education

Department:
Education
PROVINCE OF KWAZULU-NATAL

CURRICULUM GRADE 10 -12 DIRECTORATE

NCS (CAPS)

LEARNER SUPPORT DOCUMENT GRADE 12

PHYSICAL SCIENCES

STEP AHEAD PROGRAMME

2022

PREFACE

This support document serves to assist Physical Sciences learners on how to deal with curriculum gaps and learning losses because of the impact of COVID-19 in 2021. It also addresses the challenging topics in the Grade 12 curriculum in Term 1 and Term 2.

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

Learner Notes

Revised National ATP (2021-2023)

[WEEK 1: 2hrs]

- Define & calculate the momentum of a moving object: p = mv
- Describe the vector nature of momentum & draw vector diagrams.
- State Newton's second law in terms of momentum: $F_{net} = \frac{\Delta p}{\Delta t}$
- Calculate the change in momentum when a resultant force acts on an object.

[WEEK 2: 4hrs]

- Define impulse
- Use the impulse-momentum theorem ($F_{net}\Delta t = m\Delta v$) in calculations for a variety of situations (one dimension).
- Impulse and safety considerations.
- State the principle of conservation of linear momentum.
- Explain what is meant by an isolated system, internal and external forces.

[WEEK 3: 4hrs]

- Apply conservation of momentum to collisions of two objects (one dimension).
- Distinguish between elastic and inelastic collisions by calculation.

MOMENTUM

2021 EXAMIMATION GUIDELINES

Momentum

- **Define *momentum* as the product of an object's mass and its velocity.**
- Describe *linear momentum* 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 cases above.

Newton's second law in terms of momentum

- **State Newton's second law of motion in terms of momentum: The net (or resultant) force acting on an object is equal to the rate of change of momentum of the object in the direction of the net force.**
- Express Newton's second law of motion in symbols: $F_{net} = \frac{\Delta p}{\Delta t}$
- Explain the relationship between net force and change in momentum for a variety of motions.
- 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 net force acts on the object.**
- Use the impulse-momentum theorem, $F_{net}\Delta t = m\Delta v$, to calculate the resultant/net 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 *system* (in Physics).
- Explain (when working with systems) what is meant by *internal* and *external forces*.
- Explain what is meant by ***an isolated system*** **(in Physics), i.e. a system on which the net external force is zero.**
- (An isolated system excludes 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 an isolated 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.

<u>NOTES AND EXAMPLES</u>

DEFINITIONS

1. Momentum is the product of an object's mass and its velocity.
2. Impulse is the product of the resultant/net force acting on an object and the time the net force acts on the object.
3. Isolated system is a system on which the net external force is zero.

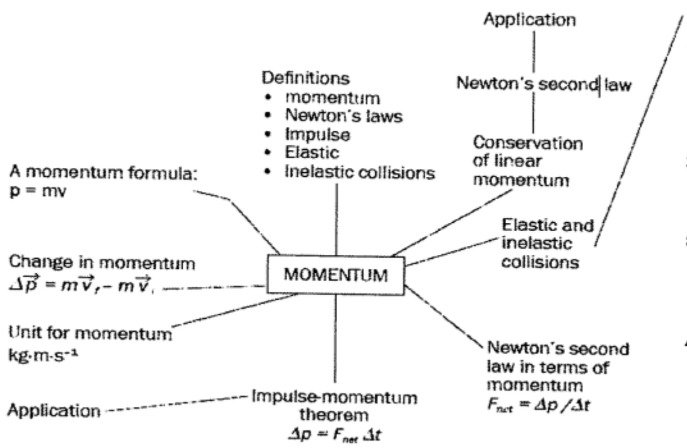
LAWS

1. Newton's second law of motion in terms of momentum states that the net (or resultant) force acting on an object is equal to the rate of change of momentum of the object in the direction of the net force.
2. State Newton's third law of motion: When object A exerts a force on object B, object B SIMULTANEOUSLY exerts an oppositely directed force of equal magnitude on object A.

PRINCIPLE

1. Principle of conservation of linear momentum states that, the total linear momentum of an isolated system remains constant (is conserved).

2.



Problem types:

1. **Two objects collide and continue to move as separate objects after the collision:**
   $\sum\vec{p}_i = \sum\vec{p}_f$
   $m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$
2. **Two objects collide and unite:**
   $\sum\vec{p}_i = \sum\vec{p}_f$
   $m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = (m_1 + m_2)\vec{v}_f$
3. **Two moving objects that are initially joined, then separate:**
   $\sum\vec{p}_i = \sum\vec{p}_f$
   $(m_1 + m_2)\vec{v}_1 = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$
4. **Two stationary objects that are initially joined, separate (e.g. during an explosion):**
   $\sum\vec{p}_i = \sum\vec{p}_f$
   $(m_1 + m_2)\vec{v}_1 = m_1f_{1f} + m_2\vec{v}_{2f}$
   $0 = m_1v_{1f} + m_2\vec{v}_{2f}$
   $m_1\vec{v}_{1f} = -m_2\vec{v}_{2f}$
5. **An object falls vertically onto another object that is moving horizontally below it:**
   $\sum p_i = \sum p_f$
   $m_1v_{1i} + m_2v_{2i} = (m_1 + m_2)v_f$
   $m_1v_{1i} + m_2(0) = (m_1 + m_2)v_f$
   $m_1v_{1i} = (m_1 + m_2)v_f$

Momentum is a vector quantity with the same direction as the object's velocity.

QUANTITIES AND SI UNITS

QUANTITY	SYMBOL	UNIT NAME	UNIT SYMBOL
Momentum	p	kilogram metre per second	kg·m·s^{-1}
Mass	m	kilogram	kg
Velocity	v	metre per second	m·s^{-1}
Force	F	Newton	N
Time interval	Δt	Second	s
Time	t	Second	s
Kinetic energy	K	Joule	J

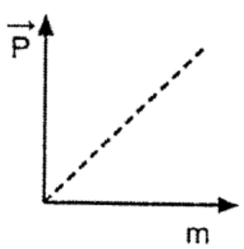
FORMULA

The formula to calculate the momentum of a moving object is:

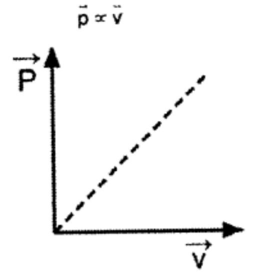
$$p = mv.$$

Momentum of an object is directly proportional to the mass of the object.

$\vec{p} \propto m$



Momentum is directly proportional to the velocity of the object



STEPS TO FOLLOW WHEN SOLVING PROBLEMS

1. Make a sketch (on your rough work page) of the situation.
2. Always choose and indicate direction and write it down clearly. It is recommended that you choose a positive direction (e.g. to the right is positive).
3. Write down the information in symbols. Remember to include the correct signs for the directions of the initial and final velocity.
4. Choose the correct formula from the information sheet.
5. Substitute the values into the formula.
6. Solve for the unknown variable

WORKED EXAMPLE 1

1.1. Determine the momentum of a 6 kg object moving at 5 m·s^{-1} to the right.

p = mv.
p = (6)(5)
p = 30 kg·m·s^{-1}, to the right

1.2. What is the magnitude of the velocity of 10 kg object that has a momentum of 90 kg·m·s^{-1} ?

p = mv.
90 = 10v
v = 9 ·m·s^{-1}

1.3. What is the mass of an object that has a momentum of 60 kg·m·s^{-1} east and a velocity of 30 m·s^{-1}east?

p = mv.
60 = m (30)
m = 2 kg

1.4. A car has a momentum of 20 000 kg·m·s^{-1}. What will the car's new momentum be if its mass is doubled (by adding more passengers and a greater load) and it travels at the same velocity? Explain.

Answer: Momentum will be 40 000 kg·m·s^{-1}in the same direction. Momentum is directly proportional to the mass of the object. If the mass of the car increases, the momentum of the car will also increase in the same direction.

VECTOR NATURE OF MOMENTUM

A car travelling at 120 km·hr^{-1} will have a larger momentum than the same car travelling at 60 km·hr^{-1}.

Momentum is also related to velocity; the smaller the velocity, the smaller the momentum. Different objects can also have the same momentum, for example a car travelling slowly can have the same momentum as a motorcycle travelling relatively fast.

EXAMPLE 2

Consider a car of mass 1000 kg with a velocity of 8 m·s^{-1} (about 30 km·hr−1) East. The momentum of the car is therefore:

$$p = mv$$
$$p = (1000)(8)$$
$$p = 8000 \text{ kg·m·s}^{-1} \text{ East}$$

Now consider a motorcycle, also travelling East, of mass 250 kg travelling at 32 m·s^{-1} (about 115 km·hr^{-1}).

The momentum of the motorcycle is:

$$p = mv$$
$$p = 250\,(32)$$
$$p = 8000 \text{ kg·m·s}^{-1} \text{ East}$$

Even though the motorcycle is considerably lighter than the car, the fact that the motorcycle is travelling much faster than the car means that the momentum of both vehicles is the same.

Particles or objects can collide with other particles or objects, we know that this will often change their velocity (and maybe their mass) so their momentum is likely to change as well.

CHANGE IN MOMENTUM

Momentum of an object changes with its velocity

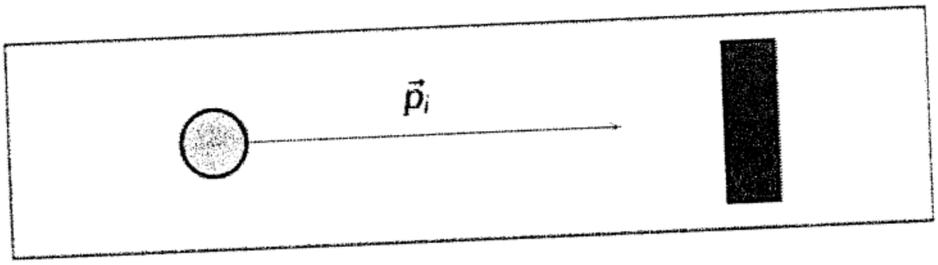
STEPS TO FOLLOW WHEN DRAWING THE VECTOR DIAGRAM

1. Draw the first vector (mv_i).
2. Draw the second vector (mv_f), from the tail of the first vector.
3. The change in momentum is the vector drawn from the head of the first vector to the head of the second vector.

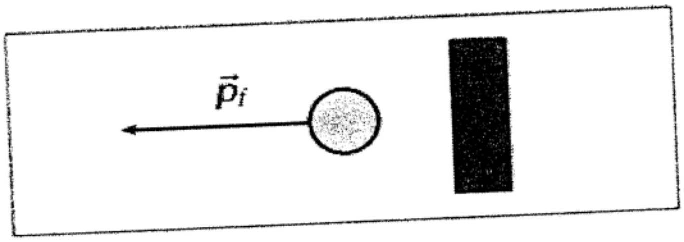
Case 1: Object bouncing off a wall

Let's start with a simple picture, a ball of mass, m, moving with initial velocity, v_i, to the right towards a wall.

It will have momentum $p_i = mv_i$ to the right as shown in this picture:



The ball bounces off the wall. It will now be moving to the left, with the same mass, but a different velocity, v_f and therefore, a different momentum, $p_f = mv_f$, as shown in this picture:

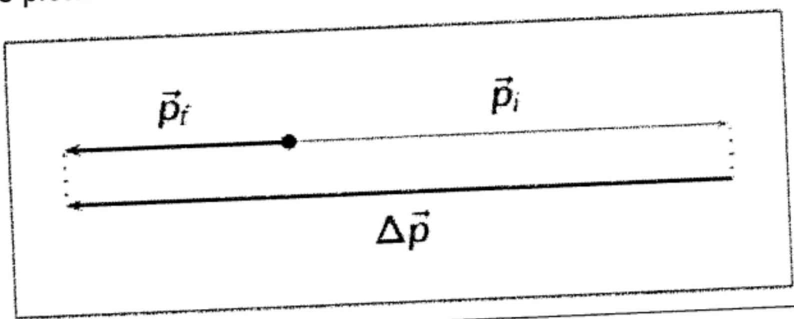


The final momentum vector must be the sum of the initial momentum vector.

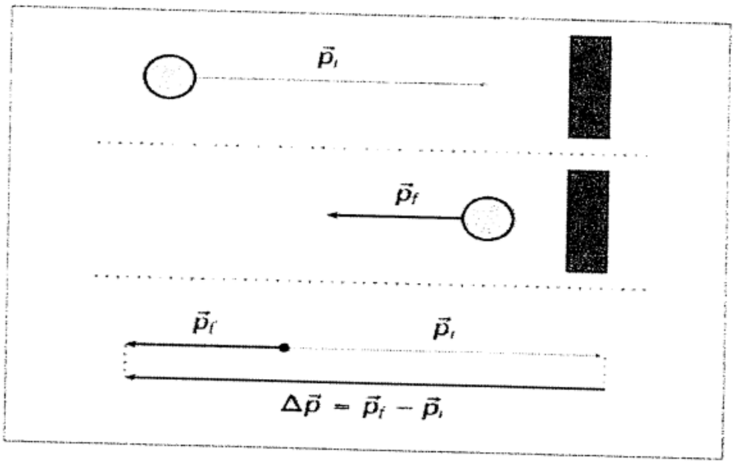
The change in momentum vector, $\Delta p = m\Delta v$.

This means that, using tail to-head vector addition,

Δp, must be the vector that starts at the head of p_i and ends on the head of p_f as shown in this picture:



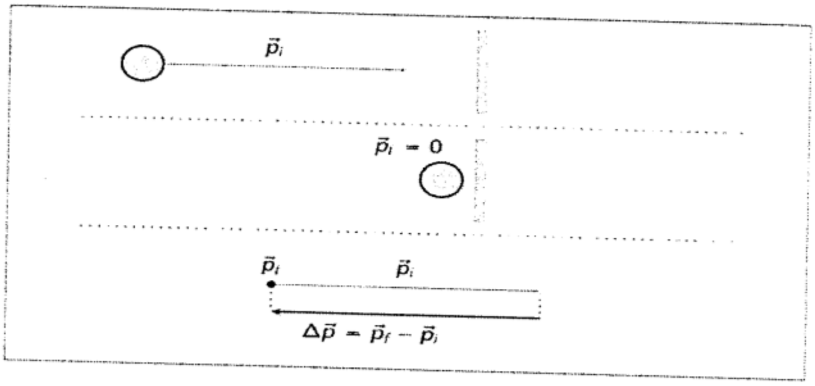
If we put this all together we can show the sequence and the change in



momentum in one diagram:

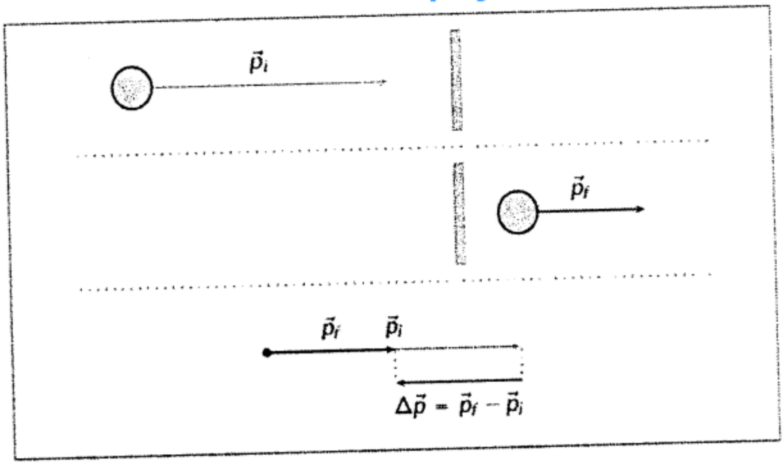
<u>Case 2:</u> Object stops

A tennis ball hitting the net. The net stops the ball but doesn't cause it to bounce back. At the instant before it falls to the ground its velocity is zero.



<u>Case 3:</u> Object continues more slowly

The object continues in the same direction but more slowly.
To give this some context, this could happen when a ball hits a glass window and goes through it or an object sliding on a frictionless surface encounters a small rough patch before carrying on along the frictionless surface.

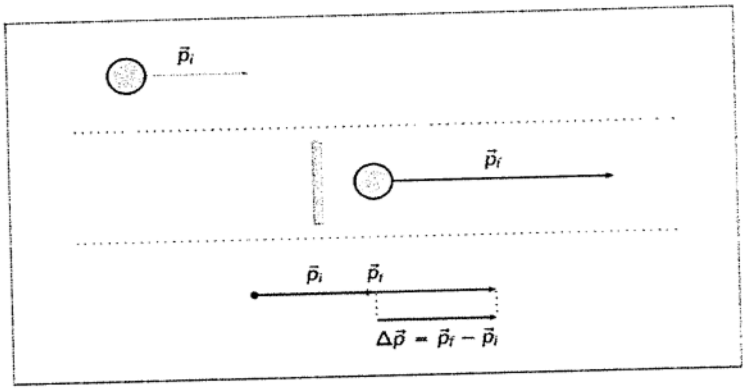


Note that even though the momentum remains in the same direction the change in momentum is in the opposite direction because the magnitude of the final momentum is less than the magnitude of the initial momentum.

<u>Case 4:</u> Object gets a boost

In this case the object interacts with something that increases the velocity it has without changing its direction.

In squash the ball can bounce off a back wall towards the front wall and a player can hit it with a racquet in the same direction, increasing its velocity,



EXAMPLE 1

A 10 000 kg train travelling at 10 m.s^{-1} east collides with a 2 000 kg car travelling at 30 m.s^{-1} in the opposite direction. Calculate:

1.1 The momentum of the train before the collision.

Choose east as positive

$p_i = mv_i$

$p = 10\ 000\ (10)$

$p = 100\ 000$ kg·m·s^{-1} East

1.2 The momentum of the car before the collision.

$p = mv$

$p = 2\ 000\ (-30)$

$p = 60\ 000$ kg·m·s^{-1} West

The train is brought to rest during the collision and the car bounces backwards with a speed of 20 $m.s^{-1}$ after the collision.

1.3 Calculate the change in momentum of the train during the collision.

$$\Delta p = mv_f - mv_i$$

$$\Delta p = 100\,000(0) - 100000(10)$$

$$\Delta p = -10\,000 \text{ kg·m·s}^{-1} \text{ West}$$

1.4 Calculate the change in momentum of the car during the collision.

$$\Delta p = mv_f - mv_i$$

$$\Delta p = 2\,000(20) - 2\,000(-30)$$

$$\Delta p = 40\,000 + 60\,000$$

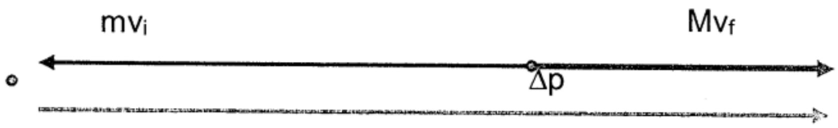
$$\Delta p = 100\,000 \text{ kg·m·s}^{-1} \text{ East}$$

1.5 Draw a labelled momentum vector diagram to illustrate the initial, final and change in momentum vectors for the car.

$mv_i = 60\,000 \text{ kg·m·s}^{-1}$West

$mv_f = 40\,000 \text{ kg·m·s}^{-1}$East

$\Delta p = 100\,000 \text{ kg·m·s}^{-1}$East



NEWTON'S SECOND LAW IN TERMS OF MOMENTUM

Newton's second law of motion in terms of momentum states that, the net (or resultant) force acting on an object is equal to the rate of change of momentum of the object in the direction of the net force.

Newton's second law of motion in symbols: $F_{net} = \frac{\Delta p}{\Delta t}$

Newton's Second Law of Motion can be used to find the object's acceleration due to the net force, and the object's change in momentum due to the net force.

The object's change in momentum is always directly proportional to the net force acting on the object and the time that the net force acts on the object in the direction of the net force acting on the object.

$$\Delta p \propto F_{net}$$

$$\Delta p \propto \Delta t$$

EXAMPLE 1

Why is it less painful for a high jumper to land on foam-rubber carpet than on the ground?

SOLUTION

$F_{net} = \frac{\Delta p}{\Delta t}$

The F_{net} needed to bring the jumper to rest (v_f = 0 m·s−1) depends on Δp and Δt. When he lands on the foam-rubber, he comes to rest over a longer period of time (Δt) than if he lands on the ground. So, time taken (Δt) to change his momentum *increases* F net *decreases* (F net ∝ Δt). The magnitude of F_{net} determines the amount of pain
experienced, so it is less painful to land on foam-rubber.

IMPULSE

Impulse is another way to define momentum.
Impulse is the product of the resultant/net force acting on an object and the time the net force acts on the object. The formula for Impulse is:

Impulse = FΔt where
F is force in newtons N
Δt is change in time in seconds

The SI unit of impulse is N.s

EXAMPLE 2

A spaceship has a mass of 1 000 kg. The rocket engines discharge for 5 s and increase the rocket's velocity from 25 to 30 m·s^{-1}.
1. Calculate the force exerted by the engines to cause this change in momentum.

