

# PHYSICAL SCIENCES

**GRADE 12**

2024

# LAST PUSH

**TEACHER AND LEARNER  
CONTENT MANUAL**



# PHYSICAL SCIENCES

## PAPER 1

### # 45 PLUS.

We expect learners to be able to get at **least 45 in each paper**. These 45 marks are obtainable from the following topics AND multiple-choice questions.

#### ASSUMPTIONS:

There **may** be at least one definition per topic.

**Formulae and substitutions:** assume a learner chooses at least 1 correct formula and makes a substitution.

TOPICS	MIN MARK
<b>1 Newton's laws</b>	<b>7</b>
<b>Definitions</b> <ol style="list-style-type: none"> <li>normal force <math>N</math></li> <li>frictional force, <math>f</math>, / <i>static frictional force, <math>f_s</math>, kinetic frictional force, <math>f_k</math></i></li> <li>Inertia</li> <li>Newton's Laws 1, 2, 3</li> <li>Newton's Law of Universal Gravitational Law</li> <li>Weight</li> </ol>	<b>2</b>
<b>Free body diagram and force body diagram</b>	<b>4</b>
<b>Formulae and substitutions</b>	<b>1</b>
<b>2 Projectile motion</b>	<b>5</b>
<b>Definitions</b> <ol style="list-style-type: none"> <li>Free fall</li> <li>Projectile</li> </ol>	<b>2</b>
<b>Formulae and substitution</b>	<b>1</b>
<b>Graphs</b> <ol style="list-style-type: none"> <li><math>v/t</math> or <math>x/t</math> or <math>a/t</math></li> <li>Correct <math>x</math> and <math>y</math> axis with labels and units</li> </ol>	<b>2</b>
<b>3 Momentum and impulse</b>	<b>3</b>
<b>Definitions</b> <ol style="list-style-type: none"> <li>Momentum</li> <li>Newton 2 in terms in momentum</li> <li>Impulse</li> <li>Conservation of momentum</li> <li>Isolated / closed system</li> <li>Elastic and inelastic collisions</li> </ol>	<b>2</b>

<b>Formulae and substitutions</b>	<b>1</b>
<b>4 Work, Energy, Power</b>	<b>7</b>
<b>Definitions</b> <ol style="list-style-type: none"> <li>1. Conservation of mechanical energy</li> <li>2. Isolated system</li> <li>3. Work energy theorem</li> <li>4. Conservative and non-conservative forces</li> <li>5. Power</li> </ol>	<b>2</b>
<b>Free body diagram</b>	<b>4</b>
<b>Formulae and substitutions</b>	<b>1</b>
<b>5 Doppler effect</b>	<b>7</b>
<b>Definitions</b> <ol style="list-style-type: none"> <li>1. Doppler effect</li> </ol>	<b>2</b>
<b>Formulae and substitutions</b>	<b>1</b>
<b>Application</b> <ol style="list-style-type: none"> <li>1. Doppler flow meter</li> <li>2. Sonar/ Radar</li> </ol>	<b>2</b>
Red shift / blue shift	<b>2</b>
<b>6 Electrostatics (Coulombs Law &amp; Electric fields)</b>	<b>11</b>
<b>Definition</b> <ol style="list-style-type: none"> <li>1. Coulombs Law</li> </ol>	<b>2</b>
Free body diagram	<b>3</b>
<b>Formulae and substitutions</b>	<b>1</b>
<b>6Definition</b> <ol style="list-style-type: none"> <li>1. Electric field at a point</li> </ol>	<b>2</b>
Pattern around the charges (repelling and attracting charges) direction of field lines	<b>2</b>
<b>Formulae and substitutions</b>	<b>1</b>
<b>7 Circuits</b>	<b>4</b>
<b>Definitions</b> <ol style="list-style-type: none"> <li>1. Ohm's Law</li> <li>2. Internal resistance</li> <li>3. Emf</li> <li>4. Potential difference</li> <li>5. kilowatt hour (kWh)</li> </ol>	<b>2</b>
<b>Formulae and substitutions</b>	
<b>8 Electrodynamics (generators, motors)</b>	<b>6</b>
<b>Theory</b> <ol style="list-style-type: none"> <li>1. Energy conversions</li> <li>2. Labelling of components and functions</li> <li>3. Difference between AC and DC generator – features</li> <li>4. Examples of uses.</li> </ol>	<b>2</b>

<b>Alternating current</b>	
<b>Theory</b> 1. State the advantages of alternating current over direct current. 2. Graphs 3. rms	<b>2</b>
<b>Formulae and substitutions</b>	<b>1</b>
<b>9 Photoelectric effects</b>	<b>5</b>
<b>Definitions</b> 1. The photoelectric effect 2. Threshold frequency, $f_0$ 3. Work function, $W_0$	<b>2</b>
<b>Formulae and substitutions</b>	<b>1</b>
<b>Spectra</b> Explain the difference between <i>atomic absorption spectra</i> and <i>atomic emission spectra</i> .	<b>2</b>
<b>TOTAL</b>	<b>±55</b>

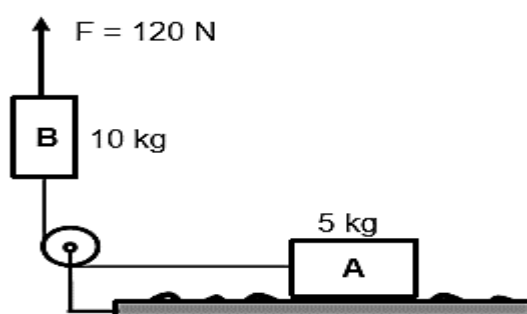
<b>Skill (may not be included in this paper)</b> 1. Formulate an Investigative question. 2. Formulate a hypothesis. 3. Independent / dependent / control variable. Fair test	<b>2</b>
<b>Graphs (may not be included in this paper)</b> 1. Labelling axes 2. Plotting points 3. Reading values from graph 4. Gradient	<b>2</b>



# 1 Newton's laws

## QUESTION 1

- 1.1 A block A of mass 5 kg, at rest on a rough horizontal table, is connected to another block B of mass 10 kg by means of a light inextensible string which passes over a light frictionless pulley. A force of 120 N is applied vertically upwards on block B as shown in the diagram below.



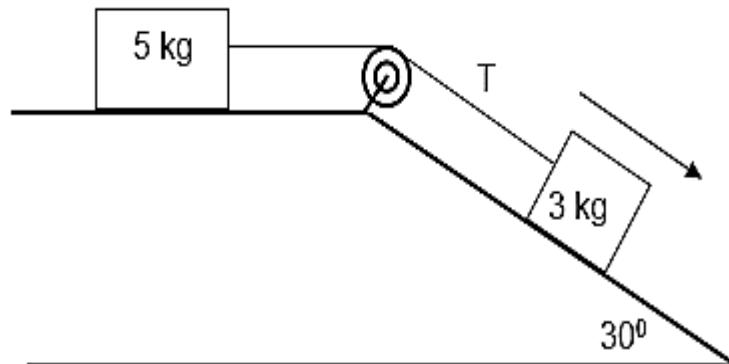
The coefficient of kinetic friction between the surface and block A is 0,3. Ignore the effects of air friction.

- 1.1.1 State Newton's Second Law in words. (2)
- 1.1.2 Draw a labelled free-body diagram of ALL forces acting on block B. (3)
- Calculate the magnitude of the:
- 1.1.3 Friction force acting on block A (3)
- 1.1.4 Tension force acting on block B (6)
- 1.2 A man on the surface of planet Y weighs HALF his weight compared to his weight on the surface of the Earth. The mass of planet Y is TWICE that of the Earth.
- 1.2.1 State Newton's Law of Universal Gravitation in words. (2)
- 1.2.2 Calculate the radius of planet Y in terms of the radius of the Earth. (4)

[20]

### QUESTION 2

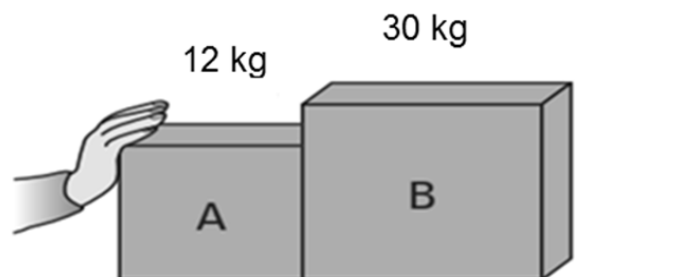
Two blocks of masses 5 kg and 3 kg respectively are connected by a light inextensible string that runs over a light frictionless pulley as shown in the diagram below. The 5 kg block experience a frictional force of 8 N and the coefficient of kinetic friction between the 3 kg block and the surface of the inclined plane is 0,15.



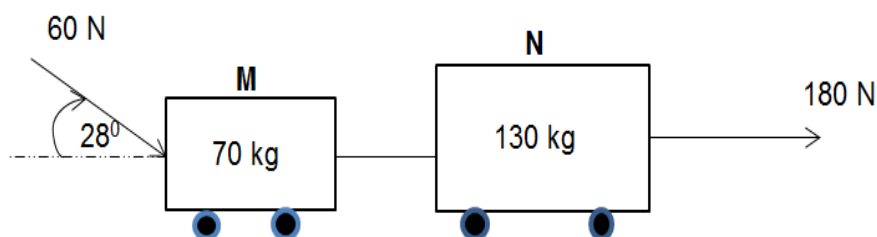
- 2.1 Define the term *frictional force*. (2)
  - 2.2 Draw a labelled free-body diagram to indicate all the forces acting on the 3 kg block. (3)
  - 2.3 Calculate the:
    - 2.3.1 Magnitude of the frictional force acting between the 3 kg block and the surface of the inclined plane (3)
    - 2.3.2 Magnitude of the tension **T** in the string (6)
- [14]**

### QUESTION 3

Crate **A** and crate **B**, of different masses, are placed next to each other on a horizontal rough surface. A hand pushing crate **A** causes both crates to accelerate at **2,3 m.s<sup>-2</sup>** to the right. Crate **B** experiences a frictional force of **25,3 N**



- 3.1 State Newton's *Third Law* of Motion in words. (3)
- 3.2 Calculate the force exerted by crate **B** on crate **A**. (6)
- 3.3 Two workers, Sipho and Mbali, are moving two trolleys, **M** and **N**, connected by a light inextensible string, as shown in the diagram below. Sipho pulls trolley **N** with a force of **180 N** to the east. Mbali pushes trolley **M** with a force of **60 N** at an angle of **28°** to the horizontal



