PHYSICAL SCIENCES
Grade 12
TERM 1
RESOURCE PACK

Contents

WORKSHEETS

Topic 2: Momentum and Impulse

WORKSHEET

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

1.1 The momentum of the train before the collision. (3)

1.2 The momentum of the car before the collision. (3)

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

1.3 Calculate the change in momentum of the train during the collision. (4)

1.4 Calculate the change in momentum of the car during the collision. (4)

1.5 Draw a labelled momentum vector diagram to illustrate the initial, final and change in momentum vectors for the car. (3)

2. Car A (mass 600 kg) was travelling at 5 $m{\cdot}s^{-1}$ north when it was struck from behind by car B (mass 800 kg) which was travelling at 12 $m{\cdot}s^{-1}$ north. Car A travels forward (north) at 10 $m{\cdot}s^{-1}$ after the collision. Car B continues moving forward (north) at 8,25 $m{\cdot}s^{-1}$ after the collision.

2.1 Calculate the momentum of car B before the collision. (3)

2.2 Calculate the change in momentum of car B during the collision. (4)

2.3 Calculate the change in momentum of car A during the collision. (4)

2.4 Use Newton's laws to explain why the momentum of car B decreases during the collision. (3)

3. A man of mass 85 kg on roller skates, moving horizontally at a constant speed of 5 $m{\cdot}s^{-1}$ in a straight line, sees a child of mass 20 kg standing directly in his path. The man grabs the child and they both continue moving forward at 2 $m{\cdot}s^{-1}$. The collision between the man and the child lasts for 1,3 s.

3.1 Calculate the average net force acting on the man during the collision. (5)

3.2 What is the magnitude and direction of the average net force acting on the child during the collision? (2)

4. A man of mass 80 kg wearing a seatbelt, is driving a car at 20 $m{\cdot}s^{-1}$ which collides with the back of a stationary truck causing the car to bounce backwards at 2 $m{\cdot}s^{-1}$ after the collision. The collision lasts for 0,2 s. Calculate the average force of the seatbelt on the man during the collision. (5)

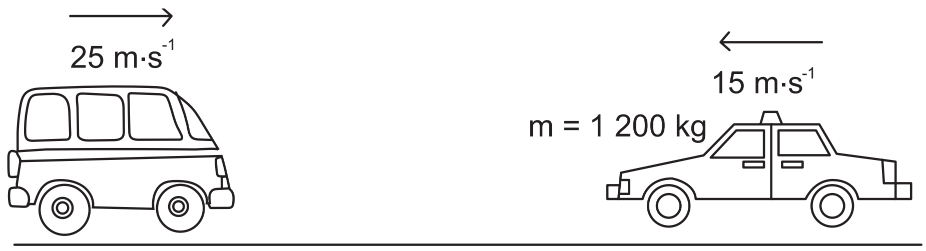
5. Two boys, each of mass m, are standing at the back of a flatbed trolley of mass 4 m. The trolley is at rest on a frictionless horizontal surface.The boys jump off simultaneously at one end of the trolley with a horizontal velocity of 2 $m \cdot s^{-1}$ east. The trolley moves in the opposite direction.

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

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

5.3 The two boys jump off the trolley one at a time. How will the velocity of the trolley compare to that calculated in QUESTION 5.2? Write down only GREATER THAN, SMALLER THAN or EQUAL TO. (1)

6. The average mass of a minibus taxi on South African roads is 1 500 kg. The law states that the combined mass of all the passengers in a minibus taxi and the taxi itself should not exceed 3 500 kg.



A minibus taxi with an unknown number of passengers travels at 25 $m \cdot s^{-1}$ when it collides with a car with a mass of 1 200 kg (passengers included), travelling at 15 $m \cdot s^{-1}$ in the opposite direction, as shown. During the collision the vehicles stick together and travel at 14 $m \cdot s^{-1}$ immediately after the collision in the direction of the original motion of the taxi.

6.1 Ignore friction. Use momentum principles to determine whether the minibus taxi was overloaded, that is, above the legal combined mass of 3 500 kg. (7)

6.2 Is the collision between the vehicles elastic or inelastic? Support your answer with an appropriate calculation. (6)

7. A man of mass 80 kg wearing a seat belt, is driving a car which collides with the back of a stationary truck causing the car to be brought to rest in 0,2 s. At the instant of the collision the car is travelling at 20 $m \cdot s^{-1}$.

7.1 Calculate the average force exerted by the seat belt on the man. (5)

The front ends of many modern cars are deliberately designed to crumple in a head-on collision.

7.2 Briefly explain why it is desirable that the front end of a car should crumple in a head-on collision. Support your answer by means of a relevant equation. (4)

8. Suppose you are travelling in a bus when an insect suddenly splatters onto the front window.

8.1 How does the force that the insect exerts on the bus compare to the force exerted by the bus on the insect? (2)

8.2 How does the change in momentum of the bus compare to the change in momentum of the insect? Explain your answer. (3)

8.3 Which experiences the greater acceleration? Explain your answer. (3)

9. A 5 000 kg truck enters an arrestor bed travelling at 30 $m \cdot s^{-1}$ south. The trucks speed is decreased to 20 $m \cdot s^{-1}$ over 5 s. Calculate the average net horizontal force acting on the truck. (5)

CONSOLIDATION EXERCISE

TOTAL: 50 MARKS

1. A car of mass 1 000 kg travelling at 40 m·s^{-1} east collides head-on with a truck of mass 5 000 kg moving west at 20 m·s^{-1}. After the collision, the car and the truck move together. Ignore the effects of friction.

1.1 State the law of conservation of linear momentum. (2)

1.2 Calculate the velocity of the car-truck system immediately after the collision. (5)

1.3 Research has shown that forces greater than 85 000 N during collisions may cause fatal injuries. The collision lasts for 0,5 s. Determine, by means of a calculation, whether the collision above could result in a fatal injury. (5)

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 lying 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. (4)

2.2 Calculate the impulse provided to the school bag. (4)

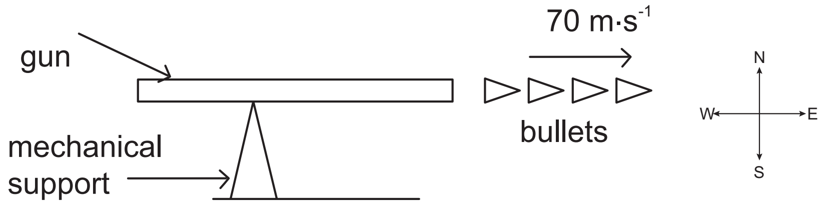
2.3 The learner experienced an average force of 100 N during the collision with the bag. Determine how long the collision lasted. (4)

2.4 Without any further calculations, compare the acceleration of the learner and the school bag during the collision. (3)

2.5 Is the collision elastic? Use a calculation to support your answer. (6)

2.6 After grabbing the bag, he continues at a velocity of 3 m·s^{-1} until he enters a horizontal gravel path. He continues for 2 m along the gravel path before coming to rest. Calculate the frictional force acting on the skate board. (5)

3. The diagram below shows a gun mounted on a mechanical support which is fixed to the ground. The gun is capable of firing bullets rapidly in a horizontal direction.



Each bullet travels at a speed of 700 $m \cdot s^{-1}$ in an easterly direction when it leaves the gun.

(Take the initial velocity of a bullet, before being fired, as zero.)

The gun fires 220 bullets per minute. The mass of each bullet is 0,03 kg.

3.1 Define the term impulse in words. (2)

3.2 Calculate the magnitude of the momentum of each bullet when it leaves the gun. (3)

3.3 Calculate the average net force that each bullet exerts on the gun. (5)

3.4 Without any further calculation, write down the average net horizontal force that the mechanical support exerts on the gun. (2)

WORKSHEETS

MARKING GUIDELINES

1.1 Choose east as positive:

$p_{ti} = mv_i = (10\ 000)(+10✓) = 10\ 0000\ \text{kg·m·s}^{-1}$ ✓east ✓ (3)

1.2 $p_{ci} = mv_i = (2\ 000)(-30✓) = -6\ 000$

therefore $p_{ci} = 60\ 000\ \text{kg·m·s}^{-1}$ ✓west✓ (3)

1.3 $\triangle p = mv_f - mv_i$

$\triangle p = (10\ 000)(0✓) - (10\ 000)(+10✓)$

$\triangle p = 0 - 100\ 000$

$\triangle p = -100\ 000$

$\triangle p = 100\ 000\ \text{kg·m·s}^{-1}$ ✓west✓ (4)

1.4 $\triangle p = mv_f - mv_i$

$\triangle p = (2\ 000)(+20✓) - (2\ 000)(-30✓)$

$\triangle p = 40\ 000 + 60\ 000$

$\triangle p = +100\ 000$

$\triangle p = 100\ 000\ \text{kg·m·s}^{-1}$ ✓east✓ (4)

1.5 $\leftarrow$ $mv_i = 60\ 000\ \text{kg·m·s}^{-1}$ west✓

$\rightarrow$ $mv_f = 40\ 000\ \text{kg·m·s}^{-1}$ east✓

$\longrightarrow$ $\triangle p = 100\ 000\ \text{kg·m·s}^{-1}$ east✓ (3)

2.1 Choose north as positive:

$Pbi = mv_i = (800)(+12✓) = 9\ 600\ \text{kg·m·s}^{-1}$ ✓north✓ (3)

2.2 $\triangle p = mv_f - mv_i$

$\triangle p = (800)(+8,25✓) - (800)(+12✓)$

$\triangle p = 6\ 600 - 9\ 600$

$\triangle p = -3\ 000$

$\triangle p = 3\ 000\ \text{kg·m·s}^{-1}$ ✓south✓ (4)

2.3 $\triangle p = mv_f - mv_i$

$\triangle p = (600)(+10✓) - (600)(+5✓)$

$\triangle p = 6\ 000 - 300$

$\triangle p = +3\ 000$

$\triangle p = 3\ 000\ \text{kg·m·s}^{-1}$ ✓north✓ (4)

2.4 Car B exerts a forward force on car A during the collision ✓. According to Newton's third law, car A exerts an equal and opposite force on car B ✓.
Car B experiences a backward net force during the collision, decreasing its velocity and therefore momentum ✓. (3)

3.1 Choose forward as positive:

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

$F_{net} = \frac{mv_f - mv_i}{\Delta t}$

$F_{net} = \frac{(85)(+2)\checkmark - (85)(+5)}{1,3\checkmark}$

$F_{net} = \frac{170 - 425}{1,3}$

$F_{net} = -196,2$

therefore $F_{net} = 196,2$ N✓backwards✓ (5)

3.2 $F_{net} = +196,2 = 196,2$ N✓forwards✓ (2)

4. Choose forward as positive:

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

$F_{net} = \frac{mv_f - mv_i}{\Delta t}$

$F_{net} = \frac{-160 - 1\,600}{0,2}$

$F_{net} = -8\,800$

Therefore $F_{net} = 8\,800$ N✓backwards✓ (5)

5.1 The total linear momentum of an isolated system ✓ remains constant (is conserved)✓ (2)

5.2 Choose east as positive:

$\varepsilon p_{before} = \varepsilon p_{after}$

$m_T v_{Ti} = m_b v_{bf} + m_b v_{bf} + m_t v_{tf}$

$(6m)(0)\checkmark = (m)(+2) + (m)(+2)\checkmark + (4m)v_f\checkmark$

$0 = 4m + 4mv_f$

$v_f = -1$

therefore $v_f = 1\ \text{m·s}^{-1}$✓west✓ (5)

5.3 Equal to ✓

The total change in momentum of the trolley is equal to the sum of the changes in momenta of the boys. (1)

6.1 Choose the original direction of the taxi as positive:

$\varepsilon p_{before} = \varepsilon p_{after}$

$m_T v_{Ti} + m_c v_{ci} = m_{Total} v_f$

$(m_T)(+25)\checkmark + (1\,200)(-15)\checkmark = (m_T + 1\,200\checkmark)(+14)\checkmark$

$25m_T - 18\,000 = 14m_T + 16\,800$

$11m_T = 3\,163,64$ kg✓

Not overloaded (7)

6.2 $E_{k\ before} = \frac{1}{2}(3\ 163,64)(25)^2 ✓ + \frac{1}{2}(1\ 200)(15)^2 ✓ = 1\ 123\ 637,5\ \text{J} ✓$

$E_{k\ after} = \frac{1}{2}(4\ 363,64)(14)^2 ✓ = 427\ 613,2\ \text{J} ✓$

Inelastic collision✓ (6)

7.1 Choose forward as positive:

$F_{net} \triangle t = \triangle p$

$F_{net} \triangle t = mv_f - mv_i$

$F_{net}(0,2✓) = (80)(0) ✓ - (80)(+20) ✓$

$F_{net}(0,2) = -1\ 600$

$F_{net} = \frac{-1\ 600}{0,2} = -8\ 000$

therefore $F_{net} = 8\ 000$ N✓ backwards✓ (5)

7.2 When the front end crumples, the momentum of the car is decreased ✓ over a longer ✓ time interval.

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

The net force is inversely proportional to the contact time ✓

If Δt increases the net force decreases ✓, reducing the risk of injury. (4)

8.1 The force of the insect on the bus is equal in magnitude ✓ but opposite in direction ✓ to the force of the bus on the insect (Newton's third law). (2)

8.2 The change in momentum of the insect is equal in magnitude ✓ but opposite in direction ✓ to the change in momentum of the bus. (3)

8.3 The net force on each object is the same but the masses are different. ✓

According to Newton's second law, the acceleration is inversely proportional ✓ to the mass of an object.

$a = \frac{F_{net}}{m}$

The insect has the smaller mass and therefore experiences the greater ✓ acceleration. (3)

9. Choose south as positive:

$F_{net} \triangle t = \triangle p$

$F_{net} \triangle t = mv_f - mv_t$

$F_{net}(5✓) = (5\ 000)(+20) ✓ - (5\ 000)(+30) ✓$

$F_{net}(5) = 100\ 000 - 150\ 000$

$F_{net} = \frac{-50\ 000}{5} = -10\ 000$ (5)

therefore $F_{net} = 10\ 000$ N✓north✓

CONSOLIDATION EXERCISE

TOTAL: 50 MARKS

1.1 The total linear momentum of an isolated system remains constant (is conserved) ✓✓ (2)

1.2 Choose east a positive:

$\varepsilon p_{before} = \varepsilon p_{after}$

$m_c v_{ci} + m_T v_{Ti} = m_{total} v_f$

$(1\,000)(+40)✓ + (5\,000)(-20)✓ = (6\,000)v_f✓$

$40\,000 - 100\,000 = 6\,000 v_f$

$-60\,000 = 6\,000 v_f$

$v_f = -10$

therefore $v_f = 10\ \text{m·s}^{-1}$✓west✓ (5)

1.3 $F_{net} \triangle t = \triangle p$

$F_{net} \triangle t = mv_f - mv_t$

$F_{net}(0{,}5✓✓) = (1\,000)(-10)✓ - (1\,000)(+40)✓$

$F_{net}(0{,}5) = -50\,000$

$F_{net} = -100\,000\ \text{N}✓$

The collision will be fatal (5)

2.1 Choose forward as positive:

$\varepsilon p_{before} = \varepsilon p_{after}$

$m_L v_{Li} + m_B v_{Bi} = m_{total} v_f$

$(68)v_{Li}✓ + (20)(0)✓ = (88)(+3)✓$

$(68)v_{Li} + 0 = 264$

$v_{Li} = 3{,}88\ \text{m·s}^{-1}$ (4)

2.2 $F_{net} \triangle t = \triangle p$

$F_{net} \triangle t = mv_f - mv_t$

$F_{net} \triangle t = (20)(+3)✓ - (20)(0)✓$

$F_{net} \triangle t = 60\ \text{N·s}$✓forward✓ (4)

2.3 $F_{net} \triangle t = \triangle p$

$F_{net} \triangle t = mv_f - mv_t$

$(-100✓) \triangle t = (68)(+3)✓ - (68)(+3{,}88)✓$

$-100 \triangle t = -59{,}84$

$\triangle t = 0{,}60\ \text{s}✓$ (4)

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 ✓. (3)

2.5 $E_{k\,before} = \frac{1}{2}m_L v_L^2 + \frac{1}{2}m_B v_B^2$

$E_{k\,before} = \frac{1}{2}(68)(3,88)^2 \checkmark + 0 \checkmark = 511,85\ \text{J} \checkmark$

$E_{k\,after} = \frac{1}{2}m_T v_T^2$

$E_{k\,after} = \frac{1}{2}(88)(3)^2 \checkmark = 396\ \text{J} \checkmark$

Inelastic collision (6)

2.6 $v_f^2 = v_i^2 + 2a \triangle x$

$0 = (3\checkmark)^2 + 2a(2\checkmark)$

$a = \frac{-9}{4} = -2,25\ \text{m·s}^{-2} \checkmark$

$f = F_{net} = m.a = (88)(-2.25) = -198$

therefore $f = 198$ N✓ backwards✓ (5)

3.1 The product of the net force and the contact time ✓✓ (2)

3.2 p=mv=(0,03 ✓).(700 ✓)=21 kg·m·s^{-1} ✓ (3)

3.3 $F_{net} \triangle t = \triangle p$

$F_{net} \triangle t = mv_f - mv_i$

$F_{net}\left(\frac{220}{60}\right) \checkmark = (0,03)(+700) \checkmark - (0,03)(0) \checkmark$

$F_{net}\left(\frac{220}{60}\right) = 21 - 0$

$F_{net} = \frac{(21).(60)}{220} = 5,73\ \text{N}$

The average net force of the bullet on the gun is 5,73 N✓ west✓ (5)

3.4 5,73 N ✓ east ✓ (2)

Topic 3: Vertical Projectile Motion in One Dimension

WORKSHEET

1. A boy stands on the edge of a cliff. He throws a stone vertically upwards with an initial velocity of 12 $m \cdot s^{-1}$. The stone strikes the ground below the cliff after 4 s. Ignore air resistance.

