2) is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them:
- Solve problems using the equation $F = \frac{kQ_1Q_2}{r^2}$ for charges in one dimension (1D) (restrict to three charges).
- Solve problems using the equation $F = \frac{kQ_1Q_2}{r^2}$ for charges in two dimensions (2D) – for three charges in a right-angled formation (limit to charges at the 'vertices of a right- angled triangle').

Electric field

- Describe an *electric field* as a region of space in which an electric charge experiences a force. The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point.
- Draw electric field patterns for the following configurations:
  - A single point charges.
  - Two-point charges (one negative, one positive OR both positive OR both negative)
  - A charged sphere

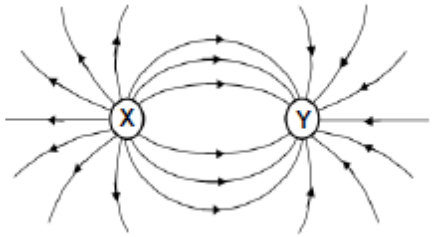
  NOTE: Restrict to situations in which the charges are identical in magnitude.

- Define the *electric field at a point*: The electric field at a point is the electrostatic force experienced per unit positive charge placed at that point. In symbols: $E = \frac{F}{q}$
- Solve problems using the equation. $E = \frac{F}{q}$
- Calculate the electric field at a point due to a number of point charges, using the equation to determine the contribution to the field due to each charge. Restrict to three charges in a straight line. $E = \frac{kQ}{r^2}$

Question 1
Multiple choice questions

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer.

1.1. The diagram below shows the electric field pattern due to two point charges **X** and **Y**.



Which ONE of the following represents the charge on **X** and **Y** respectively?

	POINT CHARGE X	POINT CHARGE Y
A	Negative	Negative
B	Positive	Positive
C	Positive	Negative
D	Negative	Positive

1.2. Two charges of + 2 nC and - 2 nC are located on a straight line. **S** and **T** are two points that lie on the same straight line as shown in the diagram below.

Which ONE of the following correctly represents the directions of the RESULTANT electric fields at **S** and at **T**?

	DIRECTION OF THE RESULTANT ELECTRIC FIELD AT POINT S	DIRECTION OF THE RESULTANT ELECTRIC FIELD AT POINT T
A	Right	Left
B	Left	Left
C	Right	Right
D	Left	Right

1.3. The magnitude of an electric field, a distance *r* from a point charge is ***E***. The magnitude of an electric field, a distance 2*r* from the same point charge will be …

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

1.4. Two charged spheres of magnitudes 2Q and Q respectively are placed a distance r apart on insulating stands.

If the sphere of charge Q experiences a force **F** to the east, then the sphere of charge 2Q will experience a force …

A F to the west
B F to the east
C 2F to the west
D 2F to the east

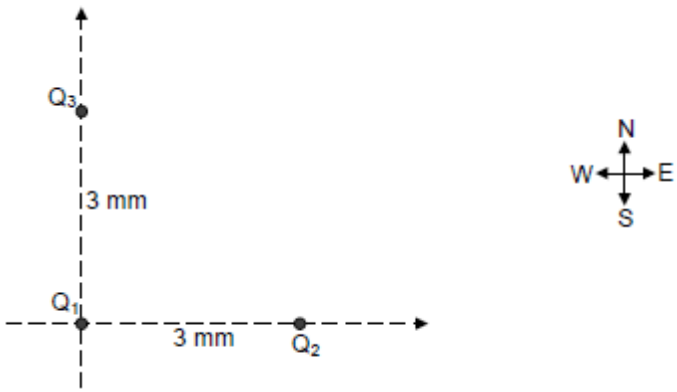
1.5. P, Q and R are three charged spheres. When P and Q are brought near each other, they experience an attractive force. When Q and R are brought near each other, they experience a repulsive force.

Which ONE of the following is TRUE?

A P and R have charges with the same sign.
B P and R have charges with opposite signs.
C P, Q and R have charges with the same sign.
D P, Q and R have equal charges.

Question 2

Three small, identical metal spheres, Q_1, Q_2 and Q_3, are placed in a vacuum. Each sphere carries a charge of – 4 µC. The spheres are arranged such that Q_2 and Q_3 are each 3 mm from Q_1 as shown in the diagram below.



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

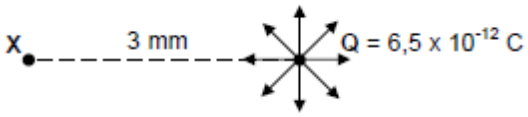
2.2 Draw a force diagram showing the electrostatic forces exerted on Q_1 by Q_2 and Q_3. (2)

2.3 Calculate the net force exerted on Q_1 by Q_2 and Q_3. (8)

[12]

Question 3

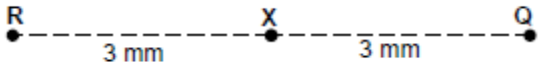
An isolated point charge **Q** is located in space as shown in the diagram below. Point charge **Q** contributes to an electric field as shown. Point **X** is located 3 mm away from point charge **Q**.

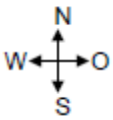


3.1 Define the term *electric field* at a point. (2)

3.2 Calculate the magnitude of the electric field at point X. (3)

3.3 Point charge R carrying a charge of + 6,5 x 10^{-12} C is placed 3 mm away from point **X** as shown in the diagram below.

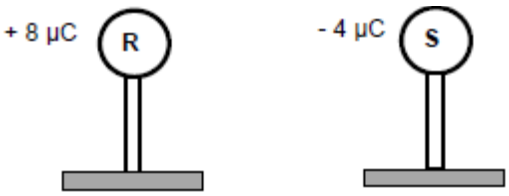




Calculate the net electric field at point X. (4)
[9]

Question 4

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



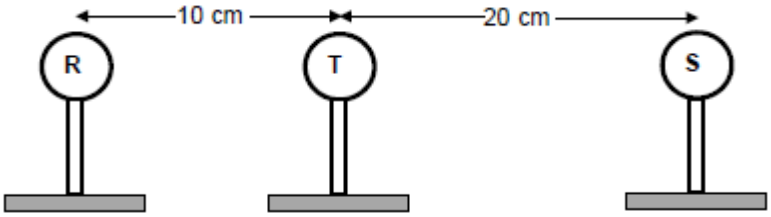
4.1Explain why the spheres were placed on wooden stands. (1)

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

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

4.3 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.



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

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

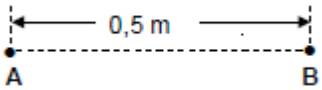
4.6 Define the *electric field at a point*. (2)

4.7 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 5

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.



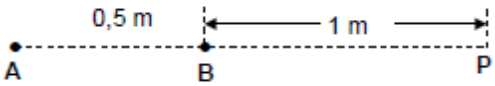
5.1 State Coulomb's law in words. (2)

5.2 Calculate the:

5.2.1 Magnitude of the charge on each sphere. (4)

5.2.2 Excess number of electrons on sphere B (3)

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



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

5.3.2 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)

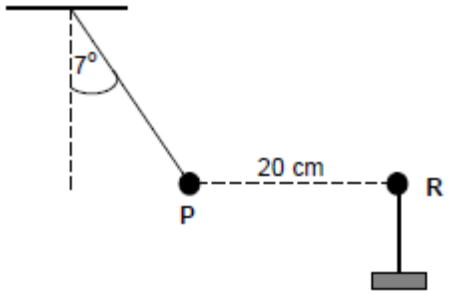
[18]

Question 6

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.