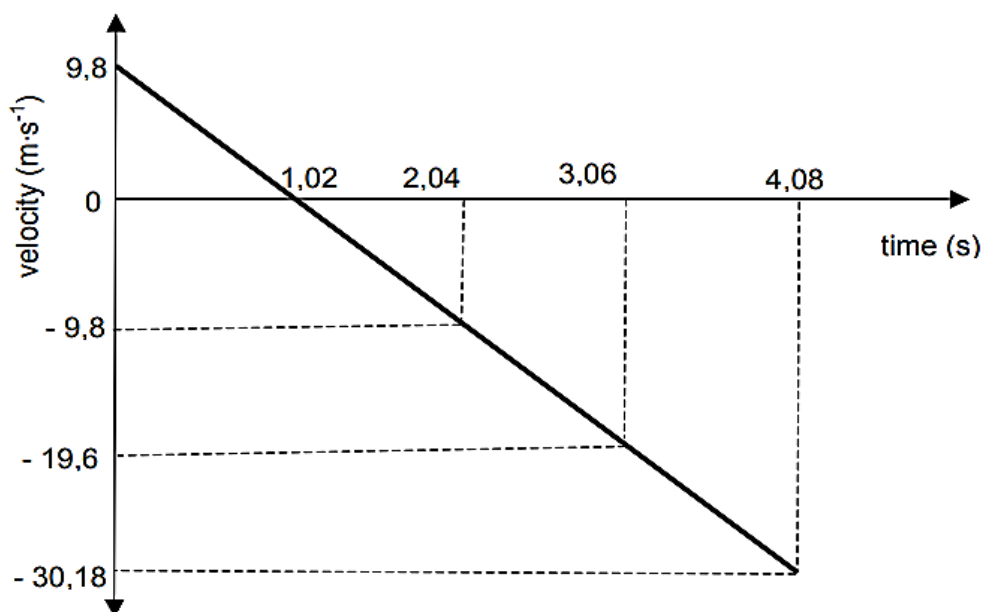
The frictional force experienced by trolley **M** is 6,4 N and that of trolley **N** is 8,58 N.

- 2.3.1 State Newton's Second Law of Motion in words. (2)
- 2.3.2 If the system accelerates at  $1,09 \text{ m.s}^{-2}$ , calculate the tension (**T**) in the String. (4)
- 2.4 If Sipho's pulling force is now applied at an angle of  $60^\circ$  with the horizontal, what will happen to the frictional force experienced by trolley **N**? Write only INCREASES, DECREASES or REMAINS THE SAME (1)
- 2.5 Explain your answer in QUESTION 4.4. (3)
- [19]**

## 2 Projectile motion

### QUESTION 1

A boy throws a ball vertically into the air from the top of a building. The ball strikes the ground after 4,08 s. The velocity-time graph below represents the entire motion of the ball. Ignore the effects of air friction.

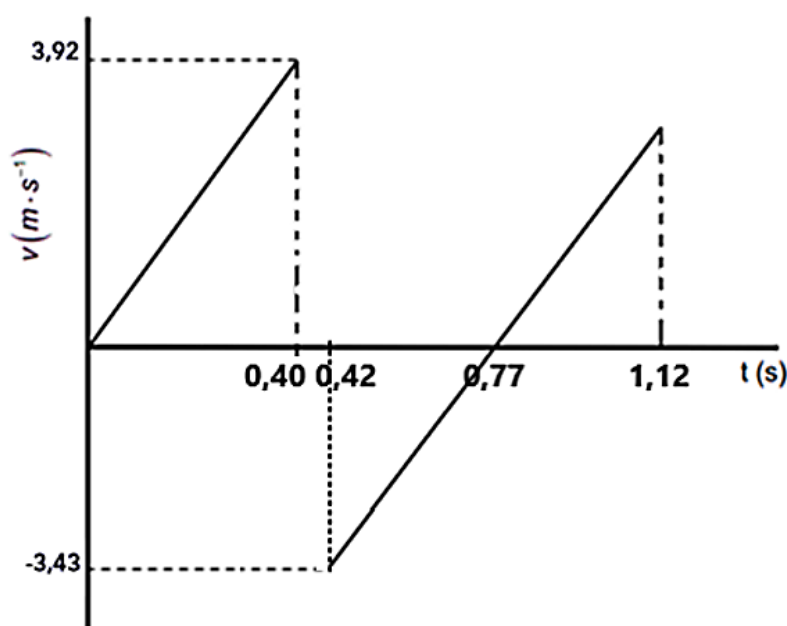


- 1.1 Explain what is meant by a projectile. (2)
- 1.2 What is the acceleration of the ball at time 1,02 s? (2)

- 1.3 Calculate the maximum height reached by the ball above the top of the building. (3)
- 1.4 Calculate the displacement of the ball. (4)
- 1.5 Sketch a position versus time graph for the entire motion of the ball. Take the **top of the building as point of reference**. Indicate the following on the graph:
- Initial position
  - Maximum height
  - Final position
  - Time (t) values
- (4)
- [12]**

## QUESTION 2

A 50 g ball is dropped from a certain height. The velocity-time graph below represents the motion of the ball as it bounces vertically on a concrete floor. The time of contact during the bounce is 0,02 s. Ignore all effects of air friction.



- 2.1 Define a projectile. (2)
- 2.2 Write down the magnitude of the velocity with which the ball leaves the ground after bouncing (1)
- 2.3 Draw a labelled free-body diagram showing all the forces acting on the ball at 0,77 s. (2)
- 2.4 Use the information given on the graph and calculate the:
- 2.4.1 Acceleration of the ball (3)
- 2.4.2 Height from which the ball was dropped (4)
- 2.5 On a set of axes, draw a position-time graph for the motion of the ball from 0 s to 1,12 s. Use the ground as zero reference. Indicate the height



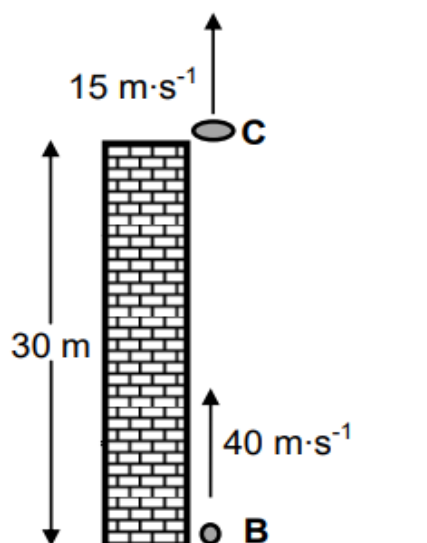
from which the ball was dropped and all the relevant times on the t-axis (4)  
on your graph.

[14]

#### QUESTION 4

A small disc, **C**, is thrown vertically upwards at a speed of  $15 \text{ m}\cdot\text{s}^{-1}$  from the edge of the roof of a building of height 30 m. AFTER 0,5 s, a small ball **B** is shot vertically upwards from the foot of the building at a speed of  $40 \text{ m}\cdot\text{s}^{-1}$  to hit disc **C**.

Ignore the effects of air resistance.



- 3.1 Explain the term projectile. (2)
- 3.2 Calculate the:
  - 3.2.1 Time taken by disc **C** to reach its maximum height (3)
  - 3.2.2 Maximum height above the ground reached by disc **C** (4)
- 3.3 Calculate the time from the moment that disc **C** was thrown upwards until the time ball **B** hits the disc. (6)
- 3.4 On the same set of axes, sketch graphs of velocity versus time for disk **C** and ball **B** from the moment that disc **C** was thrown upwards until ball **B** hits disc **C**.

Label the graph for ball **B** as B and the graph for disc **C** as C.

Clearly indicate the following on the graphs:

The initial velocities of ball **B** and disc **C**

The time at which ball **B** was shot upward

The time at which disc **C** reaches its maximum height

The time at which ball **B** hits disc **C**

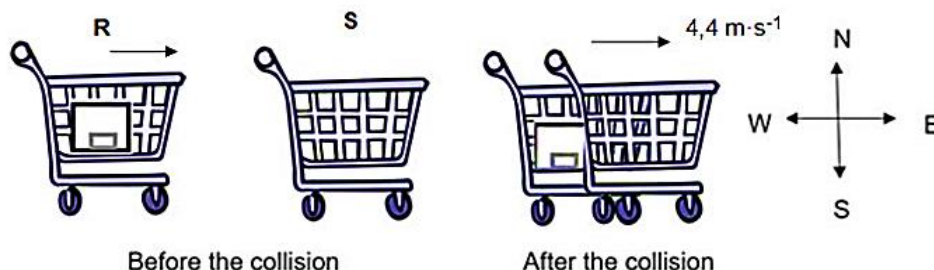
(5)

[20]

# 3 Momentum and impulse

## QUESTION 1

A trolley **R**, of mass 15 kg, travelling east collides with a stationary trolley **S** of mass 13,5 kg, and they stick together on impact. After the collision, they continue to move eastwards with a velocity of  $4,4 \text{ m} \cdot \text{s}^{-1}$ . Ignore the effects of friction.



- 1.1 State the principle of conservation of momentum in words. (2)
- 1.2 Calculate the speed of trolley **R** before collision. (3)

After the collision, the coupled trolleys enter a rough surface and come to rest in 3 s.

- 1.3 Calculate the magnitude of the frictional force that brought the trolleys to rest. (4)
- [9]

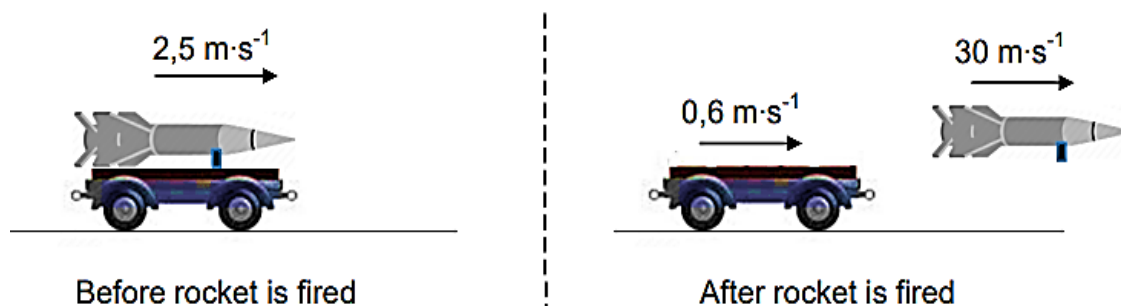
## QUESTION 2

- 2.1 What is meant by an isolated system in physics? (2)

During an experiment, a rocket of unknown mass is mounted on a toy cart of mass 20 kg. The cart- rocket combination moves at a constant speed of  $2,5 \text{ m} \cdot \text{s}^{-1}$  along a horizontal floor.

At a certain instant, the rocket is fired horizontally in the direction of motion at a speed of  $30 \text{ m} \cdot \text{s}^{-1}$ . As a result, the cart slows down to a speed of  $0,6 \text{ m} \cdot \text{s}^{-1}$ , as shown in the diagram below.

Ignore frictional effects.