Solutions

Let the direction of the initial velocity be positive.

$$F_{net} = \frac{\Delta p}{\Delta t}$$

$$F_{net} = \frac{(1000)(30)-(1000)(25)}{5}$$

F net = 1 000 N in the initial direction of motion.

2. Assume the direction of the initial velocity is positive and the answer you obtain in the above problem is negative, what would be the direction of the exerted force?

Solutions

The same i.e. in the initial direction of motion.

EXAMPLE 2

A cricket ball of mass 175 g is thrown horizontally towards a player at 12 m·s^{-1}. It is hit back in the opposite direction with a velocity of 30 m·s^{-1}. The ball is in contact with the bat for a period of 0,05s.
1. Calculate the impulse of the ball.

Choose the direction towards the player as positive

M= 125g = $\frac{125}{1000}$ = 0, 125kg

Impulse = FΔt = Δp = mv_f - mv_i

Impulse = 0,125 (-30) – 0.125(12)

Impulse = - 7, 35 N·s Therefore 7,35 N·s away from the bat.

2. Calculate the force exerted on the ball by the bat.

$F\Delta t = \text{Impulse}$

$-7{,}35 = F(0{,}005)$

$F = -147\text{N}$

Therefore 7,35 N·s away from the bat.

3. Calculate the force exerted on the bat by the ball. Motivate your answer by referring to a law of motion.

SOLUTION

147N towards the bat, according to Newton's third law of motion, the force of the bat on the ball is equal to the force of the ball on the bat, but in the opposite direction.

CONSERVATION OF MOMENTUM AND ELASTIC AND INELASTC COLLISION

Principle of conservation of linear momentum states that, the total linear momentum of an isolated system remains constant (is conserved).

Isolated system (in Physics) is a system on which the net external force is zero.

An isolated system excludes external forces that originate outside the colliding bodies, e.g. friction. Only internal forces, e.g. contact forces between the colliding objects, are considered.)

The external force of friction acting on a system is negligible, the momentum of the system immediately before the collision is the same as the momentum of the system immediately after the collision.

SYMBOLS

m_1	Mass of object 1
m_2	Mass of object 2
v_{i1}	Initial velocity of object 1
v_{i1}	Initial velocity of object 2
v_{f2}	Final velocity of object 1
v_{f2}	Final velocity of object 2
p_i	Initial momentum
p_f:	Final momentum
$\sum$	Sum
$\sum p_i$	Total momentum before collisions
$\sum p_f$	Total momentum after collisions

FORMULA

$\sum p_i = \sum p_f$

$m_1 v_{i1} + m_2 v_{i2} = m_1 v_{f1} + m_2 v_{f2}$

Steps for solving problems on conservation of linear momentum

Step 1. Choose a direction as positive.

Step 2. Sketch the situation – draw a block to represent each object.

Step 3. Write down the equation for the Conservation of Momentum:

$\Sigma p_i = \Sigma p_f$

Step 4. Expand this equation according to the type of collision.

Step 5. Substitute the known values into the equation. Remember to check the direction of the objects' velocities and to use the correct signs for the directions.

Step 6. Calculate the answer.

Step 7. Write the answer, include units and indicate the direction.

REMEMBER

Remember if an object is stationery or at rest its velocity is **ZERO (0)**

Always remember to include units in your answer.

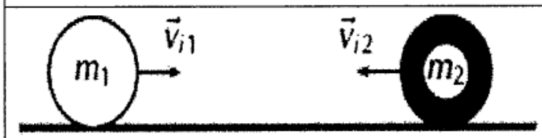
Remember that the +/- signs represent direction. If objects are moving in the opposite direction before or after collision, consider one object's direction as positive (+) and the other object as negative (-) (signs for the velocities of the objects).

CASE 1: Two objects collide and continue to move as separate objects after the collision:

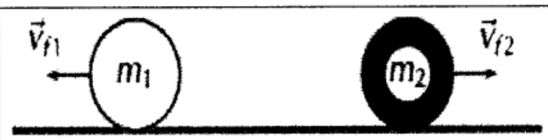
$\sum p_i = \sum p_f$

$m_1 v_{i1} + m_2 v_{i2} = m_1 v_{f1} + m_2 v_{f2}$

Before collision



After collision



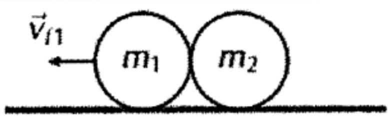
CASE 2: Two objects collide and continue to move together after the collision:

$\sum p_i = \sum p_f$

$m_1 v_{i1} + m_2 v_{i2} = (m_1 + m_2) v_{f2}$

Before collision

After collision

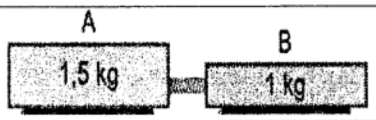


CASE 3: Two moving objects that are initially joined, then separate: or Two stationary objects that are initially joined, separate (e.g. during an explosion):

$\sum p_i = \sum p_f$

$(m_1 + m_2) v_{i1} = m_1 v_{f1} + m_2 v_{f2}$

Before collision



After collision

TYPES OF COLLISIONS

1. Elastic collision
2. Inelastic collision

Elastic collision: both total momentum and total kinetic energy are conserved.

Inelastic collision: only total momentum is conserved; total kinetic energy is not conserved.

DIFFERENTIATING BETWEEN ELASTIC AND INELASTIC COLLISIONS

Elastic Collisions	Inelastic Collisions
• Linear momentum is conserved	• Linear momentum is conserved
• Colliding objects remain separate and are not changed in any way.	• Colliding objects are joined or change their shapes
• Total kinetic energy is conserved: $\sum E_{ki} = \sum E_{kf}$	• total kinetic energy is not conserved: $\sum E_{ki} > \sum E_{kf}$
• E_k before collision = E_k after collision	• E_k before collision > E_k after collision
• The initial kinetic energy is not transformed into any other forms of energy.	• Some of the initial kinetic energy is transformed into other forms of energy e.g. heat, light, sound.

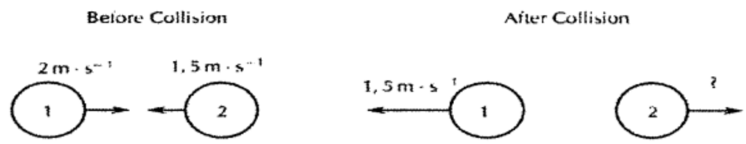
EXAMPLE 1

Two billiard balls each with a mass of 150 g collide head-on in an elastic collision. Ball 1 was travelling at a speed of 2 m·s−1 and ball 2 at a speed of 1,5 m·s−1. After the

collision, ball 1 travels away from ball 2 at a velocity of 1,5 m·s−1.

1. Calculate the velocity of ball 2 after the collision.
2. Prove that the collision was elastic. Show calculations.

SOLUTION



Choose to the right as positive.

1. $\sum p_i = \sum p_f$

$m_1 v_{i1} + m_2 v_{i2} = m_1 v_{f1} + m_2 v_{f2}$

$(0,15)(2) + (0,15)(-1,5) = (0,15)(-1,5) + (0,15) v_{f2}$

$v_{f2} = 3 \text{ m·s}^{-1}$

2. $EK_{Before} = \frac{1}{2} m_1 v_{i1}^2 + \frac{1}{2} m_2 v_{i2}^2$

$EK_{Before} = \frac{1}{2}(0,15)(2^2) + \frac{1}{2}(0,15)(2^2)(-1,5)^2$

$EK_{Before} = 0,47 J$

$EK_{After} = \frac{1}{2} m_1 v_{i1}^2 + \frac{1}{2} m_2 v_{i2}^2$

$EK_{After} = \frac{1}{2}(0,15)(1,5^2) + \frac{1}{2}(0,15)(2^2)(2)^2$

$EK_{After} = 0,47J$

Therefore, collision is elastic

EXAMPLE 2

A learner of mass 68 kg on a skateboard, moving horizontally at constant speed in a
straight line, sees his 20 kg school bag standing directly in his path. He grabs the school
bag and continues to move in a straight line at 3 m·s $^{-1}$.

2.1 Calculate the learner's speed immediately before he grabs the school bag. Ignore the effects of friction.

2.2 Calculate the impulse provided to the school bag.

2.3 The learner experienced an average force of 100 N during the collision with the bag. Determine how long the collision lasted.

2.4 Without any further calculations, compare the acceleration of the learner and the
school bag during the collision.

2.5 Is the collision elastic? Use a calculation to support your answer.

SOLUTION

Choose forward as positive

2.1. $\sum p_i = \sum p_f$

$m_1 v_{i1} + m_2 v_{i2} = (m_1 + m_2) v_{f2}$

$(68)(v_{i1}) + (20)(0) = (68 + 20)(3)$

$v_{i1} = 3,88$ m·s $^{-1}$

2.2. $F_{net} = \frac{\Delta p}{\Delta t}$

Impulse = $F\Delta t$

Impulse = $mv_f - mv_i$

Impulse = (20) (30) – (20) (0)

Impulse = 60 N·s

2.3 $F_{net} = \frac{\Delta p}{\Delta t}$

$(100)(\Delta t) = (68)(3) - (68)(3,88)$

$\Delta t = 0,60s.$

2.4. Both the learner and the bag experience the same net force in opposite directions.

The acceleration is inversely proportional to the mass of the object. The school bag has the smaller mass and therefore experiences the greater acceleration.

2.5. $E_{K\,Before} = \frac{1}{2} m_1 v_{i1}^2 + \frac{1}{2} m_2 v_{i2}^2$

$E_{K\,Before} = \frac{1}{2}(68)(3.38)^2 + \frac{1}{2}(20)(2^2)$

$E_{K\,Before} = 511,85\text{J}$

$E_{K\,After} = \frac{1}{2}(m_1\ m_2)v_f^2$

$E_{K\,After} = \frac{1}{2}(88)(3)^2) + \frac{1}{2}(20)(0)^2$

$E_{K\,After} = 396\text{J}$

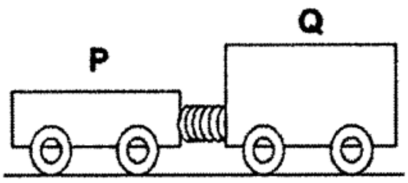
Therefore, collision is inelastic

QUESTION 1: Multiple Choice Questions

1.1 A toy cannon is fixed to a small cart and both move to the right with speed v along a straight track. The cannon points in the direction of motion. When the cannon fires a projectile the cart and cannon are brought to rest. If M is the mass of the cart and cannon combined without the projectile, and m is the mass of the projectile, what is the speed of the projectile relative to the ground immediately after it is fired?

A. Mv/m
B. (M + m)v/m
C. (M-m)v/m
D. mv/M

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

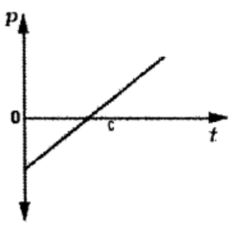
1.3 Impulse is equal to the …

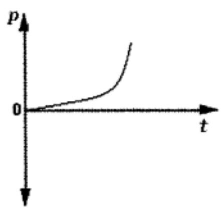
A rate of change in momentum of a body
B final momentum of a body.
C initial momentum of a body.
D change in momentum of a body.

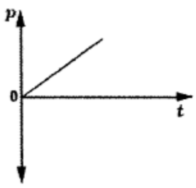
1.4 A collision between two objects is elastic if …

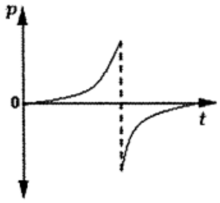
A. the total momentum and kinetic energy is conserved
B. the total momentum is conserved
C. the total kinetic energy is conserved
D. they join after impact.

1.5 A ball is released from rest at a certain height. Which of the following momentum-time graphs correctly describe the motion of the ball from the time it is released to the time just before it hits the ground? (Take the downward direction as positive.)

A


C


B


D


STRUCTURED QUESTIONS

QUESTION 2

2. A ball (mass 0,35 kg) strikes a wall with a speed of 20 m·s^{-1}, rebounding with a speed of 18 m·s^{-1}. The collision with the wall lasts for 0,05 s.

2.1 Calculate the initial momentum of the ball. (3)

2.2 Calculate the final momentum of the ball. (3)

2.3 Calculate the change in momentum of the ball. (3)

2.4 Draw a vector diagram showing: (3)

- the initial momentum,
- final momentum and
- change in momentum of the ball.

2.5 State Newton's second law of motion in terms of momentum. (2)

2.6 Calculate the net force acting on the ball during its collision with the wall. (3)

2.7 Determine the net force acting on the wall during the collision. Justify your answer. (2)

QUESTION 3

3 A car (mass 1 200 kg) accelerates from 20 m·s $^{-1}$ to 40 m·s $^{-1}$ in 8 s.

3.1 Calculate the change in momentum of the car.

3.2 Draw vector diagrams to show the initial momentum, the final momentum, and the change in momentum of the car.

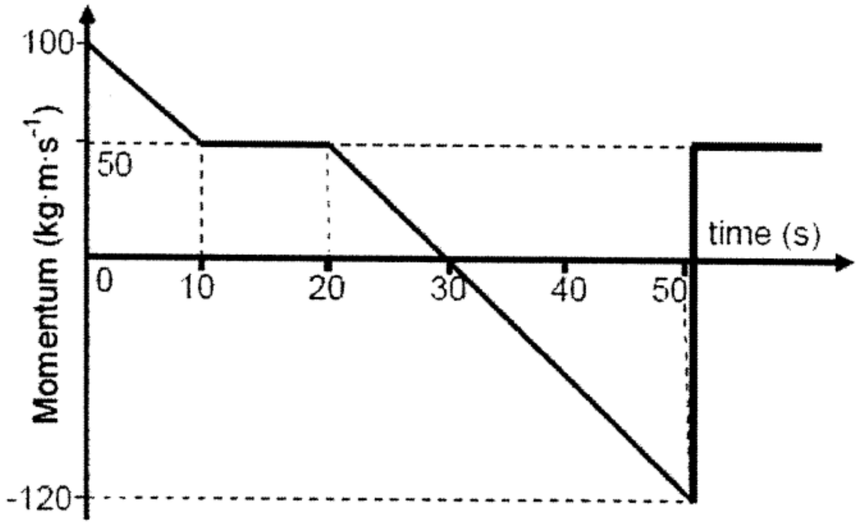
3.3 Calculate the net force acting on the car.

QUESTION 4

4 A football player kicks a soccer ball (mass 450 g) away from him with a speed of 15 m·s^{-1}. His foot is in contact with the ball for 0,6 s. The change in momentum of the ball is 8,1 kg·m·s^{-1} away from the player.

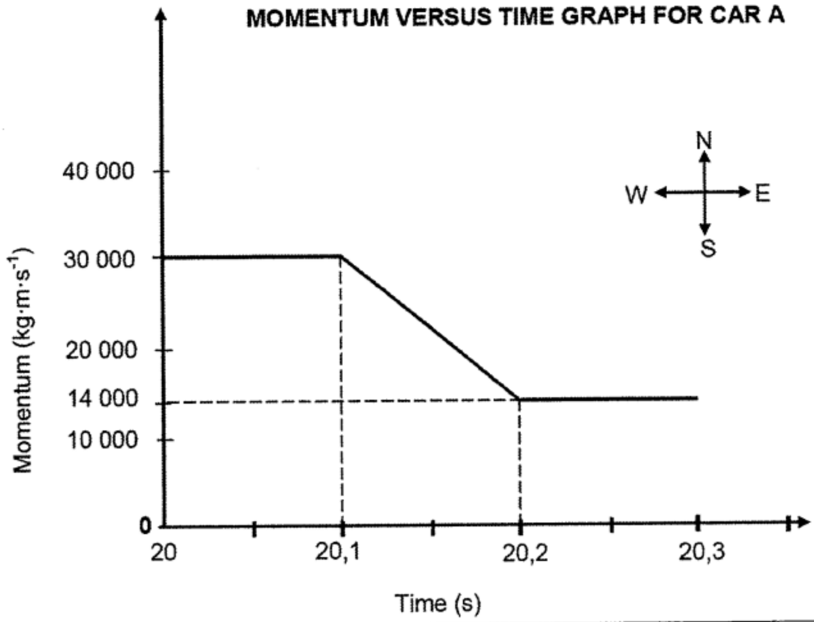
4.1 Calculate the initial speed of the ball. (3)

4.2 Calculate the magnitude of net force of the player's foot on the ball. (3)

QUESTION 5 (PHSC P1 NSCE Feb/March 2014 – Question 4)			
5	The momentum versus time graph of a car, originally moving horizontally EAST, is shown below. 		
	5.1	Write down the definition of momentum in words.	(2)
	5.2	The net force acting on a car is zero between t = 10 s and t = 20 s. Use the graph and a relevant equation to explain why this statement is TRUE.	(2)
	5.3	Calculate the magnitude of the impulse that a car experiences between t = 20 s and t = 50 s.	(3)
	5.4	At t = 50 s, a car collides with a bakkie, which has a momentum of 70 kg·m·s^{-1} EAST. Use the information from the graph and the relevant principle to calculate the momentum of a bakkie after the collision.	(5)

QUESTION 6 (PHSC P1 NSCE November 2016 – Question 4)	
6	The graph below shows how the momentum of car **A** changes with time *just before* and *just after* a head-on collision with car **B**. Car **A** has a mass of 1 500 kg, while the mass of car **B** is 900 kg. Car **B** was travelling at a constant velocity of 15 m·s^{-1} west before the collision.

Take east as positive and consider the system as isolated.



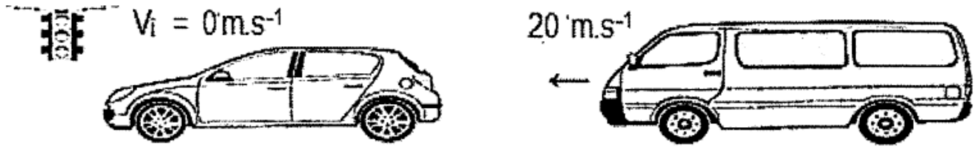
Use the information in the graph to answer the following questions.
Calculate the:

6.1	Magnitude of the velocity of car **A** just before the collision	(3)
6.2	Velocity of car **B** just after the collision	(5)
6.3	Magnitude of the net average force acting on car **A** during the collision	(4)

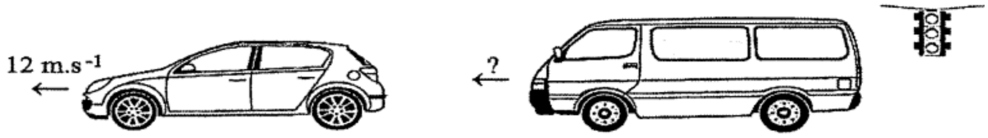
Question7: Eastern Cape PHSC P1 September 2014

A car of mass 1 500 kg is stationary at a traffic light. It is hit from behind by a minibus of mass 2 000 kg travelling at a speed of 20 $m \cdot s^{-1}$. Immediately after the collision the car moves forward at 12 $m \cdot s^{-1}$.

BEFORE



AFTER



	7.1	State the LAW OF CONSERVATION OF LINEAR MOMENTUM in words.	(2)
	7.2	Calculate the speed of the minibus immediately after the collision.	(4)
	7.3	The driver of the minibus is NOT wearing a seatbelt. Describe the motion that the driver undergoes immediately after the collision.	(1)
	7.4	State the law of physics which can be used to explain your answer about the motion of the driver in the previous question.	(2)

VERTICAL PROJECTILE

Projectile is an object upon which the only force acting is the force of gravity.

Free fall is the motion in which an object is moving under the influence of gravitational force only where there is no air resistance

Projectile motion refers to the free fall motion of an object after it has been projected (launched). It is therefore important for learners to understand clearly what is meant by free fall, during free fall, an object accelerates at the acceleration due to gravity,

g = 9, 8 $m.s^{-2}$ downwards. This means that the velocity of a projectile changes by 9.8 $m.s^{-2}$ each second, since a= $\Delta v/\Delta t$

EQUATIONS OF MOTION IN A VETICAL PLANE

$v_f = v_i + a\Delta t$
$v_f^2 = v_i^2 + 2a\Delta y$
$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$
$\Delta y = (\frac{v_i + v_f}{a})\Delta t$

Solving projectile Motion problems

The following procedures summarizes the problem-solving approach.

Carefully read the problem and list known and unknown information in terms of the symbols of the kinematic equations. identify the unknown quantity which the problem requests you to solve for. Select relevant equation to solve for the unknown quantity you are requested to find.in all calculations except those that need application of simultaneous equations, you just need to have one unknown and three known quantities.