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

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



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

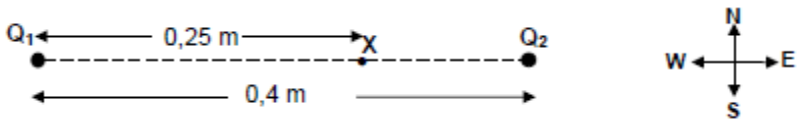
6.3 State Coulomb's law in words. (2)

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

[13]

Question 7

Two charged particles, Q_1 and 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:

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

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

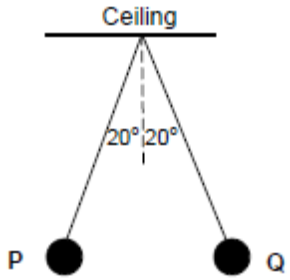
The – 2 x 10^{-9} C charge is replaced with a charge of – 4 x 10^{-9} C at point X.

7.3 **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 8

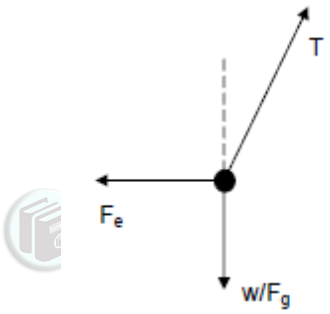
Two identical spherical balls, **P** and **Q**, each of mass 100 g, are suspended at the same point from a ceiling by means of identical light, inextensible insulating strings. Each ball carries a charge of +250 nC. The balls come to rest in the positions shown in the diagram below.



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

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

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



Calculate the:

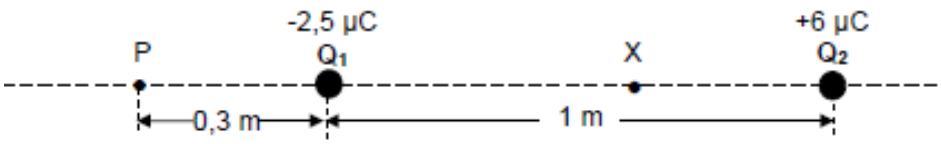
8.3.1 Magnitude of the tension (T) in the string. (3)

8.3.2 Distance between balls **P** and **Q.** (5)

[11]

Question 9

A sphere 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 Q_2. The diagram is not drawn to scale.



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

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

(6)

[10]

SESSION 10

Electric Circuits

Ohm's law

- State Ohm's law in words: The potential difference across a conductor is directly proportional to the current in the conductor at constant temperature.
- Determine the relationship between current, potential difference and resistance at constant temperature using a simple circuit.
- State the difference between *ohmic conductors* and *non-ohmic conductors* and give an example of each.
- Solve problems using $R = \frac{V}{I}$ for series and parallel circuits (maximum four resistors).

Power, energy

- Define *power* as the rate at which work is done.
- Solve problems using $P = \frac{W}{\Delta t}$.
- Solve problems using $P = VI$, $P = I^2R$, of $P = \frac{V^2}{R}$.
- Solve circuit problems involving the concepts of power and electrical energy.
- Deduce that the kilowatt hour (kWh) refers to the use of 1 kilowatt of electricity for 1 hour.
- Calculate the cost of electricity usage given the power specifications of the appliances used, the duration and the cost of 1 kWh.

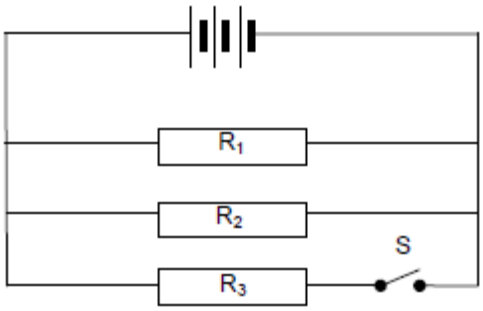
Internal resistance, series and parallel networks

- Solve problems involving current, voltage and resistance for circuits containing arrangements of resistors in series and in parallel (maximum four resistors).
- Explain the term *internal resistance*.
- Solve circuit problems using $\varepsilon = V_{load} + V_{internal\ resistance}$ or $\varepsilon = IR_{ext} + Ir$.
- Solve circuit problems, with internal resistance, involving series-parallel networks of resistors (maximum four resistors).

Question 1
Multiple choice questions

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer.

1.1. Consider the circuit diagram below.

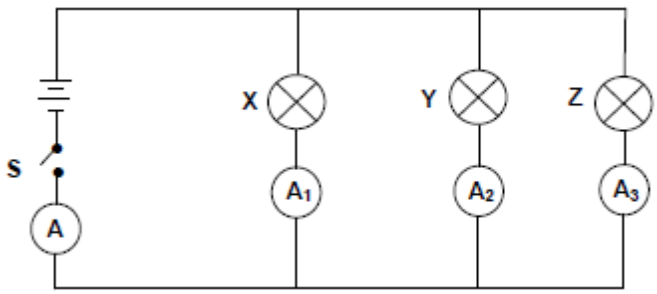


Which ONE of the following correctly describes the change in total resistance and total current when switch **S** is closed?

	TOTAL RESISTANCE	TOTAL CURRENT
A	Decrease	Decrease
B	Increase	Increase
C	Decrease	Increase
D	Increase	Decrease

1.2. Three light bulbs, **X**, **Y** and **Z** with resistances *R*, 2*R* and *R* respectively, are connected in a circuit as shown below. The battery has negligible internal resistance.

When switch **S is closed**, all the bulbs light up. The reading on ammeter **A** is 2,5 A.

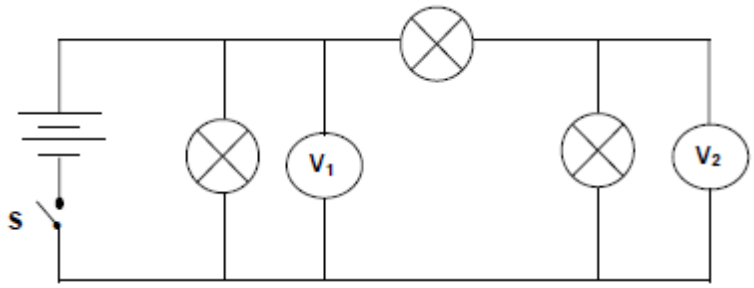


Which ONE of the following correctly describes the readings on the ammeters (in amperes) when bulb **Z** burns out?

	A_1	A_2	A_3	A
A	1,25	1,25	0	2,5
B	1,6	0,8	0,1	2,5

C	0,75	0,75	0	1,5
D	1	0,5	0	1,5

1.3. Three identical light bulbs are connected in a circuit as shown below. The resistances of the battery and connecting wires can be ignored.

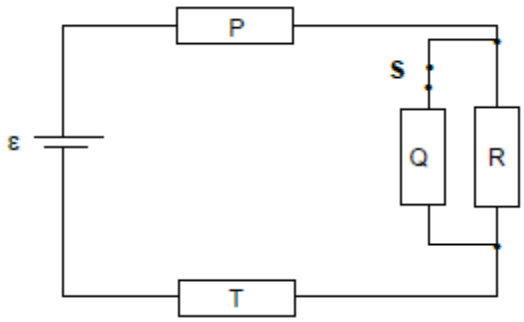


Which ONE of the following statements is CORRECT when switch **S** is closed?

The reading on V_1 is …

A half that on $\mathbf{V_2}$
B equal to that on $\mathbf{V_2b}$
C twice that on $\mathbf{V_2}$
D three times that on $\mathbf{V_2}$

1.4. The four resistors **P**, **Q**, **R** and **T** in the circuit below are identical. The cell has an emf ε and negligible internal resistance. The switch is initially CLOSED.



Switch **S** is now OPENED. Which ONE of the following combinations of changes will occur in **P**, **R** and **T**?