1.1 What is the magnitude and direction of the acceleration of the stone:

1.1.1 when it is moving upwards? (2)

1.1.2 when it reaches its maximum height? (2)

1.1.3 when it is falling down? (2)

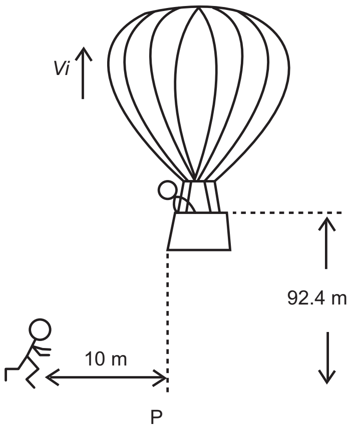
1.2 At what time(s) does the stone have a speed of 3 $m \cdot s^{-1}$? (6)

1.3 How long does the stone take to reach its maximum height? (2)

1.4 Determine the height of the cliff. (3)

2. In an experiment, a learner drops a brick A from a height of 8 m. After 0,6 s another learner throws a second brick B downwards from the same height. Both bricks, A and B, hit the ground at the same time. Ignore the effects of friction and calculate the speed at which brick B was thrown. (7)

3. A hot-air balloon is moving vertically upwards at a constant speed. A camera is accidentally dropped from the balloon at a height of 92,4 m as shown in the diagram below. The camera strikes the ground after 6 s. Ignore the effects of friction.

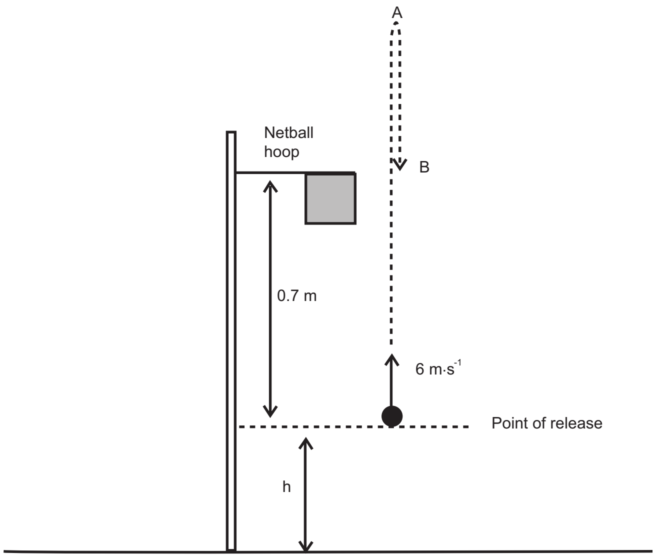


3.1 At the instant that the camera is dropped, it moves upwards. Give a reason for this observation. (1)

3.2 Calculate the speed v_i at which the balloon is rising when the camera is dropped. (4)

3.3 If a jogger, 10 m away from point P as shown in the above diagram and running at a constant speed of 2 m·s^{-1}, sees the camera at the instant it starts falling from the balloon, will he be able to catch the camera before it strikes the ground? (4)

4. A netball player, throws a netball at 6 m·s^{-1} vertically upward, from a height h above the ground. Ignore the effects of friction.



The ball travels past the top of the netball hoop and returns to her hand which is still a fixed height, h, above the ground.

4.1 Determine the displacement of the netball when it returns to the player's hand. (1)

4.2 Calculate the maximum height (point A) that the ball reaches above the point of release. (4)

4.3 Hence, determine the distance covered by the ball when it returns to the player's hand. (2)

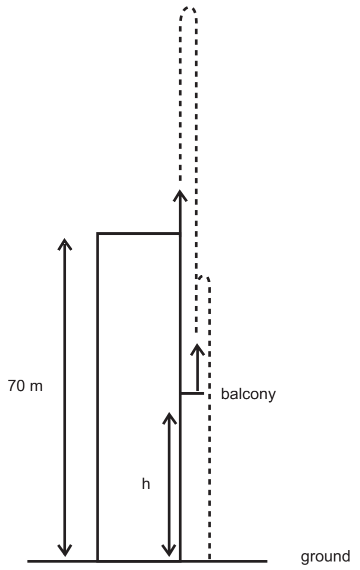
4.4 If the top of the netball hoop (point B) is at a height of 0,7 m above the player's outstretched hand, calculate the time taken for the ball, from the moment it was thrown until it reaches point B on its way back down. (5)

4.5 Assume the ball is not caught by the player, but hits the ground 1,53 s after being thrown.

4.5.1 Determine the height, *h*, above the ground from which the player originally released the ball. (3)

4.5.2 Calculate the velocity of the ball when it hits the ground. (3)

5. A ball is projected vertically upwards at 11 m·s^{-1} from the roof of a building which is 70 m high. It strikes the balcony below after 3 s. The ball then bounces off the balcony and strikes the ground as illustrated below. Ignore the effects of friction.



5.1 What is the direction of the acceleration of the ball at its maximum height? (1)

5.2 Calculate the:

5.2.1 velocity of the ball when it strikes the balcony. (4)

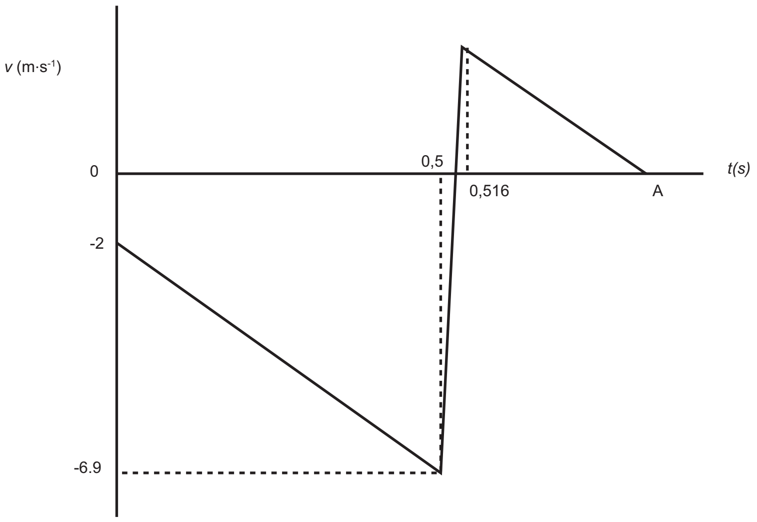
5.2.2 height, h, of the balcony above the ground. (4)

The ball bounces off the balcony at a velocity of 15 m·s^{-1} and eventually hits the ground below. The ball is in contact with the balcony for 0,04 s.

5.3 Draw a velocity versus time graph to represent the motion of the ball from the moment it is projected from the top of the building until it strikes the ground. Take UP as positive. Indicate the following velocity and time values on the graph:
- the initial velocity at which the object was projected from the roof of the building
- the velocity at which the object strikes the balcony
- the time when the object strikes the balcony
- the velocity at which the object bounces off the balcony. (7)

5.4 Draw a position versus time graph for the entire motion of the ball. Take the ground as the reference point. Show the height h on your graph. (5)

6. A 0,6 kg basketball ball is thrown downwards from a ladder. Half a second later, it hits the ground and rebounds to a height of 1,3 m. The collision is not elastic. The following velocity versus time graph shows the motion of the ball. It is not drawn to scale. Ignore air resistance.



6.1 Use the graph to determine the height from which the ball was thrown down. (4)

6.2 Show that the magnitude of the rebound velocity for the ball is 5,05 m·s^{-1}. (3)

6.3 Calculate the time that should be written on the x-axis at A. (4)

6.4 Draw a graph of position versus time for the full motion of the ball. Use the point of release as your reference point. No values are needed. (4)

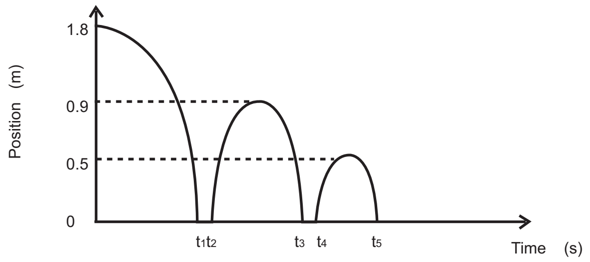
Topic 3: Vertical Projectile Motion in One Dimension

WORKSHEET

CONSOLIDATION EXERCISE

TOTAL: 55 MARKS

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



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

Calculate the:

1.2 magnitude of the time t_1 indicated on the graph (5)

1.3 velocity with which the ball rebounds from the ground during the first bounce. (4)

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

1.4 Calculate the magnitude of the force exerted by the ground on the ball during the first bounce, if the ball strikes the ground at 6,27 m·s⁻¹. (6)

1.5 Draw a velocity-time graph for the motion of the ball from the time that it is projected to the time when it rebounds to a height of 0,9 m.

Clearly show the following on your graph:

- the time when the ball hits the ground
- the velocity of the ball when it hits the ground
- the velocity of the ball when it rebounds from the ground (6)

2. A ball of mass 0,2 kg is dropped from a height of 0,8 m onto a hard floor. It bounces to a maximum height of 0,6 m. The floor exerts a force of 50 N on the ball. Ignore the effects of friction.

2.1 Write down the magnitude and direction of the force that the ball exerts on the floor. (2)

2.2 Calculate the:

2.2.1 velocity at which the ball strikes the floor and the (4)

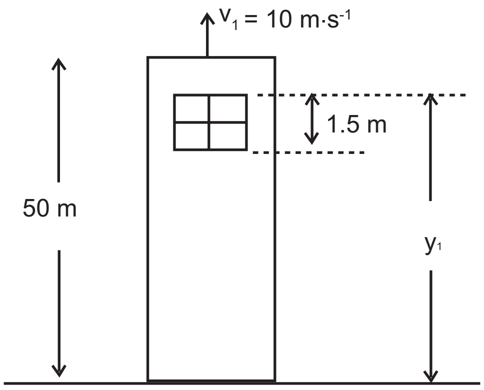
2.2.2 time that the ball is in contact with the floor, if it bounces off the floor at a speed of 3,43 $m \cdot s^{-1}$. (4)

2.3 The ball takes 0,404 s from the moment it is dropped until it strikes the floor. Sketch a graph (not to scale) of position versus time representing the entire motion of the ball. USE THE GROUND AS THE REFERENCE POINT.

Indicate the following on the graph:

- height from which the ball was dropped
- height reached by the ball after the bounce
- time at which the ball bounces off the floor (5)

3. A stone is thrown vertically upward at a velocity of 10 $m \cdot s^{-1}$ from the top of a tower of height 50 m. After some time the stone passes the edge of the tower and strikes the ground below the tower. Ignore the effects of friction.



3.1 Calculate the time taken by the stone to reach its maximum height above the ground. (4)

3.2 Calculate the maximum height the stone reaches above the tower. (4)

3.3 Sketch the position time graph for the motion of the stone. (3)

3.4 On its way down, the stone takes 0,1 s to pass a window of height 1,5 m, as shown in the diagram above. Calculate the distance y_1 from the top of the window to the ground. (7)

MARKING GUIDELINES

1.1.1 9,8 $m \cdot s^{-2}$ ✓ downwards ✓ (2)

1.1.2 9,8 $m \cdot s^{-2}$ ✓ downwards ✓ (2)

1.1.3 9,8 $m \cdot s^{-2}$ ✓ downwards ✓ (2)

1.2 Choose up as positive:

Moving upwards at 3 $m \cdot s^{-1}$

$v_f = v_i + a \triangle t$

$(+3✓) = (+12✓) + (-9,8✓) \triangle t$

$-9 = -9,8 \triangle t$

$\triangle t = 0,92$ s✓

Moving downwards at 3 $m \cdot s^{-1}$

$v_f = v_i + a \triangle t$

$(+3✓) = (+12✓) + (-9,8✓) \triangle t$

$-15 = -9,8 \triangle t$

$\triangle t = 1,53$ s✓ (6)

1.3 $v_f = v_i + a \triangle t$

$0✓ = (+12) + (-9,8) \triangle t$

$-12 = -9,8 \triangle t$ (2)

$\triangle t = 1,22$ s✓

1.4 $\triangle y = v_i \triangle t + \frac{1}{2} a \triangle t^2$

$\triangle y = (+12)(4)✓ + \frac{1}{2}(-9,8)(4)^2✓$

$\triangle y = 48 - 78,4$

$\triangle y = -30,4 = 30,4$ m

The height of the cliff is 30,4 m✓ (3)

2. Choose down as positive:

Velocity of brick A when it reaches the ground:

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

$v_f^2 = (0)^2 + 2(+9,8)(+8)✓$

$v_f^2 = 0 + 156,8$

$v_f = 12,52$ $m \cdot s^{-1}$✓

Time take for brick A to reach the ground:

$v_f = v_i + a \triangle t$

$+12,52 = (0) + (+9,8) \triangle t✓$

$12,52 = 9,8 \triangle t$

$\triangle t = 1,28$ s✓

Time take for brick B to reach the ground:

$\triangle t = 1,28 - 0,6 = 0,68 \text{ s}✓$

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

$+8 = v_i(0,68) + \frac{1}{2}(+9,8)(0,68)^2 ✓$

$8 = 0,68 v_i + 2,266$

$5,734 = 0,68 v_i$

$v_i = 8,43 \text{ m·s}^{-1} ✓$ (7)

3.1 The camera has the same speed upwards as the balloon when it is released. (1)

3.2 Choose up as positive:

The reference point is the point of release:

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

$-92,4✓ = v_i(6✓) + \frac{1}{2}(-9,8✓)(6)^2$

$-92,4 = 6v_i - 176,4$

$84 = 6v_i$

$v_i = +14$

Therefore the speed is 14 m·s^{-1} (4)

3.3 $v = \frac{\triangle x}{\triangle t}$

$\triangle t = \frac{\triangle x}{v} = \frac{10✓}{2✓} = 5 \text{ s}$

Yes he will catch the camera✓ (4)

4.1 $\triangle x = 0✓$ (The ball has returned to its initial position) (1)

4.2 Choose up as positive:

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

$0✓ = (+6✓)^2 + 2(-9,8✓) \triangle y$

$0 = 36 - 19,6 \triangle y$

$-36 = -19,6 \triangle y$

$\triangle y = +1,84 = 1,84 \text{ m}✓$ (4)

4.3 Distance $= 1,84 + 1,84✓ = 3,68 \text{ m}✓$ (2)

4.4 Choose east as positive:

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

$v_f^2 = (+6✓)^2 + 2(-9,8)(+0,7✓)$

$v_f^2 = 36 - 13,72$

$v_f^2 = 22,28$

$v_f = -4,72$ m·s^{-1}✓i.e. the velocity at point B is 4,72 m·s^{-1} down

$v_f = v_i + a \triangle t$

$-4,72✓ = (+6) + (-9,8) \triangle t$

$-10,72 = -9,8 \triangle t$

$\triangle t = 1,09$ s✓ (5)

4.5.1 $\triangle t = 1,53 - 1,09 = 0,44s$✓

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

$\triangle y = (+6✓)(1,53) + \frac{1}{2}(-9,8)(1,53)^2$

$\triangle y = 9,18 - 11,47$

$\triangle y = -2,3$ m

$h = 2,3$ m✓ (3)

4.5.2 $v_f = v_i + a \triangle t$

$v_f = (+6) + (-9,8)(1,53)$✓

$v_f = -8.99$

therefore $v_f = 8,99$ m·s^{-1}✓downwards✓ (3)

5.1 Downwards ✓ (1)

5.2.1 Choose up to be positive:

$v_f = v_i + a \triangle t$

$v_f = (+11✓) + (-9,8)(3)$✓

$v_f = -18,4$

therefore $v_f = 18,4$ m·s^{-1}✓downwards✓ (4)

5.2.2 Take the top of the building as the reference point:

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

$\triangle y = (+11)(3✓) + \frac{1}{2}(-9,8)(3)^2$✓

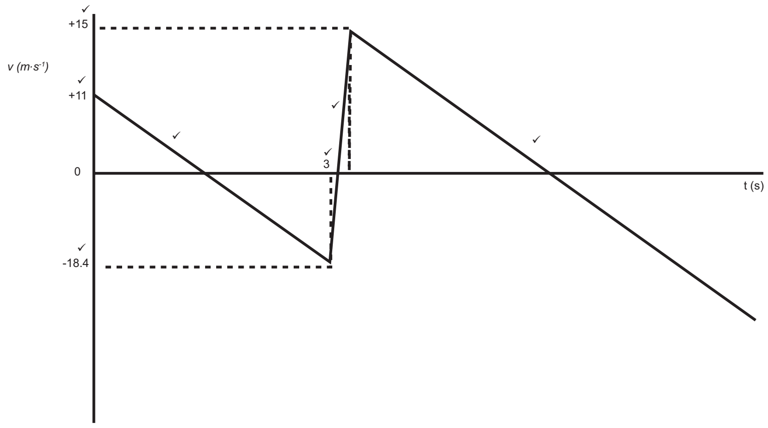
$\triangle y = +33 - 44,1$

$\triangle y = -11,1$✓

i.e. 11,1 m below the top of the building

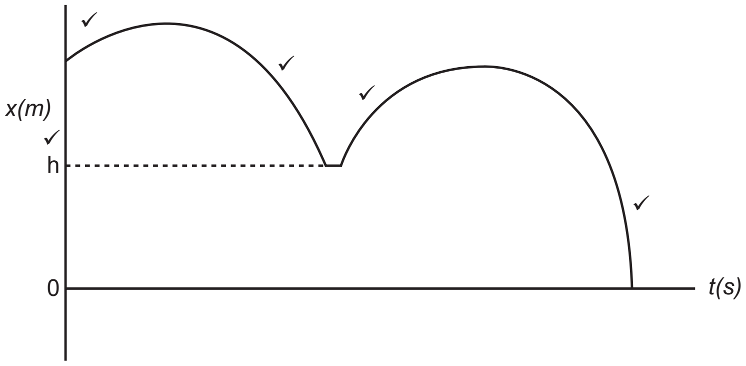
$h = 70 - 11,1 = 58,9$ m (4)

5.3



(7)

5.4



(5)

6.1 Choose up as positive:

$\triangle x = Area\ under\ graph = (-2)(0,5)\checkmark + \frac{1}{2}(0,5)(-4.9)$

$\triangle x = -1 - 1,225$

$\triangle x = -2,225\checkmark$

Height $= 2,23$ m✓above the ground (4)

6.2 $v_f^2 = v_i^2 + 2a \triangle y$

$0\checkmark = v_i^2 + 2(-9,8)(1,3\checkmark)$

$v_i^2 = 25,48$

$v_i = 5,05\ \text{m·s}^{-1}\checkmark$ (3)