Remember:

- **So in all cases you will have g = 9, $8m.s^{-2}$ unless otherwise you are required to prove it. Keeping this data in mind and able to interpret the information given in the statement will make calculations easy.**
- **Start by deciding which motion (up or down) will be positive.**
- **Velocity will be zero at the highest point (turning point) of the object.**
- **Displacement will be positive for an object above its starting point and negative for one below.**
- **If the object is dropped, the initial velocity e.g $vi = 0$ $m.s^{-1}$VERTICAL**

-

-
-
-
-

- **PROJECTILES GRAPHS**

Velocity vs time graph

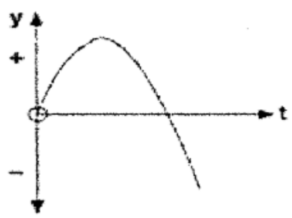
The velocity vs time graph is best describe by the formula $vf = vi + a\Delta t$, this equation can be written mathematically this is in the form $vf = a\Delta t + vi$ which is a straight line , so the graph of velocity vs time will always be a straight or combinations of straight line in case of a bouncing object.

Displacement/position vs time graph

The position vs time graph is best described by the formula $\Delta y = vi\Delta t + \frac{1}{2}a\Delta t^2$

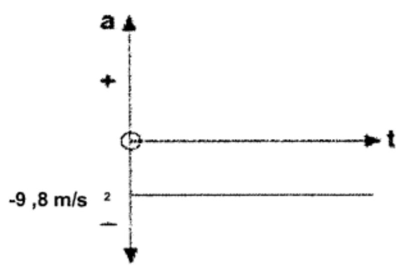
This equation can be written mathematically this is in the form of $y = ax^2 + bx + c$

Which is a parabola, so the graph of position vs time will always be a parabola or combinations of parabolic shape in case of a bouncing object. So a graph can be a full parabolic shape or a part of depending on the question. Teachers must assist in this regard



Acceleration vs time graph

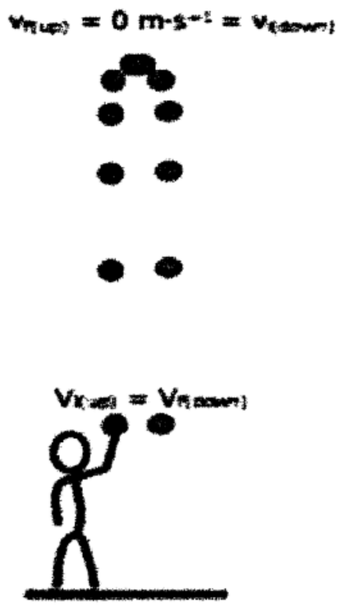
These two are the graphs of acceleration vs time depending on which direction you have taken as positive or negative.

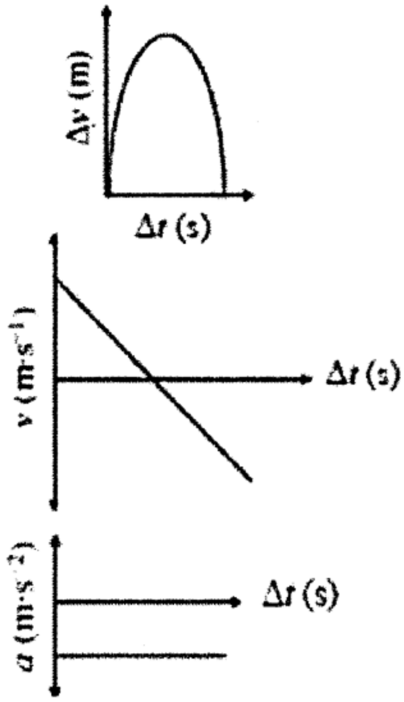


OBJECT THROWN VERTICALLY UPWARD AND RETURNS TO THE SAME POSITION

is

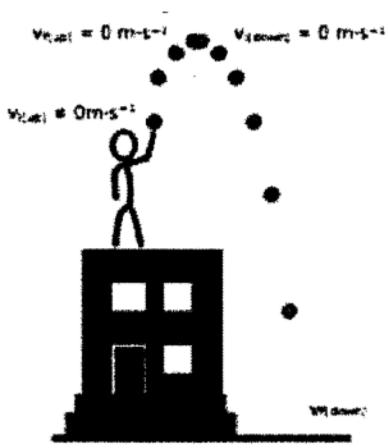
- The object slows down as it moving up in the air.
- The final velocity of the object when it reaches the throwers hand is the same in magnitude but opposite in direction as when it left the throwers hand.
- The time taken from the point of projection to maximum height is equal to the time taken from the maximum height back to the point of projection.
- The object momentarily stops at the maximum height; vf = 0 m.s^{-1}

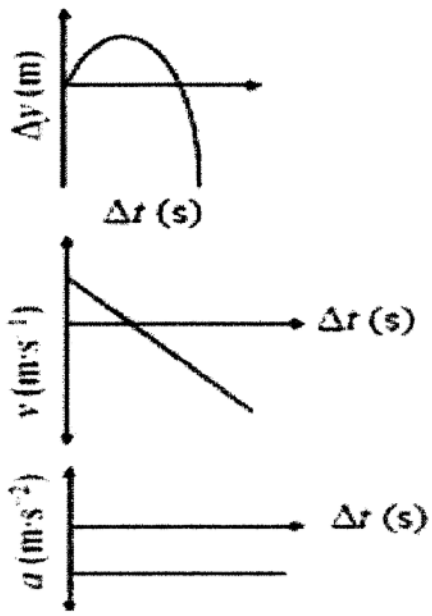




OBJECT THROWN VERTICALLY UPWARD AND PASSES THE POINT OF PROJECTION

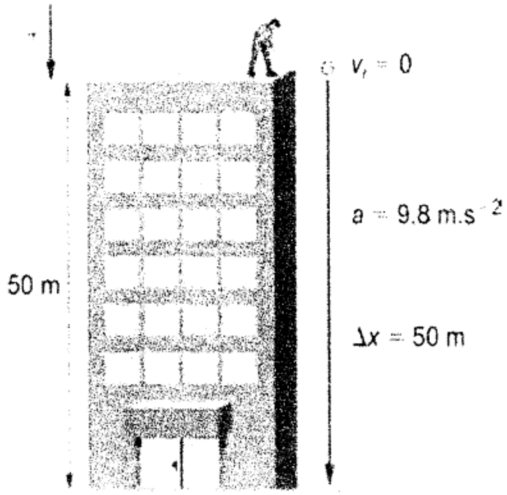
- If the object goes beyond throwers hand, then $v_f > v_i$.
- If the object goes beyond throwers hand, time taken as it moves up is not equal to time taken as it moves down.





EXAMPLE 1:

A ball is dropped from a building which is 50 m high as shown in Figure 2.6. Calculate the ball's velocity just before it hits the ground. Ignore the effects of air resistance.



Solution

Given data: $v_i = 0$ m·s^{-1} $a=$ 9,8 m·s^{-2}

Δy = 50 m

$v_f = ?$

$$v_f^2 = v_i^2 + 2a\Delta y$$

$$= (0^2) + 2\,(9{,}8)(50)$$

$$= 980$$

$v_f = 31{,}30$ m·s^{-1} downward

EXAMPLE 2:

An object is projected vertically upwards. 4 seconds later, it is caught at the same height (point of release) on its way downwards. Ignore all effect of friction

2.1 Calculate the velocity with which the object was projected upwards.

2.2 What is the magnitude and direction of the acceleration at the maximum height reached by the object?

2.1 $v_f = v_i + a\Delta t$

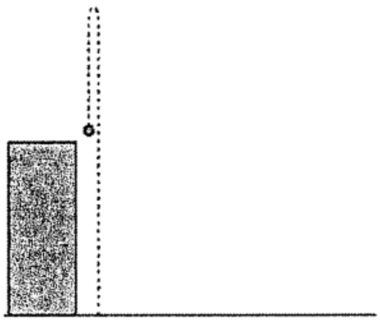
$0 = v_i + (9.8)(2)$

$v_i = 19.6$ m·s^{-1} upwards

2.2 9,8 m·s^{-2} downwards

EXAMPLE 3

A child throws a coin vertically upwards from the window of a high building with an initial velocity of 15 m.s^{-1}. It strikes the ground travelling at 35 m.s^{-1}. Ignore the effects of air resistance.



3.1 Describe the motion of the coin.

3.2 Calculate the time taken for the coin to reach its maximum height above the ground.

3.3 Calculate the time taken for the coin to reach the ground.

3.4 Calculate the height of the building.

3.5 Calculate the distance that the coin has travelled when it hits the ground.

3.6 The position of the coin relative to the top of the building at 4 s.

SOLUTIONS

3.1 Constant (uniform) acceleration downwards.

3.2 **Take up positive**

$v_f = v_i + a\Delta t$

$0 = +15 + (-9,8)\ \Delta t$

$0 - 15 = (-9,8)\ \Delta t$

$\Delta t = 1,53\ s$

3.3 $v_f = v_i + a\Delta t$

$-35 = +15 + (-9,8)\ \Delta t$

$-50 = -9,8\ \Delta t$

$\Delta t = 5,10$ s

3.4 $v_f^2 = v_i^2 + 2a\Delta y$

$(-35^2) = (+15)^2 + 2(-9,8)\Delta y$

$1225 = 225 - 19,6\Delta y$

$\Delta y = -51$

∴ Height= 51m

3.5 $v_f^2 = v_i^2 + 2a\Delta y$

$0 = 15^2 + 2(-9,8)\Delta y$

$0 = 225 - 19,6\Delta y$

$0 - 225 = -19,6\Delta y$

$\Delta y = 11,48$ m

∴ distance travelled = 11,48m

11,48 + 51 = 73,96 m

3.6 Reference point is the top of the building:

$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$

$= (15)(5,10) + \frac{1}{2}(9,8)(5,10)^2$

$= 60 - 78,4$

$\Delta y = -18,4$ m

$\Delta y = 18,4$ m below the top of the building

IMPORTANT TO REMEMBER

- At the starting point its displacement is ZERO, $\Delta y = 0$ m.
  - All displacements for upward motion or downward motion stay positive above starting point.
  - The magnitude of upward displacement from starting position to its highest point is equal to the magnitude of downward displacement from the height point back to the starting point.
- At all times the object accelerates downwards due to the force of gravity.
- At any point during the journey the acceleration of the object is equal to the gravitational acceleration, g.
  - g= 9,8 $m.s^{-2}$ downwards. The velocity of the object changes by 9.8$m.s^{-2}$ in one second throughout the motion.
  - g is independent of the mass of the object.
  - g is dependent upon the distance from the centre of the earth.

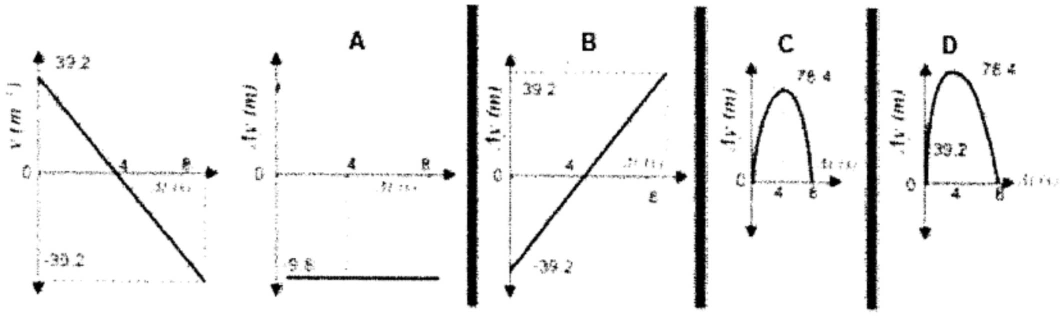
Question 1: Multiple Choice

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 Momentum
- C kinetic energy
- D velocity

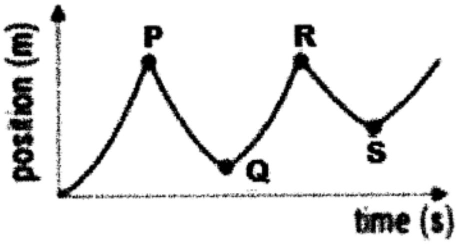
1.2 A 30 kg iron sphere and a 10 kg aluminium sphere with the same diameter fall freely from the roof of a tall building. Ignore the effects of friction. When the spheres are 5 m above the ground, they have the same ...
- A momentum
- B kinetic energy
- C acceleration
- D potential energy

1.3 When a projectile is moving vertically upwards, it …
- A has zero acceleration
- B accelerates downwards with a constant acceleration
- C loses its mass
- D has maximum velocity at its highest point.

1.4 Norma hits a cricket ball from the ground straight up in the air. A graph of velocity vs time was drawn. Upwards is taken as positive. Which of the following graphs represents the corresponding position vs time graph?



1.5 A ball is released from rest from a certain height above the floor and bounces off the floor a number of times. The position-time graph represents the motion of the bouncing ball from the instant it is released from rest.



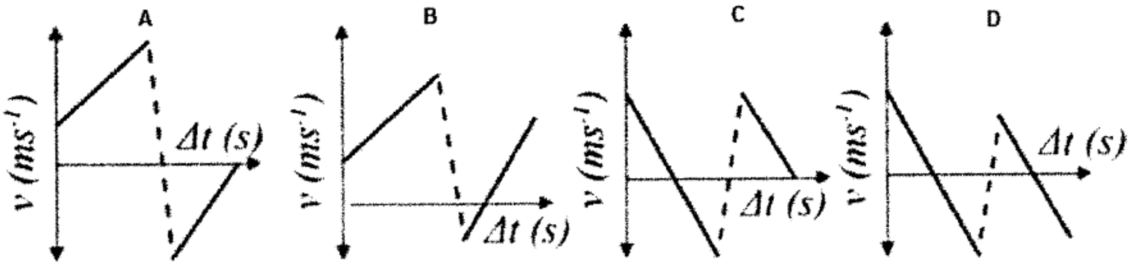
When ignoring air resistance, which point (P, Q, R or S) on the graph represents the position-time coordinates of the maximum height reached by the ball after the SECOND bounce?

A **P**
B **Q**
C **R**
D **S**

1.6 An object is observed and a graph of its distance versus time is constructed. The graph has a slope of +5,0, when the distance is measured in metres and the time is measured in seconds. The object was ...

A motionless
B decelerating
C moving at a constant speed of 5,0 $\mathrm{m \cdot s^{-1}}$
D accelerating at 5,0 $\mathrm{m \cdot s^{-2}}$

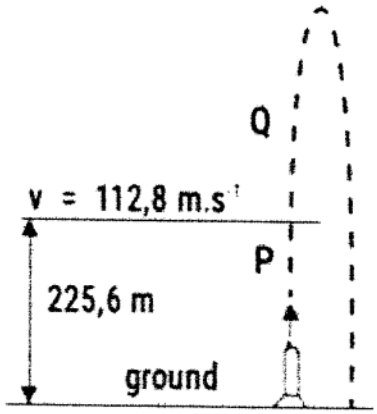
1.7 An object is thrown vertically downwards towards the ground from height h, with a velocity, v. The object strikes the ground and bounces upwards. It is caught when it reaches its maximum height after the bounce. Which ONE of the following graphs for velocity versus time best represents the motion of the object?



Structured Questions

Question 2

A stationary rocket on the ground is launched vertically upwards. After 4 s, the rocket's fuel is used up and it is 225,6 m above the ground. At this instant, the velocity of the rocket is 112,8 m·s-1. The diagram below shows the path followed by the rocket. Ignore the effects of air friction.



2.1 Write down the direction of the acceleration of the rocket at point:

2.1.1 P

2.1.2 Q

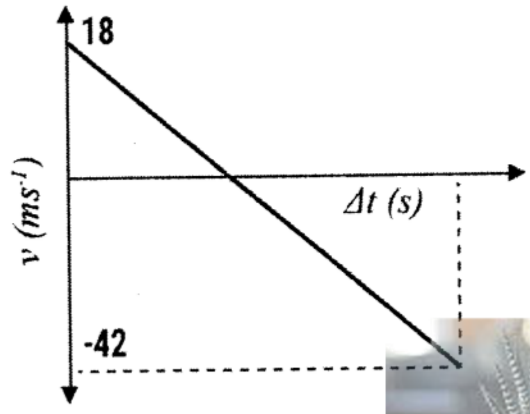
2.2 At which point (P or Q) is the rocket in free fall? Give a reason for your answer.

2.3 TAKING UPWARD MOTION AS POSITIVE, USE EQUATIONS OF MOTION to calculate the time taken from the moment the rocket is launched until it strikes the ground.
Sketch a velocity versus time graph for the motion of the rocket from the moment it runs out of fuel until it strikes the ground. Take the time when the rocket runs out of fuel as t = 0 s. Indicate the following values on the graph.

- Velocity of the rocket when it runs out of fuel.
- Time at which the rocket strikes the ground.

Question 3

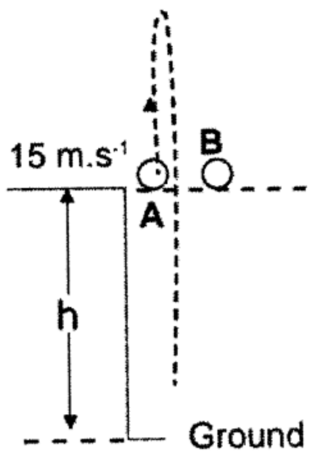
The velocity time graph describes the motion of an object that is projected vertically. Study the graph and answer the following questions:



3.1 After how many seconds does the object reach maximum height?
3.2 What height above its starting point does the object reach?
3.3 How many seconds after its launch does the object hit the ground?
3.4 Calculate the initial height of the object when it was projected.

Question 4

A ball (A) is thrown vertically upward from a height, h, with a speed of 15 m·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.



4.1 Explain the term free fall.
4.2 Calculate the time it takes for ball A to return to its starting point.
4.3 Calculate the distance between ball A and ball B when ball A is at its maximum height.

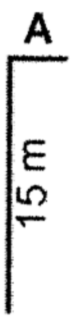
4.4 Sketch a velocity-time graph in your ANSWER BOOK for the motion of ball A from the time

it is projected until it hits the ground.
Clearly show the following on the graph:

- the initial velocity
- the time it takes to reach its maximum height;
- the time it takes to return to its starting point

Question 5

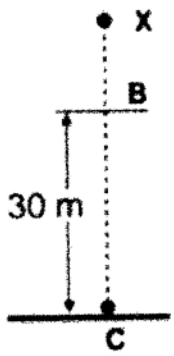
A cricket ball with a mass of 156 g, is dropped from point A on a tall building that is 15 m high. It strikes the concrete pavement and then bounces to a maximum height of 4 m.



5.1 Calculate the velocity with which the cricket ball strikes the pavement.
5.2 If the effects of air friction are NOT ignored during the fall of the ball, how would the value you calculated in the previous question change? Write HIGHER, LOWER or STAYS THE SAME.
5.3 The cricket ball is in contact with the concrete pavement of 0,8 s. Ignore the effects of air friction. Take DOWNWARD motion as POSITIVE.
5.3.1 Calculate the impulse of the cricket ball on the pavement.
5.3.2 Calculate the (net) average force exerted by the pavement on the cricket ball.
5.4 Sketch the position versus time graph for the motion of the cricket ball from the moment it is dropped until it reaches its maximum height after the bounce. USE POINT A AS THE ZERO POSITION. Indicate the following on the graph:
The height from which the cricket ball is dropped.
The height reached by the cricket ball after the bounce.
The length of time that the cricket ball is in contact with the concrete pavement
5.5 The cricket ball is now replaced with a softer ball of similar mass. State how the (net) average force exerted by the concrete pavement on the softer ball compares with your answer in question 5.3.2. (Write down only GREATER, SMALLER or STAYS THE SAME). Use physics principles to explain your answer.

Question 6

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



6.1 Name the type of motion described above.

6.2 Calculate the:

6.2.1 The magnitude of the velocity of the object at point B.

6.2.2 The height of point X above the ground. After hitting the ground, the object bounces once and then comes to rest on the ground.

6.3 Sketch an acceleration-time graph for the entire motion of the object (ignore values of time)

ORGANIC MOLECULES- NOMENCLATURE

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

Learners should be able to...

Write down condensed structural formulae, structural formulae and molecularformulae (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, structural formula; hydrocarbon; homologous series; saturated compounds; unsaturated compounds; functional group; structural isomer
- 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.

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 halo 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.