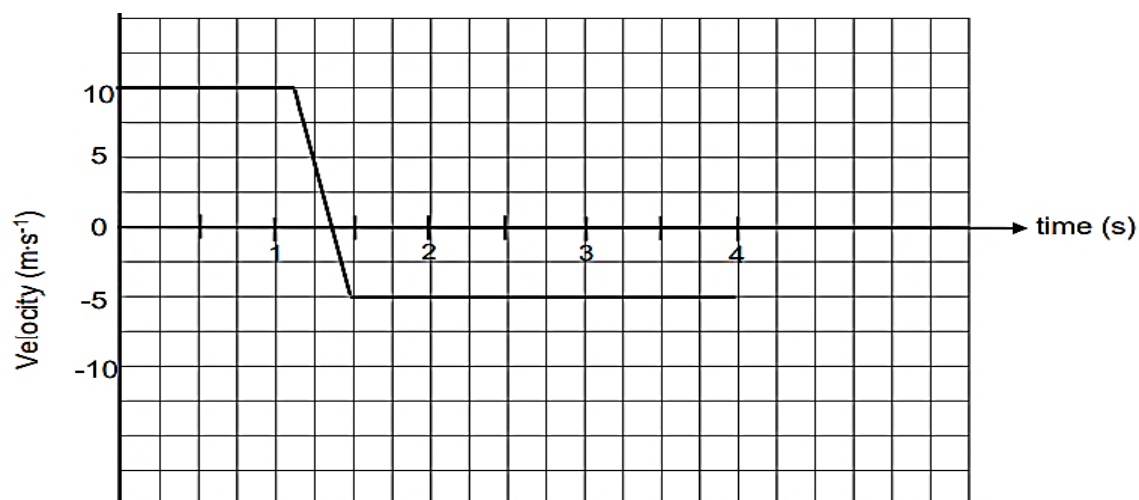
- 2.2 Use relevant physics principles to explain why the firing of the rocket will slow down the cart. (2)
- 2.3 Calculate the mass of the rocket at the instant the rocket was fired from the toy cart (5)

[9]

### QUESTION 3

Car **P**, mass  $m$ , is initially travelling eastwards when it collides with another car **Q** of mass  $1.7m$  which is travelling westwards at  $15 \text{ m.s}^{-1}$ . Ignore the rotation effects of the wheels and friction.

The graph below shows how the velocity of car **P** changes with time. Take the initial motion of car **P** as positive.



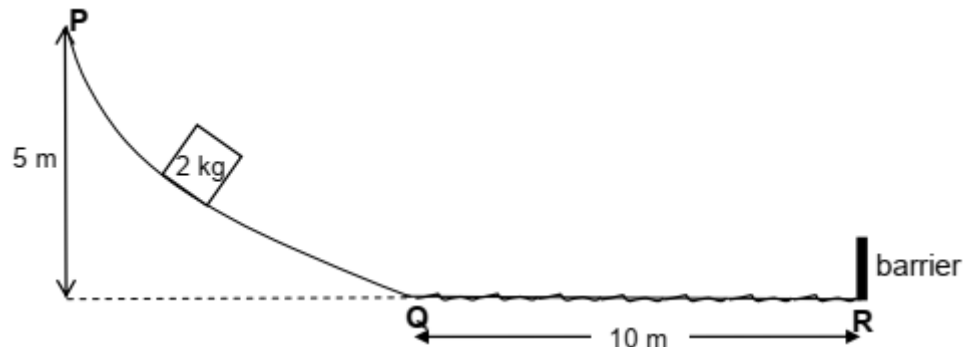
- 3.1 Define the term impulse in words. (2)
- 3.2 Calculate the velocity of car **Q** after the collision. (5)
- 3.3 It is observed that the kinetic energy of the system DECREASES by 175000 J after the collision.
  - 3.3.1 Is the collision ELASTIC or INELASTIC? (1)
  - 3.3.2 Calculate mass  $m$ . (5)
  - 3.3.3 USING THE GRAPH, calculate the magnitude of the net force exerted on car **P** during the collision. (4)

[17]

## 4 Work, Energy, Power

### QUESTION 1

A 2 kg box is released from rest at point **P**, 5 m above the ground. It slides down a smooth frictionless curved track **PQ**. See the diagram below.



1.1. State the principle of conservation of mechanical energy in words (2)

1.2. Use the PRINCIPLE OF CONSERVATION OF MECHANICAL ENERGY to calculate the speed of the box when it reaches point **Q** (3)

The box passes point **Q** and moves 10 m on a rough horizontal surface before striking a barrier at point **R** at a speed of  $4 \text{ m.s}^{-1}$

1.3 Use ENERGY PRINCIPLES to calculate the magnitude of the average frictional force acting on the box as it moves from **Q** to **R**. (4)

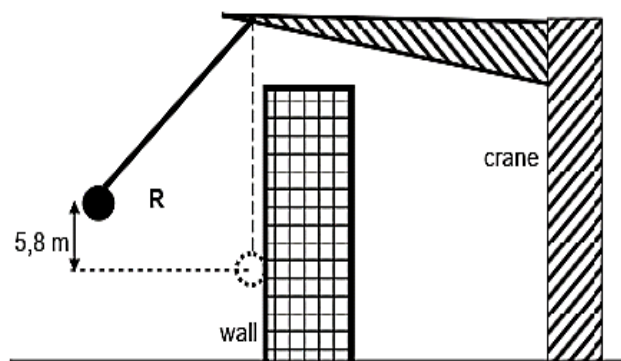
The barrier exerts an impulse of 14 N.s to the LEFT on the box when the box strikes the barrier.

1.4 Calculate the change in kinetic energy of the box after striking the barrier (5)  
[14]

### QUESTION 2

A demolition ball is used by a crane to break the wall of a building.

The demolition ball, of mass 1 250 kg, is lifted by the crane to a point **R** at a height of 5,8 m above its lowest position in 60 s. Ignore air friction.

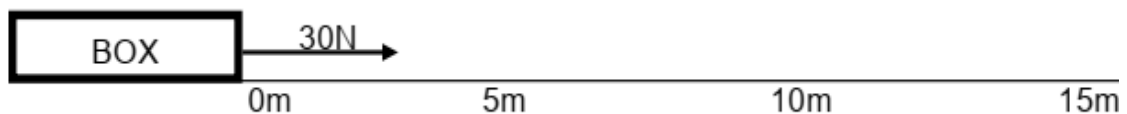


- 2.1 . Define the term *power* in words (2)
- 2.2 Calculate the average power dissipated by the crane in lifting the demolition ball to point **R**. (3)
- 2.3 The demolition ball is released from point **R** and strikes the wall at the lowest point of its swing. The ball then moves 0,25 m HORIZONTALLY into the wall before coming to rest.
- 2.3.1 Define the term *conservative force* (2)
- 2.3.2 Is the force which the wall exerts on the ball a CONSERVATIVE or a NON-CONSERVATIVE force? (1)
- 2.3.3 State the energy conversion that takes place during the downward swing of the demolition ball (1)
- 2.3.4 Using **energy principles**, calculate the magnitude of the average force exerted on the ball while it moves into the wall. (5)

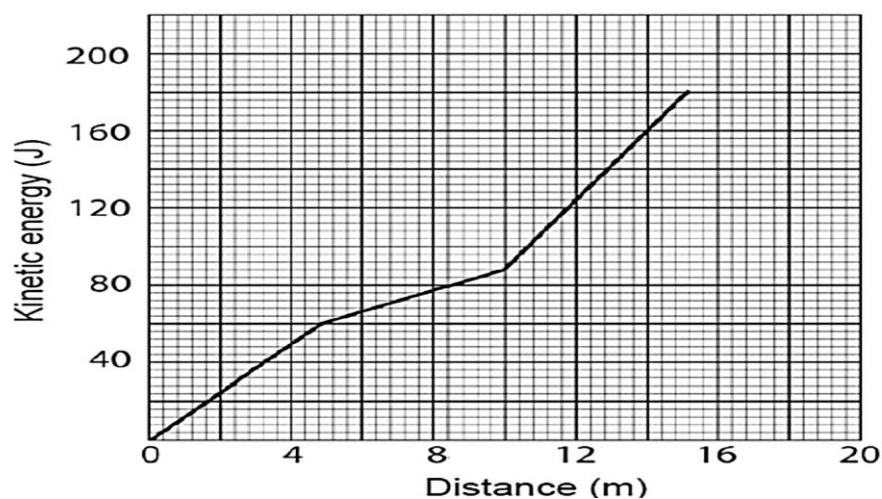
[14]

### QUESTION 3

A box is pushed from rest with a constant applied force of 30 N over a horizontal surface which has three different regions. Each region is 5 m long and exerts a different frictional force on the box as it moves through.



The graph below shows the kinetic energy of the object as a function of the distance from the starting position as the object experiences the constant applied force of 30 N. The first region is from (0 to 5) m, the second region is from (5 to 10) m and the third region is from (10 to 15) m.



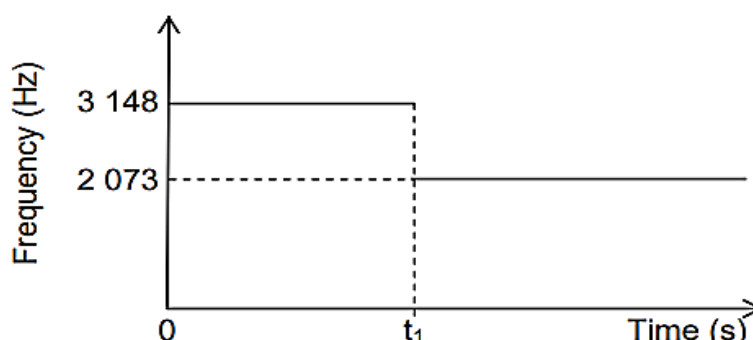
- 5.1 State the work-energy theorem in words. (2)
- 5.2 Use the work-energy theorem to show that the gradient (slope) of the graph represents the net force experienced by the object. (2)
- 5.3 Calculate the net force experienced by the object in the third region between 10 m and 15 m. (2)
- 5.4 Hence determine the magnitude of the force of friction experienced by the block as it moves over the third region. (3)
- 5.5 Which region, FIRST, SECOND or THIRD offers the largest frictional force (1)
- 5.6 Explain your answer in QUESTION 5.5 without any calculation. (2)

[14]

## 5 Doppler effect

### QUESTION 1

The siren of a train, moving at a constant speed along a straight horizontal track, emits sound with a constant frequency. A detector, placed next to the track, records the frequency of the sound waves. The results obtained are as shown in the graph below.



- 1.1 State the Doppler effect in words. (2)
- 1.2 Does the detector record the frequency of 3 148 Hz when the train moves TOWARDS the detector or AWAY from the detector? (1)
- 1.3 Calculate the speed of the train. Take the speed of sound in air as  $340\text{m}\cdot\text{s}^{-1}$ . (6)  
The detector started recording the frequency of the moving train's siren when the train was 350 m away.
- 1.4 Calculate time  $t_1$  indicated on the graph above. (2)

[11]

## QUESTION 2

A car moves at a **constant speed** of  $10 \text{ m.s}^{-1}$  TOWARDS a stationary sound source. The sound source emits sound waves of frequency  $880 \text{ Hz}$ .