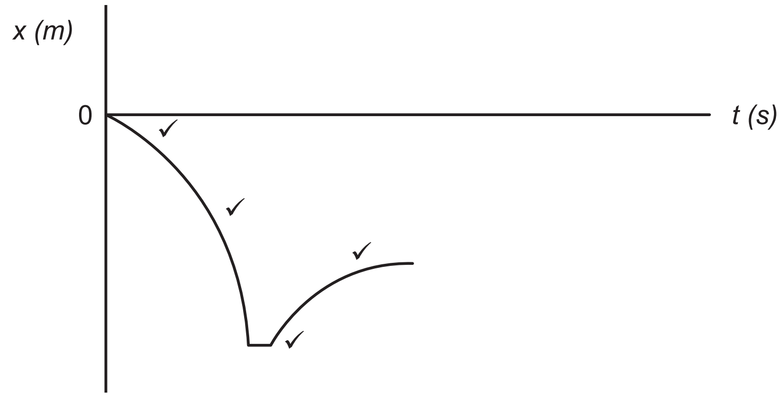
6.3 $v_f = v_i + a \triangle t$

$0\checkmark = (+5,05\checkmark) + (-9,8) \triangle t$

$\triangle t = 0,52\ \text{s}\checkmark$

$t_A = 0,516 + 0,52 = 1,036\ \text{s}\checkmark$ (4)

6.4



(4)

CONSOLIDATION EXERCISE

TOTAL: 55 MARKS

1.1 0,5 m ✓ (1)

1.2 The gradient of the position-time graph (velocity) is negative.

Choose down as negative:

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

$v_f^2 = (-2✓)^2 + 2(-9,8✓)(-1,8✓)$

$v_f^2 = 39,28$

$v_f = -6,27 \text{ m·s}^{-1}✓$

$v_f = v_i + a \triangle t$

$-6,27 = (-2) + (-9,8) \triangle t$

$\triangle t = 0,44 \text{ s}✓$ (5)

1.3 $v_f^2 = v_i^2 + 2a \triangle y$

$0✓ = v_i^2 + 2(-9,8)(+0,9✓)$

$v_i^2 = 17,64$

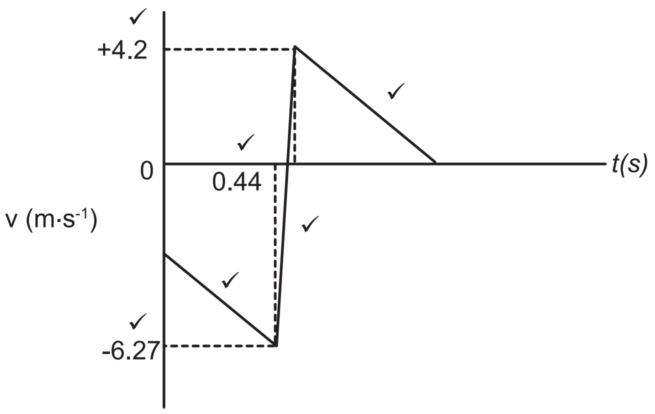
$v_i = 4,2 \text{ m·s}^{-1}✓\text{upwards}✓$ (4)

1.4 $F_{net} = \dfrac{\triangle p}{\triangle t} = \dfrac{mv_f - mv_i}{\triangle t} = \dfrac{(0,5✓)(+4,2✓) - (0,5)(-6,27✓)}{0,2✓} = 26,18 \text{ N}✓\text{upwards}$

$F_{net} = F_{ground} - w$

$F_{ground} = F_{net} + w = 26,17 + 4,9✓ = 31,07 \text{ N}✓$ (6)

1.5



(6)

2.1 50 N ✓ downwards ✓ (2)

2.2.1 Choose up as positive:

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

$v_f^2 = 0 + 2(-9{,}8✓)(-0{,}8✓)$

$v_f^2 = 15{,}68$

$v_f = -3{,}96 = 3{,}96\ \text{m·s}^{-1}$ ✓down✓ (4)

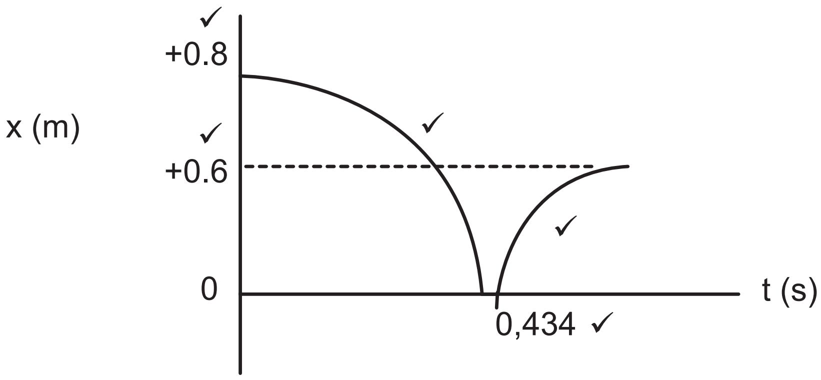
2.2.2 $F_{net}\,.\,\Delta t = mv_f - mv_i$

$(F - W)\,.\,\Delta t = (0{,}2)\,.\,(+3{,}43)$ ✓ $-(0{,}2)\,.\,(-3{,}96)$ ✓

$(50 - 1{,}96✓)\,.\,\Delta t = 1{,}478$

$\Delta t = 0{,}03$ s✓ (4)

2.3



(5)

3.1 Choose up as positive:

$v_f = v_i + a\,\Delta t$

$0✓ = (+10✓) + (-9{,}8✓)\,\Delta t$

$-10 = -9{,}8\,\Delta t$

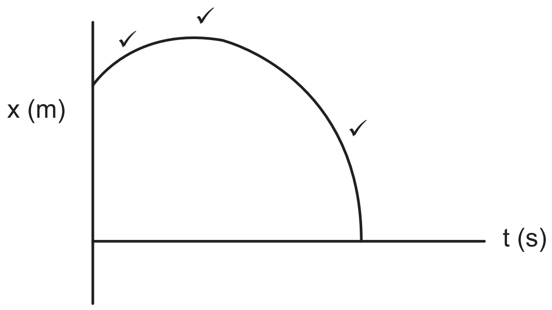
$\Delta t = 1{,}02$ s✓ (4)

3.2 $v_f^2 = v_i^2 + 2a\,\Delta y$

$0✓ = (+10✓)^2 + 2(-9{,}8✓)\,\Delta y$

$\Delta y = 5{,}10$ m✓ (4)

3.3



(3)

3.4 $\triangle y = v_i \triangle t + \frac{1}{2} a \triangle t^2$

$-1,5\checkmark = v_i(0,1\checkmark) + \frac{1}{2}(-9,8\checkmark)(0,1)^2$

$v_i = -14,51 \text{ m·s}^{-1}\checkmark$

Downwards from top of tower to top of window:

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

$(-14,51)^2 = (-10\checkmark)^2 + 2(-9,8) \triangle y$

$\triangle y = -5,64 \text{ m}\checkmark$

$y_1 = 50 - 5,64 = 44,36 \text{ m}\checkmark$ (7)

Topic 4: Organic Chemistry

WORKSHEET

1. Which one of the following compounds belongs to the same homologous series as C_3H_8?

A C_2H_2

B C_3H_6

C C_3H_4

D C_4H_{10} (2)

2. Which of the following is the fourth member of the alkenes?

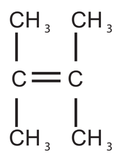
A. C_4H_8

B. C_4H_{10}

C. C_4H_6

D. C_4H_4 (2)

3. Consider the structure of the organic compound below:



The IUPAC name of this compound is …

A 2,3-dimethylbut-2-ene

B 2,2-dimethylbut-2-ene

C 1,1,2-trimethylprop-1-ene

D 1,1,2,2-tetramethylethene (2)

4. Which ONE of the following represents a SUBSTITUTION REACTION?

A $CH_2=CH_2 + HBr \rightarrow CH_3CH_2Br$

B $CH_2=CH_2 + H_2O \rightarrow CH_3CH_2OH$

C $CH_3CH_2OH \rightarrow CH_2=CH_2 + H_2O$

D $CH_3CH_2OH + HBr \rightarrow CH_3CH_2Br + H_2O$ (2)

5. The reaction represented by the balanced chemical equation $C_{13}H_{28} \rightarrow C_8H_{18} + C_5H_{10}$ takes place in the presence of a catalyst. This reaction is an example of:

A cracking

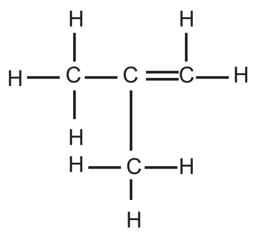
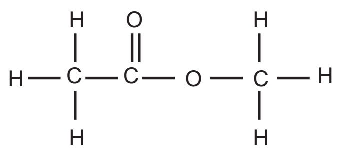
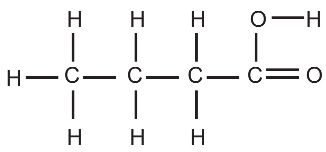
B addition

C substitution

D oxidation (2)

LONG QUESTIONS

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

A		B	Ethyl ethanoate
C	2,3-dibromo-3-methylpentane	D	Polyethene
E		F	

1.1 Write down the LETTER/S that represents the following:

- **a.** a hydrocarbon (1)
- **b.** a functional isomer of compound F (1)
- **c.** A compound which belongs to the same homologous series as
  - **i.** compound B (1)
  - **ii.** a plastic (1)

1.2 Write down the STRUCTURAL FORMULA for EACH of the following:

- **a.** compound C (3)
- **b.** the acid used to prepare compound B (2)
- **c.** the monomer used to make compound D (2)

1.3 Compound A reacts with an unknown reactant, X, to form 2-methylpropane. Write down the:

- **a.** name of reactant X (1)
- **b.** type of reaction that takes place (1)

2. Learners investigate factors which influence the boiling points of alcohols. They use equal volumes of each of the alcohols and heat them separately in a water bath. The temperature at which each boils is measured. The results obtained are shown in the table below.

Alcohols	Boiling Points of Alcohols (°C)
Butan-1-ol	117,7
Pentan-1-ol	138,5
Hexan-1-ol	157,0

2.1 Define the term boiling point. (2)

2.2 What property of alcohols requires them to be heated in a water bath? (1)

2.3 The boiling points of the alcohols are compared with each other.

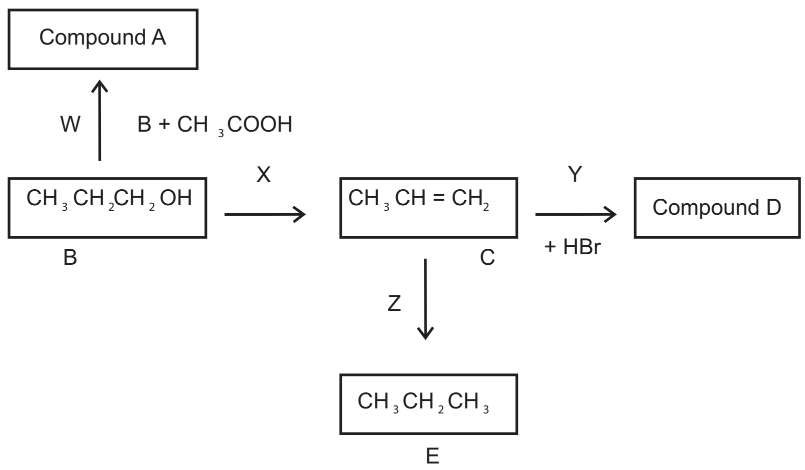
- **a.** What structural requirements must the alcohols meet to make it a fair comparison? (2)
- **b.** Fully explain the trend in the boiling points. (3)

2.4. How will the boiling point of hexan-1-ol be affected if the volume of hexan-1-ol used is doubled? Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

2.5. In a separate investigation, the learners compare the boiling points of hexan-1-ol and hexanal.

- **a.** Write down the independent variable for this comparison. (1)
- **b.** They find that the boiling point of hexan-1-ol is higher than that of hexanal. Fully explain this observation. (4)

3. In the flow diagram below, W, X, Y and Z represent different reactions involving the organic compounds A, B, C, D and E



3.1 Define the term homologous series. (2)

3.2 Name the homologous series to which compound B belongs. (1)

3.3. State what type of reaction is represented by:

- **a.** X (1)
- **b.** Y (1)

3.4 Give the structural formula for compound A. (3)

3.5 Give the IUPAC name of compound A. (2)

3.6 Give the chemical formula of:

- **a.** the catalyst used in reaction W (1)
- **b.** the inorganic product of reaction W (1)
- **c.** give the IUPAC name of compound D. (1)

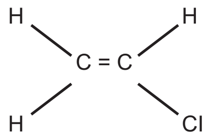
3.7 NAME the reactant which reacts with compound C to form compound E in reaction Z. (1)

3.8 Using molecular formulae write the balanced chemical equation to show the complete combustion of compound E. (3)

3.9 Define the term isomer. (2)

3.10 Give the name of a functional isomer of compound A. (1)

4. The monomer chloroethene (vinyl chloride) polymerises to form the polymer polychloroethane by means of an addition polymerisation reaction.



Addition polymerisation is a three step process where step 1 is initiated by a free radical represented by the symbol – R .

4.1 What is meant by the term 'free radical'? (2)

4.2 Using the structural formula of chloroethene given above, show how a monomer of chloroethene reacts with the free radical. (3)

4.3 Read the passage below:

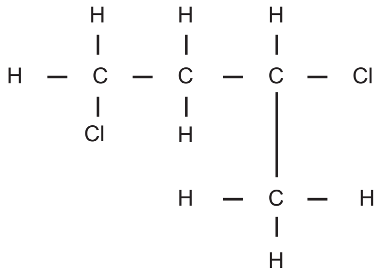
> Vinyl chloride is a chemical intermediate, not a final product. Due to the hazardous nature of vinyl chloride to human health, there are no end products that use vinyl chloride in its monomer form. Polyvinyl chloride is very stable, storable, and nowhere near as acutely hazardous as the monomer.

Based on its stability, storability and non-toxicity, suggest TWO possibilities where polyvinyl chloride can be most effectively used in society. (2)

CONSOLIDATION EXERCISE

TOTAL: 59 MARKS

1. What is the IUPAC name of the compound represented by the structural formula below?



A 2,4-dichloro-2-methylpropane

B 1,3-dichloro-1-methylpropane

C 1,3-dichlorobutane

D 2,4-dichlorobutane (2)

2. Consider the following reaction:

$CH_3 - CH = CH_2 + HCl \rightarrow CH_3 - CH_2 - CH_2Cl$

A The product is an isomer of chloro-propane.

B The reaction is a substitution reaction.

C The reaction is slow and needs UV light.

D The product is an ester. (2)

3. What product will be formed when an alkene reacts with water vapour (H_2O) in the presence of an acid catalyst?

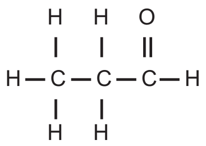
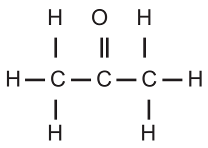
A Ester

B Alkane

C Alcohol

D Aldehyde (2)

4. Consider the two organic molecules I and II below

	
I	II

Which one of the following represents the correct homologous series to which each molecule belongs?

	Molecule I	Molecule II
A	Ketones	Alcohols
B	Aldehydes	Ketones
C	Aldehydes	Alcohols
D	Ketones	Aldehydes

(2)

5. Consider the reaction represented below:
$CH_3CH_2CH_2CH_2CH_3 \rightarrow CH_3CHCH_2 + X$

Which one of the following correctly gives the type of reaction that takes place and the IUPAC name of product X?

	Type of reaction	**Product X**
A	Cracking	Alcohols
B	Elimination	Alkanes
C	Cracking	Alkenes
D	Addition	Alkanes

(2)

LONG QUESTIONS

1. Consider the following data:

Name	**Boiling point (°C)**
Methanol	65,0
Ethanol	78,5
Propan-1-ol	97,0
Butan-1-ol	117,7
Pentan-1-ol	137,9

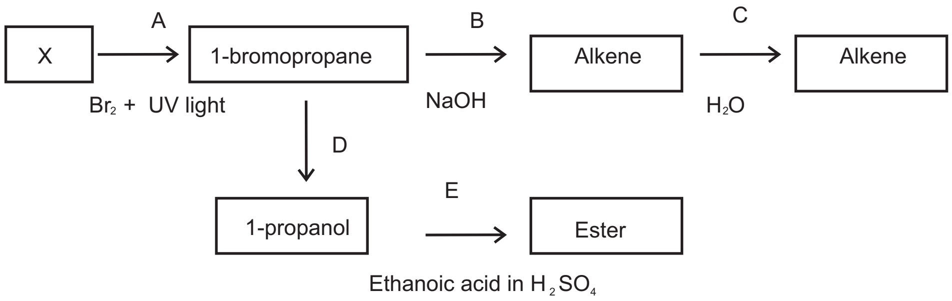
1.1 Which homologous series is represented in the table above? (1)

1.2 Explain what is meant by the term functional group. (2)

1.3 Name the functional group of the compounds in the table above. (1)

1.4. Identify the intermolecular forces that exist between these compounds and explain why their boiling points are steadily increasing. (4)

2. A number of basic organic reactions, with the reaction conditions, are shown in the flow diagram below:



2.1 Identify the type of reaction that takes place in each of A, B, C and D. (4)

2.2 Name substance X. (1)

2.3 Suggest a reactant to complete reaction D. (1)

2.4 Use structural formulae to write down balanced equations for both reactions A and E. (8)

2.5 Name the ester in reaction E. (2)

2.6 Name the unsaturated compound shown in one of the blocks. (1)

3. Explain fully what is meant by the following terms:

3.1 alkyl substituents (2)

3.2 saturated hydrocarbons. (2)

4. Draw the following organic compounds:

4.1 3-methylpent-2-ene (condensed structural formula) (2)

4.2 2,3 – dichlorobutane (full structural formula) (2)

5. Several organic compounds are listed below by either their molecular or their condensed structural formula as represented by the letters A to G

A. CH_3CHO	B. $CH_3CH(CH_3)CH_2CH_3$	C. $CH_3CH_2CH_2Cl$
D. C_5H10	E. CH_3COOH	F. CH_3COCH_3
G. C_2H_2		

5.1 Which compound or compounds are saturated hydrocarbons? (2)

5.2 Which compound or compounds are unsaturated hydrocarbons? (2)

5.3 Identify TWO compounds which contain a carbonyl group. (2)

5.4 To what homologous series does compound C belong? (1)

5.5 Using condensed structural formulae, draw and give IUPAC names for TWO isomers of compound B. (4)

5.6 The table below compares the boiling points of compounds A and E from the list above:

Organic compound	Structure	Boiling point (°C)
A	CH_3CHO	20
E	CH_3COOH	118

Explain why compound E has a higher boing point than compound A. (5)

MARKING GUIDELINES

1. D ✓✓ C_3H_8 is an alkane (C_nH_{2n+2}) ✓ select another alkane which fits this general formula, C_4H_{10}. (2)

2 A ✓✓ C_nH_{2n} is the general formula for alkenes. (2)

3 A ✓✓ Longest carbon chain is 4 (But) , double bond (alkene!) between C2 and C3, two methyl attachments at C2 and C3. (2)

4 D ✓✓ A and B are addition reactions, C is an elimination reaction. (2)

5 A ✓✓ Cracking is an elimination reaction when a long chain alkane is broken down into a shorter chain alkane and an alkene. (2)

LONG QUESTIONS

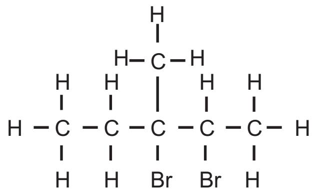
1.1 a. A (or D) ✓ (1)

b. B ✓ (1)

c. i. E ✓ (1)

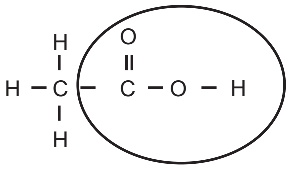
ii. D ✓ (1)

1.2 a.