Physical properties

relationshipbetween 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

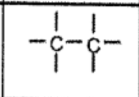
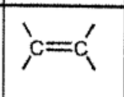
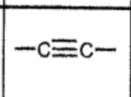
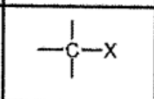
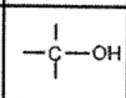
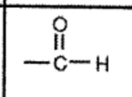
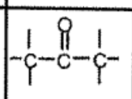
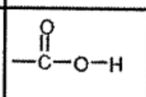
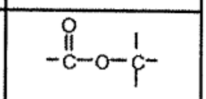
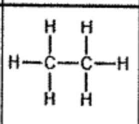
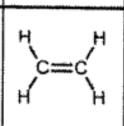
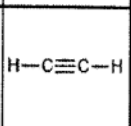
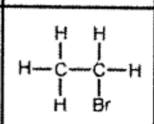
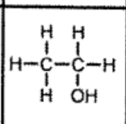
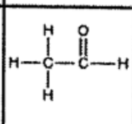
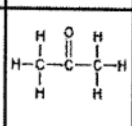
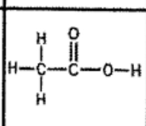
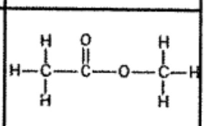
- Identify reactions as elimination, substitution or addition.
- Write down, using structural formulae, equations and reaction conditions for the followingaddition reactions of alkenes:
  - Hydrohalogenation
  - Halogenation
  - Hydration
  - Hydrogenation
- Write down, using structural formulae, equations and reaction conditions for the followingelimination reactions:
  - Dehydrohalogenation of haloalkanes
  - Dehydration of alcohols
  - Cracking of alkanes
- Write down, using structural formulae, equations and reaction conditions for the followingsubstitution reactions:
  - Hydrolysis of haloalkanes
  - Reactions of HX (X = Cℓ, Br) with alcohols to produce haloalkanes
  - Halogenation of alkanes
- Distinguish between *saturated* and *unsaturated hydrocarbons* using bromine water.

Plastics and polymers (only basic polymerisation as application of organic chemistry)

- Distinguish between *addition polymerisation* and *condensation polymerization.*
- Identify monomers from given addition polymers.

- Write down an equation for the polymerisation of ethene to produce polythene.
- State the industrial uses of polythene.

TOPIC MIND MAP

ORGANIC MOLECULES									
Homologous series	Hydrocarbons: Alkanes	Hydrocarbons: Alkenes	Hydrocarbons: Alkynes	Haloalkanes	Alcohols	Aldehydes	Ketones	Carboxylic acids	Esters
General formula	C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}	$C_nH_{2n+1}X$	$C_nH_{2n+1}OH$	$C_nH_{2n}O$	$C_nH_{2n}O$	$C_nH_{2n}O_2$	$C_nH_{2n}O_2$
Functional group									
Example structural formula									
Example IUPAC name	Ethane	Ethene	Ethyne	Bromoethane	Ethanol	Ethanal	Propanone	Ethanoic acid	Methyl ethanoate
Intermolecular forces	London forces (all series)								
				Dipole-dipole forces (Haloalkanes to Esters)					
								Hydrogen Bonding (Carboxylic acids, Esters)	
Chemical reactions	Oxidation Cracking Substitution	Addition		Substitution Elimination	Elimination Substitution Esterification			Esterification	

- Organic Chemistry is the **chemistry of carbon compounds**.

Homologous series

A family of organic compounds is referred to as a homologous series. Per definition a **homologous series** is a group of organic compounds that can be described by the same general formula and have the same functional group OR in which one member differs from the next with a $-CH_2$ group.

General formulae

A **general formula** can be used to determine the molecular formula of any member in

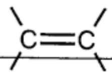
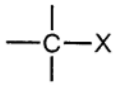
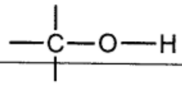
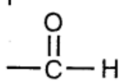
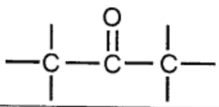
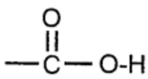
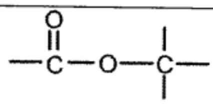
Table 1: General formulae of organic compound

Homologous series	General formula
Alkanes	C_nH_{2n+2}
Alkenes	C_nH_{2n}
Alkynes	C_nH_{2n-2}
Haloalkanes	$C_nH_{2n+1}X$
Alcohols	$C_nH_{2n+1}OH$
Aldehydes	$C_nH_{2n}O$
Ketones	$C_nH_{2n}O$
Carboxylic acids	$C_nH_{2n}O_2$
Esters	$C_nH_{2n}O_2$

Functional groups

properties of a group of organic compounds.

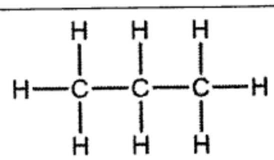
The functional groups of the nine homologous series' that you must learn are listed in the table below.

Homologous series	**Structure of functional group**	
	Structure	**Name/Description**
Alkanes	Only C-H and C-C single bonds	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		-

Representing organic molecules

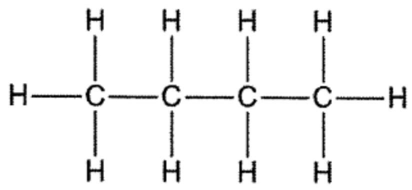
structures may be used.The table below summarises the different types of formulae and structures that can be used.

Table 3: Representation of organic molecules

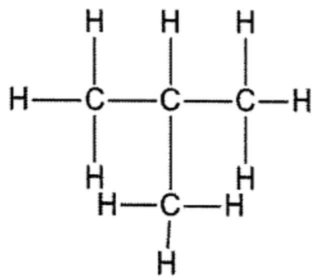
Type of formula	Definition	Example
Molecular formula	A chemical formula that indicates the type of atoms and the correct number of each in a molecule.	C_3H_8
Condensed structural formula	This notation shows the way in which atoms are bonded together in the molecule, but DOES NOT SHOW ALL bond lines.	$CH_3CH_2CH_3$
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 andlines are used to represent ALL the bonds that hold the atoms together.	
Skeletal formula or line structure	Lines represent bonds, and intersections represent C atoms. H atoms are not indicated. Other atoms shown as in structural formula.	

Isomers are compounds with the same molecular formula,but different structures.

Structural isomers are compounds with the molecular formula, but different structural formulae.



Butane



2-methylpropane

These two compounds have the same number and type of atoms but are different compounds due to the different arrangement of the atoms.

Structural isomers can be further divided into chain isomers, positional isomers and functional isomers.

- **Chain isomers**

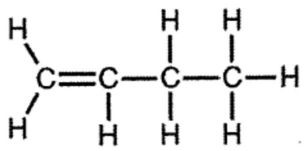
  Chain isomers have the same molecular formula, but different types of chains. Butane and2-methylpropane are chain isomers

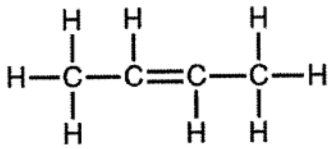
  .

- **Positional isomers**

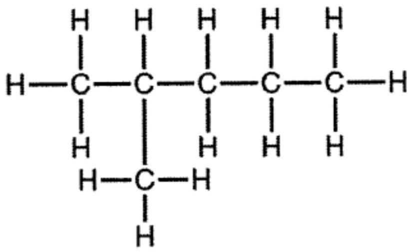
  Positional isomers have the same molecular formula, but different positions of the side chain, substituents or functional groups on the parent chain. Examples of positional isomers are shown below.

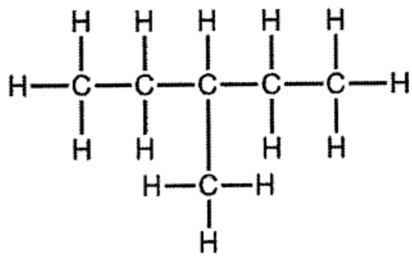
Different positions of the functional group


But-1-ene


But-2-ene

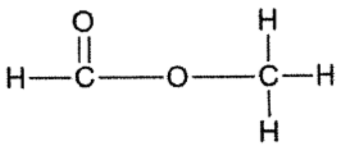
Different positions of the side chain or substituent

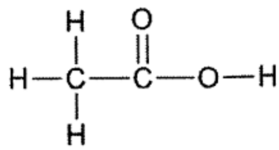

2-methylpentane


3-methylpentane

- **Functional isomers**

  Functional isomer have the same molecular formula, but different functional groups, e.g.methyl methanoate and ethanoic acid.


methyl methanoate


ethanoic acid

Nomenclature of organic compounds

The IUPAC name of every organic molecule has three parts:

- The **parent name** indicates the number of C atoms in the longest continuous carbon chainin the molecule.
- The **suffix** indicates what functional group is present.
- The **prefix** reveals the identity, location and number of substituents attached to the carbonchain.

prefix	parent	suffix
What and where are thesubstituents	How many carbons?	What is the functional group/homologous series?

Table: Parent name for one to eight carbon atoms

Number of carbon atoms	Parent name	Number of carbon atoms	Parent name
1	meth	5	pent
2	eth	6	hex
3	prop	7	hept
4	but	8	oct

Hydrocarbons are compounds consisting of carbon and hydrogen only. These compounds Include alkanes, alkenes and alkynes.

(a) Alkanes

- Alkanes are organic compounds containing only C-H and C-C single bonds.
- General formula: C_nH_{2n+2}
- Functional group: Only C-H and C-C single bonds
- Alkanes are saturated hydrocarbons

  Why hydrocarbons? They consist of hydrogen and carbon atoms only.

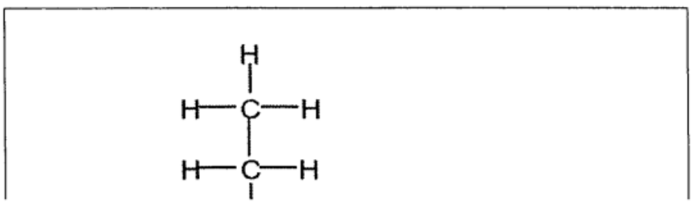
  Why saturated? They have only C-C single bonds or each C atom is bonded to themaximum number of atoms i.e. four.
- Many alkanes occur in nature, mainly as natural gas and petroleum, which are both non-renewable sources of energy. Natural gas is mainly methane, the first alkane in the series. Petrol consists mainly of the alkanes containing from six to twelve carbon atoms.

Example 1

The IUPAC name of the accompanying compound can be determined as follows:

- The compound is a hydrocarbon with only C-C single bonds — an alkane. The name ends on – *ane*.
- The longest chain contains 6 C atoms - the parentname is *hex-*.
- One substituent has 1 C atom - *methyl* group. Another substituent contains 2 C atoms - an *ethyl* group.
- Numbered from the left, the *methyl* group is on C4 and the *ethyl* group on C3.
- Numbered from the right, the *methyl* group is on C3 and the *ethyl* group on C4.
- Numbering from either side gives the same result, but alphabetically *ethyl* comes before *methyl.* Commas separate numbers, while hyphens separate numbers and prefixes.

  The compound is **3-ethyl-4-methylhexane**.

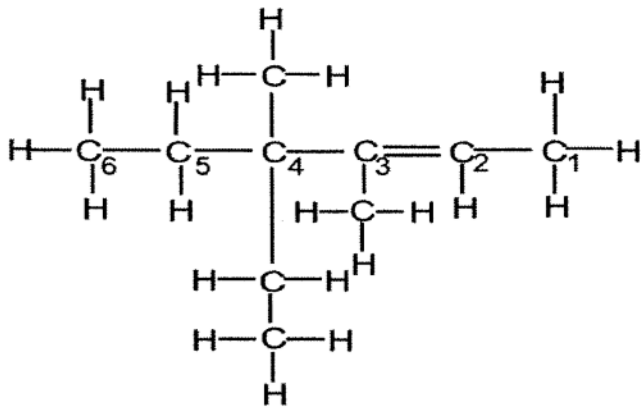


(b) Alkenes

- An alkene is a compound of carbon and hydrogen that contains a **carbon-carbon double bond.**
- General formula: C_nH_{2n}
- Functional group: carbon-carbon double bond
- Alkenes are **unsaturated hydrocarbons.**
  Why hydrocarbons? They consist of hydrogen and carbon atoms only.Why unsaturated? They have carbon-carbon double bonds.

Example 2

- The IUPAC name of the accompanying compound can be determined as follows:
- The compound is a hydrocarbon with a carboncarbon double bond – an alkene.
- The name ends on –ene.
- The longest chain containing the double bond has 6 C atoms - the parent name is hex-.
- If numbered from the right, the double bond is after C2. If numbered from the left, the double bond is after C4. The former gives the double bond the lower number.
- Place the number -2- of the double bond between the parent name and the suffix. Use a hyphen between the number and the suffix and between the number and the parent name.
- The substituents are on C3 and C4. Ethyl before methyl and two methyl groups become dimethyl. **The compound is 4-ethyl-3, 4-dimethylhex-2-ene.**



(c) Alkynes

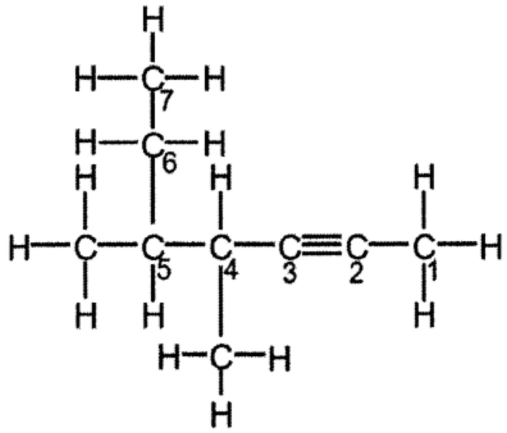
- An alkyne is a compound of carbon and hydrogen that **contains a carbon-carbontriple bond.**
- General formula: C_nH_{2n-2}
- Functional group: carbon-carbon triple bond
- Alkynes are **unsaturated hydrocarbons.**

  Why hydrocarbons? They consist of hydrogen and carbon atoms only.Why unsaturated? They have carbon-carbon triple bonds.
- The **first alkyne** in the homologous series, **ethyne** (acetylene, H−C≡C−H) is a colourless gas that burns in oxygen to form CO_2 and H_2O. The combustion of acetylene releases more energy per mole of product formed than any other hydrocarbons. It burns with a very hot flame and is an excellent fuel.

Example 3

The IUPAC name of the accompanying compound can bedetermined as follows:

- The compound is a hydrocarbon with a carbon-carbon triple bond – an alkyne.
- The name ends on *–yne*.
- The longest chain containing the triple bond has 7 C atoms
  - the parent name is *hept-*.
- Numbered from the other end of the chain, the triple bond is after C2. Numbered from the left, the triple bond is after C5. The former gives lower number.
- Place the number -2- of the triple bond between the parent name and the suffix. Use a hyphenbetween the number and the suffix and between the number and the parent name.
- The substituents, two *methyl* groups, are on C4 and C5

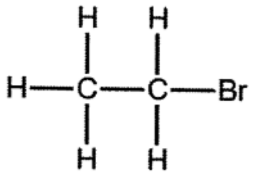
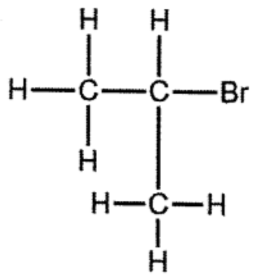
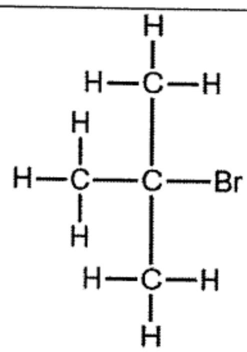


- The compound is **4,5-dimethylhept-2-yne**.

IUPAC names of other homologous series

(d) Haloalkanes

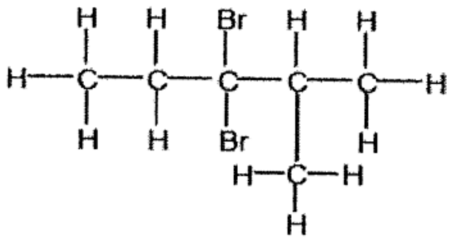
- A haloalkane (or an alkyl halide) is an organic compound in which **one or more H atomsin an alkane have been replaced with halogen atoms.**
- General formula: $C_nH_{2n+1}X$ (X = F, Cℓ, Br or I)
- Functional group: a halogen bonded to a saturated C atom i.e. a C atom forming foursingle bonds
- Haloalkanes can be classified as primary, secondary or tertiary depending on thenumber of C atoms bonded to the carbon with the halogen.

Primary haloalkane	Secondary haloalkane	Tertiary haloalkane
One C atom is bonded to the C atom bonded to the halogen.	Two C atoms bonded to the C atom bonded to the halogen.	Three C atoms bonded to the C atom bonded to the halogen.
		

Example 4

The IUPAC name of the accompanying compound can bedetermined as follows:

- The compound is an alkane containing two halogen H atoms – a haloalkane. The longest chain contains 5C atoms - the parent name is *pentane*.
- Three substituents are present: a *methyl* group andtwo bromine atoms. Numbered from the left, the *methyl* group is on C4, and the Br atoms on C3. Numbered from the right, the *methyl* group is on C2, and the Br atoms on C3. The latter gives the lower numbers.
- Alphabetically *bromo* comes before *methyl.*

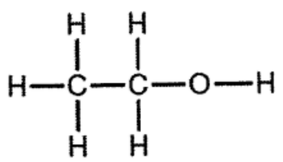
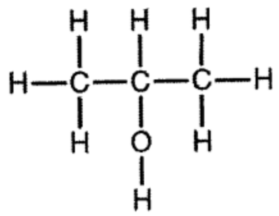
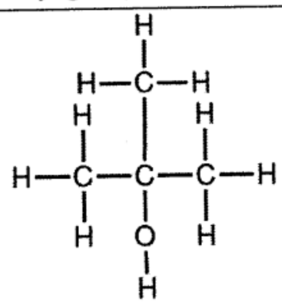


-
- The compound is 3,3-dibromo-2-methylpentane.

(e) Alcohols

- An alcohol (or alkanol) is an organic compound in which **H atoms in an alkane have been substituted with hydroxyl groups (-OH groups).**
- General formula: $C_nH_{2n+1}OH$
- Functional group: a hydroxyl group (OH) bonded to a saturated C atom (sp^3 C atom)
- Alcohols are regarded as organic derivatives of water in which one H atom of water is replaced by an organic group.

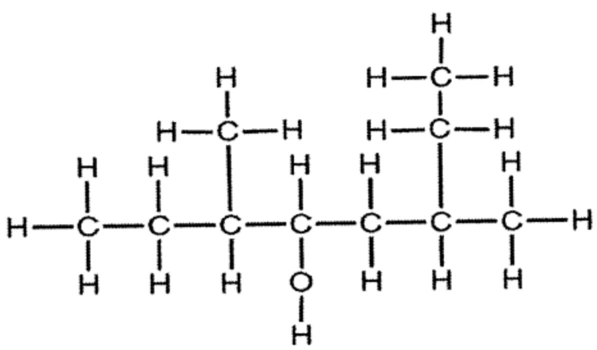
- Methanol (CH_3OH) and ethanol (CH_3CH_2OH) are two of the most important industrial chemicals. Methanol is toxic to humans and causes blindness in small doses. Ethanol is, apart from numerous other industrial uses, used in alcoholic beverages.
- Alcohols can be classified as **primary, secondary or tertiary** depending on the number of C atoms bonded to the carbon atom containing the hydroxyl group.
-

Primary alcohol	Secondary alcohol	Tertiary alcohol
One C atom is bonded to the carbon bonded to hydroxyl group.	Two C atoms bonded to the carbon that is bonded to hydroxyl group.	Three C atoms bonded to carbon that is bonded to hydroxyl group
		

Example 5

The IUPAC name of the accompanying compound can be determined as follows:

- The compound is an alkane containing a *hydroxyl* group — an alcohol. The suffix –*ol* replaces the -*e* in the corresponding alkane.
- The longest chain containing the hydroxyl H group has 8 C atoms - the parent name is *oct-*
- Numbered from the right, the *hydroxyl* group is on C5. Numbered from the left it is on C4. The latter gives the lower number. The number is written between the parent name and the suffix. Hyphens separate the number from the parent name and from the suffix i.e. octan- 4-ol.
- Two substituents are present: two *methyl* groups on C3 and C6.



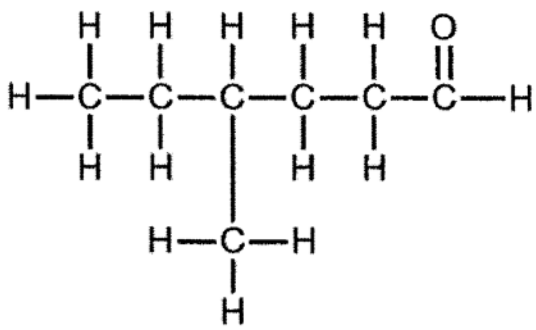
The compound is **3,6-dimethyloctan-4-ol.**

(f) Aldehydes

- Aldehydes are organic compounds having the general structure RCHO where R = H or alkyl.
- General formula: RCHO (R = alkyl group)
- Functional group: -CHO i.e. a carbonyl group (>C=O, pronounced car-bo-**neel**) with at least one H atom bonded to the carbonyl C atom. The -CHO group is called a formyl group.
- The **first aldehyde** in the homologous series, **methanal,** is an important industrial chemical. It is used in the production of many plastics. Its common name is **formaldehyde** and its aqueous solution is sold as formalin used as preservative for biological specimens.