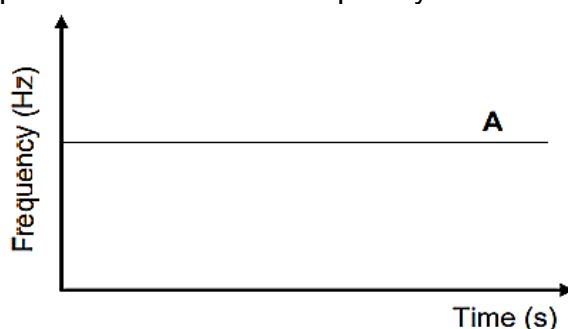
A sound detector **A** is attached to the car and another sound detector **B** is attached to the sound source. Detector **B** detects the sound waves reflected from the car.

The speed of sound in air is  $340 \text{ m.s}^{-1}$ .



- 2.1 State the Doppler effect in words. (2)
- 2.2 Calculate the wavelength of the sound waves emitted by the source. (3)
- 2.3 Calculate the frequency of the sound waves detected by detector **A**. (4)

The sketch graph below shows the frequency recorded by detector **A**.



- 2.4 Redraw the graph above for detector **A** in your ANSWER BOOK. On the same set of axes, sketch the graph of the frequency recorded by detector **B**. Label this graph as **B**. (2)

[11]

## QUESTION 3

The Doppler effect is applicable to both sound and light waves. It also has very important applications in our everyday lives.

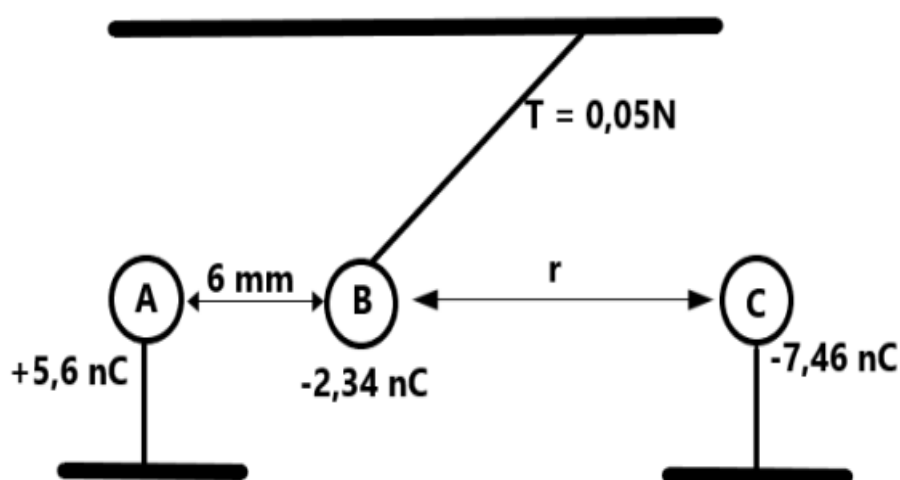
- 3.1 A siren on a stationary train emits sound with a frequency of  $520 \text{ Hz}$ , as detected by a person standing on the platform. Assume that the speed of sound is  $340 \text{ m.s}^{-1}$  in still air. Calculate the: (2)
  - 3.1.1 Wavelength of the sound detected by the person. (2)
  - 3.1.2 Wavelength of the sound detected by the person when the train moves Towards him/her at a constant speed of  $15 \text{ m.s}^{-1}$  with the siren still emitting sound. (6)
- 3.2 Explain why the wavelength calculated in QUESTION 3.1.1 differs from that obtained in QUESTION 3.1.2
- 3.3 Use your knowledge of the Doppler effect to explain red shifts. (2)

[12]

## 6 Electrostatics

### QUESTION 1

A small polystyrene sphere, **B**, hangs from the ceiling and is attached by a string of negligible mass. Two other spheres, **A** and **C** are suspended on insulated stands. The charges on each sphere are **A** = +5,6 nC, **B** = - 2,34 nC and **C** = -7,46 nC. The mass of sphere **B** is  $5,085 \times 10^{-3}$  kg. Assume that the surfaces of all the three spheres are conducting.



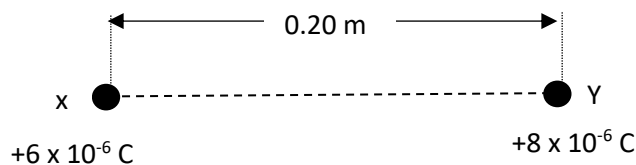
- 1.1 Define electrical field strength at a point. (2)
- 1.2 Sketch the electric field pattern around spheres **B** and **C** if **A** was removed. (3)
- 1.3 Charge **B** experiences a net force of 0,004078 N due to charges **A** and **C**. Find the distance,  $r$ , between charges **B** and **C**. (5)
- 1.4 Charges **A** and **B** are allowed to touch and then moved back to the original distance between them.
  - 1.4.1 Calculate the new charge on each sphere. (2)
  - 1.4.2 Explain the change, if any, to the field pattern between **B** and **C**. (3)

[15]



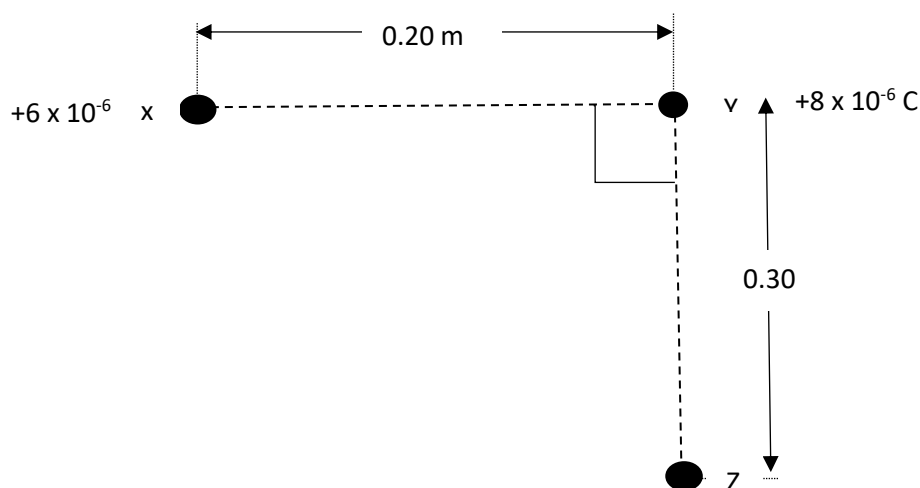
### QUESTION 2

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



- 2.1 State Coulomb's law in words. (2)  
2.2 Calculate the magnitude of the electrostatic force experienced by charged sphere **X**. (4)

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

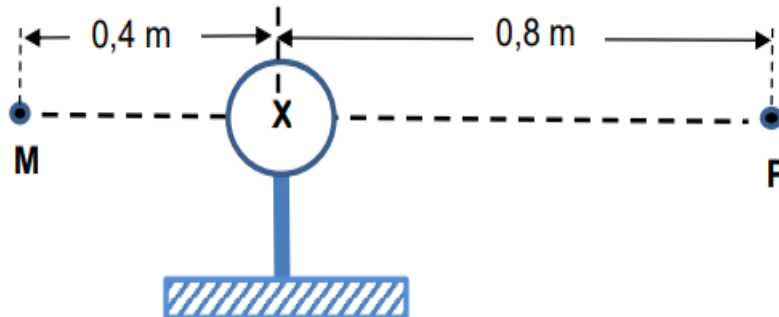


- 2.3 Draw a vector diagram showing the directions of the electrostatic forces and the net force experienced by charged sphere **Y** due to the presence of charged spheres **X** and **Z** respectively. (3)  
2.4 The magnitude of the net electrostatic force experienced by charged sphere **Y** is 15,20 N. Calculate the charge on sphere **Z**. (4)

[13]

### QUESTION 3

The diagram below shows a metal sphere **X** of negligible mass on an insulated stand in a vacuum.  $3,125 \times 10^{10}$  electrons have been removed from the sphere.



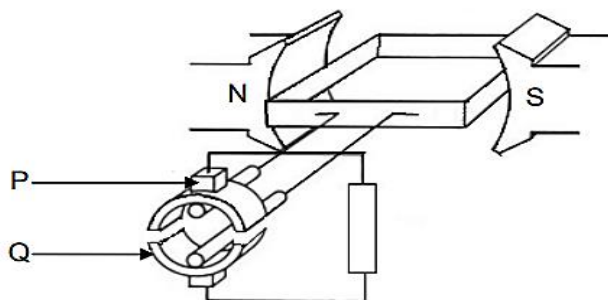
- 3.1 Draw the electric field pattern associated with sphere **X**. (2)
- 3.2 Describe an electric field. (2)
- 3.3 Calculate the net charge on the sphere. (3)
- 3.4 Calculate the electric field at point **P**. (3)
- 3.5 How does the magnitude of the electric field at point **M** compare with the value calculated in QUESTION 3.4? Write down only GREATER THAN, EQUAL TO or SMALLER THAN. Give a reason for the answer. (2)
- 3.6 A metal sphere **Y**, on an insulated stand carrying a charge of  $-4 \text{ nC}$ , is now placed at point **M**. Show by calculations where a positive point charge **Q** should be placed so that it is in equilibrium. (4)

[16]

## 7 Electrodynamics

### QUESTION 1

AC generators and DC generators differ in their construction and the type of current they deliver. The simplified sketch below represents a DC generator.



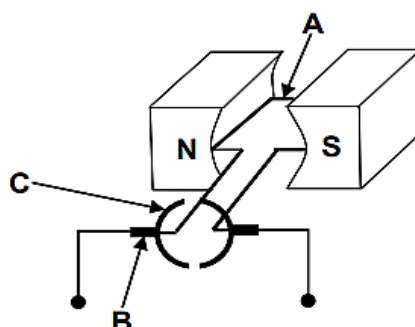
- 1.1 Which component (P or Q) enables this generator to produce DC? (1)

- 1.2 What structural change must be made to this generator to change it to an AC generator? (1)
- 1.3 An AC generator delivers  $240\text{ V}_{\text{rms}}$  to a  $60\text{ W}$  light bulb. The peak current in the light bulb is  $0,35\text{ A}$ . Calculate the:
- 1.3.1 rms current in the light bulb (3)
- 1.3.2 Resistance of the light bulb (3)

[8]

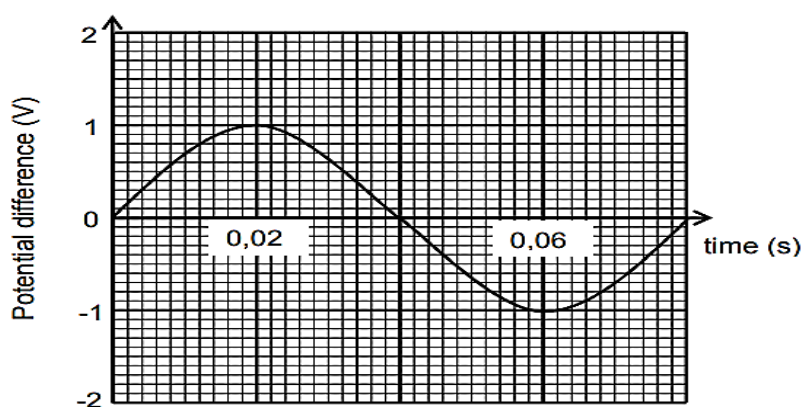
## QUESTION 2

A simplified diagram of an electric motor is shown below.