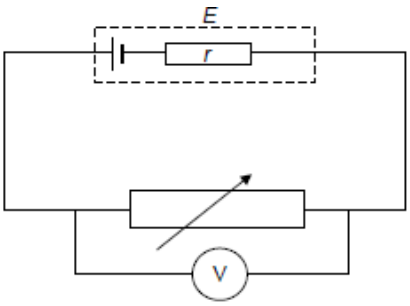
	CURRENT IN P	CURRENT IN R	CURRENT IN T
A	Decreases	Remains the same	Decreases
B	Increases	Remains the same	Increases
C	Increases	Increases	Increases
D	Decreases	Increases	Decreases

1.5. The minimum value of the resistance that can be obtained by connecting two 4 Ω resistors is …

A 1 Ω
B 2 Ω
C 3 Ω
D 8 Ω

Question 2

2.1. In an experiment, learners use the circuit below to determine the internal resistance of a cell.

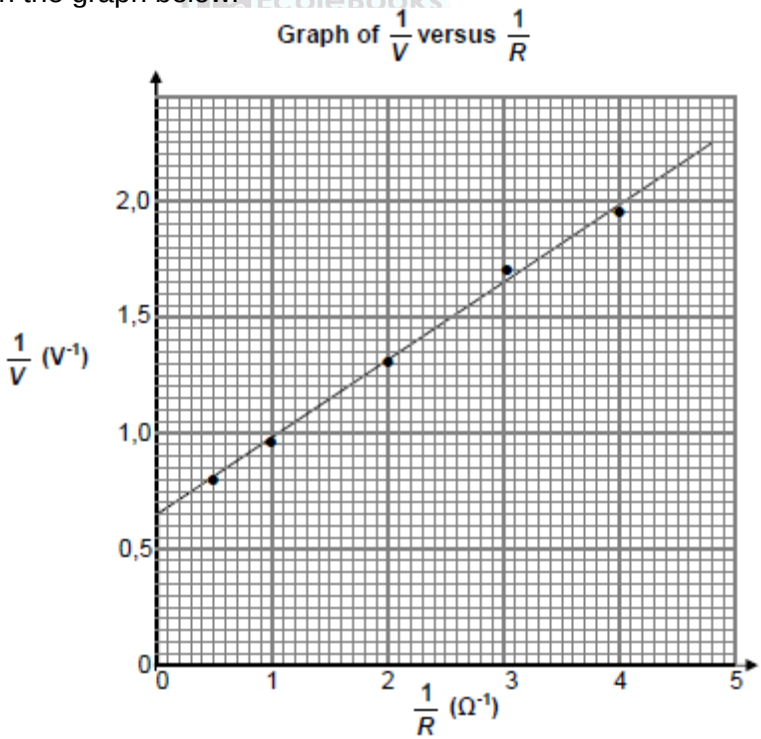


The circuit consists of a cell of emf *E* and internal resistance *r*. A voltmeter is placed across a variable resistor which can be set to *known values* R.

The equation used by the learners is:

$$\frac{1}{V} = \frac{1}{ER} + \frac{1}{E}$$

They obtain the graph below.



2.1.1. Write down a mathematical relationship for the slope of the graph.

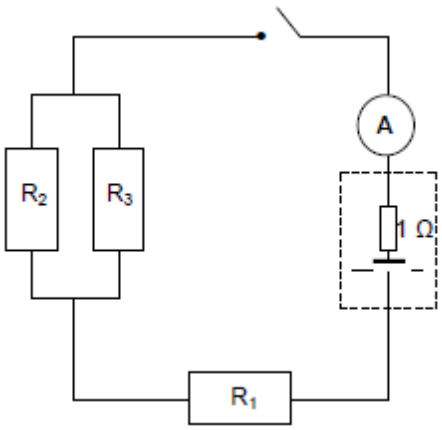
(1)

Use the information in the graph and calculate the:

2.1.2. Emf of the cell. (2)

2.1.3. Internal resistance of the cell. (3)

2.2. In the electrical circuit shown below, the battery has an emf of 6 V and an internal resistance of 1 Ω. The total external resistance of the circuit is 9 Ω.



2.2.1. Calculate the current in R_1 when the switch is closed. (3)

The power dissipated in resistor R_1 is 1,8 W. The resistance of resistor R_3 is 4 times that of resistor R_2. ($R_3 = 4R_2$)

2.2.2. Calculate the resistance of resistor R_2. (5)

2.3. A hair dryer operates at a potential difference of 240 V and a current of 9,5 A.

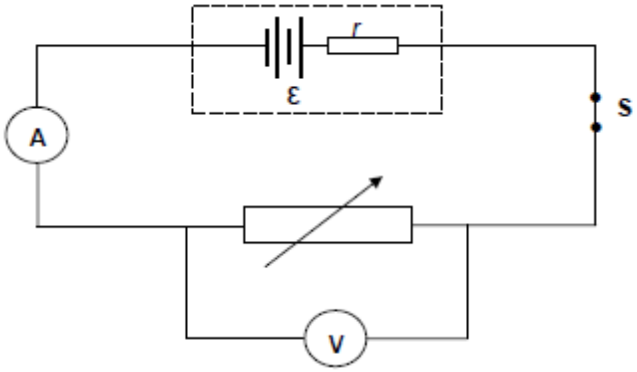
It takes a learner 12 minutes to completely dry her hair. Eskom charges energy usage at R1,47 per unit. Calculate the cost of operating the hairdryer for the 12 minutes. (1 unit = 1 kW·h)

(4)

[18]

Question 3

3.1 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 (V)
2	0,58
3	0,46
4	0,36
5	0,24
6	0,14

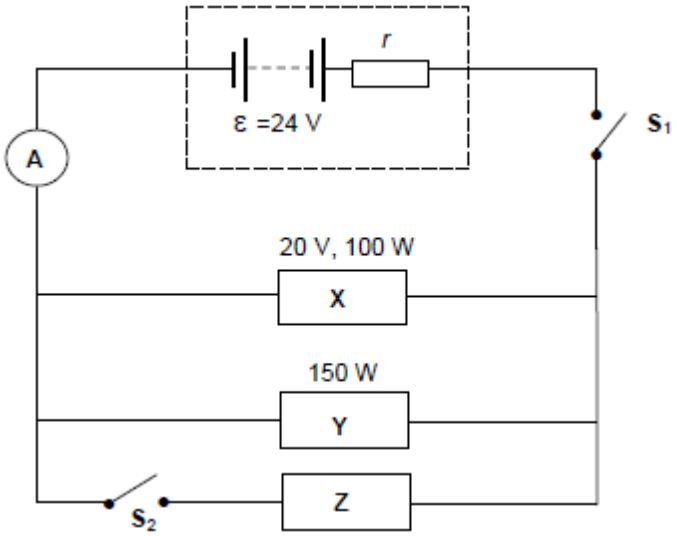
3.1.1 State ONE factor which must be kept constant during the experiment. (1)

3.1.2 Using the information in the table above, plot the points and draw the line of best fit on the attached GRAPH SHEET. (3)
Use the graph drawn in QUESTION 3.1.2 to determine the following:

3.1.3 Emf (ε) of the battery. (1)

3.1.4 Internal resistance of the battery, WITHOUT USING ANY FORM OF THE EQUATION ε = I(R + r). (3)

3.2 Three electrical devices, **X**, **Y** and **Z**, are connected to a 24 V battery with internal resistance *r* as shown in the circuit diagram below. 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:

3.2.1 Current in **X**. (3)

3.2.2 Resistance of **Y**. (3)

3.2.3 Internal resistance of the battery. (5)

Now switch S_2 is also closed.