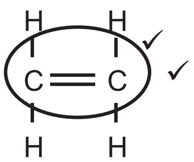
✓ 5C Longest chain,
✓ 2 x Br on C2 and C3
✓ 1x CH_3 substituent on C3 (3)

1.2 b.



✓ 2 x C's
✓ correct functional group
(2)

1.2 c.



✓ 2 x C's
✓ C = C functional group
(2)

1.3 a. Hydrogen Gas ✓ (1)

b. Addition or Hydrogenation reaction ✓ (1)

2.1 The temperature at which the vapour pressure equals atmospheric (external) pressure. ✓✓ (2)

2.2 Flammable / Catch fire easily / Volatile ✓ (1)

2.3 a. Use straight chain ✓ primary alcohols ✓ (2)

2.3 b. Structure: Chain length / more C atoms in chain / molecular size / surface area increases from top to bottom / butan-1-ol to hexan-1-ol. ✓
Intermolecular forces: Van der Waals forces / London forces / dispersion forces increases from top to bottom / butan-1-ol to hexan-1-ol. ✓
Energy : More energy needed to overcome / break intermolecular forces increases from top to bottom / butan-1-ol to hexan-1-ol. ✓ (3)

2.4 Remains the same ✓ (1)

2.5 a. Functional group / Type of homologous series ✓ (1)

b. Type of intermolecular forces between molecules of aldehyde / hexanal are dipole-dipole forces ✓between molecules of alcohols / hexan -1- ol are hydrogen bonds. ✓ Strength of intermolecular forces: Dipole-dipole forces are weaker than hydrogen bonds. ✓ (or Hydrogen bonds are stronger than dipole-dipole forces.) More energy needed to overcome / break intermolecular forces in hexan -1-ol. ✓ (or Less energy needed to overcome / break intermolecular forces in hexanal) (4)

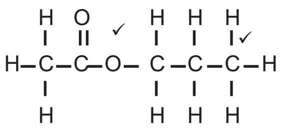
3.1 A series of similar compounds which have the same functional group and general formula, ✓ in which each member differs from the previous one by a single CH_2 unit. ✓ (2)

3.2 Alcohols. ✓ (1)

3.3 a. Elimination ✓ (dehydration) (1)

b. Addition ✓ (hydrohalogenation) (1)

3.4



✓ correct functional group
✓✓ correct number of carbons on either side (3)

3.5 Propyl ✓ ethanoate ✓ (2)

3.6 a. H_2SO_4 (conc) ✓ (1)

b. H_2O ✓ (1)

c. 1-bromopropane ✓ or 2–bromopropane (1)

3.7 Hydrogen ✓ (1)

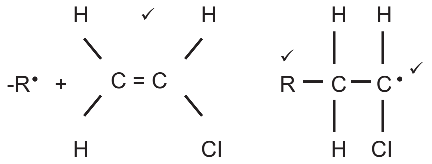
3.8 $2C_3H_8O + 9O_2 \rightarrow 6CO_2 + 8H_2O$ ✓✓✓ (3)

3.9 Compounds having the same molecular formula, ✓ but different structural formulae. (2)

3.10 Pentanoic acid. ✓ (1)

4.1 A molecular fragment with an unpaired electron. ✓✓ (2)

4.2



✓ correct ethene monomer
✓ Radical (R) attached to monomer
✓ unpaired electron on monomer fragment (3)

4.3 Any 2 possible practical and actual uses of PVC

- Pipes
- Floor tiles
- Garden furniture
- Bottle top lids (2)

CONSOLIDATION EXERCISE

TOTAL: 59 MARKS

1. C ✓✓ Although the main chain is bent it is still a CONTINUOUS chain of 4 C's butane. Number from the left to give lowest possible positions for the chloro functional groups (1,3 rather than 2,4). (2)

2. A ✓✓ The addition of hydrochloric acid to propene produces a chloro-propane. (2)

3. C ✓✓ Hydration of an alkene produces an alcohol. 2)

4. B ✓✓ Recognition of the carbonyl group as either terminal or in the chain. Molecule I is terminal hence aldehyde, molecule II is in the chain, hence ketone. (2)

5. B ✓✓ One reactant forming 2 products:- elimination reaction
An alkane (pentane) produced an alkene (propene) and alkane (ethane) (2)

LONG QUESTIONS

1.1 Alcohols ✓ (1)

1.2 This is an bond, atom or group of atoms that identify to which homologous series compound belongs ✓. It is also the centre of chemical reactivity of the molecule. ✓ (2)

1.3 Hydroxyl ✓ (1)

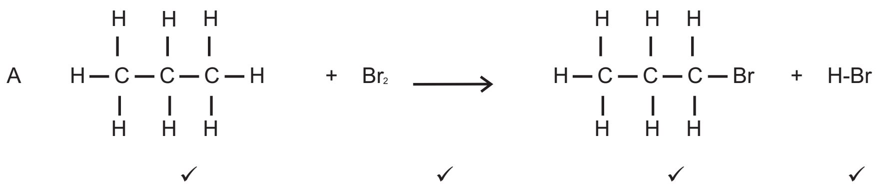
1.4 Hydrogen bonding ✓
All the molecules are primary alcohols thus all will have hydrogen bonding between the OH groups on the molecules. ✓ This is the polar end of the molecule. However, there is the carbon chain which offers a non-polar end to the molecule. As the size of the molecules increases, due to a longer chain length, there is a larger electron cloud density offering more points of contact for intermolecular forces to occur between the chains. ✓ This causes the intermolecular force strength to increase, ✓ thus more energy is required to overcome these forces, hence the boiling point of the alcohols get larger. (4)

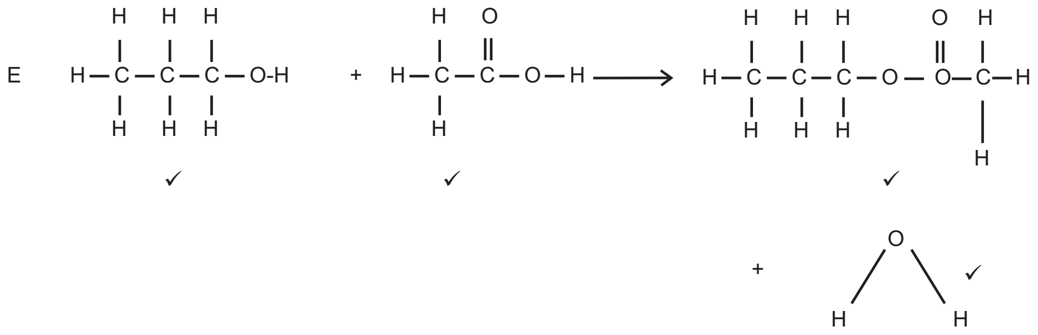
2.1 **A** Substitution ✓
B Elimination (or dehydrohalogenation) ✓
C Addition (or hydration) ✓
D Substitution ✓ (4)

2.2 Propane ✓ (1)

2.3 KOH ✓ (dilute) or NaOH (1)

2.4





(8)

2.5 Propyl ethanoate ✓✓ (2)

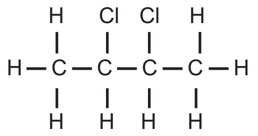
2.6 Propene ✓ (1)

3.1 These are carbon based side branches ✓ attached to the main carbon chain. ✓ (2)

3.2 Organic compounds consisting of C and H atoms only ✓ and have only single bonds to the C atoms in the chain. ✓(All four bonds to the C in chain singularly occupied) (2)

4.1 $CH_3\ CHC(CH_3)\ CH_2\ CH_3$ (2)

4.2



✓ for Cl in correct position

✓ for correct chain and structure (2)

5.1 B ✓✓ (2)

5.2 D ✓and G ✓ (2)

5.3 A, E and F (any two) ✓✓ (2)

5.4 Alkyl halides (haloalkanes or halogenoalkanes) ✓ (1)

5.5 $CH_3CH_2CH_2CH_2CH_3$ ✓ Pentane ✓
$CH_3C(CH_3)_2CH_3$ ✓ 2,2 – dimethylpropane ✓ (4)

5.6 **E:** has – OH group which causes strong ✓hydrogen bonding ✓ between its molecules ✓
A: has polar molecules causing dipole – dipole intermolecular forces ✓ between molecules which are weaker ✓ than hydrogen bonding.
More energy is thus needed to overcome the stronger hydrogen bonds. ✓ (5)

FORMAL EXPERIMENT

FORMAL EXPERIMENT

GRADE 12 TERM 1: CHEMISTRY

Preparation of Esters

30 MARKS

This section provides guidance and assessment of the learner's knowledge and understanding when carrying out a virtual experiment using the NECT video of the same name.

If your class is carrying out the experiment using laboratory apparatus and taking down their own results, you must set up your classroom appropriately and give the learners the relevant instructions. You may find it useful to refer to the Technical Instructions which precede the Learner's Instructions while preparing for this experiment.

If the learners are proceeding with the virtual experiment, then continue with the NECT programme by using the information, handouts and marking guidelines contained in this section of this Resource Book.

Formal Experiment

TECHNICAL INSTRUCTIONS

AIM: To prepare esters from alcohols and carboxylic acids.

APPARATUS

2 × test tubes
2 × 100 ml beakers
1 × 250 ml beaker ("empty" beaker)
Hot plate (or Bunsen burner, tripod and gauze mat)
Tongs or a test tube holder
4 × droppers (propettes)
Spatula
1 × 3 ml test tube ("small" test tube)
Electronic balance (or triple beam balance)
Methanol
Ethanol
Ethanoic acid
Salicylic acid
Concentrated sulfuric acid
2 × 250 ml beakers half-filled with sodium carbonate solution

SAFETY MEASURES OR PRECAUTIONS

- Do not allow anyone to sniff any of these chemicals directly. They can all cause respiratory problems, as well as irritate the mucous linings of the nostrils and throat.
- In particular sniffing either methanol or ethanol can cause temporary loss of vision. Sniffing methanol can cause permanent blindness.
- Concentrated sulfuric acid is corrosive, an oxidant, and a dehydrating agent. It must be handled with extreme care. Wear gloves to protect your hands.
- Wear goggles to protect your eyes from the fumes of these substances.
- Supervise the laboratory work carefully to ensure that everyone respects each other's safety.

METHOD

A. Preparing an ester from two liquid substances: ethanol and ethanoic acid

1. Add about 20 drops (20 ml) of ethanoic acid to a clean, dry test tube.
2. Add about 20 drops (20 ml) of ethanol to the ethanoic acid in the test tube.
3. Swirl the contents of the test tube a few times to mix the substances.
4. Add two or three drops of concentrated sulfuric acid to the test tube, by letting the sulfuric acid run slowly down the side of the test tube. Do this slowly so that the contents of the test tube do not become too hot, and the acid does not splatter out of the test tube.
4. Put 20 ml of water in a 100 ml beaker.
5. Carefully lower the tube test into the beaker so that it is is supported and stands up.
6. Place the beaker of water with its test tube on a tripod and gauze mat, and light the burner. Heat until the water starts to boil, and then stop heating.
7. Allow the test tube to stand for 1 minute in the hot water. If the mixture in the tube boils, use tongs to lift test tube out of the water until boiling stops, then return it to the hot water.
8. After 1 minute, using tongs, carefully remove the test tube and allow it to cool in an empty beaker or in a test tube stand.
9. When the test tube is cool, pour the mixture into a beaker half-full of dilute sodium carbonate solution. There will be some effervescence.
10. Use a stirring rod to mix the contents of the beaker well. A layer of ester will separate and float on top of the aqueous layer.
11. Smell the product by gently wafting the odour towards your nose with your hand – do not put your nose near the top of the tube!

B. Preparing an ester from a solid acid: salicylic acid and methanol.

1. Weigh out 0,5 g of salicylic acid (2-hydroxybenzoic acid) in a small (3 ml) test tube.
2. Add the acid to a clean dry test tube. Then add 3 ml of methanol to the small test tube to wash the remainder of the salicylic acid crystals into the reaction test tube.

Proceed as above from step 3 to 11.

NAME: ____ GRADE:__________

Formal Experiment

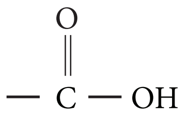
PREPARATION OF ESTERS

AIM: To prepare esters from alcohols and carboxylic acids.

30 MARKS

THEORY

An ester has the functional group:



This functional group is also called “an ester link”.

In this experiment esters are prepared from an alcohol and a carboxylic acid in the presence of concentrated sulfuric acid (which acts a catalyst). The reaction between an alcohol and a carboxylic acid to form an ester is known as esterification. It is an example of a condensation reaction because the two molecules of alcohol and carboxylic acid link up by eliminating a small molecule (a water molecule).

The reaction takes place very slowly at room temperature so, we heat up the reactants to about 60 °C. Because the two alcohols (ethanol and methanol) which we will use in this experiment are inflammable, we cannot heat the reaction test tube directly in case the contents catch fire. Therefore, we use a water bath to heat the reactants. We also use concentrated sulfuric acid as a catalyst to increase the rate of production of the esters.

The alcohols and the carboxylic acids generally have their own distinct odours, and the esters that are produced smell completely different from their reactants. The products of the reaction are poured into a solution of sodium carbonate which dissolves the alcohol and reacts with any remnants of carboxylic acid as well as with the sulfuric acid, leaving the oily ester floating on the surface of the solution. This helps us to distinguish the fragrance of the ester more easily.

Be aware of the safety precautions that should be adhered to during this experiment.

APPARATUS

2 × test tubes
2 × 100 ml beakers
1 × 250 ml beaker ("empty" beaker)
Hot plate (or Bunsen burner, tripod and gauze mat)
Tongs or a test tube holder
4 × droppers (propettes)
Spatula
1 × 3 ml test tube ("small" test tube)
Electronic balance (or triple beam balance)
Methanol
Ethanol
Ethanoic acid
Salicylic acid
Concentrated sulfuric acid
2 × 250 ml beakers half-filled with sodium carbonate solution

SAFETY MEASURES OR PRECAUTIONS

- Do not sniff any of these chemicals directly. They can all cause respiratory problems, as well as irritate the mucous linings of the nostrils and throat.
- In particular sniffing either methanol or ethanol can cause temporary loss of vision. Sniffing methanol can cause permanent blindness.
- Concentrated sulfuric acid is corrosive, an oxidant, and a dehydrating agent. It must be handled with extreme care. Wear gloves to protect your hands.
- Wear goggles to protect your eyes from the fumes of these substances.
- Work carefully and respect each other's safety.

VARIABLES

Independent variable:	Type of alcohol and carboxylic acid
Dependent variable:	Smell of the ester (name of the ester)
Controlled variable:	Amount of alcohol and carboxylic acid

METHOD

A. Preparing an ester from two liquid substances: ethanol and ethanoic acid

1. Add about 20 drops (20 ml) of ethanoic acid to a clean, dry test tube.
2. Add about 20 drops (20 ml) of ethanol to the ethanoic acid in the test tube.
3. Swirl the contents of the test tube a few times to mix the substances.

4. Add two or three drops of concentrated sulfuric acid to the test tube, by letting the sulfuric acid run slowly down the side of the test tube. Do this slowly so that the contents of the test tube do not become too hot, and the acid does not splatter out of the test tube.
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5. Carefully lower the tube test into the beaker so that it is is supported and stands up.
6. Place the beaker of water with its test tube on a tripod and gauze mat, and light the burner. Heat until the water starts to boil, and then stop heating.
7. Allow the test tube to stand for 1 minute in the hot water. If the mixture in the tube boils, use tongs to lift test tube out of the water until boiling stops, then return it to the hot water.
8. After 1 minute, using tongs, carefully remove the test tube and allow it to cool in an empty beaker or in a test tube stand.
9. When the test tube is cool, pour the mixture into a beaker half-full of dilute sodium carbonate solution. There will be some effervescence.
10. Use a stirring rod to mix the contents of the beaker well. A layer of ester will separate and float on top of the aqueous layer.
11. Smell the product by gently wafting the odour towards your nose with your hand – do not put your nose near the top of the tube!

B. Preparing an ester from a solid acid: salicylic acid and methanol.

1. Weigh out 0,5 g of salicylic acid (2-hydroxybenzoic acid) in a small (3 ml) test tube.
2. Add the acid to a clean dry test tube. Then add 3 ml of methanol to the small test tube to wash the remainder of the salicylic acid crystals into the reaction test tube.