Example 6

The IUPAC name of the accompanying compound can be determined as follows:



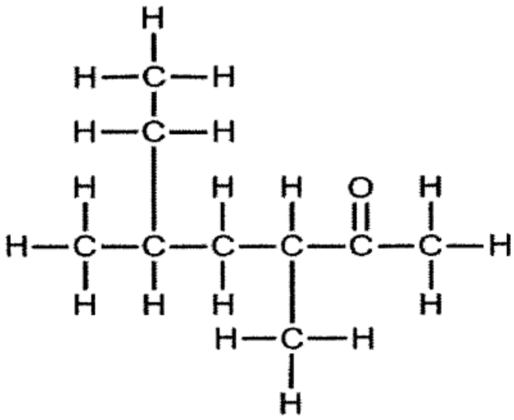
- The compound contains a –CHO group – an aldehyde.
- The suffix *–al* replaces the *-e* in the name of the corresponding alkane
- The longest chain containing the –CHO group has 6 C atoms - the parent name is *hex-*.
- The compound is a *hexanal.*
- One substituent is present: a *methyl* group on C4 (the carbonyl C atom is always C1).
- Thecompound is **4-methylhexanal**.
-

(g) Ketones

- Ketones are organic compounds with two alkyl groups (R and R') bonded to thecarbon atom of a carbonyl group.
- General formula: RCOR' (R & R' = alkyl groups)
- Functional group: a carbonyl group (>C=O, pronounced car-bo-**neel**) with two alkylgroups bonded to it (keto group)
- The **third ketone** in the homologous series, **propan-2-one** (or just propanone), is wellknown as **acetone**. It is an industrial solvent.

Example 7

The IUPAC name of the accompanying compound can bedetermined as follows:



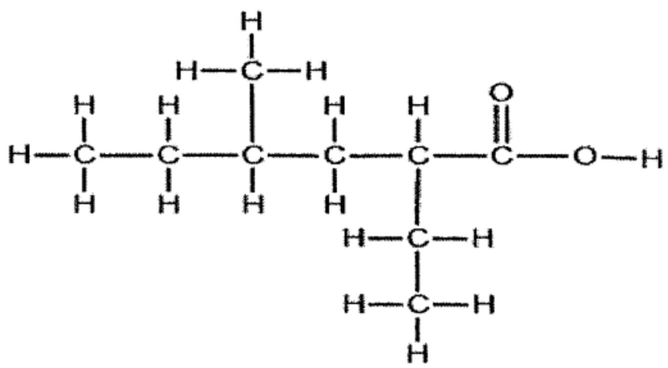
- The compound contains a RCOR' group – a ketone. The –*e* in the corresponding alkane is replaced with *-one*.
- The longest chain containing the carbonyl group has 7 C H atoms - the parent name is *hept.*
- Numbered from the left, the carbonyl C atom is C6. Numbered from the right it is C2. The latter gives the lower number. The number is written between the parent name and the suffix. Hyphens separate the number from the parent name and from thesuffix, i.e. heptan-2-one.
- Two substituents are present: two *methyl* groups on C3 and C5.
- The compound is **3,5-dimethylheptan-2-one.**

(h) Carboxylic acids

- A carboxylic acid is an organic compound containing a carboxyl group (-COOH group). Carboxylic acids have the general structure RCOOH.
- General formula: $C_nH_{2n+1}COOH$ (or RCOOH)
- Functional group: a carboxyl group (-COOH) bonded to a saturated C atom (sp^3 C atom)
- Many carboxylic acids are found in nature. Methanoic acid (HCOOH), the first carboxylic acid in the homologous series, has a biting taste and is responsible for the sting of some ants. Ethanoic acid (CH_3COOH), the second carboxylic acid, is sour component of vinegar. Oxidation of ethanol to ethanoic acid causes "bad" wine to taste sour.

Example 8

The IUPAC name of the accompanyingcompound can be determined as follows:



- The compound contains a –COOH group – a carboxylic acid. The suffix *–oic acid* H replaces the *-e* in the corresponding alkane.
- The longest chain containing the carboxylgroup has 6 C atoms – the parent name is*hex-*.
- Two substituents are present. The carboxyl C atom is always C1, but the number is not shown in the name. An ethyl group is on C2 and a methyl group on C4. Hyphens separate numbers and prefixes.

The compound is **2-ethyl-4-methylhexanoic acid.**

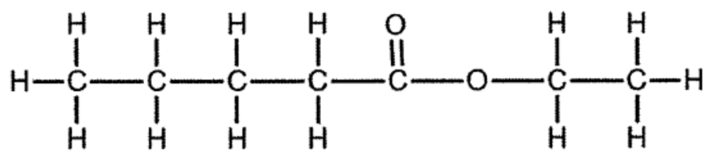
(i) Esters

- An ester is an organic compound with the general structure RCOOR' (R = H or alkylgroup; R' = alkyl group).
- General formula: RCOOR'
- Functional group: –COOR' (R'= alkyl group)
- Esters are derivatives of carboxylic acids and can be prepared by the reaction of analcohol and a carboxylic acid.
- Many esters have pleasant and very characteristic odours.
- The name of an ester has two parts: the first part comes from the alcohol and the last part from the carboxylic acid from which it is derived.

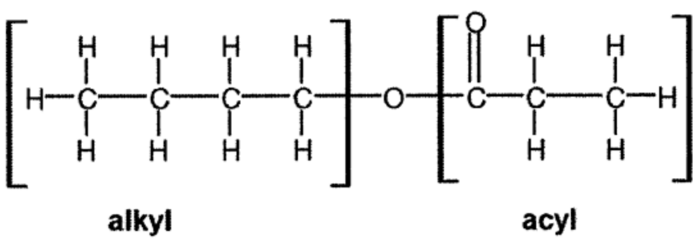
Example 9

The IUPAC name of the accompanying compound can be determined as follows:

- The compound contains a -COOR group – an ester.



The ester has two groups, an alkyl and an acyl, that are named separately:



- The **alkyl group** (originally form butanol) has 4 C atoms. The parent alkane, butane,
- is changed to an alkyl group, i.e. *butyl*. This is the first part of the name of the ester.
- The **acyl group** (originally from propanoic acid) has 3 C atoms. The parent

acid is propanoic acid. The *–ic* in the name is changed to *–ate*, i.e. propanoate. This is the second part of the name of the ester.

- The name of the compound is **butyl propanaoate**.

NOMENCLATURE ACTIVITIES

QUESTION 1

Give one word or term for each of the following statements.

1.1 Organic compounds with the functional group —OH

1.2 The homologous series to which propan-2-one belongs

1.3 The IUPAC name of the alkene with two carbon atoms

1.4 The homologous series to which the compound $CH_3C\ell$ belongs

1.5 The general term that describes compounds that consist of hydrogen and carbonatoms only

1.6 The homologous series to which $H - C \equiv C - H$ belongs

1.7 The IUPAC name of the first aldehyde in the homologous series

1.8 Atoms, groups of atoms or bonds that give a homologous series its characteristicproperties

1.9 The IUPAC name of the first alkyne in the homologous series

1.10 The IUPAC name of the first ketone in the homologous series

1.11 A group of organic compounds with the carbonyl group as functional group

1.12 An atom or a group of atoms that gives an organic compound its chemical properties

1.13 Hydrocarbons containing triple bonds

1.14 Alkanes in which a hydrogen atom has been substituted by a halogen atom

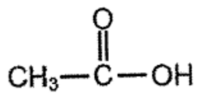
1.15 Compounds with the same molecular formula but different structural formulae

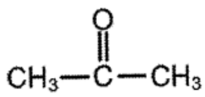
QUESTION 2

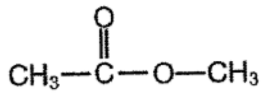
Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number.

2.1 Which formula shown below represents a molecule of an ester?

A $CH_3—OH$

B 

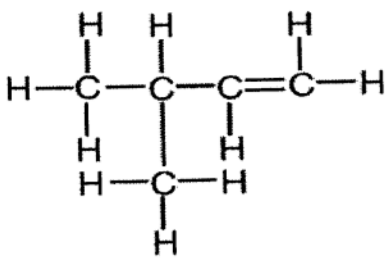
C 

D 

2.2 Which ONE of the following CANNOT be an ester or a carboxylic acid?

A C_3H_6O B $C_3H_4O_2$ C CH_2O_2 D $C_2H_4O_2$

2.3 Consider the organic compound represented below.



The compound is ...

A saturated and branched.

B unsaturated and branched.

C saturated and straight-chained.

D unsaturated and straight-chained.

2.4 A structural isomer of butane is ...

A propane.

B 2-methylbutane.

C 2-methylpropane.

D 2,2-dimethylpropane.

2.5 The alcohols form a homologous series. This means that alcohols have ...

A similar chemical properties.
B similar physical properties.
C the same molecular formula.
D the same structural formula.

2.6 Which ONE of the following general formulae represents alkynes?

A. C_nH_{2n+2} B. C_nH_{2n-2} C. C_nH_{2n} D. C_nH_{2n-1}

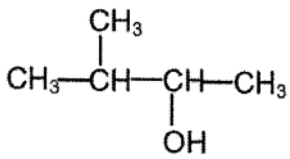
2.7 Which ONE of the following homologous series does NOT contain a CARBONYL group (C O)?

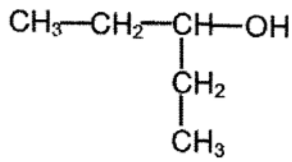
A Aldehydes B Alcohols
C Carboxylic acids D Esters

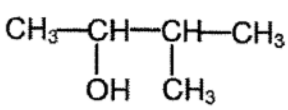
2.8 Which ONE of the following compounds CANNOT be an alkene?

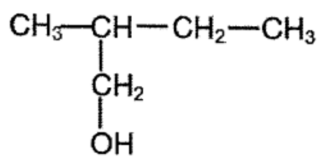
A C_2H_4
B C_3H_6
C C_3H_8
D C_4H_8

2.9 The structures of four organic compounds are shown below.

I


II


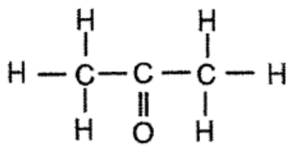
III


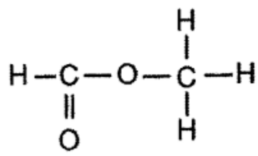
IV


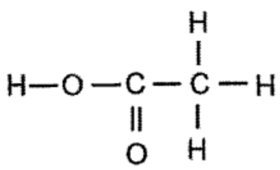
Which of the above compounds have the same IUPAC name?

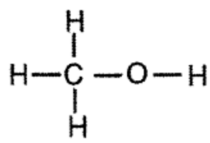
A I and II only B III and IV only
C I and III only D II and IV only

2.10 Which ONE of the following compounds represents a ketone?

A


B


C


D


2.11 Consider the compound with molecular formula C_4H_{10}. How many structural isomers does this compound have?

A 1 B 2 C 3 D 4

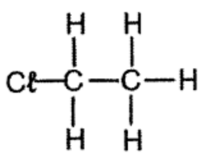
2.12 Which ONE of the following is an alkane?

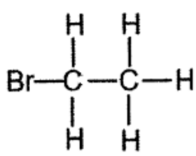
A C_8H_{16} B C_6H_{14} C C_7H_{10} D C_7H_{12}

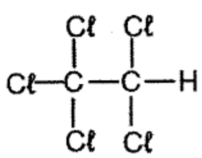
2.13 Which ONE of the following organic compounds is represented by the molecularformula $C_5H_{10}O_2$?

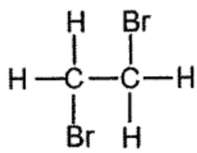
A Ethyl ethanoate
B Butyl ethanoate
C Ethyl propanoate
D Propyl butanoate

2.14 Which ONE of the following compounds has structural isomers?

A


B


C


D


2.15 Consider the organic compounds (**I** to **IV**) shown below.

I $CH\equiv C-CH_2-CH_3$ **II** $CH_3-C\equiv C-CH_2-CH_3$

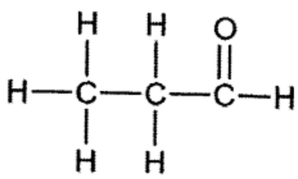
III $CH_3-C\equiv C-CH_3$ **IV** $CH_3-C\equiv CH$

Which of the compounds above are structural isomers?

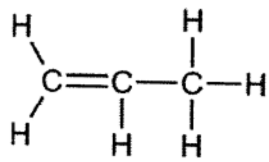
A I and II B I and III C I and IV D II and III

2.16 Which ONE of the compounds represented below is an UNSATURATEDhydrocarbon?

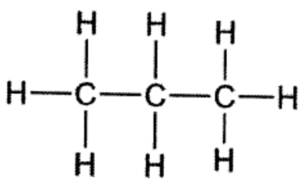
A



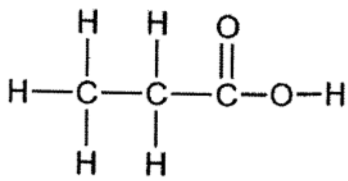
B



C



D

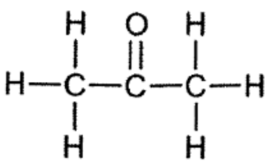


2.17 Which ONE of the following compounds is saturated?

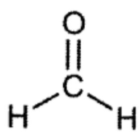
A C_4H_{10} B C_5H_{10} C C_5H_9OH D C_6H_{10}

2.18 Consider the two organic compounds represented by **I** and **II**, as shown below.

I



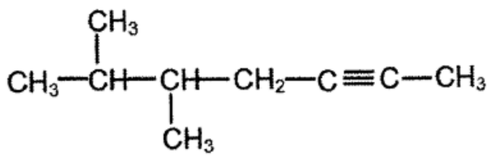
II



Which ONE of the following correctly represents the homologous series to which each belongs?

	I	II
A	aldehyde	alcohol
B	ketone	alcohol
C	ketone	aldehyde
D	aldehyde	ketone

2.19 The structural formula of an organic compound is given below.



The IUPAC name of this compound is ...

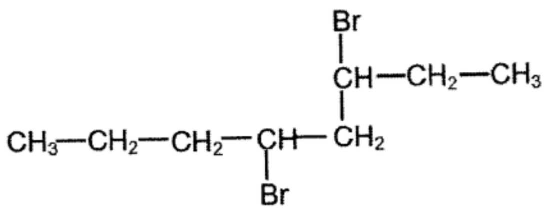
A 2,3-dimethylhept-5-yne.

B 5,6-dimethylhept-2-yne.

C 2,3-methylhept-2-yne.

D 5,6-dimethylhept-3-yne.

2.20 The condensed structural formula of an organic compound is shown below:



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

A 4,6-dibromooctane

B 4-bromo-5-bromo-5-propylpentane

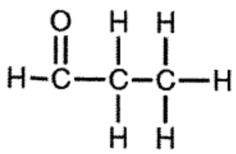
C 3,5-dibromooctane

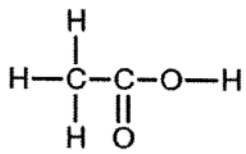
D 2-bromo-1-bromo-1-propylpentane

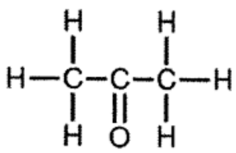
2.21 Which ONE of the following compounds belongs to the same homologousseries as but-2-yne?

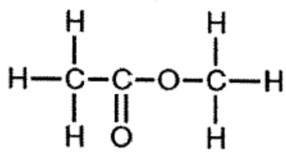
A CH_3CCH
B CH_2CHCH_2
C $CH_3CHCHCH_3$
D $CH_3CH_2CH_2CH_3$

2.22 Which ONE of the following compounds is an isomer of CH_3CH_2COOH?

A


B


C


D


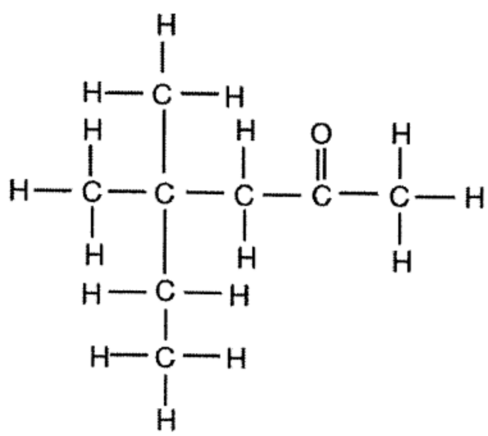
2.23 When the group – C- O - is present in a compound, the compound may be …

A propanal.
B 1-propanol.
C propan-2-one
D methyl ethanoate

QUESTION 3

Consider the organic compounds labelled **A – C**.

A $CH_3CH_2CH_2CH_2CH_2CH_3$

B


C CH_2CH_2

3.1 To which homologous series does compound **C** belong?

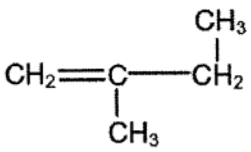
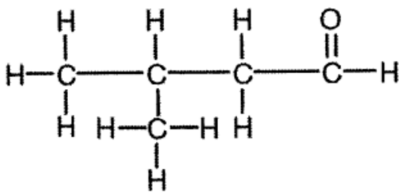
3.2 Compound **C** reacts with chlorine gas in an inert solvent. Using structural formulae, write a balanced equation for the reaction that takes place.

3.3 Write down the IUPAC name for compound **B**.

3.4 Write down the structural formula of an isomer of compound **A** that has only FOUR carbon atoms in the longest chain.

QUESTION 4

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

A	$CH \equiv C - CH_2 - CH_2 - CH_3$	**B**	$CH_3CH_2CH_2CH(OH)CH_3$
C		**D**	Pentanoic acid
E		**F**	$CH_3 - CH_2 - O - C(=O) - CH_2 - CH_3$

4.1 Write down the letter(s) that represent(s) each of the following:

4.1.1 An alkyne

4.1.2 Two compounds that are structural isomers

4.1.3 A compound containing a carboxyl group

4.1.4 An aldehyde

4.1.5 An alcohol

4.2 Write down the:

4.2.1 IUPAC name of compound **C**

4.2.2 Structural formula of compound **D**

4.3 Compound **F** is prepared in the laboratory.

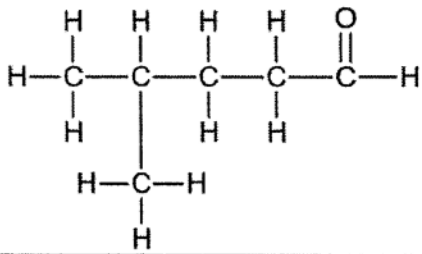
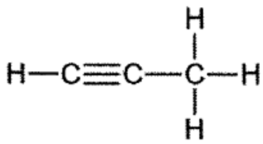
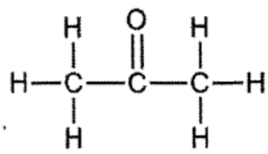
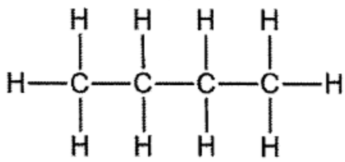
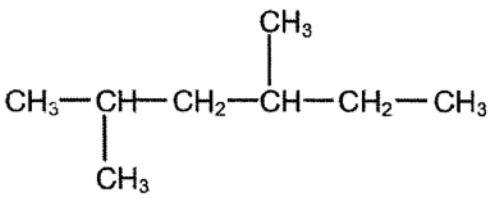
4.3.1 How can one quickly establish whether compound **F** is indeed being formed?

4.3.2 Write down the IUPAC name of the alcohol needed to prepare compound **F**.

4.3.3 Write down the IUPAC name of compound **F**.

QUESTION 5

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

A	**B**
	
C	**D**
	
E	**F**
	ethyl butanoate

5.1 Write down the letter that represents the following:

5.1.1 A ketone

5.1.2 A compound which is an isomer of methylpropane

5.2 Write down the IUPAC name of the following:

5.2.1 Compound **A**

5.2.2 Compound **B**

5.2.3 Compound **E**

5.3 Write down the NAME or FORMULA of EACH of the TWO products formed during thecomplete combustion of compound **D**.

5.4 Compound **F** is the organic product of the reaction between a carboxylic acid andethanol. Write down the following:

5.4.1 The name of the homologous series to which compound **F** belongs

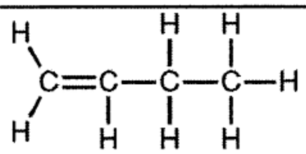
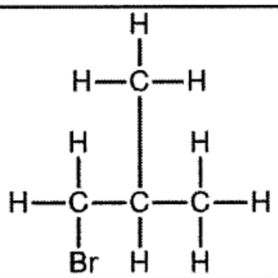
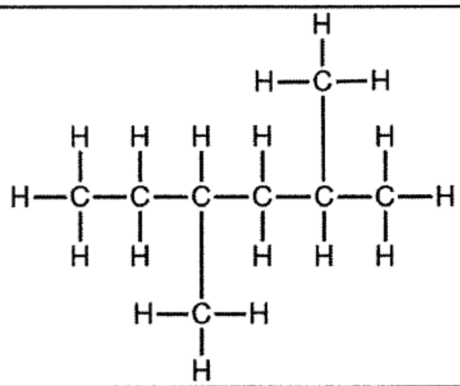
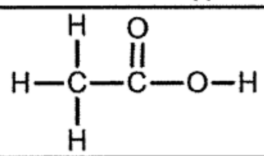
5.4.2 The structural formula of the FUNCTIONAL GROUP of carboxylic acids

5.4.3 The IUPAC name of the carboxylic acid from which compound **F** is prepared

5.4.4 The structural formula of compound **F**

QUESTION 6

The chemical properties of organic compounds are determined by their functional groups.The letters **A** to **F** in the table below represent six organic compounds.