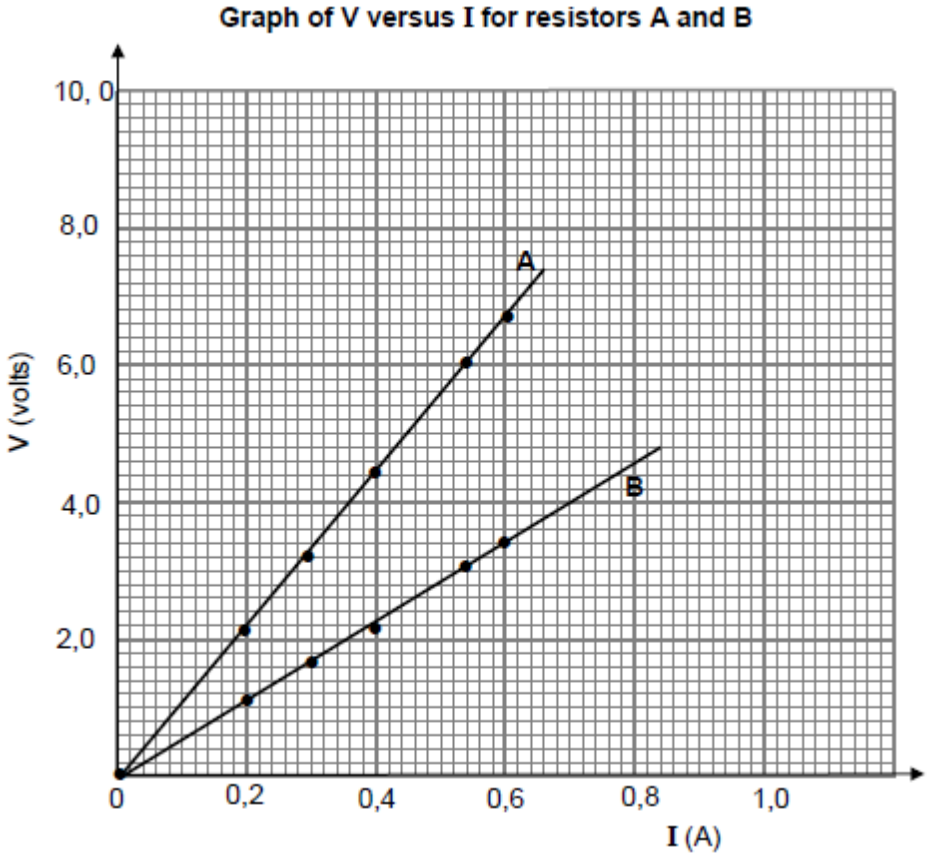
3.2.4 Identify device **Z** which, when placed in the position shown, can still enable **X** and **Y** to operate as rated. Assume that the resistances of all the devices remain unchanged. (1)

3.2.5 Explain how you arrived at the answer to QUESTION 3.2.4. (2)

[22]

Question 4

4.1 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 below.

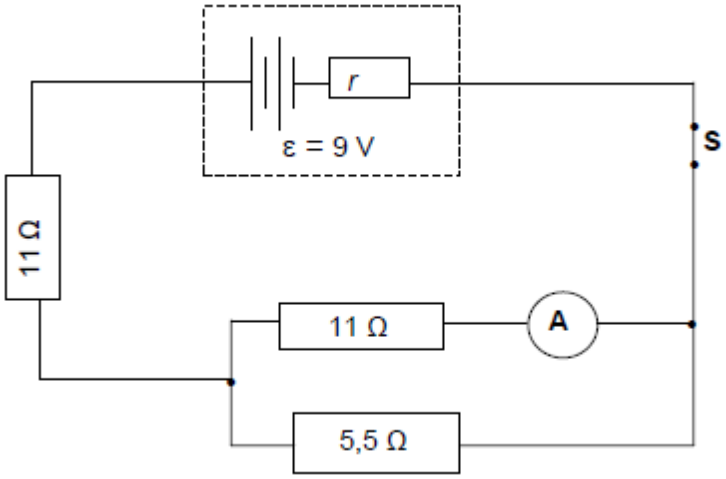


4.1.1 Apart from temperature, write down TWO other factors that the learners should consider to ensure a fair test when choosing which wire to use. (2)

4.1.2 Assuming all other factors are kept constant, state which ONE of the two wires will be the most suitable to use in the heater.

4.1.3 Use suitable calculations to show clearly how you arrive at the answer. (8)

4.2 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*.



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

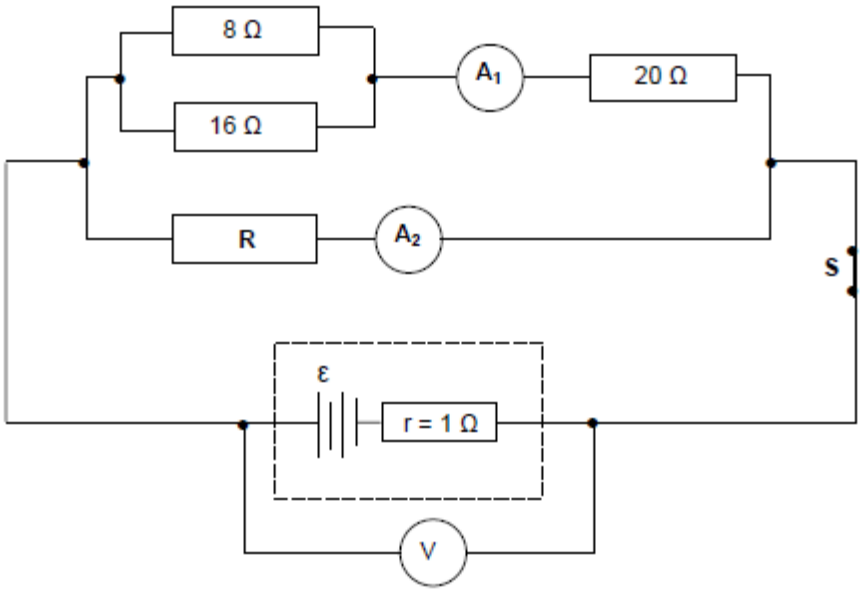
4.2.2 Calculate the internal resistance of the battery. (7)

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

[22]

Question 5

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. **A_1** and A_2 represent ammeters of negligible resistance.



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

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

5.2 Calculate the reading on ammeter **A_1**. (4)

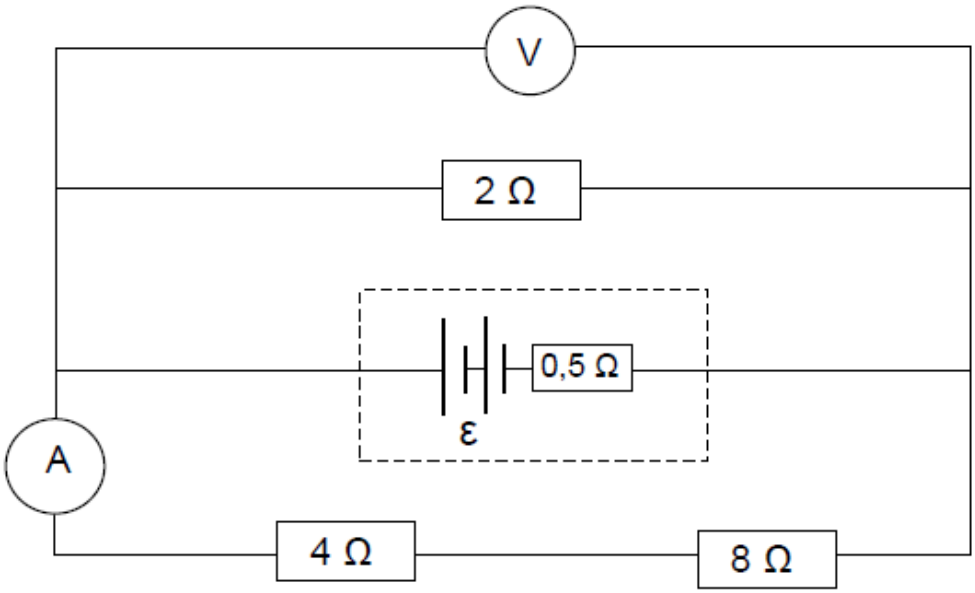
5.3 If device R delivers power of 12 W, calculate the reading on ammeter **A_2**. (5)

5.4 Calculate the reading on the voltmeter when swich **S** is open. (3)

[14]

Question 6

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 below.



The reading on the ammeter is 0,2 A.

6.1 Calculate the:

6.1.1 Reading on the voltmeter. (3)

6.1.2 The current supplied by the battery. (4)

6.1.3 Emf of the battery. (5)

6.2 How would the voltmeter be reading change if the 2 Ω resistor is removed from the circuit? Write down INCREASE, DECREASE or REMAIN THE SAME. Explain the answer. (3)

[15]

SESSION 10 &11

Organic Chemistry

Representing Chemical Change

Balanced chemical equations.