- 2.1 Name the components labelled **A**, **B** and **C**. (3)  
Write down only the name of the component next to the letter (A–C).
- 2.2 Write down the function of the component labelled **B**. (1)
- 2.3 Is this motor an AC motor or a DC motor? (1)
- 2.4 Which principle is used by the motor? (1)

A coil is rotated in a magnetic field. The varying induced emf obtained is represented in the graph below.

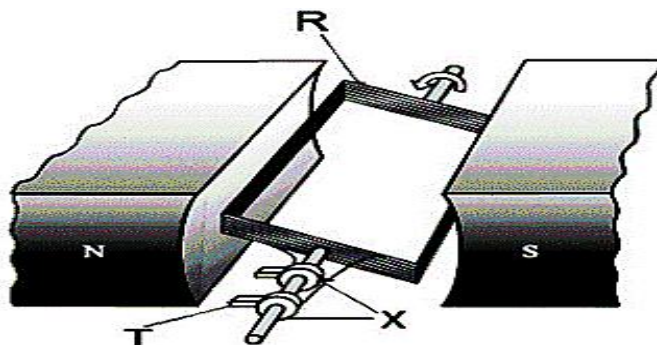


- 2.5 Calculate the induced rms potential difference. (3)
- 2.6 The coil is now rotated at TWICE the original speed. Write down the period of the new wave. (2)
- 2.7 Calculate the average power generated if the generator produces a maximum current of  $2\text{ A}$ . (4)

[15]

### QUESTION 3

3.1 The diagram shows a simplified version of a generator.



3.1.1 Write down the name of EACH part, **R**, **T** and **X**. (3)

3.1.2 Give the NAME of the law upon which the operation of the generator is based. (1)

3.2 An AC supply is connected to a light bulb. The light bulb lights up with the same brightness as it does when connected to a 15 V battery.

3.2.1 Write down the rms value of the potential difference of the AC supply. (1)

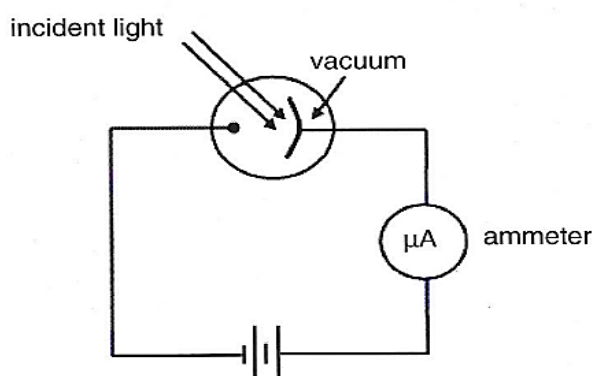
3.2.2 If the resistance of the light bulb is  $45\ \Omega$ , calculate the maximum current delivered to the light bulb. (4)

[9]

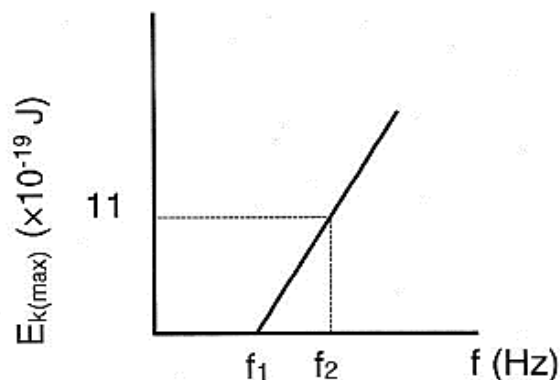
## 8 Photoelectric Effect

### QUESTION 1

The diagram below shows a simplified photocell.



The graph below shows the relationship between the maximum kinetic energy of photoelectrons and the frequency of the light when the light is shone onto the metal surface of the above photocell. The graph cuts the x-axis at  $f_1 = 5 \times 10^{14}\text{ Hz}$



- 1.1 Write down the name of the physical quantity represented by  $f_1$ . (1)
- 1.2 Define the term Work function. (2)
- 1.3 Calculate the Work function of the metal. (3)
- 1.4 Calculate the frequency,  $f_2$ , as shown in the graph. (4)
- 1.5 The intensity of the light is increased while the frequency of the light is kept constant. How will this affect the recording of the ammeter? (4)

Choose from INCREASE, DECREASE or REMAIN THE SAME (1)  
[11]

## QUESTION 2

In an experiment to demonstrate the photoelectric effect, light of different wavelengths was shone onto a metal surface of a photoelectric cell. The maximum kinetic energy of the emitted electrons was determined for the various wavelengths and recorded in the table below.

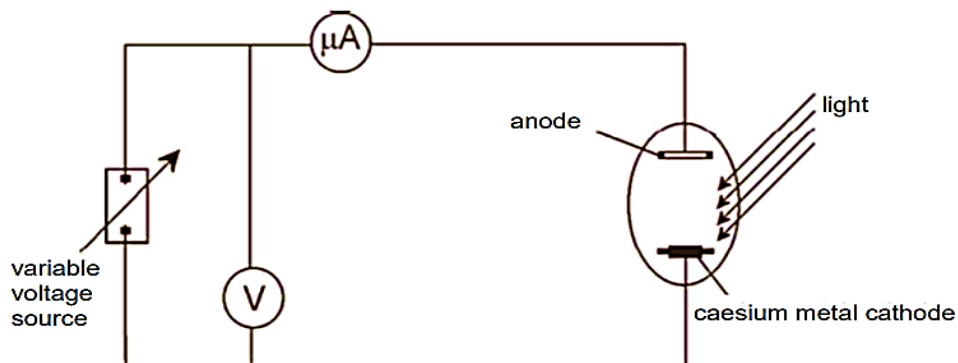
INVERSE OF WAVELENGTH $\frac{1}{\lambda} (\times 10^6 \text{ m}^{-1})$	MAXIMUM KINETIC ENERGY $E_{k(\text{max})} (\times 10^{-19} \text{ J})$
5,00	6,60
3,30	3,30
2,50	1,70
2,00	0,70

- 2.1 What is meant by the term photoelectric effect? (2)
  - 2.2 Draw a graph of  $E_{k(\text{max})}$  (y-axis) versus  $\frac{1}{\lambda}$  (x-axis). (3)
  - 2.3 USE THE GRAPH to determine:  
The threshold frequency of the metal in the photoelectric cell (4)
  - 2.4 Planck's constant (4)
- [13]

### QUESTION 3

A photoelectric cell is connected in a circuit. The lowest frequency of light that will emit electrons from its caesium surface is  $5,1 \times 10^{14}$  Hz.

Violet light of wavelength 400 nm is incident on the caesium surface.



- 3.1 Define threshold frequency. (2)
- 3.2 Calculate:
- 3.2.1 The work function of caesium (3)
- 3.2.2 The amount of energy carried by the incident photons of violet light (4)
- 3.2.3 The maximum kinetic energy of the photoelectrons emitted from the caesium surface when violet light shines on it (4)
- 3.3 Briefly explain how an emission spectrum is formed in terms of energy transitions. (2)

[15]

# PHYSICAL SCIENCES

## PAPER 2

### # 45 PLUS.

We expect learners to be able to get at **least 45 in each paper**. These 45 marks are obtainable from the following topics AND multiple-choice questions.

#### ASSUMPTIONS:

There **may** be at least one definition per topic.

**Formulae and substitutions:** assume a learner chooses at least 1 correct formula and makes a substitution.

TOPICS	MIN MARK
<b>Organic Chemistry</b>	
<b>1 Nomenclature</b>	<b>6</b>
<b>Hydrocarbons</b> <b>Homologous series</b> Functional group and general formula <ol style="list-style-type: none"> <li>Alkanes (no ring structures)</li> <li>Alkenes (no ring structures)</li> <li>Alkynes</li> <li>Halo-alkanes (primary, secondary and tertiary haloalkanes; no ring structures)</li> <li>Alcohols (primary, secondary and tertiary alcohols)</li> <li>Carboxylic acids</li> <li>Esters</li> <li>Aldehydes</li> <li>Ketones</li> </ol>	2
<b>Definitions/ name / identify/ apply</b> <ol style="list-style-type: none"> <li>Molecular formula</li> <li>Structural formula</li> <li>Condensed structural formula</li> <li>Saturated compounds, Unsaturated compounds</li> </ol>	2
Structural isomer: <ol style="list-style-type: none"> <li>chain; functional; positional</li> </ol>	1
<b>Naming</b> Identify Parent chain Identify branch	1

2 Structure and physical properties	4
<b>Definitions</b> <ol style="list-style-type: none"> <li>1. boiling point</li> <li>2. melting point</li> <li>3. vapour pressure</li> </ol>	2
<b>Intermolecular force (NOT IMF) (remember ICE)</b> <u>Identification</u> – type of Intermolecular force, e.g. London; induced dipole, dipole-dipole, hydrogen bond <u>Compare strength</u> – hydrogen bond has highest intermolecular forces. <u>Energy</u> required to overcome the intermolecular forces	2
3 Organic reactions	8
<b>Oxidation of alkanes</b> <ul style="list-style-type: none"> <li>• State the use of alkanes as fuels.</li> <li>• Write down an equation for the combustion of an alkane in excess oxygen.</li> </ul>	(2)
<b>Esterification</b> <ul style="list-style-type: none"> <li>• Write down an equation, using structural formulae, for the formation of an ester.</li> <li>• Name the <u>alcohol and carboxylic acid</u> used and the ester formed.</li> <li>• Write down reaction conditions for esterification.</li> </ul>	2
Write down, using structural formulae, equations, and reaction conditions for the following <b><u>addition reactions of alkenes</u></b> : <ol style="list-style-type: none"> <li>1. Hydrohalogenation: The addition of a hydrogen halide to an alkene</li> <li>2. Halogenation: The reaction of a halogen (<math>\text{Br}_2</math>, <math>\text{Cl}_2</math>) with a compound</li> <li>3. Hydration: The addition of water to a compound</li> <li>4. Hydrogenation: The addition of hydrogen to an alkene</li> </ol>	2
Write down, using structural formulae, equations, and reaction conditions for the following <b><u>elimination reactions</u></b> : <ol style="list-style-type: none"> <li>1 Dehydrohalogenation of haloalkanes: The elimination of hydrogen and a halogen from a haloalkane</li> <li>2 Dehydration of alcohols: Elimination of water from an alcohol</li> <li>3 Cracking of alkanes: The chemical process in which longer chain hydrocarbon molecules are broken down to shorter more useful molecules.</li> </ol> <p><i>Elimination only occurs in saturated compounds (Alkanes; halo-alkanes and Alcohols)</i> <b>Condition</b> = high temperature and concentrated strong base.</p>	2