Proceed as above from step 3 to 11.

OBSERVATIONS AND RESULTS

Watch the video and record the odours of the esters as described by the presenters. [2]

Carboxylic acid	Alcohol	Odour of ester
ethanol	ethanoic acid	(1)
methanol	salicylic acid	(1)

EXPERIMENT

ANALYSIS AND INTERPRETATION

1. Name the two homologous series of organic compounds that are used in the preparation of esters. (2)

2. Write down the structural formula of the functional group of the following compounds:
   2.1 An alcohol (1)

   2.2 A carboxylic acid (1)

3. This question concerns the reaction between ethanol and ethanoic acid. Concentrated sulfuric acid acts as a catalyst in this reaction.
   3.1 Use full structural formulae to write the balanced equation for this reaction. (4)

   3.2 Name the ester formed during this reaction. (2)

   3.3 Name an everyday substance which smells like ethanoic acid. (1)

   3.4 Would this reaction take place if the catalyst was not added to the reaction mixture? Explain briefly. (3)

3.5 Briefly explain how the presence of a catalyst speeds up the rate of a reaction. (3)

3.6 At the end of the reaction the presenters said that they could not detect the smell of ethanoic acid in the test tube. What does this tell us about the contents of the test tube? (1)

3.7 Why does dilute sodium carbonate solution fizz (effervesce) when the contents of the test tube are added to it at the end of the reaction? (3)

[21]

4. This question concerns the reaction between salicylic acid and methanol. Concentrated sulfuric acid acts as a catalyst in this reaction.

4.1 Write down the full structural formula for methanol. (1)

4.2 Which of these two alcohols has the higher boiling point? Ethanol or methanol? Explain briefly with reference to the forces between the molecules. (3)

4.3 Name the ester formed by this reaction. (2)

4.4 Give ONE use of this ester (in everyday life). (1)

[7]

Formal Experiment

MARKING GUIDELINES

Aim: To prepare esters from alcohols and carboxylic acids.

OBSERVATIONS AND RESULTS [2]

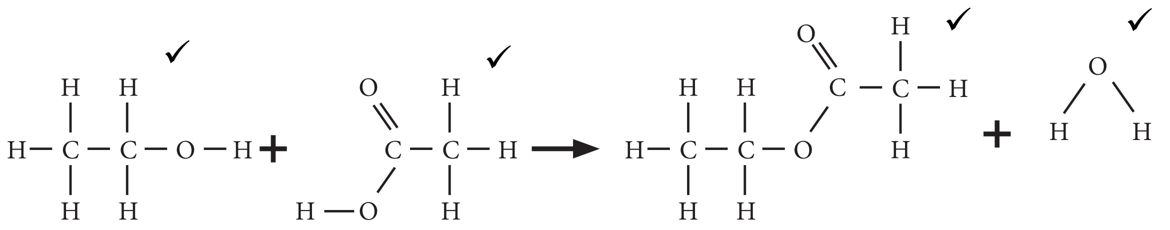
Carboxylic acid	Alcohol	Odour of ester
ethanol	ethanoic acid	Paint thinners (paint or enamel paint)✓ (1)
methanol	salicylic acid	Wintergreen (or "Deep heat" or equivalent muscle rub) ✓ (1)

ANALYSIS AND INTERPRETATION

1. Name the two homologous series of organic compounds that are used in the preparation of esters (2)
   Alcohol(s) ✓
   Carboxylic acid(s) ✓

2. Write down the structural formula of the functional group of the following compounds:
   2.1 An alcohol -OH ✓ (1)
   2.2 A carboxylic acid -COOH ✓ or $-\overset{\overset{O}{\|}}{C}-OH$ ✓ (1)

3. This question concerns the reaction between **ethanol** and **ethanoic acid**. Concentrated sulfuric acid acts as a catalyst in this reaction.
   3.1 Use full structural formulae to write the balanced equation for this reaction. (4)



   3.2 Name the ester formed during this reaction. (2)
   ethyl ✓ *ethanoate* ✓
   3.3 Name an everyday substance which smells like ethanoic acid. (1)
   vinegar ✓

3.4 Would this reaction take place if the catalyst was not added to the reaction mixture? Explain briefly. (3)
Yes. ✓ The catalyst speeds up the reaction without changing its own chemical composition ✓ so the reactants will react ***very slowly****. ✓*

3.5 Briefly explain how the presence of a catalyst speeds up the rate of a reaction. (3)
The catalyst lowers the activation energy of the reaction ✓ by providing an alternative way for the reactants to interact with each other. ✓ If the activation energy is lower there will be more molecules of the reactants with sufficient kinetic energy. This results in more effective collisions, ✓ and hence the reaction rate is increased.

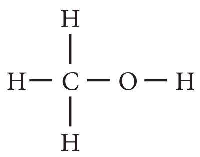
3.6 At the end of the reaction the presenters said that they could not detect the smell of ethanoic acid in the test tube. What does this tell us about the contents of the test tube? (1)
All (or most of) the ethanoic acid has reacted. ✓ (or There is no ethanoic acid left over from the reaction) or equivalent response.

3.7 Why does dilute sodium carbonate solution fizz (effervesce) when the contents of the test tube are added to it at the end of the reaction? (3)
Sodium carbonate reacts ✓with the sulfuric acid ✓ giving off carbon dioxide (gas). ✓

[21]

4. This question concerns the reaction between salicylic acid and methanol. Concentrated sulfuric acid acts as a catalyst in this reaction.

4.1 Write down the full structural formula for methanol. (1)



4.2 Which of ethanol or methanol has the higher boiling point? Explain briefly with reference to the forces between the molecules. (3)
Ethanol. ✓ Ethanol has larger molecules than methanol and therefore the London forces ✓ between its molecules are stronger than those between methanol molecules. More energy is needed to overcome the intermolecular forces in ethanol. ✓

4.3 Name the ester formed by this reaction. (2)
methyl ✓ salicylate ✓

4.4 Give ONE use of this ester (in everyday life). (1)
To treat sore muscles (sprained ankles) ✓ (or equivalent answer).

[7]

ASSESSMENTS

Topic 2: Momentum and Impulse

QUESTIONS

MULTIPLE CHOICE

1. According to Newton's Second Law of Motion, the acceleration of an object is …
   A independent of its mass.
   B always equal to its mass.
   C directly proportional to its mass.
   D inversely proportional to its mass. (2)

2. The magnitude of the impulse on a ball bouncing off a wall is equal to the ...
   A net force of the ball on the wall.
   B product of the net force on the ball and the time it acts.
   C change in velocity of the ball.
   D product of the mass and the acceleration of the ball. (2)

3. A person drops a glass bottle onto a concrete floor from a certain height and the bottle breaks. The person then drops a second, identical glass bottle from the same height onto a thick, woollen carpet, but the bottle does not break.
   Which ONE of the following is CORRECT for the second bottle compared to the first bottle for the same momentum change?

	Average force on second bottle	Time of contact with carpet
A	Larger	Smaller
B	Smaller	Smaller
C	Larger	Larger
D	Smaller	Larger

(2)

4. An object of mass *m* moving at velocity *v* collides head-on with an object of mass 2*m* moving in the opposite direction at velocity *v*. Immediately after the collision the smaller mass moves at velocity *v* in the opposite direction and the larger mass is brought to rest. Refer to the diagram below.

Ignore the effects of friction. Which ONE of the following is CORRECT?

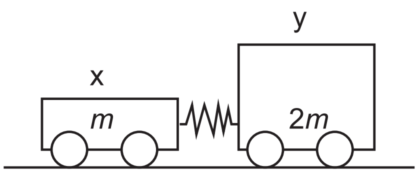
	Momentum	Mechanical energy
A	Conserved	Conserved
B	Not conserved	Conserved
C	Conserved	Not conserved
D	Not conserved	Not conserved

(2)

5. If the momentum of an object is doubled, then its kinetic energy is ...
   A halved
   B doubled
   C three times greater
   D four times greater (2)

6. Two trolleys, P and Q, of mass *m* and 2*m* respectively are at rest on a frictionless horizontal surface. The trolleys have a compressed spring between them.
   The spring is released and the trolleys move apart. Which ONE of the following statements is TRUE?
   A P and Q have equal kinetic energies.
   B The speed of P is less than the speed of Q.
   C The sum of the final kinetic energies of P and Q is zero.
   D The sum of the final momentum of P and Q is zero. (2)

7. Two trolleys, X and Y, are placed head to head with a compressed spring between them. Trolley X has mass *m*, while trolley Y has mass 2*m*. The compressed spring is released and the trolleys are shot apart.



   Immediately after the trolleys have been shot apart, trolley X moves with a speed *v*. What will be the speed of trolley Y immediately after the trolleys are shot apart?
   A ½*v*
   B *v*
   C 2*v*
   D 4*v* (2)

8. Two friends, Peter and Lana, both on ice skates, are standing on the ice. Peter has twice the mass of Lana. They press their hands together and push away from each other.
Which ONE of the following is CORRECT regarding the magnitude of the force exerted by Peter on Lana?

A $F_{Peter\ on\ Lana} = 3F_{Lana\ on\ Peter}$

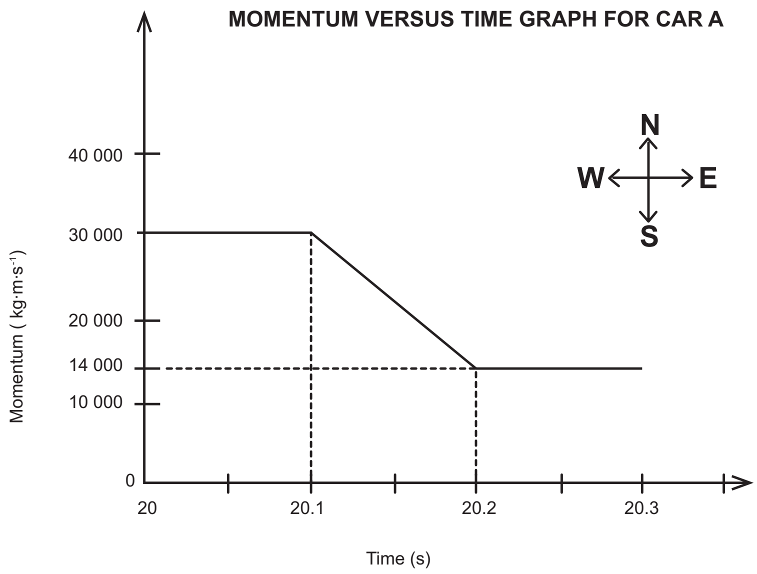
B $F_{Peter\ on\ Lana} = 2F_{Lana\ on\ Peter}$

C $F_{Peter\ on\ Lana} = F_{Lana\ on\ Peter}$

D $F_{Peter\ on\ Lana} = \frac{1}{2}F_{Lana\ on\ Peter}$ (2)

LONG QUESTIONS

1. 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.
The diagram below represents the graph of the momentum vs. time for Car A.



1.1 What do you understand by the term 'isolated system' as used in physics? (2)

1.2 Use the information from the graph to answer the following questions.
Calculate the:

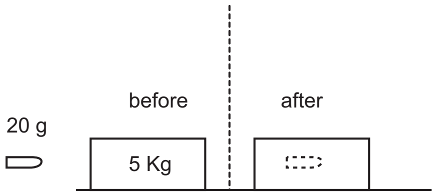
1.2.1 magnitude of the velocity of car A just before the collision. (3)

1.2.2 velocity of car B just after the collision. (6)

1.2.3 the average net force acting on car A during the collision. (5)

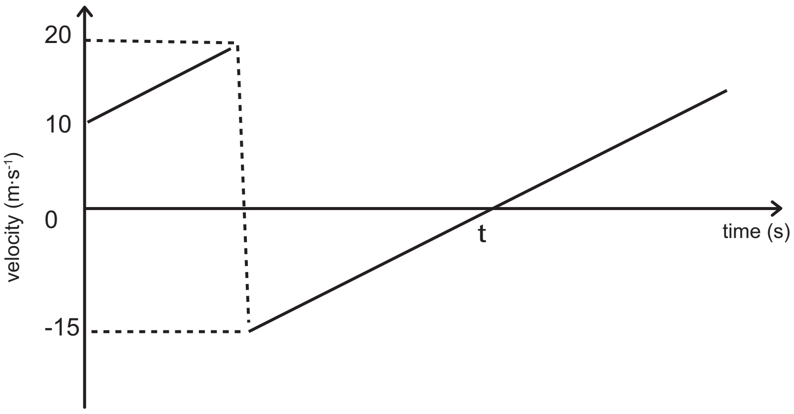
2. A bullet of mass 25 g is fired from a stationary rifle of mass 2,8 kg. Assume that the bullet moves horizontally. Immediately after firing, the rifle recoils (moves back) with a velocity of 1,8 $m{\cdot}s^{-1}$.
   2.1 State the law of conservation of linear momentum. (2)
   2.2 Calculate the speed at which the bullet leaves the rifle. (4)
   2.3 Calculate the magnitude of the impulse provided to the bullet during the explosion. (3)

   The bullet strikes a stationary 6 kg wooden block fixed to a flat, horizontal table. The bullet is brought to rest after travelling a distance of 0,4 m into the block. Refer to the diagram below.



   2.4 Calculate the average force exerted by the block on the bullet. (6)
   2.5 How does the magnitude of the force calculated in QUESTION 2.4 compare to the magnitude of the force exerted by the bullet on the block? Write down only LARGER THAN, SMALLER THAN or THE SAME. (1)

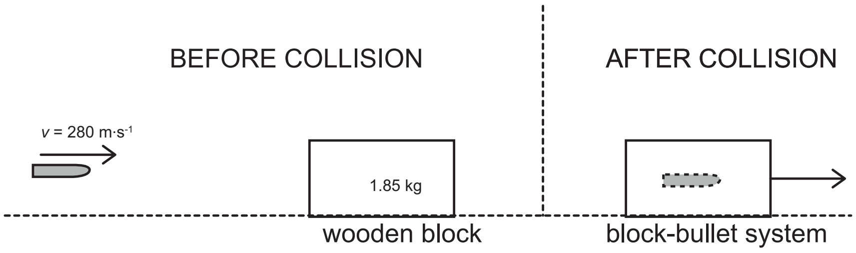
3. A ball of mass 0,2 kg is thrown vertically downwards from the top of a building to a concrete floor below. The ball bounces off the floor. The velocity versus time graph below shows the motion of the ball. Ignore the effects of air friction. Take downwards as the positive direction.



   3.1 From the graph, write down the magnitude of the velocity at which the ball bounces off the floor. (1)
   3.2 Is the collision of the ball with the floor elastic or inelastic? Refer to the data in the graph to explain your answer. (3)
   3.3 Calculate the height from which the ball is thrown. (4)
   3.4 Calculate the impulse imparted by the floor on the ball. (4)
   3.5 Calculate the magnitude of the displacement of the ball from the moment it was thrown until time *t*. (4)

ASSESSMENTS

4. A boy, on ice skates, is stationary on a frozen lake (no friction). He throws a package of mass 4 kg at 5 m·s^{-1} horizontally east. The mass of the boy is 65 kg. At the instant the package leaves the boy's hand, the boy starts moving.
   4.1 In which direction does the boy move? (1)
   4.2 Which one of Newton's laws of motion explains the direction in which the boy experiences a force when he throws the package? Name and state this law in words. (3)
   4.3 Calculate the boy's speed immediately after the package leaves his hand. Ignore the effects of friction. (5)
   4.4 How will the answer to Question 4.3 be affected if:
   (Write INCREASES, DECREASES or REMAINS THE SAME)
      4.4.1 The boy throws the same package at a higher velocity in the same direction. Explain your answer. (3)
      4.4.2 The boy throws a package of double the mass at the same velocity as in Question 4.3. Explain your answer. (3)
5. A bullet of mass 15 g, moving at 280 m·s^{-1}, strikes a wooden block of mass 1,85 kg resting on a flat horizontal surface as shown in the diagram below. The bullet becomes embedded in the block. Ignore the effects of air friction.



   5.1 State the law of conservation of linear momentum. (2)
   5.2 Calculate the speed of the block-bullet system immediately after the collision. (5)
   5.3 Calculate the impulse provided to the bullet during the collision. (4)
   5.4 Is the collision elastic or inelastic? Give a reason for your answer. (2)
   The floor exerts a constant frictional force of 6 N on the block-bullet system as it comes to rest.
   5.5 Calculate the distance that the block-bullet system moves after the collision. (4)

6. The diagram below shows a car of mass *m* travelling at a velocity of 20 m·s^{-1} east on a straight level road and a truck of mass 2*m* travelling at 20 m·s^{-1} west on the same road. Ignore the effects of friction.

   The vehicles collide and the car travels west at 8 m·s^{-1} immediately after the collision.