- Write and balance chemical equations.
- Interpret balanced reaction equations in terms of:
  - Conservation of atoms
  - Conservation of mass (use relative atomic masses)

Quantitative Aspects of Chemical Change

Molar volume of gases

- 1 mole of any gas occupies 22,4 dm^3 at 0 °C (273 K) and 1 atmosphere (101,3 kPa).

Volume relationships in gaseous reactions

- Interpret balanced equations in terms of volume relationships for gases, i.e. under the same conditions of temperature and pressure, equal number of moles of all gases occupy the same volume.

Concentration of solutions

- Calculate the molar concentration of a solution.

More complex stoichiometric calculations

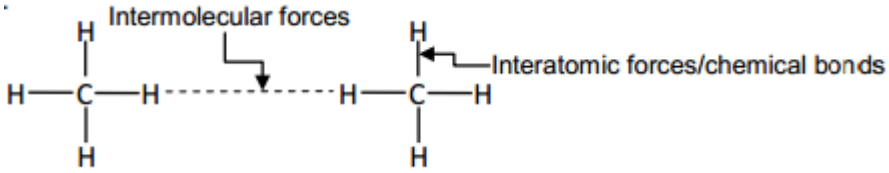
- Determine the empirical formula and molecular formula of compounds.
- Determine the percentage yield of a chemical reaction.
- Determine percentage purity or percentage composition, e.g. the percentage $CaCO_3$ in an impure sample of seashells.
- Perform stoichiometric calculations based on balanced equations.
- Perform stoichiometric calculations based on balanced equations that may include limiting reagents.

Intermolecular Forces

Intermolecular forces and interatomic forces (chemical bonds)

- Name and explain the different intermolecular forces (Van der Waal's forces):
  - i. Dipole-dipole forces:
    Forces between two polar molecules
  - ii. Induced dipole forces or London forces:
    Forces between non-polar molecules
  - iii. Hydrogen bonding:
    Forces between molecules in which hydrogen is covalently bonded to nitrogen, oxygen or fluorine – a special case of dipole-dipole forces

- Describe the difference between intermolecular forces and interatomic forces (intramolecular forces) using a diagram of a group of small molecules; and in words.
  Example:



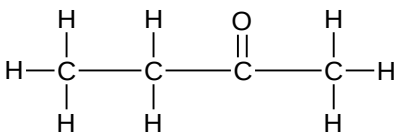
- State the relationship between intermolecular forces and molecular size. For non-polar molecules, the strength of induced dipole forces increases with molecular size.
- Explain the effect of intermolecular forces on boiling point, melting point and vapour pressure.
  Boiling point:
  The temperature at which the vapour pressure of a substance equals atmospheric pressure. The stronger the intermolecular forces, the higher the boiling point.
  Melting point:
  The temperature at which the solid and liquid phases of a substance are at equilibrium. The stronger the intermolecular forces, the higher the melting point.
  Vapour pressure:
  The pressure exerted by a vapour at equilibrium with its liquid in a closed system. The stronger the intermolecular forces, the lower the vapour pressure.

Organic Molecules

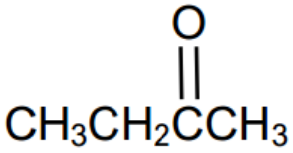
- Define organic molecules as molecules containing carbon atoms.

Organic molecular structures – functional groups, saturated and unsaturated structures, isomers

- Write down condensed structural formulae, structural formulae and molecular formulae (up to 8 carbon atoms, one functional group per molecule) for:
  - Alkanes (no ring structures)
  - Alkenes (no ring structures)
  - Alkynes
  - Halo-alkanes (primary, secondary and tertiary haloalkanes; no ring structures)
  - Alcohols (primary, secondary and tertiary alcohols)
  - Carboxylic acids
  - Esters
  - Aldehydes
  - Ketones
- Know the following definitions/terms:
  Molecular formula: A chemical formula that indicates the type of atoms and the correct number of each in a molecule.
  Example: C_4H_8O
  Structural formula: A structural formula of a compound shows which atoms are attached to which within the molecule. Atoms are represented by their chemical symbols and lines are used to represent ALL the bonds that hold the atoms together.
  Example:

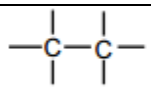
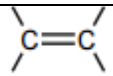
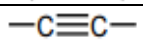
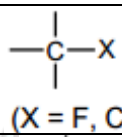
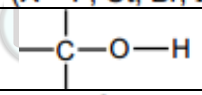
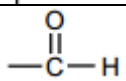
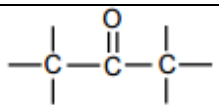
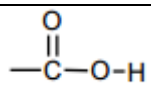
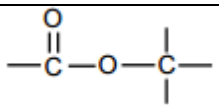


  Condensed structural formula: This notation shows the way in which atoms are bonded together in the molecule, but DOES NOT SHOW ALL bond lines.
  Example:



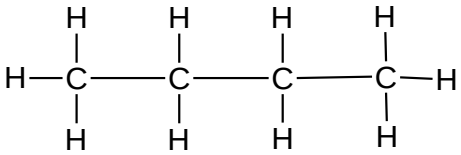
$CH_3CH_2COCH_3$ OR

Hydrocarbon: Organic compounds that consist of hydrogen and carbon only.
Homologous series: A series of organic compounds that can be described by the same general formula OR in which one member differs from the next with a CH_2 group.
Saturated compounds: Compounds in which there are no multiple bonds between C atoms in their hydrocarbon chains.
Unsaturated compounds: Compounds with one or more multiple bonds between C atoms in their hydrocarbon chains.
Functional group: A bond or an atom or a group of atoms that determine(s) the physical and chemical properties of a group of organic compounds.

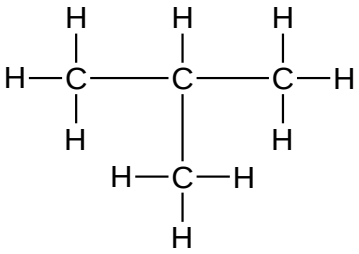
Homologous Series	Structure of functional group	
	Structure	Name / Description
Alkanes		Only C–H and C–C single bonds
Alkenes		Carbon-carbon double bond
Alkynes		Carbon-carbon triple bond
Haloalkanes	 (X = F, Cℓ, Br, I)	Halogen atom bonded to a saturated C atom.
Alcohols		Hydroxyl group bonded to a saturated C atom
Aldehydes		Formyl group
Ketones		Carbonyl group bonded to two C atoms
Carboxylic acids		Carboxyl group
Esters		-

Structural isomer: Organic molecules with the same molecular formula, but different structural formulae

- Identify compounds (up to 8 carbon atoms) that are saturated, unsaturated and are structural isomers.
- Restrict structural isomers to chain isomers, positional isomers and functional isomers.
  - **Chain isomers**: Same molecular formula, but different types of chains, e.g. butane and 2-methylpropane.