Write down, using structural formulae, equations and reaction conditions for the following <b>substitution reactions</b> :	
1 Hydrolysis of haloalkanes: Hydrolysis: The reaction of a compound with water 2 Reactions of HX (X = Cl, Br) with alcohols to produce haloalkanes 3 Halogenation of alkanes: The reaction of a halogen (Br <sub>2</sub> , Cl <sub>2</sub> ) with a compound <i>Substitution only in saturated compound (Alkanes; halo-alkanes and Alcohols)</i> <b>Condition</b> = mild heat and dilute strong base	2
<b>4.1 Energy and change</b>	<b>2</b>
<b>Define / apply</b> 1 Heat of reaction ( $\Delta H$ ) OR change in enthalpy 2 exothermic reactions $\Delta H < 0$ 3 endothermic reactions $\Delta H > 0$ 4 activation energy 5 activated complex 6 Draw or interpret fully labelled sketch graphs (potential energy versus course of reaction graphs) of catalysed and uncatalysed endothermic and exothermic reactions.	2
<b>4.2 Rates of Reaction</b>	<b>6</b>
<b>Definition</b> □ Reaction Rates	2
<b>Skills ( may not be included in this question)</b> 1. Formulate an Investigative question 2. Formulate a hypothesis 3. Independent / dependent / control variable. Fair test	(2)
<b>Apply: how the factors affect the rate of chemical reactions</b> 1. nature of reacting substances 2. surface area 3. concentration (pressure for gases), temperature 4. The presence of a catalyst. Rate is the amount of effective collisions per time unit	2
<b>Measuring rates of reaction</b> Answer questions and interpret data (tables or graphs) on different experimental techniques for measuring the rate of a given reaction.	2
<b>5 Chemical Equilibrium</b>	<b>6</b>

<b>Definitions</b> <ol style="list-style-type: none"> <li>1. Open / closed system</li> <li>2. Reversible reaction</li> <li>3. Chemical Equilibrium</li> <li>4. dynamic equilibrium</li> <li>5. State Le Chatelier's principle</li> </ol>	2
<b>Apply / list the factors that influence the position of an equilibrium!</b> <ol style="list-style-type: none"> <li>1. pressure (gases only), (high pressure favours reaction towards less mole or V and vice versa)</li> <li>2. concentration (high c favours reaction towards lower c)</li> <li>3. Temperature. (high T favours endothermic reaction and vice versa)</li> </ol>	2
<b>Write the expression for <math>K_c</math></b> <ul style="list-style-type: none"> <li>• <math>K_c</math> Expression</li> <li>• Explain the significance of high and low values of the equilibrium constant.</li> <li>• Only temperature influences <math>K_c</math>. If number of products increase, then <math>K_c</math> increases</li> </ul>	2
<b>6 Acid &amp; Base</b>	
<b>Definitions/ apply.</b> <ol style="list-style-type: none"> <li>1 Acid/ Base according to Arrhenius and Lowry-Brønsted</li> <li>2 Identify conjugate acid - base pairs.</li> <li>3 Monoprotic and Diprotic acids with examples</li> <li>4 Strong acid / weak acid with examples</li> <li>5 Strong base /weak base with examples</li> <li>6 Concentrated acid / base and dilute acid /base</li> <li>7 Ampholyte / amphiprotic with examples</li> <li>8 Neutralisation reactions</li> <li>9 Equivalence point</li> <li>10 Endpoint</li> <li>11 Choice of a specific indicator in a titration</li> <li>12 Titration experiment: List the apparatus needed or identify the apparatus from a diagram</li> <li>13 Standard solution</li> <li>14 Hydrolysis</li> </ol>	4

<b>stoichiometric</b> calculations based on titrations of an acid with a base $c = \frac{n}{V}$ ; $n = \frac{m}{nM}$ $n_a \quad c_a V_a = c_b V_b$	2
<b>pH scale</b> pH of acids / bases / neutral solution	1
<b>7 Galvanic</b>	6
<b>Properties</b> 1 Galvanic reactions are spontaneous. 2 Energy conversion Chemical to electrical. exothermic	1
<b>Definitions /apply.</b> 1 oxidation, reduction. 2 Anode; cathode. 3 reducing/oxidizing agent. 4 electrolyte;	1
<b>Salt bridge</b> and its function	1
<b>Half Reactions</b> – NO double arrows	1
<b>Standard conditions</b>	1
<b>Cell Notation</b> <b>Net reaction</b>	(1)
<b>Formulae / calculation</b> $E_{\text{cell}}^{\ominus} = E_{\text{cathode}}^{\ominus} - E_{\text{anode}}^{\ominus} / E_{\text{sel}}^{\ominus} = E_{\text{katode}}^{\ominus} - E_{\text{anode}}^{\ominus}$ $E_{\text{cell}}^{\ominus} = E_{\text{reduction}}^{\ominus} - E_{\text{oxidation}}^{\ominus} / E_{\text{sel}}^{\ominus} = E_{\text{reduksie}}^{\ominus} - E_{\text{oksidasie}}^{\ominus}$ Copied directly from data sheet NO abbreviations!	1
<b>8 Electrolytic cell</b>	6
<b>Properties</b> 1 Electrolytic reaction is non spontaneous. 2 Energy conversion: electrical to chemical. Endothermic reaction	1
<b>Half-cell reactions</b>	1

<b>5 PROCESSES</b> Reactions/ products / cell layout 1 Electrolysis of copper chloride Copper is formed at cathode and Chlorine gas formed at anode 2 Electroplating (object is cathode and anode is the metal that you want to coat with, electrolyte must have the ion anode) 3 Electrolysis of Sodium Chloride (Hydrogen gas/H <sub>2</sub> . is formed at the cathode and chlorine gas/Cl <sub>2</sub> at the anode. 4 Refining of copper (Impure copper is at the anode and pure formed at cathode)	3
<b>TOTAL</b>	<b>±51</b>

<b>Skills</b> 1 Formulate an Investigative question. 2 Formulate a hypothesis. 3 Independent / dependent / control variable. Fair test	2
<b>Graphs</b> 1 Labeling axes 2 Plotting points 3 Reading values from graph 4 Gradient	2

# 1 Nomenclature

## QUESTION 1

Consider the organic compounds **A** to **F** below.

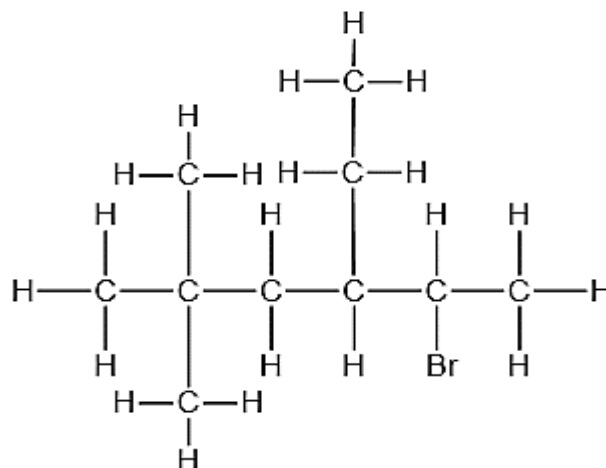
<b>A</b>		<b>B</b>	
<b>C</b>	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$	<b>D</b>	2,2-dimethylpropane
<b>E</b>		<b>F</b>	$\text{CH}_3\text{CHC}(\text{CH}_3)_2$

- 1.1 Write down the LETTER that represents a compound that:
    - 1.1.1 Has a carbonyl group (1)
    - 1.1.2 Is an alcohol (1)
    - 1.1.3 Is a CHAIN ISOMER of  $\text{CH}_3(\text{CH}_2)_3\text{CH}_3$  (1)
  - 1.2 Write down the:
    - 1.2.1 IUPAC name of compound **B** (2)
    - 1.2.2 Structural formula of compound **F** (2)
    - 1.2.3 IUPAC name of a POSITIONAL isomer of compound **A** (3)
  - 1.3 Compound **E** is formed when a carboxylic acid reacts with another organic compound.  
Write down the:
    - 1.3.1 Homologous series to which compound **E** belongs (1)
    - 1.3.2 NAME or FORMULA of the catalyst used for the preparation of compound **E** (1)
    - 1.3.3 IUPAC name of compound **E** (2)
- [14]**

## QUESTION 2

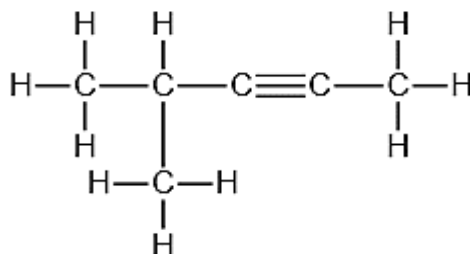
- 2.1 Define the term functional group of organic compounds. (2)
- 2.2 Write down the:
  - 2.2.1 Structural formula of the functional group of aldehydes (1)
  - 2.2.2 Structural formula of the functional group of aldehydes (1)
- 2.3 The IUPAC name of an organic compound is 2,4-dimethylhexan-3-one.  
For this compound, write down the:
  - 2.3.1 Homologous series to which it belongs (1)
  - 2.3.2 Structural formula (3)
- 2.4 Write down the IUPAC names of the following compounds:

2.4.1



(3)

2.4.2



(2)  
[13]

### QUESTION 3

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

<b>A</b>	Methanoic acid	<b>B</b>	Pentanal
<b>C</b>	$C_{10}H_{22}$	<b>D</b>	
<b>E</b>		<b>F</b>	

3.1 Write down the LETTER(S) that represent(s) the following:

- 3.1.1 A ketone (1)  
 3.1.2 TWO compounds that are FUNCTIONAL ISOMERS (1)  
 3.1.3 A hydrocarbon (1)

3.2 For compound **D**, write down the:

- 3.2.1 Homologous series to which it belongs (1)  
 3.2.2 IUPAC name (3)  
 3.3 Consider compound **F**.  
 Write down the IUPAC name of its:  
 3.3.1 POSITIONAL isomer (2)  
 3.3.2 CHAIN isomer (2)  
 3.4 During the reaction of compound, **A** with compound **E** in the presence of an acid catalyst, two products are formed.  
 For the ORGANIC product formed, write down the:  
 3.4.1 IUPAC name (2)  
 3.4.2 STRUCTURAL FORMULA of its FUNCTIONAL GROUP (1)  
 3.5 Compound **C** ( $C_{10}H_{22}$ ) reacts at high temperatures and pressures to form a three-carbon alkene **P** and an alkane **Q**, as shown below.