A		**B**	
C		**D**	Methanal
E		**F**	Methyl methanoate

6.1 Write down the LETTER that represents the following:

6.1.1 An alkene

6.1.2 An aldehyde

6.2 Write down the IUPAC name of the following:

6.2.1 Compound **B**

6.2.2 Compound **C**

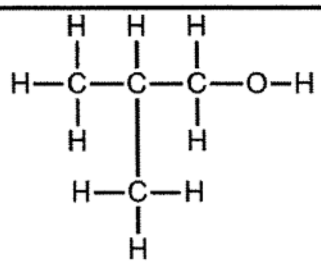
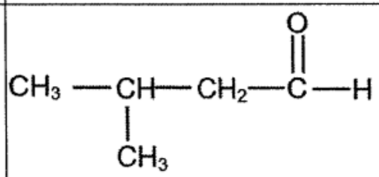
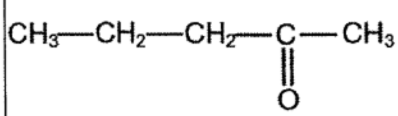
6.3 Write down the structural formula of compound **D**.

6.4 Write down the IUPAC name of the carboxylic acid shown in the table.

6.5 Write down the structural formula of compound **F**.

QUESTION 7

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

A	Pent-2-ene	**B**	
C	Propyl methanoate	**D**	2,5-dimethylheptane
E		**F**	

7.1 Write down the letter representing the compound which:

7.1.1 Is an aldehyde

7.1.2 Has the general formula C_nH_{2n}

7.1.3 Is unsaturated

7.1.4 Is a ketone

7.1.5 Is a hydrocarbon

7.1.6 Can be prepared by the reaction of an alcohol with a carboxylic acid

7.2 Write down the structural formula of:

7.2.1 Compound **A**

7.2.2 Compound **D**

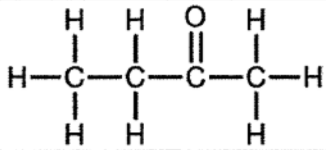
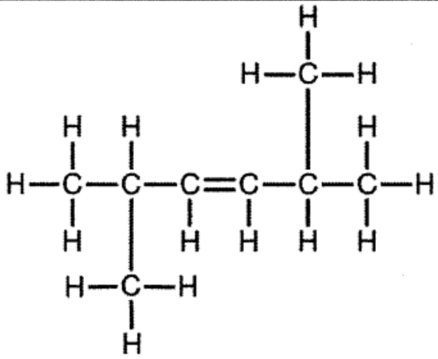
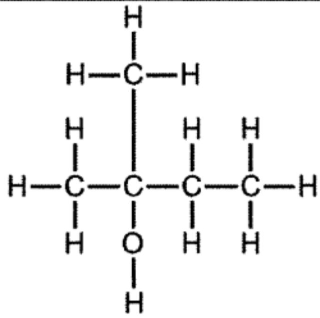
7.3 Write down the:

7.3.1 NAME of the functional group of compound **F**

7.3.2 IUPAC name of compound **B**

QUESTION 8

Millions of organic compounds are known to date. Four of these compounds, represented bythe letters **P, Q, R and S**, are shown in the table below.

P	methanal	**Q**	
R		**S**	

8.1 Write down the following:

8.1.1 Structural formula of the functional group of compound **P**

8.1.2 Homologous series to which compound **Q** belongs

8.1.3 Structural formula of a straight chain functional isomer of compound **Q**

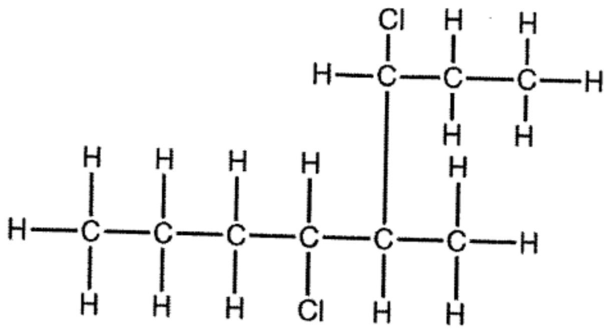
8.1.4 IUPAC name of compound **R**

8.2 Compound **S** represents an alcohol. Classify this alcohol as primary, secondary ortertiary.

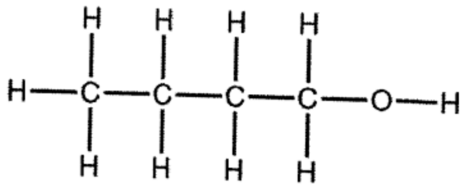
QUESTION 9

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

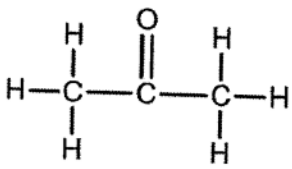
A



B



C



9.1 Write down the:

9.1.1 Name of the homologous series to which compound **C** belongs

9.1.2 IUPAC name of compound **A**

9.1.3 Structural formula of a tertiary alcohol that is a structural isomer of compound **B**

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

9.2.1 What is the role of the concentrated sulphuric acid in this reaction?

9.2.2 Write down the NAME or FORMULA of the inorganic product formed.

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

Use a calculation to determine its:

9.2.3 Empirical formula

9.2.4 Molecular formula

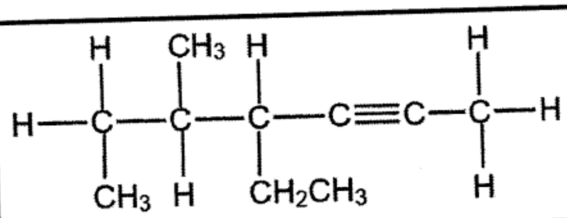
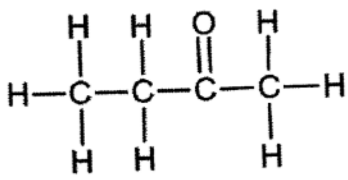
Write down the:

9.2.5 Structural formula of methanoic acid

9.2.6 IUPAC name of the ester

QUESTION 10

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

A		**B**	
C	CH_3CH_2CHO	**D**	Butane

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

10.1 Write down the:

10.1.1 Letter that represents a ketone

10.1.2 Structural formula of the functional group of compound **C**

10.1.3 General formula of the homologous series to which compound **A** belongs

10.1.4 IUPAC name of compound **A**

10.1.5 IUPAC name of compound **B**

10.2 Compound **D** is a gas used in cigarette lighters.

10.2.1 To which homologous series does compound **D** belong?

10.2.2 Write down the STRUCTURAL FORMULA and IUPAC NAME of a structural isomer ofcompound **D**.

10.2.3 Is the isomer in QUESTION 10.2.2 a CHAIN, POSITIONAL or FUNCTIONAL isomer?

10.3 Compound **D** reacts with bromine (Br_2) to form 2-bromobutane.Write down the name of the

10.3.1 Homologous series to which 2-bromobutane belongs

PHYSICAL PROPERTIES OF ORGANIC COMPOUNDS AND INTERMOLECULAR FORCES

Physical properties

- Boiling point is the temperature at which the vapour pressure of a substance is equal to the atmospheric pressure.
- Melting point is the temperature at which the solid and liquid phases of a substance are at equilibrium.
- Vapour pressure is the pressure exerted by a vapour at equilibrium with its liquid in a closed system.

Intermolecular forces.

- Revise the following intermolecular forces (van der Waal's forces) that you studies in grade 11.
  - ➢ London forces are found between molecules of non-polar compounds such as alkanes, alkenes etc. These are the weakest intermolecular forces.
  - ➢ Dipole-dipole forces are found between polar molecules such as those of aldehydes and ketones. These forces are stronger than London forces but weaker than hydrogen bonds.
  - ➢ Hydrogen bonds are the strongest intermolecular forces and they are found in compounds whose molecules contain a hydrogen atom which is bonded to an oxygen or nitrogen atom.
- Intermolecular forces occur between molecules, unlike covalent bonds which hold atoms of the same molecule together.
- Physical properties such as boiling point, melting point and vapour pressure depend on the strength of the intermolecular forces and not the other way round.
- The stronger the intermolecular forces, the higher the boiling point and melting point, but the lower the vapour pressure.
- The weaker the intermolecular forces, the lower the boiling point and melting point, but the higher the vapour pressure.

Activity.

1. Identify the type of intermolecular forces that are found in each of the following compounds:
   1.1 propane (structure)
   1.2 butanal
   1.3 propanol
   1.4 ethanoic acid

2. Which of the following compounds have hydrogen bonds?
   2.1 ethene
   2.2 propanone
   2.3 methanol
   2.4 propanal

2.5 ethyl ethanoate

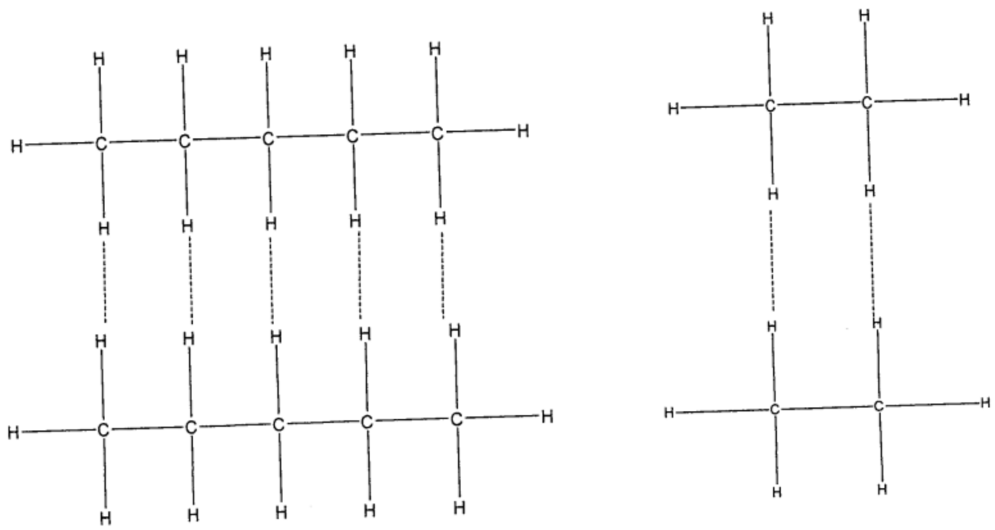
2.6 butanoic acid

2.7 2-methylbutan-1-ol

Relationship between molecular structure and physical properties

1. **Chain length (surface area)**

Consider the following two compounds which are both alkane



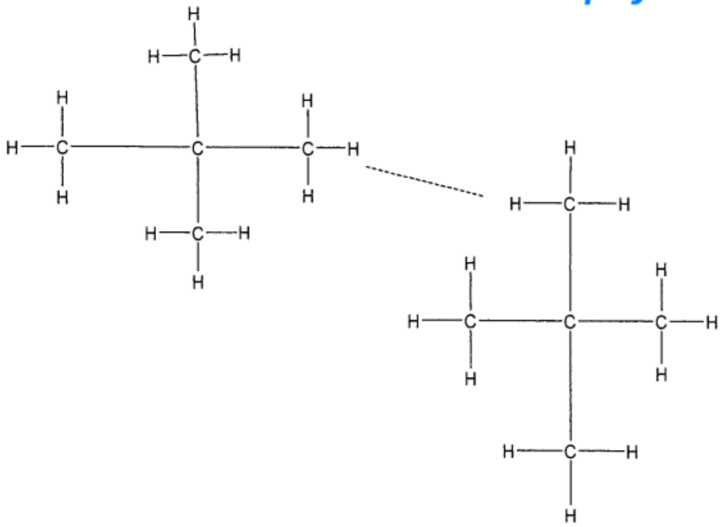
pentane ethane

- The intermolecular forces found in both compounds are London forces (represented by dotted lines).
- In the case of ethane, the London forces are acting over a small area.
- In pentane London forces are acting over a larger area.
- The combined effect of the London forces in pentane is that the two molecules will attract each other more strongly compared to the attraction between the molecules of ethane.
- We say that pentane has a larger surface area than ethane.
- It is therefore more difficult to separate molecules of pentane than those of ethane.
- Therefore, ethane has a higher boiling point than ethane.

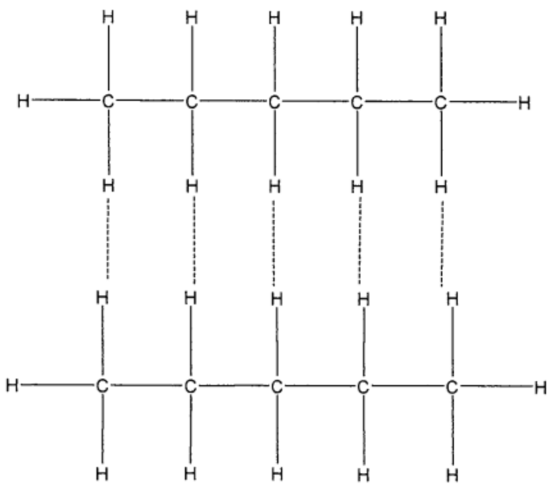
2. **Branching**

Consider the following structural isomers

2,2-dimethylpropane (branched molecule)



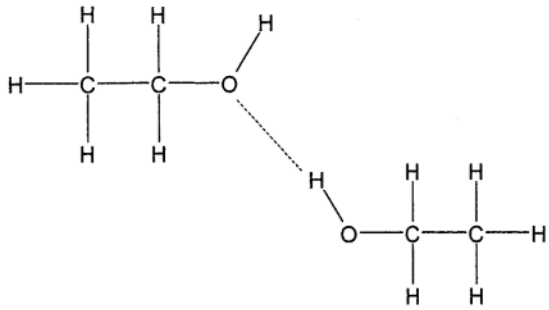
Pentane (straight chain molecule)

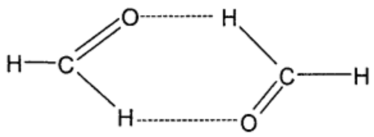


- The two compounds have the same molecular formula.
- When the two molecules come closer together, we notice that the area of contact between the two pentane molecules is larger than the area of contact between the molecules of 2,2-dimethylpropane.
- Therefore the combined effect of the London forces between pentane molecules is stronger than the attraction between the molecules of 2,2-dimethylpropane.
- Because of the larger surface area, more energy is required to separate the molecules of pentane and hence, pentane has a higher boiling point than 2,2-dimethylpropane.

3. Type of functional group

Consider the molecules of ethanol (an alcohol) and ethanoic acid (a carboxylic acid)





Ethanol methanoic acid

- Both alcohols and carboxylic acids have hydrogen bonds which are shown by the dotted lines.
- Carboxylic acids have two sites of hydrogen bonding (two dotted lines) and alcohols have only one site (one dotted line).
- Intermolecular forces in carboxylic acids are therefore much stronger than those of alcohols.
- More energy is required to separate molecules of carboxylic acids
- Therefore methanoic acid has a higher boiling point than ethanol

Worked examples

1 You are given the following organic compounds with their boiling points:

COMPOUND	CONDENSED STRUCTURAL FORMULA	BOILING POINT (°C)
A	CH_3CH_3	-89
B	$CH_3CH_2CH_3$	-42
C	$CH_3CH_2CH_2CH_3$	0

1.1 Write down the IUPAC name of compound C (1)

1.2 In which phase does compound B exist at 25°C? (1)

1.3 The boiling points of the three compounds increase down the table from A to C. Explain this observation. (3)

2 The boiling points of three isomers are given in the table below:

	ISOMER	BOILING POINT (°C)
A	2,2-dimethylpropan-1-ol	113
B	2-methylbutan-1-ol	129
C	Pentan-1-ol	138

2.1 What type of isomers are these? Write down only POSITIONAL, CHAIN or FUNCTIONAL. (1)

2.2 Explain the trend in the boiling points from compound A to compound C. (3)

2.3 Which ONE of the three compounds (A, B or C) has the lowest vapour pressure? Refer to the data in the table to give a reason for your answer. (2)

3 The melting points of two compounds are given in the table below.

COMPOUND	MELTING POINT (°C)
Propanol	-126
Ethanoic acid	16,6

3.1 Define the term melting point. (2)

3.2 Explain the difference in melting points between the two compounds. (3)

Solutions

1.1 butanol

1.2 gas

1.3 Chain length/surface area/molecular mass increases from compound A to compound C. The strength of intermolecular forces increases. More energy is required to overcome the intermolecular forces.

1.1 Chain isomers

1.2 From compound A to compound C, molecules become less branched. The strength of intermolecular forces increases. Therefore more energy is required to overcome the intermolecular forces.

1.3 Pentan-1-ol.
It has the highest boiling point.

3.1 Melting point is the temperature at which the solid and liquid phases of a substance are at equilibrium.

3.2 Both alcohols and carboxylic acids have hydrogen bonds in addition to London forces. Alcohols have only one site of hydrogen bonding and carboxylic acids have two site.

Intermolecular forces are stronger in carboxylic acids. Therefore more energy is required to overcome the intermolecular forces in carboxylic acids, hence the higher boiling point

ACTIVITIES ON PHYSICAL PROPERTIES OF ORGANIC COMPOUNDS

Question 1 – (May/June 2015)

The table below shows five organic compound represented by the letters A to E.

A	CH_4
B	CH_3CH_3
C	$CH_3CH_2CH_3$
D	$CH_3CH_2CH_2CH_3$
E	CH_3CH_2OH

1.1 Is compound B SATURATED or UNSATURATED? Give a reason for your answer. (2)

Consider the boiling points of compounds A to E given in random order below and use them, where applicable to answer the questions that follow.

0°C	-162°C	-42°C	-89°C	78°C

1.2 Write down the boiling point of :

1.2.1 Compound C (1)

1.2.2 Compound E (1)

1.3 Explain the difference in boiling points of compounds C and E by referring to the TYPE of intermolecular forces present in EACH of these compounds. (3)

1.4 Does vapour pressure INCREASE or DECREASE from compounds A to D? Fully explain your answer. (4)

1.5 How will the vapour pressure of 2-methylpropane compare to the vapour pressure of compound D? Write down only HIGHER THAN, LOWER THAN or EQUAL TO. (1)

Question 2 – (Feb/Mar 2016)

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

2.2 What is the relationship between strength of intermolecular forces and boiling point? (1)

The relationship between strength of intermolecular forces and boiling point is investigated using four organic compounds from different homologous series. The compounds and their boiling points are given in the table below.

COMPOUNDS		BOILING POINT (°C)
A	Propane	-42
B	Propan-2-one	56
C	Propan-1-ol	97
D	Propanoic acid	141

2.3 Refer to the TYPE and the STRENGTH of intermolecular forces to explain the difference in boiling points between:

2.3.1 Compounds A and B (3)

2.3.2 Compounds C and D (3)

2.4 Is compound B a GAS or a LIQUID at room temperature? (1)

Question 3 – (May/June 2018)

The boiling points of straight-chain alkanes and straight-chain alcohols are compared in the table below.

NUMBER OF CARBON ATOMS	BOILING POINTS OF ALKANES (°C)	BOILING POINTS OF ALCOHOLS (°C)
1	-162	64
2	-89	78
3	-42	98
4	-0,5	118

3.1 Explain the increase in boiling points of the alkanes, as indicated in the table. (3)

3.2 Explain the difference between the boiling points of an alkane and an alcohol, each having THREE carbon atoms per molecule, by referring to the TYPE of intermolecular forces. (4)

3.3 Does the vapour pressure of the alcohols INCREASE or DACREASE with an increase in the number of carbon atoms? (1)

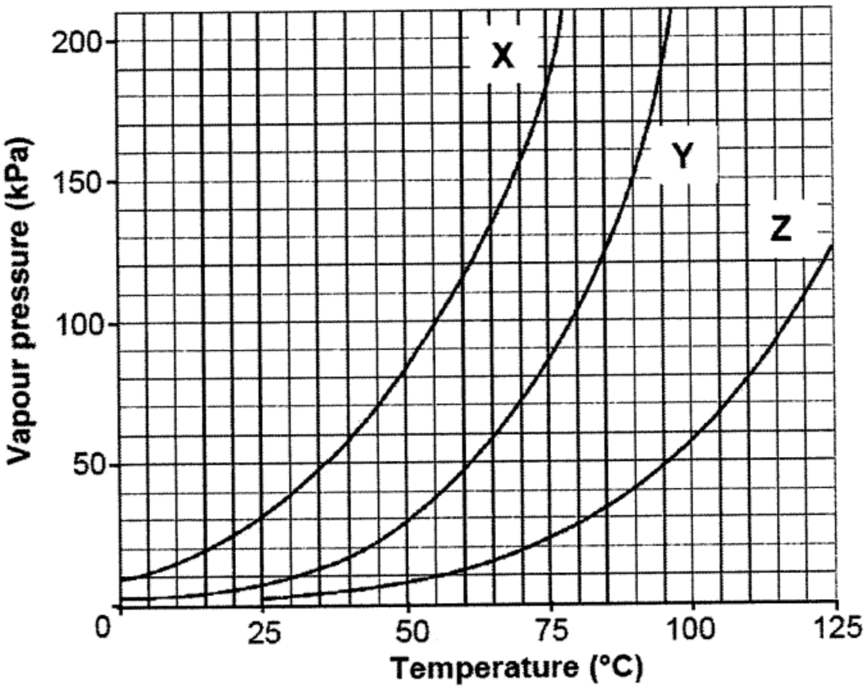
3.4 How will the boiling point of 2-methylpropane compare to that of its chain isomer? (2)

Write down HIGHER THAN, LOWER THAN or EQUAL TO. Give a reason for the answer by referring to the structural differences between the two compounds.