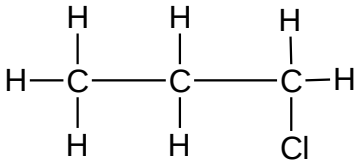


butane

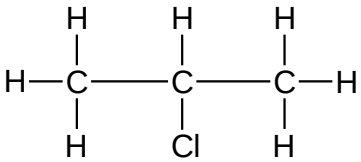


2-methylpropane

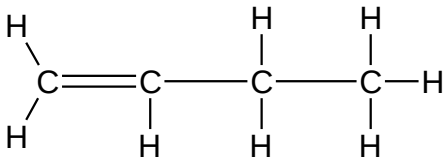
- **Positional isomers**: Same molecular formula, but different positions of the side chain, substituents or functional groups on the parent chain, e.g. 1-choropropane and 2-chloropropane or but-2-ene and but-1-ene



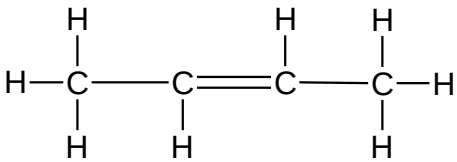
1-chromopropane



2-chromopropane

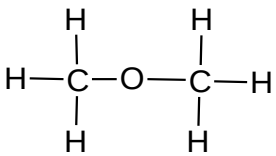


but-1-ene

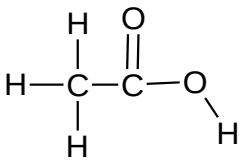


but-2-ene

- **Functional isomers**: Same molecular formula, but different functional groups, e.g. methyl methanoate and ethanoic acid



methyl methanoate



ethanoic acid

IUPAC naming and formulae

- Write down the IUPAC name when given the structural formula or condensed structural formula for compounds from the homologous series above, restricted to one functional group per compound, except for haloalkanes. For haloalkanes, maximum two functional groups per molecule.
- Write down the structural formula when given the IUPAC name for the above homologous series.
- Identify alkyl substituents (methyl- and ethyl-) in a chain to a maximum of THREE alkyl substituents on the parent chain.
- When naming haloalkanes, the halogen atoms do not get preference over alkyl groups – numbering should start from the end nearest to the first substituent, either the alkyl group or the halogen. In haloalkanes, where e.g. a Br and a Cℓ have the same number when numbered from different ends of chain, Br gets alphabetical preference.
- When writing IUPAC names, substituents appear as prefixes written alphabetically (bromo, chloro, ethyl, methyl), ignoring the prefixes di- and tri.

Structure and physical properties (boiling point, melting point, vapour pressure) relationships

- For a given example (from the above functional groups), explain the relationship between physical properties and:
  - Strength of intermolecular forces (Van der Waal's forces), i.e. hydrogen bonds, dipole-dipole forces, induced dipole forces
  - Type of functional groups
  - Chain length
  - Branched chains

Oxidation of alkanes

- State the use of alkanes as fuels.
- Write down an equation for the combustion of an alkane in excess oxygen.

Esterification

- Write down an equation, using structural formulae, for the formation of an ester.
- Name the alcohol and carboxylic acid used and the ester formed.
- Write down reaction conditions for esterification.

Substitution, addition and elimination reactions

- Identify reactions as elimination, substitution or addition.
- Write down, using structural formulae, equations and reaction conditions for the following addition reactions of alkenes:
  - **Hydrohalogenation**:
    The addition of a hydrogen halide to an alkene
  - **Halogenation**:
    The reaction of a halogen (Br_2, $C\ell_2$) with a compound
  - **Hydration**:
    The addition of water to a compound
  - **Hydrogenation**:
    The addition of hydrogen to an alkene
- Write down, using structural formulae, equations and reaction conditions for the following elimination reactions:
  - **Dehydrohalogenation of haloalkanes**:
    The elimination of hydrogen and a halogen from a haloalkane
  - **Dehydration of alcohols**:
    Elimination of water from an alcohol
  - **Cracking of alkanes**:
    The chemical process in which longer chain hydrocarbon molecules are broken down to shorter more useful molecules.
- Write down, using structural formulae, equations and reaction conditions for the following substitution reactions:
  - **Hydrolysis of haloalkanes**
    Hydrolysis: The reaction of a compound with water
  - Reactions of HX (X = Cℓ, Br) with alcohols to produce haloalkanes
  - **Halogenation of alkanes**
    The reaction of a halogen (Br_2, $C\ell_2$) with a compound
- Distinguish between saturated and unsaturated hydrocarbons using bromine water.

Plastics and polymers (ONLY BASIC POLYMERISATION as application of organic chemistry)

- Describe the following terms:
  Macromolecule: A molecule that consists of a large number of atoms

Polymer: A large molecule composed of smaller monomer units covalently bonded to each other in a repeating pattern
Monomer: Small organic molecules that can be covalently bonded to each other in a repeating pattern
Polymerisation: A chemical reaction in which monomer molecules join to form a polymer.

- Distinguish between addition polymerisation and condensation polymerisation:
  Addition polymerisation: A reaction in which small molecules join to form very large molecules by adding on double bonds.
  Addition polymer: A polymer formed when monomers (usually containing a double bond) combine through an addition reaction.
  Condensation polymerisation: Molecules of two monomers with different functional groups undergo condensation reactions with the loss of small molecules, usually water.
  Condensation polymer: A polymer formed by two monomers with different functional groups that are linked together in a condensation reaction in which a small molecule, usually water, is lost
- Identify monomers from given addition polymers.
- Write down an equation for the polymerisation of ethene to produce polythene.
- State the industrial uses of polythene.

Question 1

Multiple-choice Questions

Four options are given as possible answers to the following questions. Each question has only ONE correct answer.

1.1. Which ONE of the compounds below is an aldehyde?

A CH_3CHO
B CH_3COCH_3
C CH_3COOH
D CH_3OH (2)

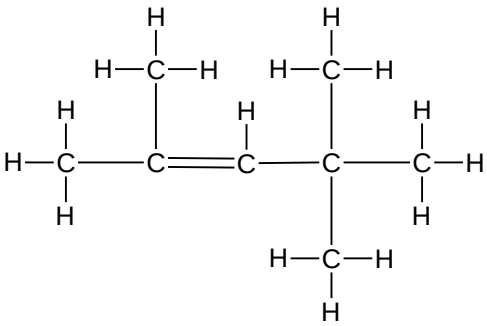
1.2. The reaction represented by the equation below takes place in the presence of a catalyst.

$$C_{13}H_{28(\ell)} \longrightarrow C_2H_{4(g)} + C_3H_{6(g)} + C_8H_{18(\ell)}$$

This reaction is an example of …

A addition.
B cracking.
C substitution.
D polymerisation. (2)

1.3. Consider the structural formula of an organic compound below.



Which ONE of the following is the correct IUPAC name of this compound?

A 2,2,4-trimethylpent-2-ene
B 2,2,4-trimethylpent-3-ene
C 2,4,4-trimethylpent-2-ene
D 2,4,4-trimethylpent-3-ene (2)

1.4. Which ONE of the following statements is CORRECT?

Alkenes …

A have the general formula C_nH_{2n+2}.
B are unsaturated hydrocarbons.
C readily undergo substitution reactions.
D have one triple bond between two carbon atoms. (2)

1.5. The following equation represents the cracking of a hydrocarbon at high temperature and pressure:

$$C_{11}H_{24} \longrightarrow 2C_2H_4 + \mathbf{Y} + C_4H_{10}$$

Which ONE of the following is the IUPAC name of product **Y**?

A Prop-1-ene.
B Propane.
C Ethene.
D Ethane. (2)

1.6. When 2-chlorobutane is strongly heated in the presence of concentrated sodium hydroxide, the major product formed is …

A but-1-ene.
B but-2-ene.
C butan-1-ol.
D butan-2-ol. (2)

1.7. Which ONE of the following compounds is an aldehyde?

A Pentanal
B Pentan-2-ol
C Pentan-2-one
D Ethyl propanoate (2)

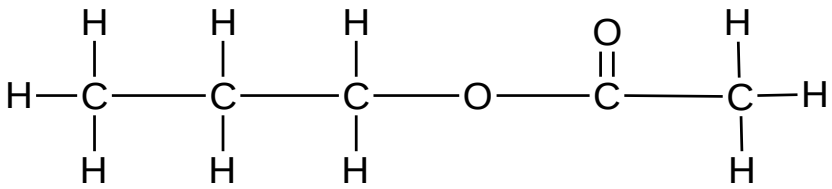
1.8. Consider the reaction represented by the equation below:

$$CH_3CHCH_2 + H_2 \longrightarrow CH_3CH_2CH_3$$

This reaction is an example of …

A hydration.
B dehydration.
C substitution.
D hydrogenation. (2)

1.9. Consider the structural formula of a compound below.



Which ONE of the following pairs of reactants can be used to prepare this compound in the laboratory?