6.1 State the law of conservation of linear momentum. (2)

6.2 Calculate the velocity of the truck immediately after the collision. (6)

6.3 On impact the car exerts a force of magnitude F on the truck and experiences an acceleration of magnitude a.

6.3.1 Determine, in terms of F, the magnitude of the force that the truck exerts on the car on impact. Give a reason for your answer. (2)

6.3.2 Determine, in terms of a, the acceleration that the truck experiences on impact. Give a reason for your answer. (2)

6.3.3 Both drivers are wearing identical seat belts. Which driver is likely to be more severely injured on impact? Explain the answer by referring to acceleration and velocity. (3)

MARKING GUIDELINES

MULTIPLE CHOICE

1. D ✓ ✓ [CL 1] (2)
2. B ✓ ✓ [CL 1] (2)
3. D ✓ ✓ The contact time is longer.
   The net force on the bottle is inversely proportional to the contact time.
   [CL 3] (2)
4. C ✓ ✓
   $p_{before} = mv + (2m)(-v) = -mv$
   $p_{after} = m(-v) + 0 = -mv$
   $E_{k\ before} = \frac{1}{2}mv^2 + \frac{1}{2}(2m)v^2 = \frac{3}{2}mv^2$
   $E_{k\ after} = \frac{1}{2}mv^2 + 0 = \frac{1}{2}mv^2$ [CL 3] (2)
5. D ✓ ✓
   $p = mv$
   $v = \frac{p}{m}$
   $E_k = \frac{1}{2}mv^2 = \frac{1}{2}m(\frac{p}{m})^2 = \frac{p^2}{2m}$
   $E_{k\ new} = \frac{(2p)^2}{2m} = 4(\frac{p^2}{2m}) = 4E_k$ [CL 4] (2)
6. D ✓ ✓ Total linear momentum before the explosion is zero.
   Total linear momentum after the collision must also be zero. [CL 3] (2)
7. A ✓ ✓
   $\varepsilon p_{before} = \varepsilon p_{after}$
   $0 = m(-v) + 2mv_Y$
   $v = 2v_Y$
   $v_Y = \frac{1}{2}v$ [CL 3] (2)
8. C ✓ ✓ Newton's third law [CL 2] (2)

LONG QUESTIONS

1.1 A system that has no net external forces acting on it ✓ ✓ [CL1] (2)

1.2.1 $p = mv$

$v = \frac{p}{m} = \frac{30\ 000✓}{1\ 500✓} = 20\ m{\cdot}s^{-1}$ ✓ [CL 2] (3)

1.2.2 $p_{before} = p_{after}$

$m_A v_{Ai} + m_B v_{Bi} = m_A v_{Af} + m_B v_{Bf}$

$(+30\ 000)$✓$+ (900)(-15)$✓$= (+14\ 000)$✓$+ (900)v_{Bf}$ ✓

$30\ 000 - 13\ 500 = 14\ 000 + 900v_{Bf}$

$900v_{Bf} = 2\ 500$

$v_{Bf} = 2{,}78\ m{\cdot}s^{-1}$ ✓ to the right ✓ [CL 3] (6)

1.2.3 $F_{net}\Delta t = \Delta p$

$F_{net}\Delta t = mv_f - mv_i$

$F_{net}(0,1✓) = +14\,000✓ - (+30\,000✓)$

$F_{net}(0,1) = -16\,000$

$F_{net} = -160\,000$

$\therefore F_{net} = 160\,000$ N ✓ to the left ✓ [CL 3] (5)

2.1 The total linear momentum of an isolated system remains constant. ✓ ✓ [CL 1] (2)

2.2 Choose forward as positive:

$\varepsilon p_{before} = \varepsilon p_{after}$

$m_T v_{Ti} = m_R v_{Rf} + m_b v_{bf}$

$(2,825)(0)✓ = (2,8)(-1,8)✓ + (0,025✓)v_{bf}$

$0 = -5,04 + 0,025v_{bf}$

$v_f = 201,60\ m{\cdot}s^{-1}$ ✓ [CL 3] (4)

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

$F_{net}\Delta t = mv_f - mv_i$

$F_{net}\Delta t = (0,025)(+201,60)✓ - 0$ ✓

$F_{net}\Delta t = 5,04$ N·s ✓ [CL 3] (3)

2.4 $v_f^2 = v_i^2 + 2a\Delta x$

$0✓ = (201,6✓)^2 + 2a(0,4✓)$

$a = -50\,803,2\ m{\cdot}s^{-2}$

$F_{net} = ma$

$F_{net} = (0,025)(-50\,803,2) = -1\,270,08$

$\therefore F_{net} = 1\,270,08$ N ✓ to the left ✓ [CL 3] (6)

2.5 THE SAME ✓ (Newton's third law) [CL2] (1)

3.1 $15\ m{\cdot}s^{-1}$ ✓ [CL2] (1)

3.2 Inelastic ✓

The ball leaves the ground with a lower speed ✓ than it hit the ground, therefore kinetic energy is not conserved ✓. [CL2] (3)

3.3 $v_f^2 = v_i^2 + 2a\Delta x$

$(20✓)^2 = (10✓)^2 + 2(9,8✓)\Delta x$

$\Delta x = 15,31$ m ✓ [CL3] (4)

3.4 $F_{net}\Delta t = \Delta p$

$F_{net}\Delta t = mv_f - mv_i$

$F_{net}\Delta t = (0,2)(-15)✓ - (0,2)(+20)✓✓$

$F_{net}\Delta t = -7$

$\therefore F_{net}\Delta t = 7$ N·s ✓ upwards ✓ [CL3] (4)

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

$0✓ = (-15✓)^2 + 2(9,8)\Delta x$

$\Delta x = 11,48$ m ✓

$\Delta x = 15,31 - 11,48 = 3,83$ m ✓ [CL3] (4)

4.1 West ✓ [CL 1] (1)

ASSESSMENTS

4.2 Newton's third law ✓
When object A exerts a force on object B, object B simultaneously exerts an oppositely directed force of equal magnitude on object A ✓ ✓ [CL 1] (3)

4.3 Choose east as positive:
$\varepsilon p_{before} = \varepsilon p_{after}$
$0 = m_B v_{Bf} + m_P v_{Pf}$
$0✓ = (65)\, v_{Bf}✓ + (4✓)(5✓)$
$v_{Bf} = -0{,}31$
$\therefore v_{Bf} = 0{,}31\ m{\cdot}s^{-1}$ ✓ [CL 3] (5)

4.4.1 INCREASES ✓
The easterly momentum of the package is greater✓ (since velocity has increased)
∴ The westerly momentum the boy must also increase✓ to conserve momentum.
[CL 3] (3)

4.4.2 INCREASES ✓
The easterly momentum of the package has doubled ✓ (since mass has doubled)
The westerly momentum the boy must also double ✓ to conserve momentum.
[CL3] (3)

5.1 The total linear momentum of an isolated system remains constant. ✓ ✓ [CL1] (2)

5.2 Choose forward as positive:
$\varepsilon p_{before} = \varepsilon p_{after}$
$(0{,}015✓)(280✓) + 0✓ = (2✓)\, v_f$
$v_f = 2{,}1\ m{\cdot}s^{-1}$ ✓ [CL3] (5)

5.3 $F_{net}\Delta t = \Delta p$
$F_{net}\Delta t = mv_f - mv_i$
$F_{net}\Delta t = (0{,}015)(0)✓ - (0{,}015)(+280)$ ✓
$F_{net}\Delta t = -4{,}2$
$\therefore F_{net}\Delta t = 4{,}2\ N{\cdot}s$ ✓ backwards ✓ [CL3] (4)

5.4 Inelastic ✓
Friction between the bullet and the wood will dissipate energy in the form of heat and sound. ✓ [CL2] (2)

5.5 $W_{net} = \Delta E_k$
$F_{net}\Delta x = 0 - \frac{1}{2}(2)(2{,}1)^2$ ✓
$(-6✓)\Delta x = -4{,}41$ ✓
$\Delta x = 0{,}74\ m$ ✓ [CL3] (4)

6.1 The total linear momentum of an isolated system remains constant. ✓ ✓ [CL1] (2)

6.2 Choose east as positive:
$\varepsilon p_{before} = \varepsilon p_{after}$
$m(20✓) + 2m(-20✓) = m(-8✓) + 2mv_f$ ✓
$20 - 40 = -8 + 2v_f$
$-12 = 2v_f$
$v_f = -6$
$\therefore v_f = 6\ m{\cdot}s^{-1}$✓ west ✓ [CL3] (6)

6.3.1 F ✓
Newton's third law ✓ [CL2] (2)

6.3.2 $a = \frac{F}{m}$
$a_{truck} = \frac{F}{2m✓} = \frac{1}{2}(\frac{F}{m}) = \frac{1}{2}a$ ✓ [CL4] (2)

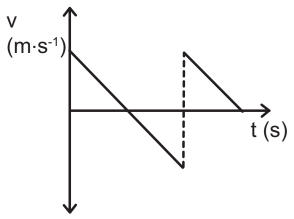
6.3.3 The car driver ✓
The car driver experiences the greater acceleration. ✓
The car driver will experience the greater change in velocity. ✓ [CL4] (3)

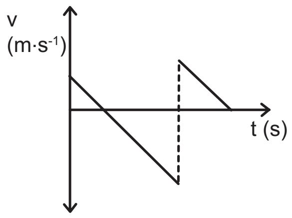
Topic 3: Vertical Projectile Motion in One Dimension

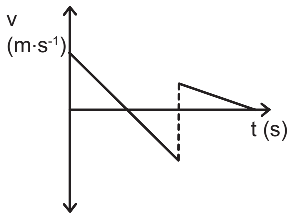
QUESTIONS

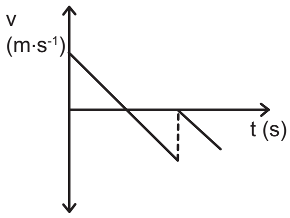
MULTIPLE CHOICE

1. A ball is projected vertically upwards from the ground. It returns to the ground, experiences an elastic collision with the ground and then bounces to a maximum height. Ignore air resistance.
   Which ONE of the following velocity-time graphs CORRECTLY describes the motion of the ball?

A


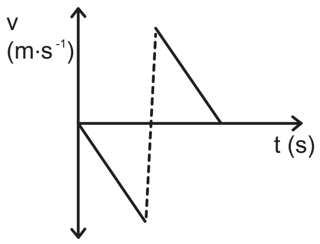
B


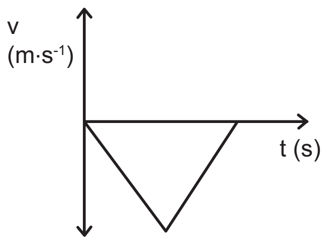
C


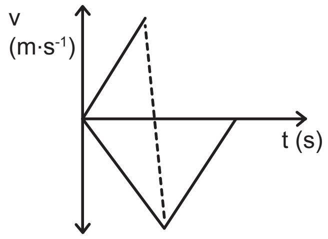
D


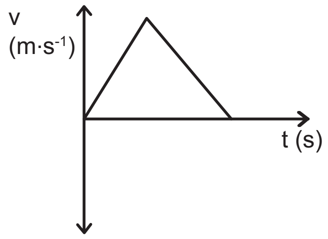
(2)

2. A ball is dropped to the ground from a certain height and bounces back to the same height. Which ONE of the following velocity versus time graphs represents the motion of the ball if downwards is taken as positive.

A


B


C


D


(2)

3. An object is thrown vertically upwards from the ground.
Which ONE of the following is CORRECT regarding the direction of the acceleration of the object as it moves upwards and then downwards? Ignore the effects of air resistance.

	Object moving upwards	Object moving downwards
A	Downwards	Upwards
B	Upwards	Downwards
C	Downwards	Downwards
D	Upwards	Upwards

(2)

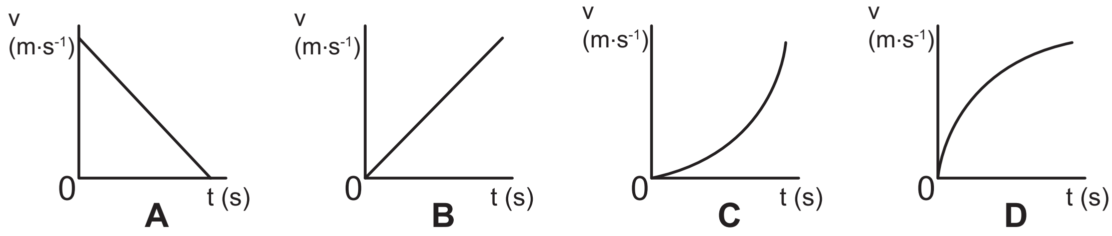
4. An object is thrown vertically upwards. Which ONE of the following regarding the object's velocity and acceleration at the highest point of its motion is CORRECT? Ignore the effects of friction.

	Velocity	Acceleration
A	Zero	Zero
B	Zero	Upwards
C	Maximum	Zero
D	Zero	Downwards

(2)

5. If air resistance is negligible, the total mechanical energy of a free-falling body …
A remains constant
B becomes zero
C increases
D decreases (2)

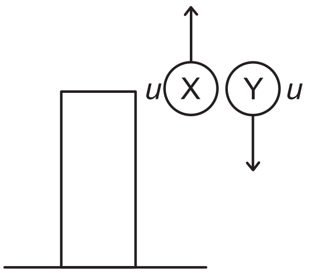
6. A ball is thrown vertically upwards. Which ONE of the following velocity-time graphs best represents the UPWARD motion of the ball? Ignore air resistance.



(2)

QUESTIONS 7. and 8. refer to the following situation:

Two identical lead balls, X and Y, are thrown simultaneously with the SAME initial speed *u* from the roof of a building. X is thrown vertically upwards, while Y is thrown vertically downwards. Ignore air friction.



7. How do the DISPLACEMENTS of the two balls compare when each ball reaches the ground at the bottom of the building?
   A The displacements will be equal.
   B The displacement of X will be greater in magnitude.
   C The displacement of Y will be greater in magnitude.
   D The displacements cannot be compared without further information. (2)

8. How does the speed and the magnitude of the acceleration of ball X compare with that of ball Y the instant before they reach the ground?

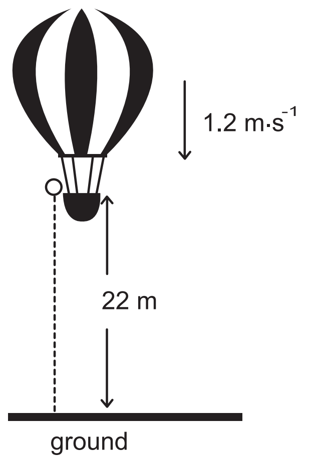
	Speed	Magnitude of acceleration
A	speed X = speed Y	acceleration X = acceleration Y
B	speed X > speed Y	acceleration X = acceleration Y
C	speed X < speed Y	acceleration X < acceleration Y
D	speed X < speed Y	acceleration X = acceleration Y

(2)

LONG QUESTIONS

1. A hot-air balloon moves vertically downwards at a constant velocity of 1,2 m·s^{-1}. When it reaches a height of 22 m from the ground, a ball is dropped from the balloon. Refer to the diagram.
   Assume that the dropping of the ball has no effect on the speed of the hot-air balloon. Ignore air friction for the motion of the ball.

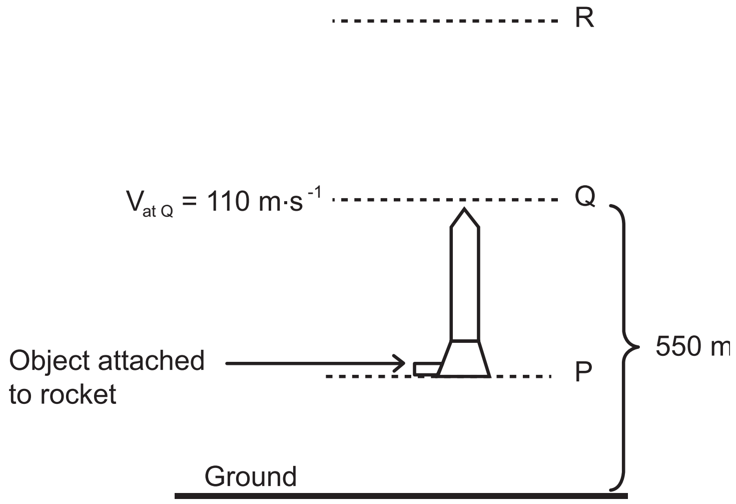
1.1 Explain the term projectile motion. (2)
1.2 Is the hot-air balloon in free fall? Give a reason for the answer. (2)
1.3 Calculate the time it takes for the ball to hit the ground after it is dropped. (4)



When the ball lands on the ground, it is in contact with the ground for 0,3 s and then it bounces vertically upwards with a speed of 15 $m{\cdot}s^{-1}$.

1.4 Calculate how high the balloon is from the ground when the ball reaches its maximum height after the first bounce. (6)

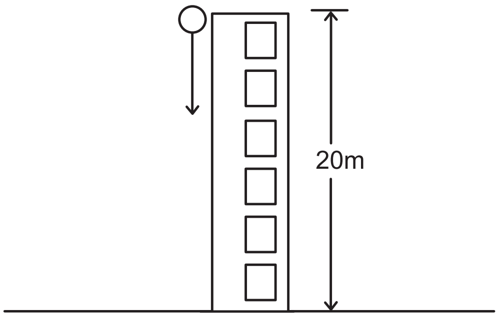
2. A stationary rocket on the ground is launched vertically upwards. When it is 550 m above the ground (point Q), an object is released from the rocket. At this instant the velocity of the rocket is 110 $m{\cdot}s^{-1}$. The object reaches its MAXIMUM height ABOVE ground at point R. Ignore the effects of air friction.



2.1 Give a reason why the object keeps moving upwards after it is released from the rocket. (1)
2.2 What is the direction of the acceleration of the object at:
  2.2.1 Point P? (1)
  2.2.2 Point R? (1)
2.3 ONLY use EQUATIONS OF MOTION to calculate the time taken by the OBJECT to:
  2.3.1 reach its maximum height after being released from the rocket at point Q. (4)
  2.3.2 reach the ground after being released from the rocket at point Q. (5)
2.4 Sketch the velocity versus time graph for the complete motion of the object from the instant it was released at Q to the time it hit the ground. On the graph indicate the following:

- initial velocity
- time to reach its maximum height
- time when it reaches the ground (4)

3. A ball is dropped from the top of a building 20 m high. Ignore the effects of air resistance.



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

3.2 Calculate the:

3.2.1 speed at which the ball hits the ground. (4)

3.2.2 time it takes the ball to reach the ground. (3)

3.3 Sketch a velocity-time graph for the motion of the ball. (No values required). (2)

3.4 Sketch a position-time graph for the motion of the ball. (No values required). (2)

3.5 Sketch an acceleration-time graph for the motion of the ball. (No values required). (2)

4. Ball A is projected vertically upwards at a velocity of 16 $m{\cdot}s^{-1}$ from the ground.

Ignore the effects of air resistance. Use the ground as zero reference.