Write down the:

- 3.5.1 Type of reaction that takes place (1)  
 3.5.2 Molecular formula of compound **Q** (2)  
 3.5.3 STRUCTURAL FORMULA of compound **P** (2)

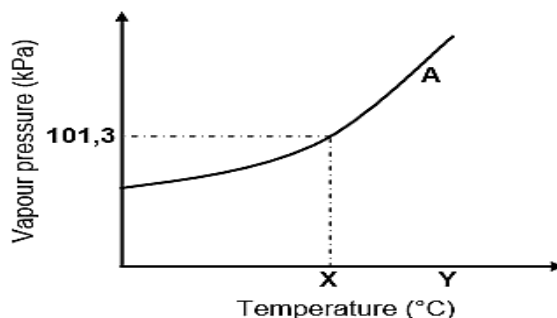
## 2 Physical Properties

### QUESTION 1

Learners use compounds **A**, **B** and **C** to investigate one of the factors that influences the VAPOUR PRESSURE of organic compounds.

<b>A</b>	Butan-1-ol
<b>B</b>	Butan-2-one
<b>C</b>	Propanoic acid

- 1.1 Define the term vapour pressure. (2)  
 1.2 Write down the independent variable for this investigation. (1)  
 1.3 Which compound, **A** or **B**, has the higher vapour pressure? (1)  
 1.4 Fully explain the answer to QUESTION 1.3. Include the TYPES OF INTERMOLECULAR FORCES in your explanation. (4)  
 1.5 The graph below represents the relationship between vapour pressure and temperature for compound **A** at sea level. **X** and **Y** represent different temperatures.



- 1.5.1 Write down the term for the temperature represented by **X**. (1)
- 1.5.2 State the phase of compound **A** at temperature **Y**. Choose from GAS, LIQUID or SOLID. (1)
- 1.5.3 Redraw the graph above in your ANSWER BOOK. On the same set of axes, sketch the curve that will be obtained for compound **C**. Clearly label curve **A** and curve **C**. (2)
- [12]**

## QUESTION 2

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

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

- 2.1 Explain the increase in boiling points of the alkanes, as indicated in the table. (3)
- 2.2 Explain the difference between the boiling points of an alkane and an alcohol, each having THREE carbon atoms per molecule, by referring to the TYPE of intermolecular forces. (4)
- 2.3 Does the vapour pressure of the alcohols INCREASE or DECREASE with an increase in the number of carbon atoms? (1)
- 2.4 How will the boiling point of 2-methylpropane compare to that of its chain isomer?

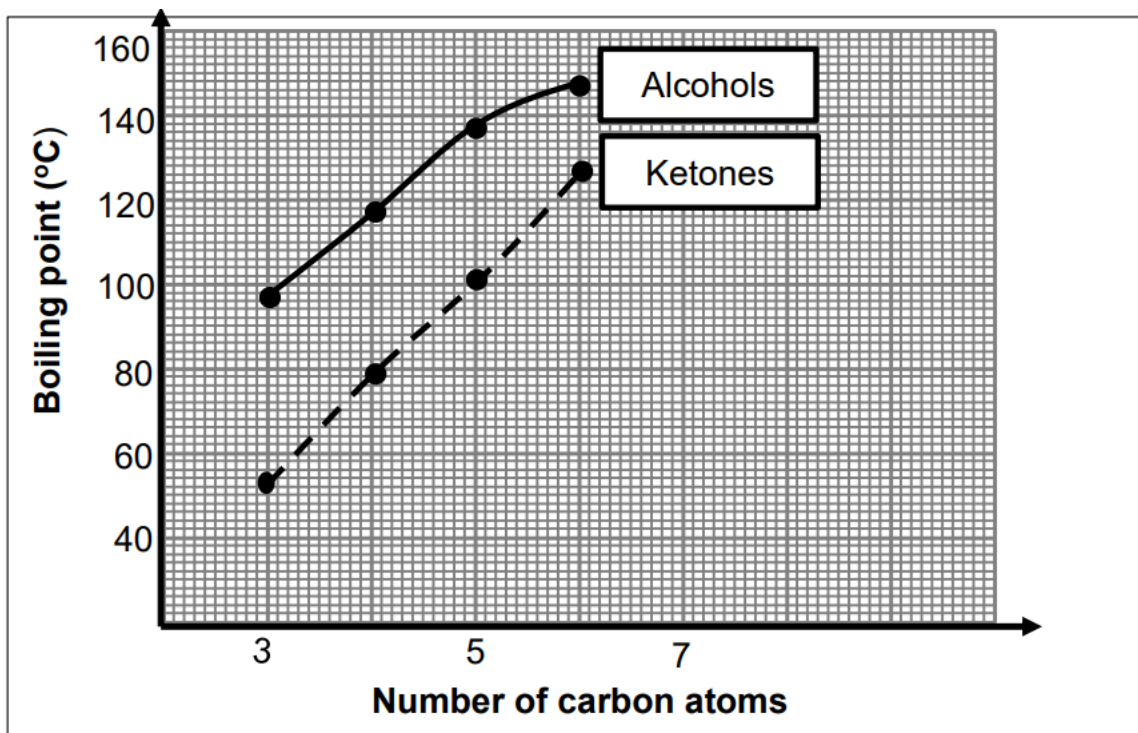
Write down HIGHER THAN, LOWER THAN or EQUAL TO. Give a reason for the answer by referring to the structural differences between the two compounds (2)

**[10]**



### QUESTION 3

The graphs below show the boiling points of straight chain primary alcohols and straight chain ketones with different number of carbon atoms.



3.1 Explain why the boiling points of alcohols increase as the number of carbon atoms increase by referring to TYPE and STRENGTH of intermolecular forces only. (2)

3.2 Explain why the curve of the alcohols is higher than that of the ketones. Refer to the TYPE and STRENGTH of intermolecular forces involved. (3)

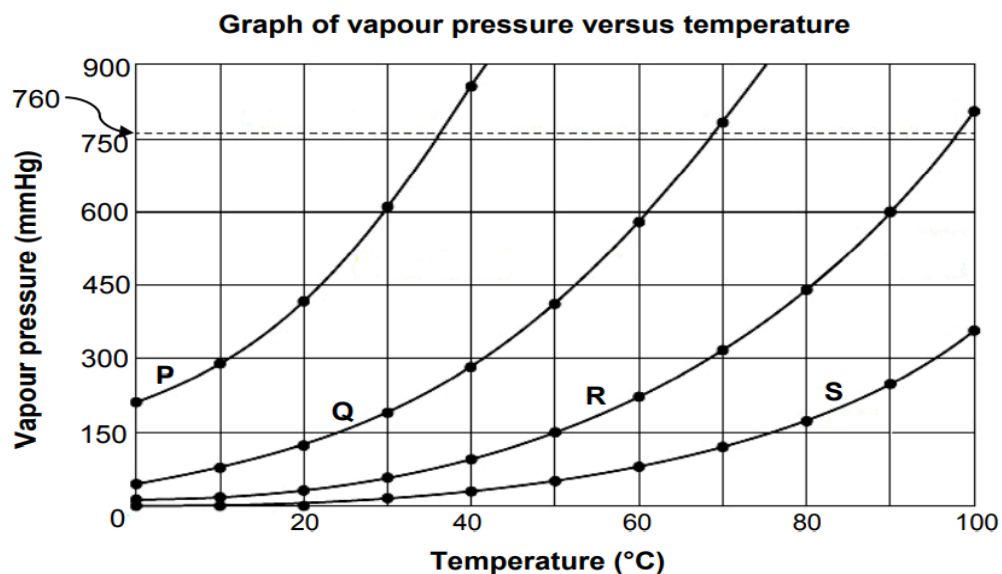
The vapour pressure of the alcohol is compared to that of a ketone at the same temperature.

3.3 Why must the alcohol and ketone which are used for the comparison have the same number of carbon atoms? (1)

3.4 Which ONE will have a higher vapour pressure: ALCOHOL or KETONE? (2)

Give a reason for the answer by referring to the data in the graph.

The vapour pressure versus temperature graph below was obtained for four straight chain (unbranched) alkanes (**P**, **Q**, **R** and **S**). FROM P TO S, EACH COMPOUND DIFFERS FROM THE PREVIOUS COMPOUND BY A  $-\text{CH}_2$  GROUP. The vapour pressures are measured in mmHg. Atmospheric pressure is 760 mmHg.



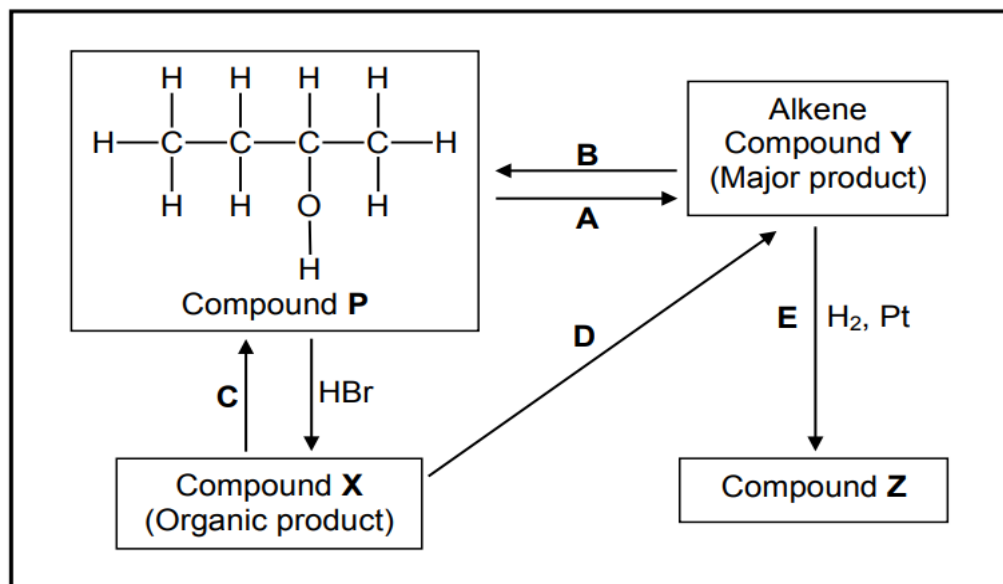
- 3.5 Use the information in the graph above to answer the following questions.
- 3.5.1 What is the effect of an increase in temperature on vapour pressure? (1)  
Choose from INCREASES, DECREASES or NO EFFECT.
- 3.5.2 Which compound has a boiling point of approximately 68 °C? Give a reason for the answer. (2)
- 3.5.3 Which compound has the longest chain length? Fully explain the answer. (4)
- 3.6 Compound **P** has FIVE carbon atoms.
- 3.6.1 Draw the structural formula of a chain isomer of **P**. Write down the IUPAC name of this isomer. (3)
- 3.6.2 How will the vapour pressure of this isomer compare with that of compound **P**? Choose from HIGHER THAN, LOWER THAN or EQUAL TO. (1)

[19]

## 3 Organic Reactions

### QUESTION 1

The flow diagram below shows how an alcohol (compound **P**) can be used to prepare other organic compounds. The letters A to E represent different organic reactions. **X**, **Y** and **Z** are organic compounds.