A Propanoic acid and ethanol
B Propanoic acid and methanol
C Ethanoic acid and propan-1-ol
D Methanoic acid and propan-1-ol (2)

1.1. Which ONE of the following compounds has dipole-dipole forces between its molecules?

A Ethanal
B Ethane
C Ethene
D Ethyne (2)

1.2. Which ONE of the following is a product formed during the hydrolysis of bromoethane?

A Water
B Ethene
C Ethanol
D Bromine (2)

1.3. Which ONE of the following is the EMPIRICAL FORMULA of 1;2-dichloroethane?

A $CHC\ell$
B $CH_2C\ell$
C $CHC\ell_2$
D $C_2H_4C\ell_2$ (2)

1.4. Which ONE of the following compounds is an aldehyde?

A CH_3COCH_3
B CH_3CH_2CHO
C CH_3CH_2COOH
D $CH_3CH_2CH_2OH$ (2)

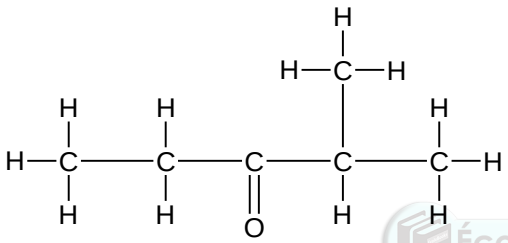
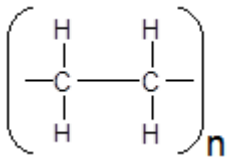
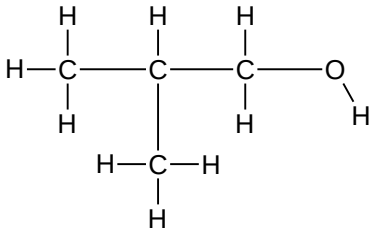
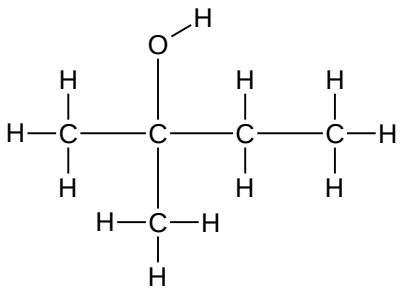
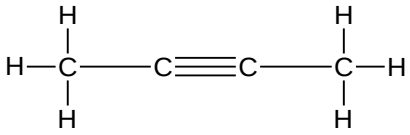
1.5. Which ONE of the following pairs of compounds are FUNCTIONAL isomers?

A Methanol and methanal
B Butane and 2-methylpropane
C Propan-1-ol and pronan-2-ol
D Propanoic acid and methyl ethanoate (2)

Questions 2 to 6 are Examples Question on the basics of Organic Chemistry.

Question 2

The letters **A** to **G** in the table below represent seven organic compounds.

A		B	
C		D	
E	Butane	F	
G	Ethyl propanoate		

2.1. Write down the:
2.1.1. Name of the homologous series to which compound **F** belongs. (1)
2.1.2. Name of the functional group of compound **D**. (1)
2.1.3. Letter that represents a primary alcohol. (1)
2.1.4. IUPAC name of compound **A**. (2)

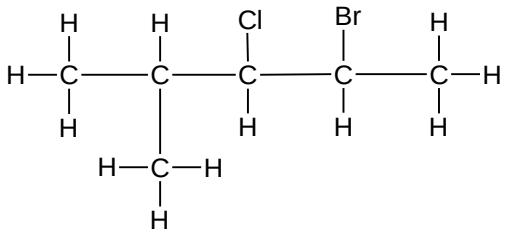
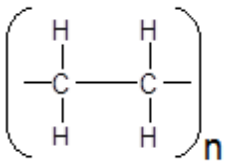
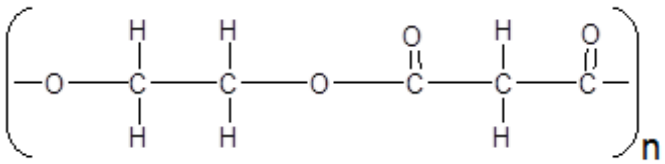
2.1.5. Structural formula of the monomer of compound **B**. (2)
2.1.6. Balanced equation, using molecular formulae, for the combustion of compound **E** in excess oxygen. (3)

2.2. Briefly explain why compounds **C** and **D** are classified as POSITIONL ISOMERS. (2)

2.3. Compound **G** is prepared using an alcohol as one of the reactants. Write down the balanced equation for the reaction using structural formulae for all the organic reagents. (7)
[19]

Question 3

Consider the organic compounds represented by the letters A to F in the table below.

A	2,2,4-trimethylhexane	B	$CH_3CH_2CH_2CH_2CHO$
C		D	
E		F	Pentan-2-one

3.1. Write down the LETTER that represents the following:
3.1.1. An aldehyde. (1)
3.1.2. A condensation polymer (1)
3.1.3. A compound which has a carbonyl group bonded to two carbon atoms as its functional group. (1)

3.2. Write down the IUPAC name of:
3.2.1. Compound **C** (3)
3.2.2. The monomer of compound **D** (1)

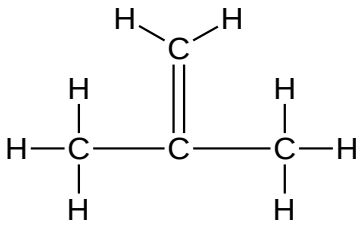
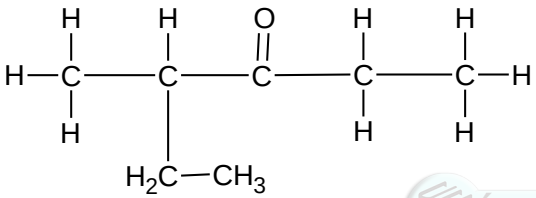
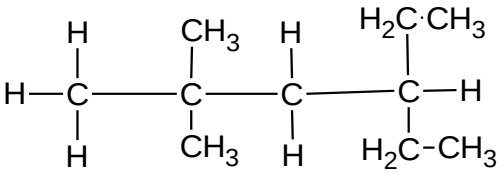
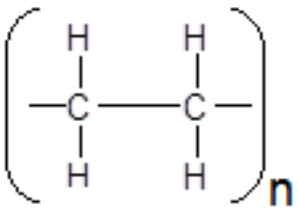
3.3. Write down the structural formula of:
3.3.1. Compound **A** (2)
3.3.2. Compound **F** (2)

3.4. The table contains compounds which are functional isomers.
3.4.1. Define the term *functional isomer*. (2)
3.4.2. Write down the LETTERS that represent two compounds that are functional isomers. (1)

[14]

Question 4

The letters **A** to **F** in the table below represent six organic compounds.

A		B	2-methylbutanoic acid
C		D	
E	But-2-ene	F	

4.1. Write down the:

4.1.1. NAME of the functional group of compound **B** (1)

4.1.2. Homologous series to which compound **C** belongs. (1)

4.1.3. Type of polymerisation reaction that produces compound **F** (1)

4.2. Write down the IUPAC name of:

4.2.1. The monomer used to prepare compound **F** (1)

4.2.2. Compound **C** (2)

4.2.3. Compound **D** (2)

4.3. Write down the NAME or FORMULA of each product formed during the complete combustion of compound **D.** (2)

4.4. Write down the structural formula of:

4.4.1. Compound **B** (2)
4.4.2. A CHAIN ISOMER of compound **A** (2)

4.5. A laboratory assistant uses bromine water to distinguish between compounds **D** and **E**. She adds bromine water to a sample of each in two different test tubes. She observes that the one compound decolourises the bromine water immediately, whilst the other one only reacts after placing the test tube in direct sunlight.