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

4.2 Sketch a velocity-time graph for ball A.

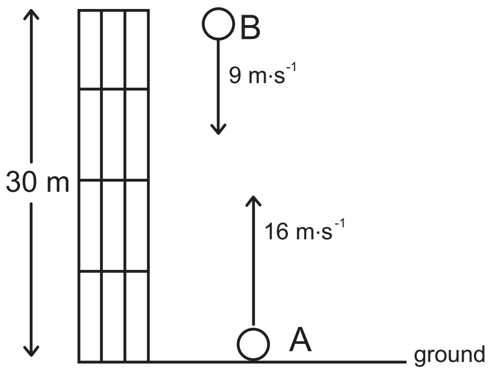
Show the following on the graph:

(a) initial velocity of ball A

(b) time taken to reach the highest point of the motion

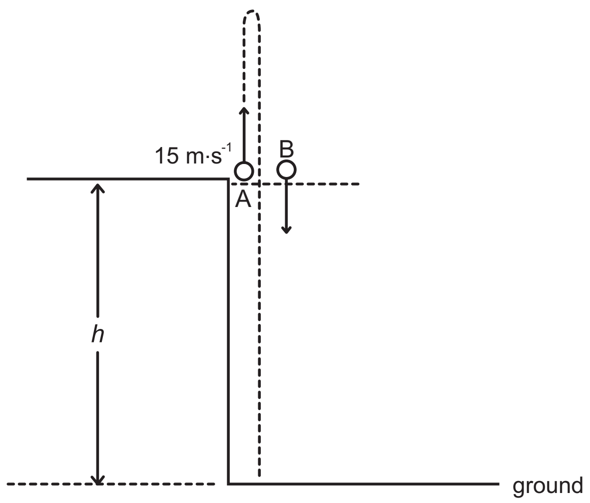
(c) time taken to return to the ground (3)

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



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

5. 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.



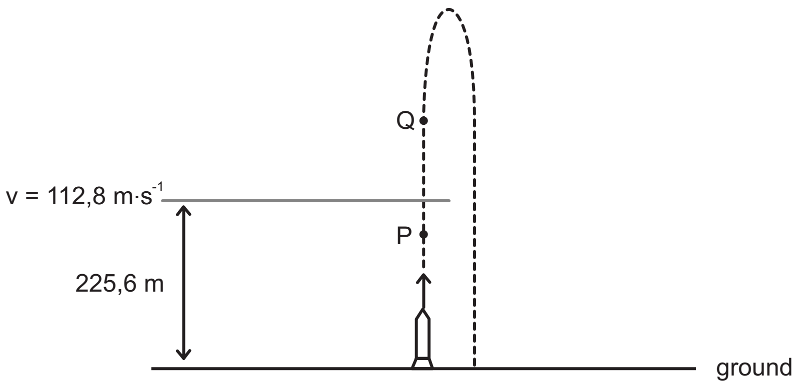
5.1 Explain the term *free fall*. (2)

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

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

5.4 Sketch a velocity-time graph for the motion of ball A from the time it is projected until it hits the ground.
Clearly show the following on your graph:
- the initial velocity
- the time it takes to reach its maximum height
- the time it takes to return to its starting point (4)

6. 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 m·s^{-1}. The diagram below shows the path followed by the rocket. Ignore the effects of air friction. Assume that *g* does not change during the entire motion of the rocket.



6.1 Write down the direction of the acceleration of the rocket at point:
- 6.1.1 P (1)
- 6.1.2 Q (1)

6.2 At which point (P or Q) is the rocket in free fall? Justify your answer. (2)

6.3 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. (6)

6.4 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 (5)

MARKING GUIDELINES

MULTIPLE CHOICE

1. A✓ ✓ No kinetic energy is lost during the collision with the ground. [CL2] (2)
2. C✓ ✓ Velocities are positive and increasing on the way down. Then it bounces and velocities become negative and are decreasing to zero. [CL2] (2)
3. C✓ ✓ The direction of the acceleration due to gravity is always downwards. [CL2] (2)
4. D✓ ✓ The velocity at the highest point is zero. The acceleration due to gravity is always downwards throughout the motion of the object. [CL2] (2)
5. A✓ ✓ The only force acting on the object is the gravitational force. The gravitational force is a conservative force. [CL2] (2)
6. A✓ ✓ Velocity is decreasing. The gradient (which represents acceleration) is constant and negative. [CL2] (2)
7. A✓ ✓ The initial and final positions are the same, therefore displacements are equal. [CL2] (2)
8. A✓ ✓ Both balls experience the same gravitational acceleration during free-fall at any point on their motion. X will return to its point of release travelling downwards with speed *u*. This is the same as Y. They both accelerate downwards with the same initial velocity and for the same displacement. They will have the same final velocities just before hitting the ground. [CL2] (2)

LONG QUESTIONS

1.1 Falling freely✓ with a downward gravitational acceleration of 9,8 m·s^{-1}.✓ [CL1] (2)
1.2 No.✓ It is moving at constant velocity✓ (zero acceleration) [CL2] (2)
1.3 Choose down as positive:

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

$v_f^2 = (+1,2✓)^2 + 2(+9,8)(+22)$ ✓

$v_f = +20,8 \text{ m·s}^{-1}$ ✓

$v_f = v_i + a\Delta t$

$+20,8 = +1,2 + (+9,8)\Delta t$

$\Delta t = 2 \text{ s}$ ✓ [CL3] (4)

1.4 Time to reach maximum height:

$v_f = v_i + a\Delta t$

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

$15 = 9{,}8\Delta t$

$\Delta t = 1{,}53 \text{ s}\checkmark$

Total time taken to reach maximum height:

$\Delta t = 2 + 0{,}3 + 1{,}53 = 3{,}83 \text{ s}\checkmark$

Downward distance moved by balloon in 3,83 s:

$\Delta y = v.\Delta t = (1{,}2).(3{,}83) = 4{,}60 \text{ m}\checkmark$

Height above ground:

$\text{Height} = 22 - 4{,}60 = 17{,}4 \text{ m}$ above the ground ✓ [CL3] (6)

2.1 Its initial velocity is 110 $m{\cdot}s^{-1}$ UPWARDS ✓ [CL1] (1)

2.2.1 Upwards ✓ (The rocket is accelerating upwards) [CL2] (1)

2.2.2 Downwards ✓ (The object is in free-fall) [CL2] (1)

2.3.1 Choose up as positive:

$v_f = v_i + a\Delta t$

$0\checkmark = (+110\checkmark) + (-9{,}8\checkmark)\Delta t$

$-110 = -9{,}8\Delta t$

$\Delta t = 11{,}22 \text{ s}\checkmark$ [CL2] (4)

2.3.2 If Q is the reference point:

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

$v_f^2 = (+110)^2\checkmark + 2(-9{,}8)(-550)\checkmark$

$v_f^2 = 22\,880$

$v_f = -151{,}26 \text{ m}{\cdot}\text{s}^{-1}\checkmark$

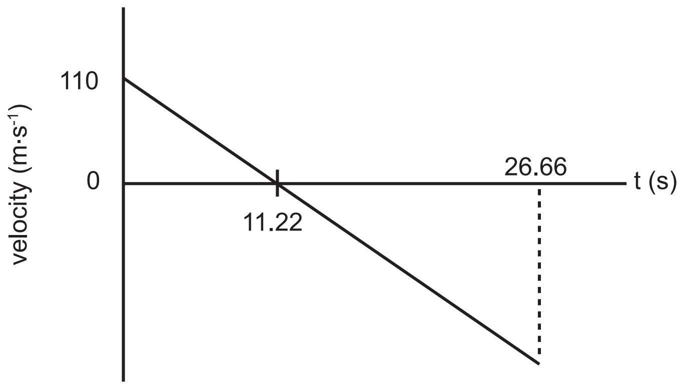
$v_f = v_i + a\Delta t$

$-151{,}26 = (+110\checkmark) + (-9{,}8)\Delta t$

$-261{,}26 = -9{,}8\Delta t$

$\Delta t = 26{,}66 \text{ s}\checkmark$ [CL3] (5)

2.4 [CL3] (4)



3.1 Moving under the sole influence of the Earth's gravitational force ✓ ✓ [CL1] (2)

3.2.1 Choose down as positive:

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

$v_f^2 = 0✓ + 2(+9,8✓)(+20)$ ✓

$v_f^2 = 392$

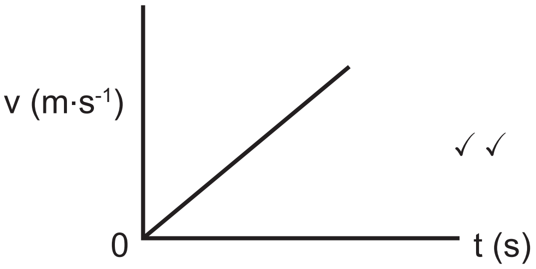
$v_f = 19,80\ m{\cdot}s^{-1}$ ✓ [CL3] (4)

3.2.2 $v_f = v_i + a\Delta t$

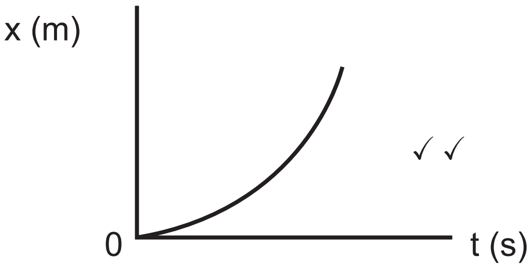
$+19,80✓ = 0✓ + (+9,8)\Delta t$

$\Delta t = 2,02\ s$ ✓ [CL2] (3)

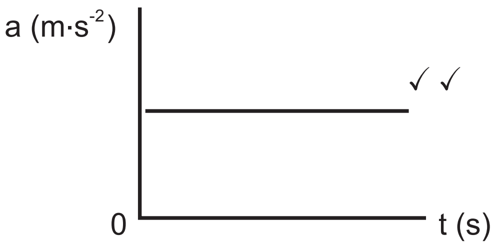
3.3 [CL2] (2)



3.4 [CL2] (2)



3.5 [CL3] (2)



[CL2] (2)

4.1 Choose upwards as positive:

$v_f = v_i + a\Delta t$

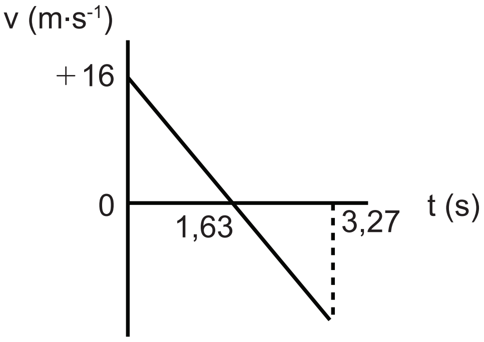
$-16✓ = (+16✓) + (-9,8✓)\Delta t$

$-32 = -9,8\Delta t$

$\Delta t = 3,27\ s$ ✓ [CL3] (4)

ASSESSMENTS

4.2 [CL3] (3)



4.3 $\Delta y_A = v_i \Delta t + \frac{1}{2} a \Delta t^2$

$\Delta y_A = 16t + \frac{1}{2}(-9,8)\,t^2$

$\Delta y_A = 16t - 4,9t^2$ ✓

$\Delta y_B = 9(t-1) + \frac{1}{2}(+9,8)(t-1)^2$ ✓

$\Delta y_B = 9t - 9 + 4,9(t^2 - 2t + 1)$

$\Delta y_B = 9t - 9 + 4,9t^2 - 9,8t + 4,9$

$\Delta y_B = 4,9t^2 - 0,8t - 4,1$ ✓

$\Delta y_A + \Delta y_B = 30$ ✓

$16t - 4,9t^2 + 4,9t^2 - 0,8t - 4,1 = 30$

$15,2t = 34,1$

$\Delta t = 2,243\text{ s}$

$\Delta y_A = 16(2,243) - 4,9$✓$(2,243)^2 = 11,24\text{ m}$ ✓ above the ground [CL4] (6)

5.1 Moving under the sole influence of the Earth's gravitational force ✓ ✓ [CL1] (2)

5.2 Choose up as positive:

$v_f = v_i + a\Delta t$

15✓$= (+15$✓$) + (-9,8)\Delta t$

$30 = 9,8\Delta t$ ✓

$\Delta t = 3,06\text{ s}$ ✓ [CL3] (4)

5.3 $\Delta y_A = v_i \Delta t + \frac{1}{2} a \Delta t^2$

$\Delta y_A = (+15$✓$)(1,53$✓$) + \frac{1}{2}(-9,8$✓$)(1,53)^2$

$\Delta y_A = 11,48\text{ m}$ up ✓

Choose down as positive:

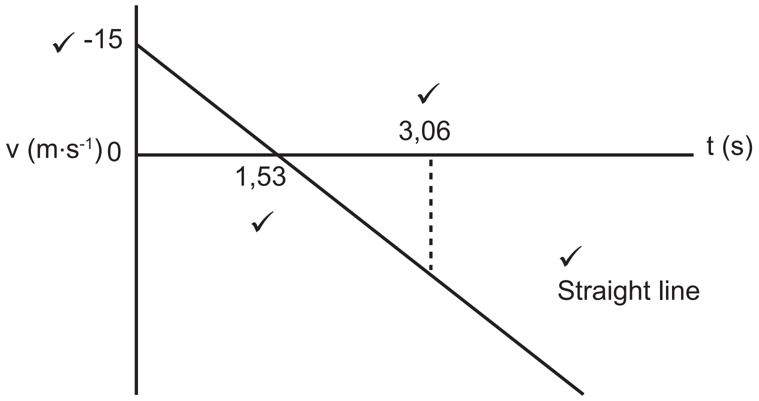
$\Delta y_B = v_i \Delta t + \frac{1}{2} a \Delta t^2$

$\Delta y_B = 0 + \frac{1}{2}(+9,8$✓$)(1,53)^2$

$\Delta y_B = 11,47\text{ m}$ down ✓

Distance between balls $= 11,48 + 11,47 = 22,95\text{ m}$ ✓ [CL3] (7)

5.4 [CL3] (4)



6.1.1 Upwards ✓ (Rocket is accelerating upwards) [CL2] (1)

6.1.2 Downwards ✓ (Acceleration due to gravity is down) [CL2] (1)

6.2 Q ✓

The only force acting on the rocket is its weight ✓ [CL2] (2)

6.3 Upward acceleration:

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

$+225,6 = (\frac{112,8 + 0}{2} ✓)\Delta t$

$\Delta t = 4 \text{ s}$ ✓

Free-fall:

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

$v_f^2 = (+112,8✓)^2 + 2(-9,8)(-225,6✓)$

$v_f = -130,94 \text{ m·s}^{-1}$

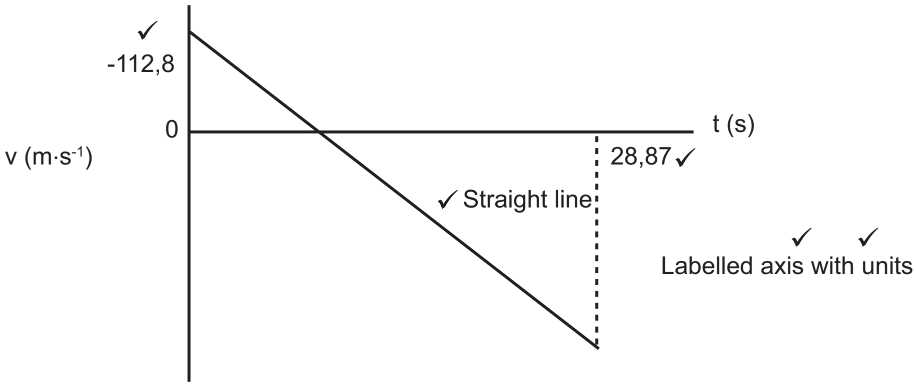
$v_f = v_i + a\Delta t$

$-130,94 = (+112,8) + (-9,8)\Delta t$

$\Delta t = 24,87 \text{ s}$ ✓

Total time $= 4 + 24,87 = 28,87 \text{ s}$ ✓ [CL3] (6)

6.4



[CL3] (5)

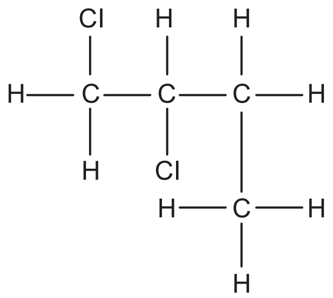
ASSESSMENTS

Topic 4: Organic Chemistry

QUESTIONS

MULTIPLE CHOICE

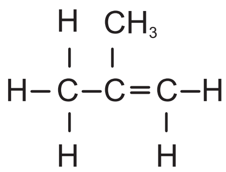
1. What is the IUPAC name for the compound represented by the following structure?



   A 1,2-dichloro-3-methylpropane
   B 3,4-dichlorobutane
   C 1,1-dichloro-3-methylpropane
   D 1,2-dichlorobutane (2)

2. Which one of the following is the general formula for alkenes?
   A C_nH_{2n+2}
   B C_nH_{2n-2}
   C C_nH_{2n}
   D C_nH_{2n-1} (2)

3. What is the correct IUPAC name for this compound?



   A but-1-ene
   B but-2-ene
   C methylpropane
   D methylpropene (2)

4. The functional isomer of butylmethanoate has the following condensed structural formula
   A $CH_3CH_2OOCCH_2CH_3$
   B $CH_3CH_2CH_2COOH$
   C $CH_3(CH_2)_3COOH$
   D $CH_3CH(CH_3)CH_2CH_2OH$ (2)

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

$$C_{16}H_{34} \longrightarrow C_8H_{18} + C_5H_{10} + C_3H_6$$

   This reaction is an example of:
   A addition
   B substitution
   C cracking
   D esterification (2)

6. Which one of the following could be the molecular formula of BOTH a carboxylic acid AND an ester?
   A CH_2O_2
   B $C_3H_4O_2$
   C $C_2H_4O_2$
   D C_3H_6O (2)

LONG QUESTIONS

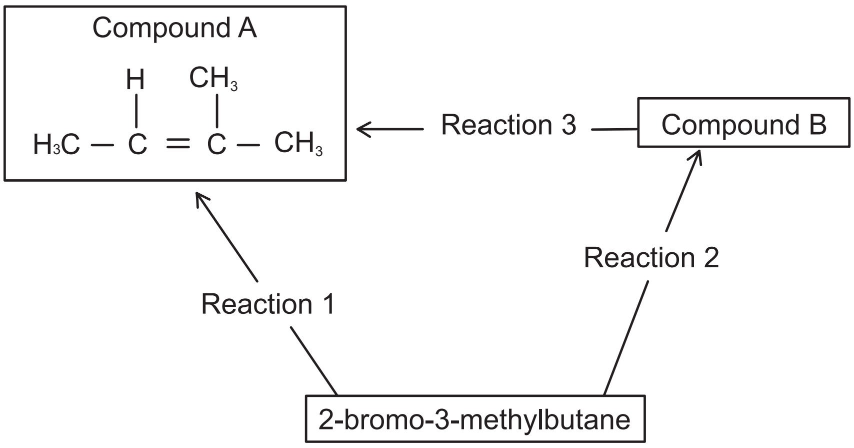
1. Consider the information given in the table below before answering the questions that follow.