Question 4 – (Feb/Mar 2018)

Study the vapour pressure versus temperature graphs for three organic compounds, X, Y and Z below which belong to different homologous series.
Atmospheric pressure is 1000 kPa.

Graphs of vapour pressure versus temperature



4.1 Write down the vapour pressure of compound Y at 90°C. (1)

4.2 The graphs can be used to determine the boiling points of the three compounds.

4.2.1 Define boiling point (2)

4.2.2 Determine the boiling point of compound X (1)

4.3 The homologous series to which the three compounds of similar molecular masses belong, were identified in random order as:

alcohol; carboxylic acid; ketone

4.3.1 Which compound (X, Y or Z) is a carboxylic acid (1)

4.3.2 Explain the answer to QUESTION 4.3.1 by referring to the type of intermolecular forces in compounds of each of the homologous series above. (4)

4.3.3 Compound X has three carbon atoms per molecule. Write down the IUPAC name of compound X. (1)

REACTIONS OF ORGANIC COMPOUNDS

There are three main types of organic reactions that will be studied here.

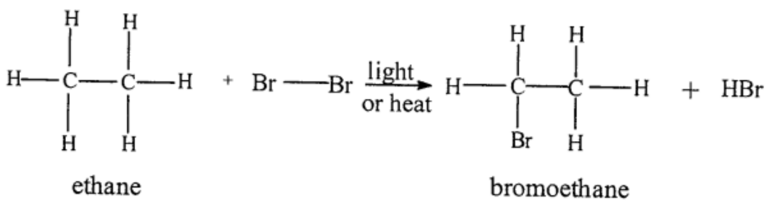
* Substitution- a hydrogen atom or a functional group is replaced by (another) functional group.
* Addition- an atom/group of atoms/functional group is added to a carbon chain across a carbon-carbon double or triple bond.
* Elimination- removal of a hydrogen atom or a functional group from a compound to form an unsaturated compound.

1. SUBSTITUTION REACTIONS

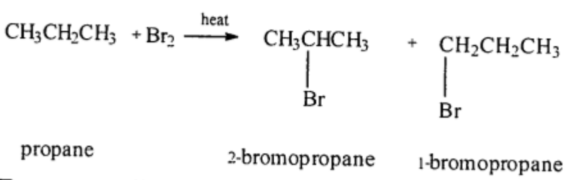
This occurs when a hydrogen atom or a functional group is removed and another functional group is put in its place on the carbon chain.
This hydrogen atom or functional group is said to be a "good leaving group"- meaning that it is readily willing to leave the carbon chain when in the presence of the new functional group.
These reactions only take place with SATURATED compounds under specific conditions.

Examples of Substitution Reactions

1.1 Halogenation of Alkanes



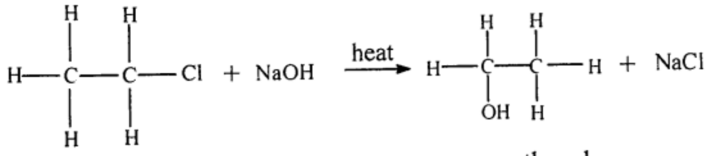
These reactions occur slowly, and take place only in the presence of sunlight/light or heat.
Hence it is possible to convert an unreactive alkane to a reactive haloalkane.
The bromination of propane can give two mono-brominated products:



By controlling the amounts of reactants it is possible to control the degree of halogenation.

1.2 Haloalkanes with Bases.

The haloalkane is dissolved in ethanol (as it is insoluble in water) and reacted with **aqueous** NaOH. The solution is heated.



chloroethane ethanol

The polar C-Cℓ bond is weaker than the pure covalent C- H bond. This makes the Cℓ a good leaving group which is then replaced by the –OH group.
This reaction is also known as a HYDROLYSIS reaction. (hydro = water; lysis = to split. Hence the splitting of water.)

1.3 Alcohols with hydrogen halide

This reaction takes place using dry hydrogen halide and H_2SO_4 (conc).
Solid NaBr is first reacted with H_2SO_4 viz:

$NaBr + H_2SO_4 \rightarrow NaHSO_4 + HBr$

$CH_3CH_2—OH + HBr \longrightarrow CH_3CH_2—Br + H_2O$

ethanol bromoethane

Activity 1

1. Name the products formed in each of the following reactions:
1.1 Bromoethane + water
1.2 2-bromopropane + KOH
1.3 Methane + excess chlorine gas in the presence of sunlight.
1.4 Propan-2-ol reacted with $HBr_{(g)}$.

2 ADDITION REACTIONS

Involves the addition of hydrogen or functional group/s to a carbon chain.
For this to happen, the carbon chain must be UNSATURATED.

Types of Addition Reactions

2.1 Hydrogenation

This reaction involves the addition of hydrogen across a carbon-carbon double or triple bond.

$CH_2{=}CH_2 + H_2(g) \longrightarrow CH_3—CH_3$

ethane ethene

The catalyst used here is usually nickel, platinum or palladium.
The product formed is an alkane.
Hydrogenation is used in the hardening of vegetable oils into fats as in the preparation of margarine.

2.2 Hydration

Is the addition of water to an alkene (across a double bond).
Strong acids such as phosphoric acid or sulphuric acid (conc) serve as catalysts.
The reaction takes place around 330 ^0C.

$$CH_2{=}CH_2 + H_2O \xrightarrow{H_2SO_4} CH_3CH_2OH$$

ethene ethanol

In some hydration reactions more than one product is theoretically possible.

$$CH_3CH{=}CH_2 + H_2O \longrightarrow CH_3CH(OH)CH_3 \quad \text{OR} \quad CH_3CH_2CH_2OH$$

Propene propan-2-ol propan-1-ol

To determine which product is formed, we use the following rule: *during addition of water to unsaturated hydrocarbons, the H atom attaches to the C atom already having the greater number of H atoms. The OH group attaches to the more substituted C atom.*

Hence the secondary alcohol, propan-2-ol, is the only product detected.

Activity 2

Give the products formed when:

2.1 But-1-ene is heated to 300 ^{0}C with water and a small amount of concentrated phosphoric acid

2.2 But-2-ene reacts with water and a small amount of concentrated sulphuric acid. The reaction mixture is heated.

2.3 Methylpropene is heated with water and a little concentrated sulphuric acid.

2.3 Halogenation

This is the addition of a halogen (X_2) across a double/triple bond.
The reaction is fast and can occur in the absence of light.
When a halogen (diatomic molecule) comes into contact with a carbon-carbon double bond, the halogen atoms add onto each of the carbons of the double bond (one halogen onto each of the C atoms).

$$CH_3CH{=}CH_2 + Cl_2 \longrightarrow CH_3CH(Cl){-}CH_2Cl$$

propene 1,2-dichloropropane

Activity 3

3.1 Give the products formed when:

3.1.1 But-1-ene reacts with Br_2

3.1.2 2-methylpropene reacts with chlorine gas.

3.1.3 But-2-ene reacts with $C\ell_2$(g)

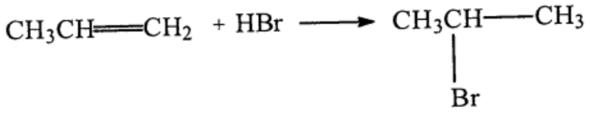
3.2 Describe a test to distinguish between an alkane and an alkene in the laboratory.

2.4 Hydrohalogenation.

This is the addition of H-X (HCℓ; HBr; HI) across a carbon-carbon double/triple bond.

No water must be present, or else the –OH will add onto the double bond instead of the halogen.

The reaction usually involves spraying dry H-X gas onto the alkene.



propene 2-bromopropane

Activity 4

Name the products (major and minor) formed when HBr reacts with:

4.1 But-1-ene

4.2 Pent-2-ene

4.3 Pent-1-ene

3 ELIMINATION REACTIONS

Is the removal of a group of atoms from two adjacent carbon atoms to give rise to an unsaturated compound.

3.1 Dehydrogenation

Also known as cracking

Eg:

$$CH_3CH_3 \xrightarrow[800^\circ C]{Pt} CH_2{=}CH_2$$

ethane ethene

Cracking- is the breaking up of long chain hydrocarbon molecules into smaller more useful ones.

Thermal Cracking- cracking at high temperatures (no catalyst is used)

Catalytic Cracking- cracking at lower temperatures and pressures in the presence of a catalyst.

During catalytic cracking an alkane and an alkene are produced

	Alkane	→	short chain alkane	+ alkene
Eg:	pentane	→	propane	+ ethene

During thermal cracking a mixture of products is obtained:

	Alkane	→	one or more alkenes + hydrogen
Eg:	octane	→	ethane + ethene + but-1-ene + H_2

3.2 Dehydration of Alcohols

Involves the removal of water.

Products are water and an alkene

$H_2SO_{4(conc)}$ is used as the catalyst. Hence this is an acid-catalysed dehydration reaction

$$CH_3CH_2{-}OH \xrightarrow[\text{heat}]{H_2SO_4} CH_2{=}CH_2 + H_2O$$

In some dehydration reactions more than one alkene is possible.
Viz:

$$CH_3CH_2CH(OH)CH_3 \xrightarrow{H_2SO_4(conc)} CH_3CH{=}CHCH_3 + H_2O$$

But-2-ene (major product)

$$CH_2{=}CHCH_2CH_3 +$$

But-1-ene (minor product)

The (major) product formed is determined by the following rule: *If more than one product is possible during elimination, then the product with the double bond that is more highly substituted will form.*

Activity 5

Name, using IUPAC rules, the products formed when concentrated sulphuric acid is reacted with:

5.1 Butan-1-ol

5.2 Pentan-2-ol.

3.3 **Dehydrohalogenation**

-is the removal of hydrogen and a halogen from a carbon chain (usually haloalkane) and the subsequent formation of an alkene.

The reaction takes place under reflux at high temperatures in the absence of water. (Reflux: vapours condense and return to the reacting vessel during heating)

A concentrated solution of a strong base (NaOH/KOH) dissolved in ethanol is used. This is called *ethanolic* NaOH.

$$CH_3CH_2Br + NaOH \xrightarrow[\text{heat}]{\text{ethanol}} CH_2{=}CH_2 + NaBr + H_2O$$

chloroethane ethene

Activity 6

Give the products formed when:

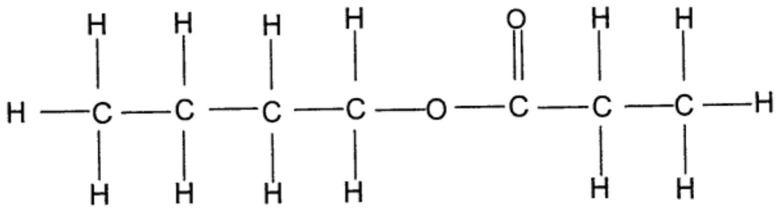
6.1 2-chlorobutane is refluxed in a solution of concentrated NaOH/ethanol

6.2 3-bromohexane is heated strongly under reflux with concentrated KOH/ethanol

4 The Esterification Reaction

When a carboxylic acid and an alcohol are heated in the presence of an acid catalyst (usually $HCℓ_{(conc)}$ or $H_2SO_{4(conc)}$, an equilibrium is established with the ester and water that is formed.
Esters are compounds known for their fruity smells.

$CH_3CH_2CH_2CH_2OH$ + CH_3CH_2COOH $\rightleftharpoons$
$CH_3CH_2CH_2CH_2OOCCH_2CH_3$ + H_2O
Butanol Propanoic acid Butyl propanoate



Butyl propanoate

During the esterification reaction, the –OH group from the acid combines with the –H from the OH of the alcohol to form water. One mole of water is produced.
Although this is an equilibrium reaction, it can be used to make esters in high yield by shifting the equilibrium position to the right (Le Chatelier's Principle). This can be accomplished by using the alcohol or acid in large excess, or by removing the ester and/or water as it is formed.

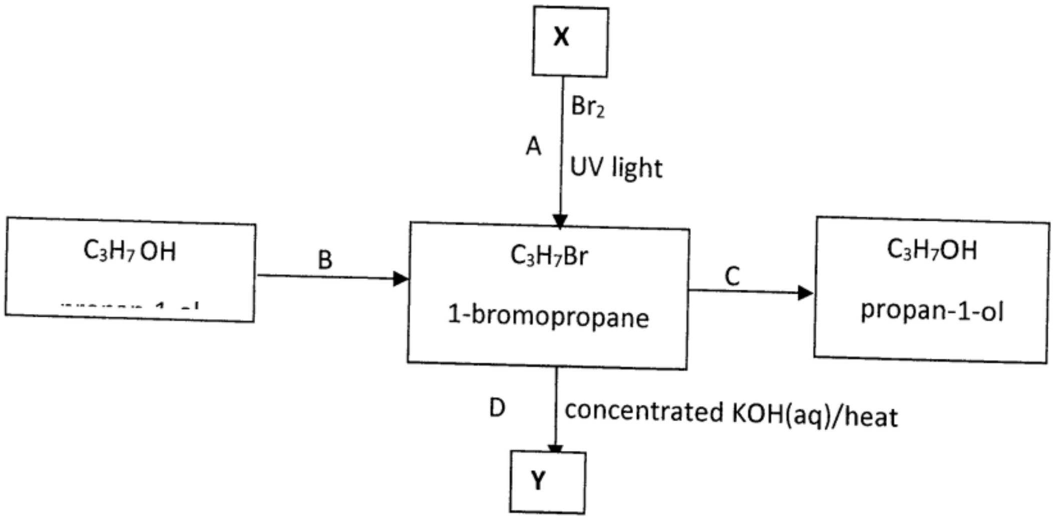
This reaction is also known as an acid-catalysed condensation reaction since two molecules are condensed into one.

Activity 7

7.1 Using structural formulae write the reaction that occurs when
7.1.1 Propanoic acid is heated with ethanol in conc. sulphuric acid.
7.1.2 Butanoic acid is heated with methanol in conc. sulphuric acid.

7.2 You are required to prepare methyl ethanoate in the laboratory.
7.2.1 Name the two reactants you would use.
The reaction takes place using sulphuric acid in concentrated form
7.2.2 What are the two functions that this acid could play in this reaction?
The reaction is said to be an equilibrium reaction
7.2.3 Mention three ways by which the yield of methyl ethanoate can be increased.
7.2.4 Using structural formulae, represent the reaction that takes place.

7.3 Some organic reactions are shown in the flow diagram below.



7.3.1 Name the type of reactions illustrated by A, B, C, D

7.3.2 Use condensed structural formulae and write a balanced equation for reaction C.

7.3.3 Write down the structural formula for compound **X**.

7.3.4 In order to obtain product **Y**, C_3H_7Br is heated with a concentrated solution of KOH under reflux. Use condensed structural formulae to write a balanced equation for the reaction.

7.3.5 A group of learners decided to heat C_3H_7Br with dilute sodium hydroxide, instead of the concentrated potassium hydroxide, under reflux. Write down the IUPAC name of the organic compound that they will obtain.

7.4 Esters are a group of organic compounds widely known for their pleasant odours. The fruity smell of apple is, for example, due to the presence of ethyl butanoate.
Write down the condensed structural formula of ethyl butanoate.

WAVES, SOUND & LIGHT

- Pulse is a single disturbance.
- Wave is a repeated disturbance.
- Period is the time taken to complete a single wave.
- Frequency is the number of vibrations passing through a point in one second.
- Unit for frequency is Hertz (Hz).
- Can be calculated using: $v = f.\lambda$ or $f = \frac{1}{T}$.

TYPES OF WAVES

1. Electromagnetic waves
2. Mechanical waves

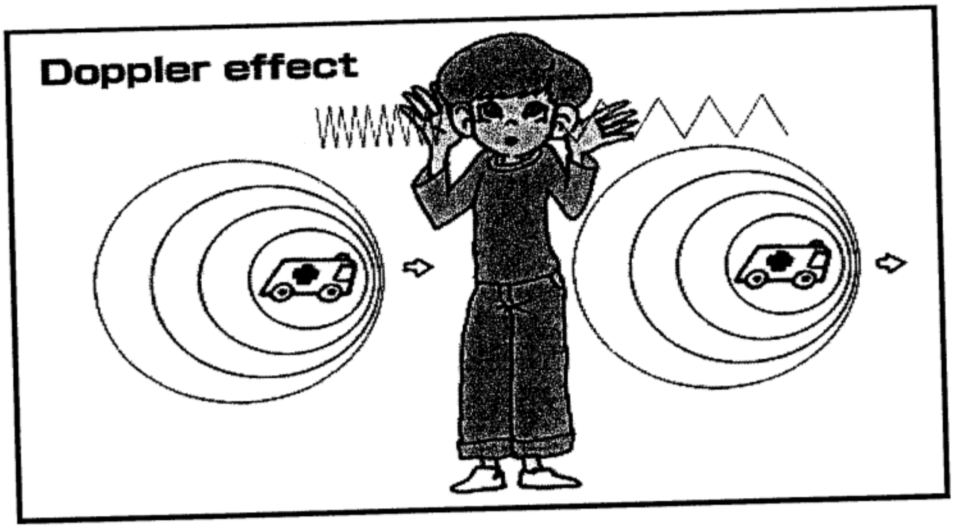
Types of Mechanical Waves

1. Transverse waves
- Particles of the medium move perpendicular to the direction of propagation of a wave.
2. Longitudinal waves
- Particles of the medium move parallel to the direction of propagation of a wave.

DOPPLER EFFECT

It is the change in frequency (or pitch) of the sound detected by a listener, because the sound source and the listener have different velocities relative to the medium of sound propagation.

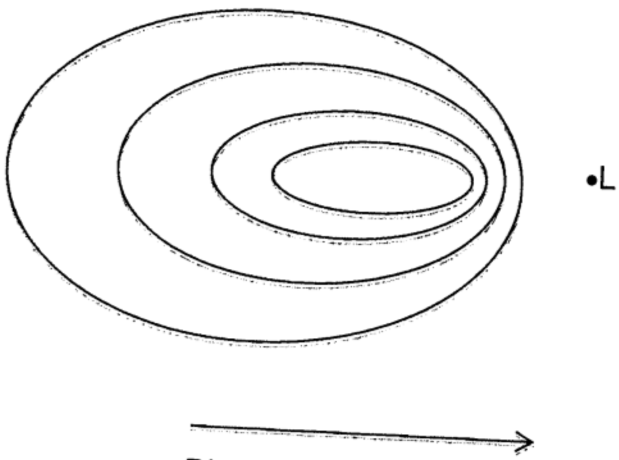
When the source of a sound is moving towards the listener, the pitch sounds higher than that of the source. When the source moves away from the listener the pitch sounds lower. This is known as the DOPPLER EFFECT.