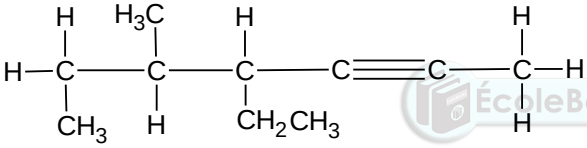
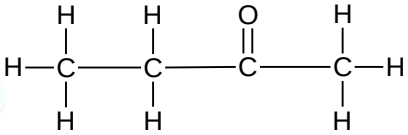
Write down the:

4.5.1. Letter (**D** or **E**) of the compound that will immediately decolorize the bromine water (1)
4.5.2. Name of the type of reaction that takes place in the test tube containing compound **D** (1)
4.5.3. Structural formula of the organic product formed in the test tube containing compound **E** (2)

[18]

Question 5

The letters **A** to **D** in the table below represents four organic compounds.

A		B	
C	CH_3CH_2CHO	D	Butane

Use the information in the table to answer the questions that follow.

5.1 Write down the:
5.1.1 Letter that represents a ketone. (1)
5.1.2 Structural formula of the functional group of compound **C**. (1)
5.1.3 General formula of the homologous series to which compound **A** belongs. (1)
5.1.4 IUPAC name of compound **A**. (3)
5.1.5 IUPAC name of compound **B**. (2)

5.2 Compound **D** is a gas used in cigarette lighters.
5.2.1 To which homologous series does compound **D** belong? (1)
5.2.2 Write down the STRUCTURAL FORMULA and IUPAC NAME of a structural isomer of compound **D**. (4)

5.3 Compound **D** reacts with bromine (Br_2) to form 2-bromobutane.
Write down the name of the:
5.3.1 Homologous series to which 2-bromobutane belongs. (1)

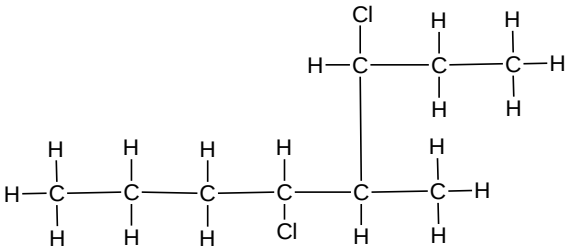
5.3.2 Type of the reaction that takes place. (1)

[16]

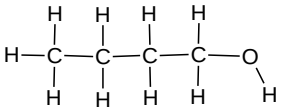
Question 6

6.1 Consider the organic compounds represented by the letters **A** to **C** below.

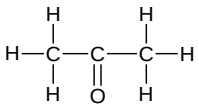
A



B



C



Write down the:

6.1.1 Name of the homologous series to which compound C belongs. (1)

6.1.2 IUPAC name of compound A. (3)

6.1.3 Structural formula of the tertiary alcohol that is a structural isomer of compound B. (2)

6.2 An alcohol and methanoic acid are heated in the presence of concentrated sulphuric acid to form an ester.

6.2.1 What is the role of the concentrated sulphuric acid in this reaction? (1)

6.2.2 Write down the NAME or FORMULA of the inorganic product formed. (1)

The ester contains 6,67% hydrogen (H), 40% carbon (C) and 53,33 % oxygen (O). The molar mass of the ester is $60\ g \cdot mol^{-1}$.

Use a calculation to determine its:

6.2.3 Empirical formula (5)

6.2.4 Molecular formula (3)

Write down the:

6.2.5 Structural formula for methanoic acid (1)

6.2.6 IUPAC name of the ester. (2)

[19]

Questions 7 to 11 are Examples of Questions on the Properties of Organic Compounds and Intermolecular Forces.

Question 7

The table below shows the results obtained from experiments to determine the boiling point of some alkanes and alcohols of comparable molecular masses.

Compound	Relative molecular mass	Boiling point (ºC)
CH_3CH_3	30	-89
CH_3OH	32	65
$CH_3CH_2CH_3$	44	-42
CH_3CH_2OH	46	78
$CH_3CH_2CH_2CH_3$	58	0
$CH_3CH_2CH_2OH$	60	97
$CH_3CH_2CH_2CH_2CH_3$	72	36
$CH_3CH_2CH_2CH_2OH$	74	117

7.1. Define the term *boiling point.* (2)

7.2. Consider the boiling points of the four alkanes in the above table.
7.2.1. Describe the trend in their boiling points. (1)
7.2.2. Fully explain the trend in QUESTION 6.2.1. (3)

7.3. The boiling point of each alcohol is much higher than that of the alkane of comparable relative molecular mass. Explain this observation by referring to the type and strength of the intermolecular forces in alkanes and alcohols.
(2)
[8]

Question 8

8.1. Give a reason why alkanes are *saturated* hydrocarbons. (1)

8.2. Write down the structural formula of:
8.2.1. The functional group of alcohols. (1)
8.2.2. A tertiary alcohol that is a structural isomer of butan-1-ol. (2)

8.3. Learners investigate factors that influence the boiling points of alkanes and alcohols. In one of the investigations, they determine boiling points of the first three alkanes.
8.3.1. Write down an investigative question for this investigation. (2)
8.3.2. Fully explain why the boiling point increases from methane to propane.
(3)

8.4. The learners find that the boiling point of propan-1-ol is higher than that of propane. Explain this observation by referring to the TYPE of INTERMOLECULAR FORCES present in each of these compounds.
(3)

[12]

Question 9

Learners use compounds **A** to **C**, shown in the table below, to investigate a factor which influences the boiling point of organic compounds.

A	$CH_3CH_2CH_2CH_3$
B	$CH_3CH_2CH_2CH_2CH_3$
C	$CH_3CH_2CH_2CH_2CH_2CH_3$

9.1. Which ONE of the compounds (**A**, **B** or **C**) has the highest boiling point? (1)

9.2. For this investigation, write down the:

9.2.1. Independent variable (1)

9.2.2. Dependent variable (1)

9.3. Write down the name of the type of Van der Waals force that occurs between the molecules of compound **B**. (1)

9.4. How will the vapour pressure of 2-methylpentane compare to that of compound **C**? Write down only HIGHER THAN, LOWER THAN or EQUAL TO. (1)

The learners now compare the boiling points of compounds **D** and **E**, shown in the table below.

D	$CH_3CH_2CH_2CH_2CH_2OH$
E	$CH_3CH_2CH_2COOH$

9.5. How does the boiling point of compound **D** compare to that of compound **E**? Write down only HIGHER THAN, LOWER THAN or EQUAL TO. Fully explain the answer. (4)

[9]

Question 10

Four compounds of comparable molecular mass are used to investigate the effect of functional groups on vapour pressure. The results obtained are shown in the table below.

COMPOUND		**VAPOUR PRESSURE (kPa at 20°C)**
A	Butane	204
B	Propan-2-one	24,6
C	Propan-1-ol	2

D	Ethanoic acid	1,6

10.1. Define the term *functional group* of an organic compound. (2)

10.2. Which ONE of the compounds (**A**, **B**, **C** or **D**) in the table has the:

10.2.1. Highest boiling point
(Refer to the vapour pressure in the table to give a reason for the answer.) (2)

10.2.2. Weakest intermolecular forces. (1)

10.3. Refer to the type of intermolecular forces to explain the difference between the vapour pressure of compound **A** and compound **B**. (3)

10.4. The vapour pressure of compounds **C** and **D** are much lower than those of compounds **A** and **B**. Name the type of intermolecular force in **A** and **B** that is responsible for this difference. (1)

10.5. Briefly explain the difference in vapour pressure between compound **C** and **D**. (2)

10.6. During a combustion reaction in a closed container of adjustable volume, $8\ cm^3$ of compound **A** (butane) reacts in excess oxygen according to the following balanced equation:

$$2C_4H_{10(g)} + 13O_{2(g)} \rightarrow 8CO_{2(g)} + 10H_2O_{(g)}$$

If the initial volume of the oxygen in the container $60\ cm^3$ was, calculate the TOTAL volume of the gases that are present in the container at the end of the reaction. All gases in the container are at the same temperature and pressure (5)

[16]