Compound	Name	Molecular formula	Molar mass ($g{\cdot}mol^{-1}$)	Boiling point (°C)
X	2,2-dimethylpropane	C_5H_{12}	72	9,5
Y	Methylethanoate	$C_3H_6O_2$	74	57,1
Z	butan-1-ol	$C_4H_{10}O$	74	117,7

1.1 Define homologous series. (3)
1.2 Name the homologous series to which compound **X** belongs. (1)
1.3 Draw the structural formula of compound **Y.** (2)
1.4 Give the IUPAC name of the organic reactants needed to make compound **Y**. (2)
1.5 Identify the functional group of compound **Z**. (1)
1.6 Which one of compounds **X**, **Y** or **Z** can be classified as a saturated hydrocarbon? (1)
1.7 Compound **Z** is dehydrated using heat and an acid catalyst.
   1.7.1 Use condensed structural formulae to write a balanced chemical equation for the dehydration of compound **Z**. It is not necessary to show heat and the acid catalyst in your equation. (3)
   1.7.2 Give the IUPAC name of the organic product formed in Question 1.7. (1)
   1.7.3 State what type of reaction the dehydration of butan-1-ol is. (1)
1.8 Write a balanced equation, using molecular formulae, for the complete combustion of compound X. (4)
1.9 Structural isomers of organic compounds can exist as chain isomers, functional isomers and positional isomers.
   1.9.1 Define the term *isomers*. (2)
   1.9.2 Give the IUPAC name of a straight **chain** isomer of compound **X**. (2)
   1.9.3 Give the IUPAC name of a **functional** isomer of compound **Y**. (2)
   1.9.4 Draw the structural formula of a **positional** isomer of compound **Z**. (2)
1.10 Although compounds **X**, **Y** and **Z** have similar molar masses, they have significantly different boiling points. With reference to the relevant intermolecular forces, explain this difference in boiling points. (6)

ASSESSMENTS

2. The flow diagram below shows how two organic compounds, A and B, can be made from 2-bromo-3-methylbutane.



2.1 Name the homologous series to which 2-bromo-3-methylbutane belongs. (1)

2.2 Draw the structural formula of 2-bromo-3-methylbutane. (3)

2.3 Reaction 1 takes place in a concentrated solution of NaOH in an ethanol solvent to form compound A.

2.3.1 Name the type of reaction which takes place. (1)

2.3.2 State the other reaction condition required for this reaction. (1)

2.3.3 Give the IUPAC name of compound A. (2)

2.4 Reaction 2 takes place in a warm aqueous dilute alkali solution.

2.4.1 Name the type of reaction which takes place. (1)

2.4.2 Give the condensed structural formula of compound B. (3)

2.5 Using molecular formulae, write a balanced equation for the combustion of compound A in excess oxygen. (3)

3. But-1-ene, an **UNSATURATED** hydrocarbon, and compound **X**, a **SATURATED** hydrocarbon, react with chlorine, as represented by the incomplete equations below:

REACTION I: but-1-ene + $Cl_2 \longrightarrow$

REACTION II: **X** + $Cl_2 \longrightarrow$ 2-chloropropane + **Y**

3.1 Explain what is meant by the term “unsaturated”. (2)

3.2 Identify the **type** of reaction that occurs in:

3.2.1 Reaction I (1)

3.2.2 Reaction II (1)

3.3 Write down the structural formula of the product formed in Reaction I. (2)

3.4 What reaction condition is necessary for Reaction II to take place? (1)

3.5 Write down the IUPAC name of reactant X. (1)

3.6 Write down the name or formula of product Y. (1)

4. Ethanol, also commonly called ethyl alcohol, drinking alcohol, or simply alcohol, is the principal type of alcohol found in alcoholic beverages. It is produced by the fermentation of sugars by yeasts. Ethanol (CH_3CH_2OH) is used as a starting material in the production of ethane. This conversion is carried out in two steps. The **incomplete** chemical equations below show the steps in the conversion process:

<u>Step 1:</u> $CH_3CH_2OH_{(aq)} \longrightarrow$ <u>COMPOUND X</u> + H_2O

<u>Step 2:</u> <u>COMPOUND X</u> + <u>COMPOUND Y</u> $\longrightarrow$ ethane

4.1 Write down COMPOUND X's structural formula. (2)

4.2. Identify the catalyst used in step 1. (1)

4.3 Identify the <u>type and name</u> of the reaction occurring in step 2. (2)

4.4 Identify <u>COMPOUND Y</u>, and write down it's molecular formula. (1)

4.5 Ethanol is used as a reactant in the production of ethyl butanoate. In the laboratory a water bath is used as a safety precaution in the production of ethyl butanoate.

4.5.1 Use structural formulae to write the chemical equation showing the production of ethyl butanoate. Include all reactants, catalyst/s and products in the chemical equation. (5)

4.5.2 What property of ethanol necessitates the use of a water bath in the production of ethyl butanoate? (1)

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

A	$CH_3CHCHCH_3$	B	$CH_3CH_2CH_2CH_2CH_3$
C	CH_3CH_2F	D	$CH_3CH(CH_3)CH_2CH_3$
E	$CH_3CH_2-O-\overset{\overset{\large O}{\|\|}}{C}-CH_2CH_3$	F	$CH_3CH_2CH_2CH_2OH$

5.1 Write down the letter(s) that represent(s) each of the following:
(A compound may be used more than once)

5.1.1 an unsaturated compound. (1)

5.1.2 two compounds which are **chain** isomers of one another. (1)

5.1.3 a compound containing a carbonyl group. (1)

5.1.4 a haloalkane. (1)

5.2 Give the IUPAC name of compound D. (2)

5.3 Compound A is prepared in the laboratory by heating of an alcohol with excess H_3PO_4.

5.3.1 How can one quickly establish whether compound A has indeed been formed? (3)

5.3.2 Write down the IUPAC name of the alcohol needed to prepare compound A. (2)

5.3.3 Write down the name of the other product formed in the reaction in 5.3.2. (1)

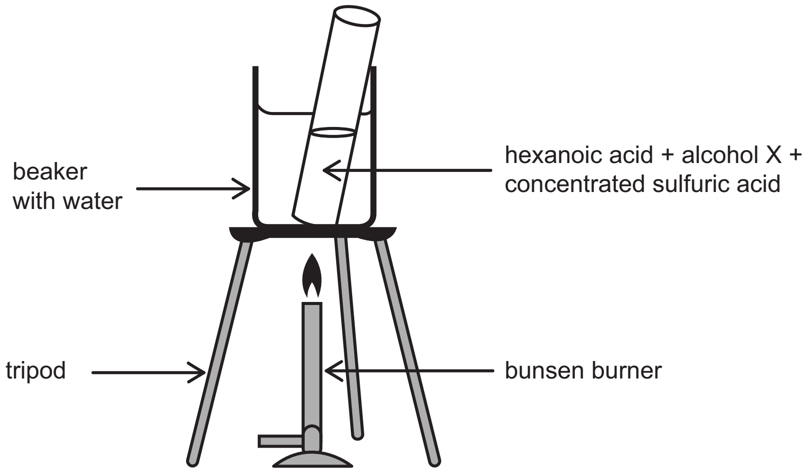
5.3.4 Name the type of chemical reaction which has taken place in 5.3.2. (1)

5.3.5 If compound A undergoes a combustion reaction what would the products be? (2)

ASSESSMENTS

5.4 The molar mass of compounds D and F are very similar. The boiling point of compound D is 28 °C yet compound F has a boiling point of 117 °C. With reference to the relevant intermolecular forces, explain why their boiling points are so different. (4)

6. Hexanoic acid is responsible for the unique odour associated with goats. When hexanoic acid reacts with alcohol **X**, ethyl hexanoate, which is used commercially as a fruit flavour, is formed.



Learners set up the apparatus shown above to prepare ethyl hexanoate in a laboratory.

6.1 Give the definition for *homologous series*. (3)

6.2 Write down the IUPAC name of alcohol **X**. (2)

6.3 What is the purpose of placing the test-tube of reactants in a beaker of water? (2)

6.4 Use **structural formulae** to write down a balanced chemical equation for the preparation of ethyl hexanoate. (5)

6.5 Write down the IUPAC name of a **functional** isomer of ethyl hexanoate. (2)

MARKING GUIDELINES

MULTIPLE CHOICE

1. D✓ ✓ Here we have a halo-alkane with longest chain being 4 carbons. There are two chloro groups and the lowest substituted position is on carbon 1 and 3, thus this is a dichloro compound. Hence the option D. [CL2] (2)

2. C✓ ✓ This is straight learning work and it is important that learners know the general formula of the three hydrocarbon homologous series. Alkenes are C_nH_{2n} thus C is the correct answer. [CL1] (2)

3. D✓ ✓ This is an alkene with the double bond on carbon 1. There is a methyl group attached to carbon 2, but due to the fact that the side branch cannot be at any other position, the carbon number to which it is attached need not be given, hence the option is D. [CL2] (2)

4. C✓ ✓ Butyl methanoate is an ester and the functional isomer of an ester is a carboxylic acid. The option that shows the –COOH group of a carboxylic acid is C. [CL3] (2)

5. C✓ ✓ In this reaction, a long chained hydrocarbon is broken down into smaller fragments. This is done through a process known as "cracking" hence the option C is the correct answer [CL2] (2)

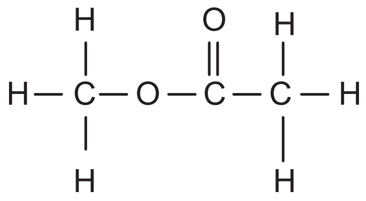
6. C✓ ✓ Carboxylic acids and esters are functional isomers of each other, thus will share the same general formula. This formula is $C_nH_{2n}O_2$. This the combination which fits this formula hence the correct option is C. [CL2] (2)

LONG QUESTIONS

1.1 A series of similar compounds which have the same functional✓ group and have the same general ✓ formula, in which each member differs from the previous one by a single CH_2 ✓ unit. [CL1] (3)

1.2 Alkanes ✓ [CL2] (1)

1.3



✓ ✓ [CL2] (2)

1.4 Methanol ✓ and ethanoic ✓ acid [CL2] (2)

1.5 OH^- / hydroxyl group ✓ [CL2] (1)

1.6 X ✓ [CL2] (1)

1.7.1 $CH_3CH_2CH_2CH_2OH \longrightarrow CH_3CH_2CHCH_2 + H_2O$

✓ ✓ ✓ [CL2] (3)

1.7.2 but-1-ene✓ [CL2] (1)

1.7.3 Elimination ✓ [CL2] (1)

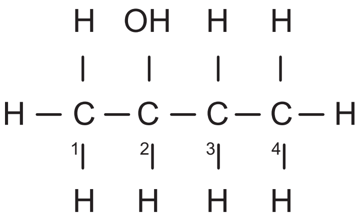
1.8 $C_5H_{12} + 8O_2$✓ $\longrightarrow$ $5CO_2$✓ $+ 6H_2O$✓ ✓balancing [CL2] (4)

1.9.1 Compounds having the same molecular formula ✓ but different ✓ structural formulae. [CL2] (2)

1.9.2 Pentane ✓ ✓ [CL2] (2)

1.9.3 Propanoic acid ✓ ✓ [CL2] (2)

1.9.4 (butan-2-oI)

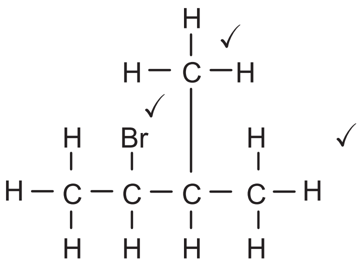

✓ ✓

[CL3] (2)

1.10 X has a low boiling point due to weak ✓ London ✓ forces between the molecules Y has a higher boiling point than X as esters have dipole –dipole ✓ van der Waals forces which are stronger than ✓ London forces ✓ more energy required to overcome them. Z has the highest boiling point as it has strong ✓ hydrogen bonds ✓ between molecules which require the most energy in order to overcome. [CL3] (6)

2.1 Haloalkanes ✓ (alkyl halides) [CL2] (1)

2.2



[CL3] (3)

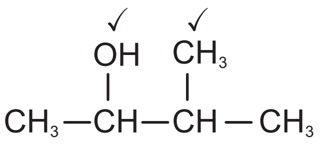
2.3.1 Elimination ✓ (dehydrohalogenation) [CL3] (1)

2.3.2 Heat ✓ [CL2] (1)

2.3.3 methyl ✓ but-2-ene ✓ (2-methyl but-2-ene) [CL3] (2)

2.4.1 Substitution ✓ [CL3] (1)

2.4.2

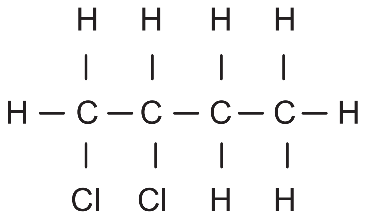

✓ **for chain** [CL3] (3)

2.5 $2C_5H_{10} + 15O_2 \longrightarrow 10CO_2$✓ $+ 10H_2O$✓ ✓balanced [CL3] (3)

3.1 An unsaturated compound is a compound *in which there is at least one double and/or triple bond between carbon atoms* ✓ [CL1] (2)

3.2.1 addition ✓ [CL2] (1)

3.2.2 substitution ✓ [CL2] (1)

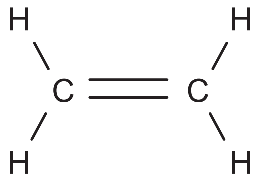
3.3 

chlorine position ✓
carbons and hydrogen atoms ✓ [CL2] (2)

3.4 UV light / sunlight/heat ✓ [CL2] (1)

3.5 propane ✓ [CL3] (1)

3.6 hydrogen chloride, HCl ✓ [CL3] (1)

4.1 

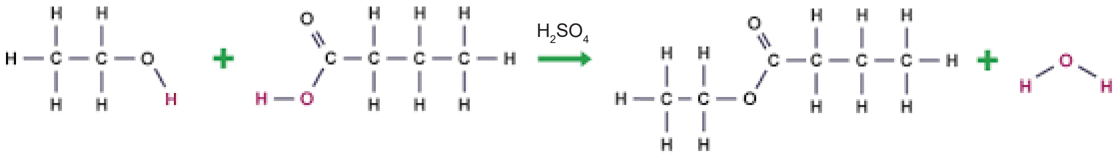
Double bond functional group ✓
2 carbon skeleton ✓ [CL2] (2)

4.2 concentrated H_2SO_4 or H_3PO_4 ✓ [CL2] (1)

4.3 addition reaction ✓ and hydrogenation ✓ [CL2] (2)

4.4 H_2 ✓ [CL1] (1)

4.5.1



[CL3] (5)

4.5.2 flammability (volatility) ✓ [CL2] (1)

5.1.1 A ✓ [CL2] (1)

5.1.2 B and D ✓ [CL2] (1)

5.1.3 E ✓ [CL2] (1)

5.1.4 C ✓ [CL2] (1)

5.2 2–methylbutane ✓ ✓ or just methylbutane [CL2] (2)

5.3.1 Test with Br_2 water. ✓ If it loses its colour ✓ rapidly ✓ it is an unsaturated compound. [CL3] (3)

5.3.2 butan–2–ol ✓ ✓ (butanol ✓) [CL2] (2)

5.3.3 Water ✓ [CL2] (1)

5.3.4 Elimination/Dehydration ✓ ✓ [CL2] (1)

5.3.5 Water ✓ & CO_2 ✓ [CL2] (2)

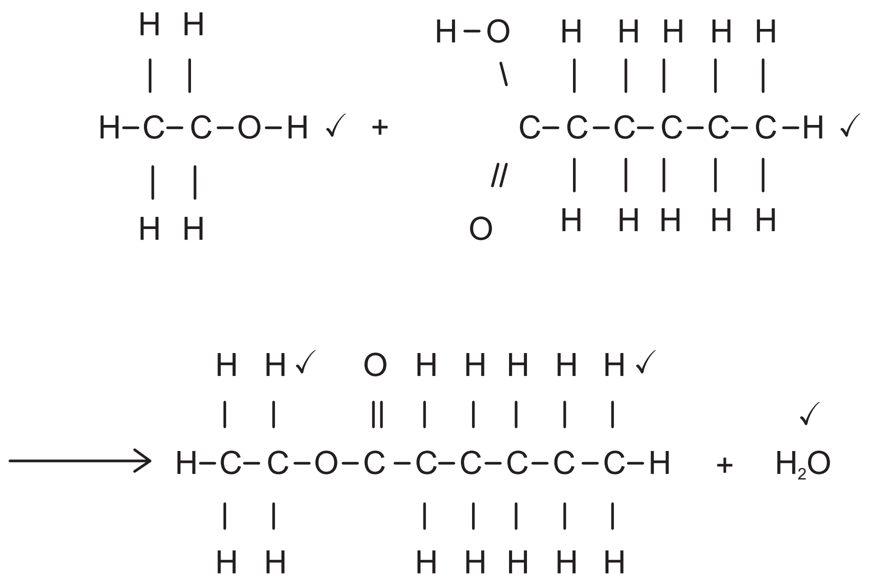
5.4 D, an alkane, (non-polar molecule) has London forces between its molecules ✓ F, an alcohol, (polar OH group) has hydrogen bonds between its molecules. ✓ Hydrogen bonds are stronger than London forces. ✓ More energy needed to break stronger INTERMOLECULAR FORCES. ✓ [CL3] (4)

6.1 Homologous series is a series of similar compounds which have the same functional group ✓ and have the same general formula, ✓ in which each member differs from the previous one by a single CH_2 unit. ✓ [CL1] (3)

6.2 Ethanol. ✓ ✓ [CL2] (2)

6.3 Organic compounds are flammable ✓ Don't heat with direct (naked) flame. ✓ [CL3] (2)

6.4



[CL3] (5)

6.5 Octanoic Acid
Oct ✓ anoic acid ✓ [CL3] (2)