Sketches of Wave Fronts

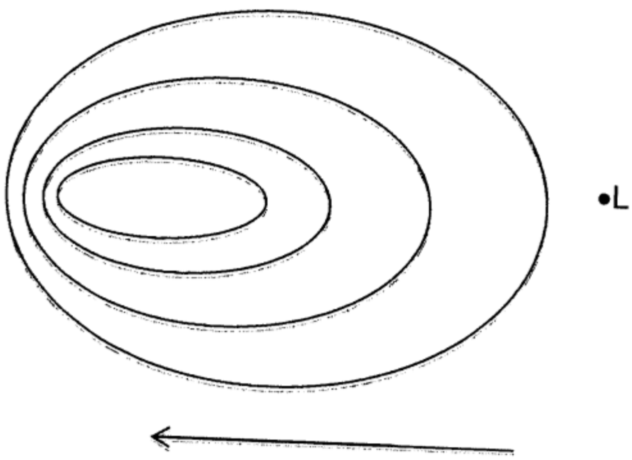
(i) Source moving towards a stationary listener (L):

- Wavelength decreases/ waves are compressed
- Frequency increases
- Velocity constant
- Pitch of sound increases



(ii) Source moving away from a stationary listener (L):

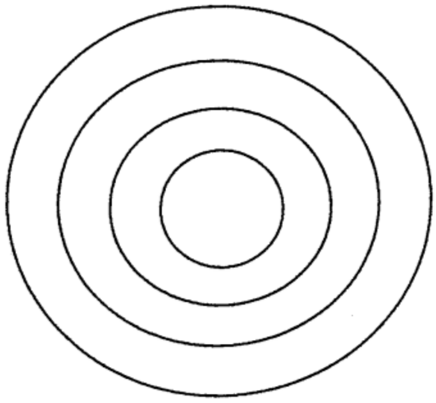
- Wavelength increases/ waves are stretched
- Frequency decreases
- Velocity constant
- Pitch of sound decreases



(iii) Stationary source & listener / Listener inside a moving source:

- Frequency is the same / wavelength is the same at all points
- No relative motion between the source and the observer

- True pitch of sound



Equation of Doppler Effect

$$f_L = \frac{v \pm v_L}{v \pm v_S} \bullet f_S$$

f_L : frequency heard by the listener in Hz
f_s : frequency produced by the source in Hz
v : speed of sound in a medium (e.g. air, water) in $m.s^{-1}$
v_L : velocity of the listener in $m.s^{-1}$
v_s : velocity of the source in $m.s^{-1}$

Applications of Doppler Effect

- Used by traffic department as speed traps.
- Blood flow rate can be measured.
- Speed of the planets and stars can be determined.
- Used to measure heartbeat of the unborn foetus in the womb.
- Used in weather stations to detect precipitation.

Red Shift

- It is the shift in the spectra of distant galaxies towards longer wavelength (i.e. towards the red end of the spectra.
- The Doppler Effect is characteristic of all waves, including light.
- All stars emit white light. Stars moving away from the Earth will display light with longer wavelengths (i.e.the red colours of the spectrum, due to the Doppler Effect).
- Astronomers have found that all stars exhibit a red shift – are moving away from the earth and from each other. This suggest that the universe is expanding.

WORKED EXAMPLES

QUESTION 1

1 In which direction will an absorption spectrum shift during a red shift?

A towards the blue end of the spectrum.
B to light of a shorter wavelength.
C to light of a lower frequency.
D. to light of a higher energy.

Solution

1.C

QUESTION 2

A police car moves away from an accident scene at a constant speed with its siren on. A paramedic at the accident observes a 7% drop in the frequency of the sound of the siren in comparison to when the car was standing still. Speed of sound in air on that day is 335 $m \cdot s^{-1}$.

2.1 State in words, the Doppler Effect. (2)
2.2 Calculate the speed of the car. (4)
2.3 An astronomer on Earth observes the missing frequencies in a line spectrum from a distant galaxy. The frequencies associated with specific elements are all lower than expected.

2.3.1 With what kind of line spectrum is the astronomer working? Answer only ABSORPTION or EMISSION (1)
2.3.2 Identify the type of shift seen by the astronomer. (1)
2.3.3 Is the distant galaxy moving towards or away from our Solar System. (1)

Solutions

2.1 The apparent change in frequency in sound heard due to the relative motion between listener and/or source.√√

2.2

$$f_L = \frac{v \pm v_L}{v \pm v_S} \bullet f_S$$

$$0{,}93f_S = \frac{335 - 0}{335 + v_S} \bullet f_S$$

$$0{,}93(335 + v_S) = 335$$

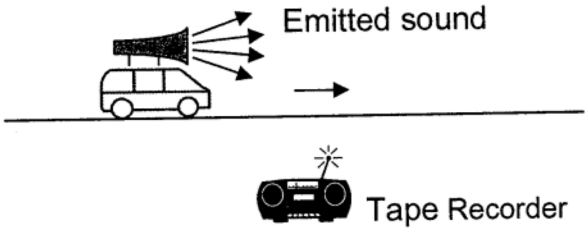
$$v_S = 25{,}22 m.s^{-1}$$

2.3.1 Absorption (line spectrum) √√
2.3.2 Red-shift √√
2.3.3 Away from √√

ACTIVITIES

QUESTION 2

In the diagram, a vehicle with a siren attached to its roof is travelling to the right. The siren emits a continuous note of frequency 450 Hz. Upon listening to a recording on the tape recorder, the siren appeared to be emitting 2 sounds of different frequencies, 464 Hz and 437 Hz.



2.1 Name the phenomenon which would have led to the recording of the two different notes. (1)

2.2 State and very briefly describe one useful application of this phenomenon (as it applies to sound or light). (3)

2.3 Use the information in the text to determine the magnitude of the velocity at which the vehicle was travelling. Take the speed of sound to be 340 $m.s^{-1}$. (4)

2.4. Explain, in terms of the wave fronts being produced, why the observed frequencies are respectively higher and lower than the frequency of the source. (4)

QUESTION 3

An ambulance approaches an accident scene at a constant velocity. The siren of the ambulance emits sound waves with a constant, unknown frequency. A detector at the scene measures the frequency as 1,07 times the frequency of the siren.

3.1 State the *Doppler Effect* for sound in words. (2)

3.2 Calculate the speed at which the ambulance approaches the accident scene. Use the speed of sound in air as 340 $m{\bullet}s^{-1}$. (5)

3.3 Explain, in terms of wave motion, why the frequency detected by the detector is higher than the frequency of the source. (2)

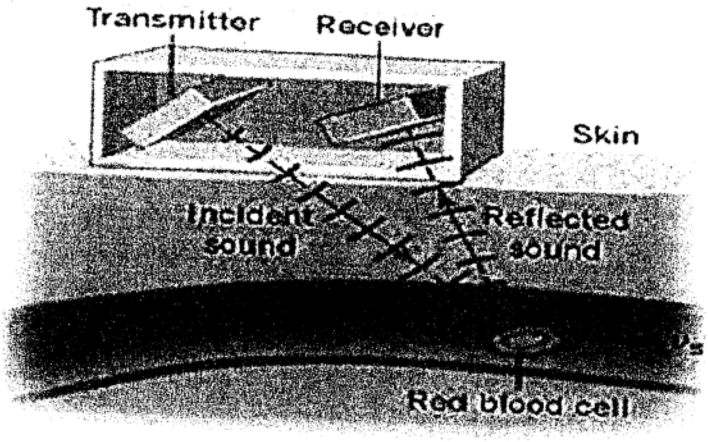
3.4 State TWO uses of the Doppler flow meter in humans. (2)

3.5 A line in a hydrogen spectrum has a frequency of 7,55 x 10^{14} Hz when measured in a laboratory. The same line in the light of a star has a frequency of 7,23 x 10^{14} Hz.

Is this star moving TOWARDS or AWAY from the Earth? Explain your answer. (2)

QUESTION 4

Use the diagram below to answer the following questions.



4.1 Identify the medical device shown in the diagram. (1)

4.2 Explain briefly how the device functions and what it may be used for. (2)

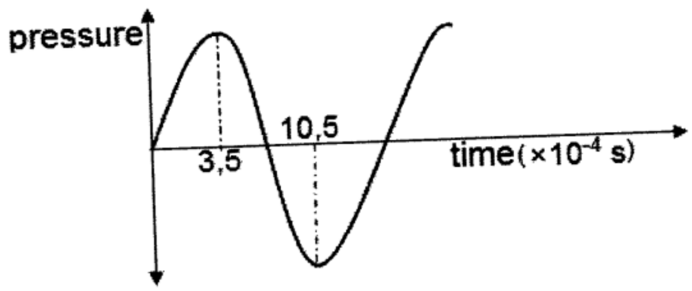
4.3 A fire truck with its siren on, moves away at constant velocity from a person standing next to the road. The person measures a frequency which is 90% of the frequency of the sound emitted by the siren of the fire truck.

4.3.1 Name the phenomenon observed. (1)

4.3.2 If the speed of sound in air is 340 $m \cdot s^{-1}$, calculate the speed of the fire truck. (4)

QUESTION 5

A man mounts a siren on the roof of his car. The siren produces a constant frequency of 600 Hz. He drives the car at a constant speed up and down a straight road while a stationary listener takes some readings. After a while, the listener obtains the following pressure-time graph from the readings taken.



5.1 Determine the period of the detected wave. (2)

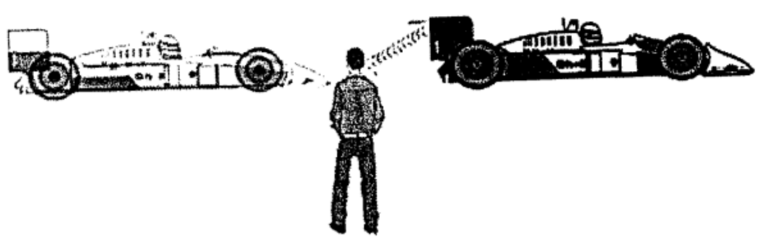
5.2 Calculate the frequency of the detected sound wave. (3)

5.3 State the *Doppler Effect* in words. (2)

5.4 Calculate the speed of the moving car.
Take the speed of sound in air as 340 m.s^{-1} (5)

QUESTION 6

A man standing on the sidewalk notices that the sound of a racing car changes when the car moves towards him at a constant speed of 200 km.h^{-1} compared to when the car is moving away from him.



Assume that the speed of sound in air is 340 m.s^{-1}.

6.1 Name and state the phenomenon illustrated above. (3)

6.2 Convert 200 km·h^{-1} to m·s^{-1}. (2)

6.3 If the frequency of sound that the man will hear when the car is approaching him is 298,84 Hz, calculate the frequency of sound produced by the car. (5)

6.4 State TWO uses of the Doppler flow meter in medical field. (2)

QUESTION 7

Some motion-sensor burglar alarms installed in homes make use of ultra-sound waves that have a frequency of 30 kHz. Waves sent out from the device are reflected by all objects in a room. If the objects are stationary then the reflected waves reach the device with the same frequency as the outgoing wave (30 kHz). If an object moves, the frequency of the reflected waves is altered. Such a change in frequency will trigger the alarm.

Take the speed of sound in air as 340 $m \cdot s^{-1}$.

7.1 Name and state the scientific phenomenon upon which this technology is based. (3)

7.2 Convert 30 kHz to Hz. (1)

7.3 Calculate the wavelength of the waves being generated by the device. (3)

7.4 How will the frequency of a wave detected by the device change when it is reflected off an object moving towards the device? Write only INCREASES, DECREASES or REMAINS THE SAME. (1)

7.5 A wave reflected off a moving object in the room is detected at a frequency of 29 500 Hz. Calculate the velocity of the object. (6)

QUESTION 8

You are on holiday in a Game Park that has lions. To protect the visitors from being attacked by the lions in this Game Park, each lion is fitted with a device that emits sound waves at a frequency of 398 Hz. The visitors are given detectors which measures the frequency of the emitted sound waves from the device fitted in the lions when the lion is a certain distance from the visitors.

On a particular occasion, the detector that you are holding in your hand registers a reading of 408 Hz, while you are sitting in your room.

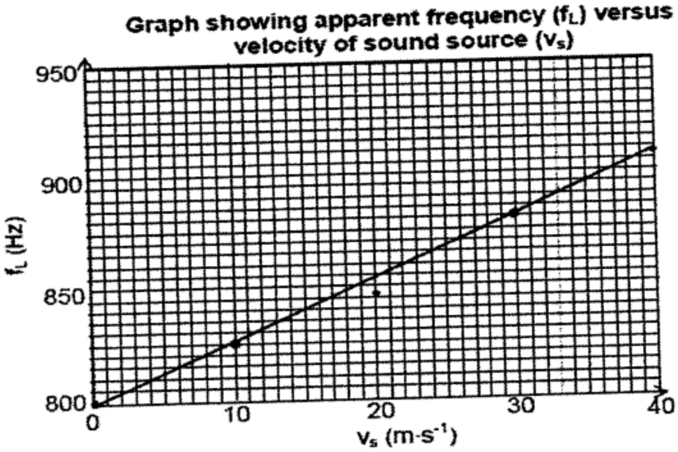
8.1 Name the effect that could be used to explain the difference between the frequency of the waves emitted by the device fitted to the lions and the frequency registered by the detector that you have. (1)

8.2 Briefly explain how the frequency registered by the detector is supposed to help protect the visitors from being attacked by the lion. (3)

8.3 Use the given information to calculate the speed with which the lion is moving if the speed of sound in air is 340 $m.s^{-1}$. (6)

QUESTION 9

The graph below shows the relationship between the apparent frequency (f_L) of the sound heard by a STATIONARY listener and the velocity (v_s) of the source travelling TOWARDS the listener.



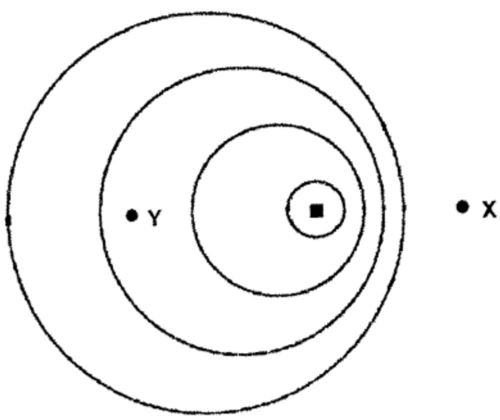
9.1 State the *Doppler Effect*, in words. (2)

9.2 Use the information in the graph to calculate the speed of sound in air. (5)

9.3 Sketch a graph of apparent frequency (f_L) versus velocity (v_s) of the sound source if the source was moving AWAY from the listener. It is not necessary to use numerical values for the graph. (2)

QUESTION 10

An ambulance is travelling towards a hospital at a constant velocity of 30 m·s^{-1}. The siren of the ambulance produces sound of frequency 400 Hz. Take the speed of sound in air as 340 m·s^{-1}.
The diagram below shows the wave fronts of the sound produced from the siren as a result of this motion.



10.1 At which side of the diagram, **X** or **Y**, is the hospital situated? (1)

10.2 Explain the answer to QUESTION 10.1. (3)

10.3 Calculate the frequency of the sound of the siren heard by a person standing at the hospital. (5)

10.4 A nurse is sitting next to the driver in the passenger seat of the ambulance as it approaches the hospital. Calculate the wavelength of the sound heard by the nurse. (3)

QUESTION 11

11.1 A police car is moving at constant velocity on a freeway. The siren of the car emits sound waves with a frequency of 330 Hz. A stationary sound detector measures the frequency of the sound waves of the approaching siren as 365 Hz.

Take the speed of sound in air as 340 $m \cdot s^{-1}$.

11.1.1 State the Doppler Effect in words. (2)

11.1.2 Calculate the speed of the car. (5)

11.2 The spectrum of a distant star when viewed from an observatory on Earth appears to have undergone a red shift.
Use your knowledge of the Doppler effect to explain the term *red shift.* (3)

QUESTION 12

A sound source, moving at a constant speed of 240 $m \cdot s^{-1}$ towards a detector, emits sound at a constant frequency. The detector records a frequency of 5 100 Hz.

Take the speed of sound in air as 340 $m \cdot s^{-1}$.

12.1 Calculate the wavelength of the sound emitted by the source. (7)

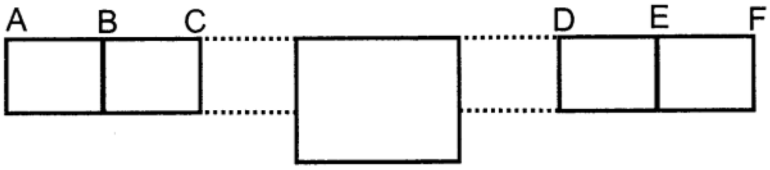
Some of the sound waves are reflected from the detector towards the approaching source.

12.2 Will the frequency of the reflected sound wave detected by the sound source be EQUAL TO, GREATER THAN or SMALLER THAN 5 100 Hz? (1)

QUESTION 13

13.1 A fire engine races towards a burning building CD with the sirens blaring.

Two pedestrians, **X** and **Y**, hear the fire engine and stand still to watch.



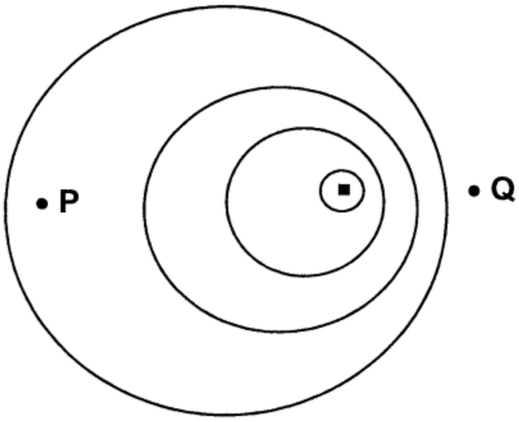
Pedestrian **X** is standing at point **B** and pedestrian **Y** is standing at point **E**.

X hears a higher pitch and **Y** hears a lower pitch.

13.1.1 Write down the NAME of the phenomenon which explains why the pedestrians hear different frequencies. (1)

13.1.2 In which direction (**E to D** or **D to E**) is the fire engine travelling? (1)

The diagram below shows the wave fronts of the sound produced from the siren as a result of the motion of the fire engine.



13.1.3 On what side of the diagram (**P** or **Q**) is pedestrian **Y** standing when he hears the lower pitch? Provide reasons why pedestrian Y hears the siren at a lower pitch by referring to **speed of sound**, **wavelength** and **frequency**. (4)

The siren emits sound of frequency 440 Hz. Assume the speed of sound in air to be 330 $m \cdot s^{-1}$.

13.1.4 Calculate the frequency of sound heard by pedestrian **X** if the fire engine is travelling at 20 $m \cdot s^{-1}$. (3)

13.1.5 Consider pedestrian **X** and sketch a graph of apparent frequency (f_L) versus velocity (v_S) of the sound source. (NO NUMERICAL VALUES NEEDED) (2)

13.2 A helium line from the spectrum of the sun has a frequency of 5,10 x 10^{14} Hz.

The frequencies of the same helium line from the Earth, which are observed in the line emission spectrum of two stars, are:

Star **A**: 5,12 x 10^{14} Hz
Star **B**: 5,02 x 10^{14} Hz

13.2.1 Which ONE of the stars (**A** or **B**) has a red shift? Give a reason for the answer. (2)

13.2.2 In which direction does star **A** move? State only: **Away from the Earth** or **Towards the Earth**. (1)

QUESTION 14

The siren of a stationary fire truck emits sound waves of frequency 1800 Hz. A car, travelling on a straight horizontal road at a constant speed of 30 m.s^{-1}, passes the fire truck and continues at the same constant speed.

14.1 Name the medical instrument that makes use of the Doppler Effect. (1)

14.2 How does the pitch of the siren, heard by the driver of the car, change when the car is moving:

Write only INCREASE, DECREASE or REMAIN THE SAME

14.2.1 Towards the fire engine? (1)

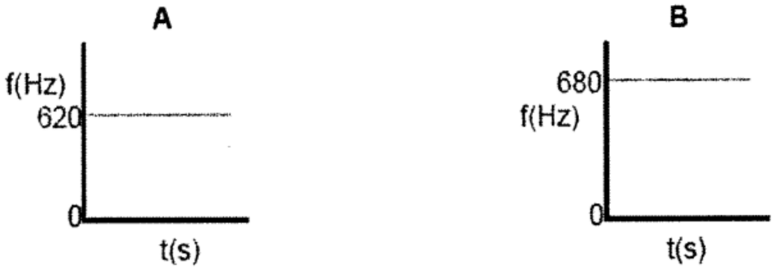
14.2.2 Away from the fire engine? (1)

14.3 Calculate the frequency detected by the driver as the car moves towards the fire trucks. (Take the speed of sound in air as 330 m.s^{-1}) (5)

14.4 Sketch a graph to show how the frequency of the siren changes as a function of time as the driver approaches and then passes the fire truck. (No numerical values are required) (3)

QUESTION 15

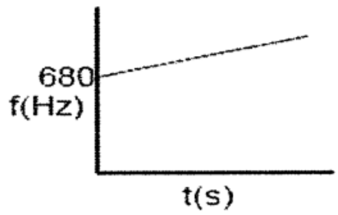
15.1 The siren of a stationary police car emits sound at a frequency of 650 Hz. An observer travelling in a car at constant velocity measures the frequency of the detected sound from the siren for two different situations. The results obtained are presented in graphs **A** and **B** below.



15.1.1 Which graph demonstrates the results obtained when the observer was travelling towards the siren. Give a reason for your answer. (2)

15.1.2 Calculate the speed of the observer using the data from graph **A**. Take the speed of sound in air as 340 $m \cdot s^{-1}$ (5)

The observer now conducts a new investigation and from the results obtained draws the graph shown below.



15.1.3 Explain the change in the shape of the graph when compared to graph **B**. (2)

15.2 State ONE use of the Doppler Effect in medicine. (1)