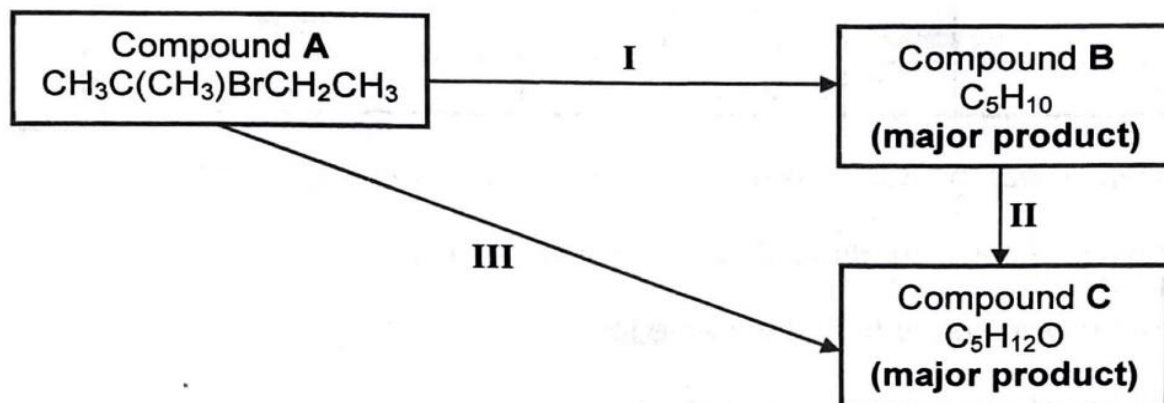
- 1.1 Is compound **P** a PRIMARY, SECONDARY or TERTIARY alcohol? Give a reason for the answer. (2)
- 1.2 Write down the type of:
  - 1.2.1 Elimination reaction represented by A (1)
  - 1.2.2 Addition reaction represented by B (1)
  - 1.2.3 Elimination reaction represented by D (1)
- 1.3 Sodium hydroxide is used as one of the reactants in reaction C.
  - 1.3.1 What type of reaction takes place here? (1)
  - 1.3.2 State the TWO reaction conditions for this reaction. (2)
  - 1.3.3 Write down the IUPAC name of compound **X**. (2)
- 1.4 Write down the FORMULA of an inorganic reactant needed for reaction D. (1)
- 1.5 Using STRUCTURAL FORMULAE, write down a balanced equation for reaction E. (3)
- 1.6 Write down the IUPAC name of compound **Z**. (1)

[15]

## QUESTION 2

The flow diagram below shows how compound **A** can be used as a starting reactant to prepare two different compounds.

**I, II and III** represent three organic reactions.



2.1 Is compound **A**, a PRIMARY, SECONDARY or TERTIARY haloalkane. (2)

Consider reaction **I**:

2.1.1 Besides heat, write down the other reaction condition needed. (1)

2.1.2 Write down the type of reaction that takes place. (1)

2.1.3 Use STRUCTURAL FORMULAE for the organic compounds, write down a balance equation for the reaction. (5)

2.2 Consider reaction **II**:

Write down:

2.2.1 STRUCTURAL FORMULA of compound **C**. (2)

2.2.2 NAME or FORMULA of the inorganic reagent needed. (1)

2.2.3 Type of addition reaction that takes place. (1)

2.3 Consider reaction **III**

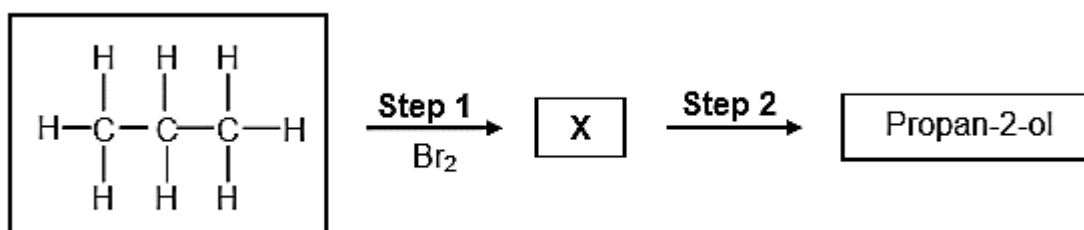
2.3.1 Write down the type of reaction that takes place. (1)

2.3.2 Besides heat, write down the other reaction condition needed. (1)

[15]

## QUESTION 3

3.1 The flow diagram below shows the conversion of propane to propan-2-ol.



3.1.1 State ONE reaction condition for **Step 1**. (1)

- 3.1.2 Write down the NAME or FORMULA of the INORGANIC product formed in **Step 1**. (1)
- 3.1.3 Name the TYPE of substitution reaction represented by **Step 2**. (1)
- 3.1.4 Write down the NAME or FORMULA of the INORGANIC reagent needed in **Step 2**. (1)
- 3.1.5 Write down the IUPAC name of compound **X**. (2)
- 3.2 Ethane can be prepared from chloroethane ( $\text{CH}_3\text{CH}_2\text{Cl}$ ) by a TWO-STEP process. You are supplied with the following chemicals:

$\text{H}_2$	$\text{HCl}$	$\text{Cl}_2$	$\text{H}_2\text{O}$	Pt	Ethanol	concentrated $\text{H}_2\text{SO}_4$	concentrated NaOH
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Select chemicals in the table above that can be used for this preparation.

Using CONDENSED structural formulae, write down a balanced equation for EACH reaction. Indicate the reaction conditions for EACH reaction

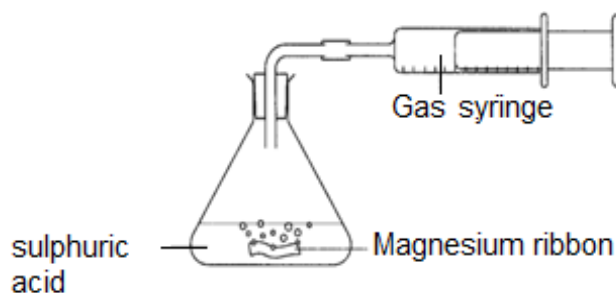
(8)  
[14]

## 4 Rates of Reactions

### QUESTION 1

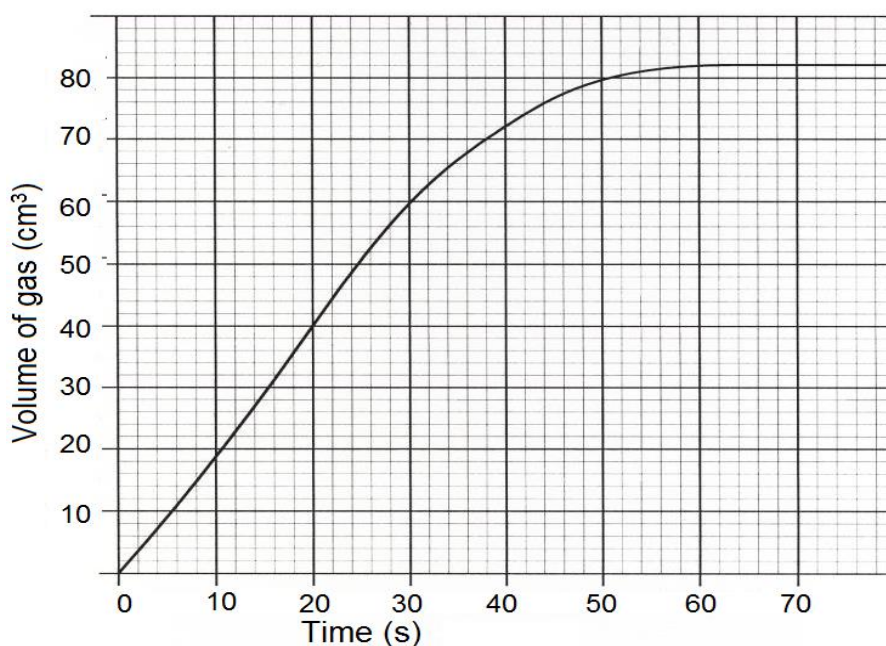
Learners use the apparatus below to investigate how the surface area of a reactant affects the rate of reaction. They use magnesium metal and excess dilute sulphuric acid.

During the reaction, the gas that forms is collected in the gas syringe.



Experiment	Mass of Mg in grams	State of division of Mg
I	20	ribbon
II	20	powder

- 1.1 Write down the dependent variable for this investigation. (1)  
The graph obtained for Experiment I is shown below.



- 1.2 Use the graph to calculate the rate of the reaction (in  $\text{cm}^3 \cdot \text{s}^{-1}$ ) for the first 30 seconds. (3)
- 1.3 Will the rate of the reaction at 50 s be GREATER THAN, LESS THAN or EQUAL TO the rate calculated in QUESTION 5.2? (2)  
Write down a reason for the answer.
- 1.4 Predict how the gradient of the results of EXPERIMENT II would compare to the gradient of the graph of EXPERIMENT I, plotted above, for the time interval between,  $t = 0 \text{ s}$  and  $t = 30 \text{ s}$ . (1)  
Write only INCREASE, DECREASE or NO CHANGE.
- 1.5 Use the collision theory to explain how the increase in surface area of the magnesium metal affects the rate of the reaction. (3)  
The balanced equation for the reaction is:  
$$\text{Mg(s)} + \text{H}_2\text{SO}_4\text{(aq)} \rightarrow \text{MgSO}_4\text{(aq)} + \text{H}_2\text{(g)}$$
- 1.6 The 20 g of magnesium metal reacts with  $100 \text{ cm}^3$  dilute sulphuric acid with a concentration of  $1 \text{ mol} \cdot \text{dm}^{-3}$ . (5)  
Calculate the mass of magnesium metal that remains after the reaction has run to completion (stopped). [15]

## QUESTION 2

Learners use the reaction between sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) and a  $0,1 \text{ mol} \cdot \text{dm}^{-3}$  sulphuric acid solution to investigate reaction rate. They pour  $150 \text{ cm}^3$  of the sulphuric acid solution into a beaker and add ENOUGH sodium carbonate powder to neutralise the acid. The temperature of the reaction mixture is kept at  $0^\circ \text{C}$ .

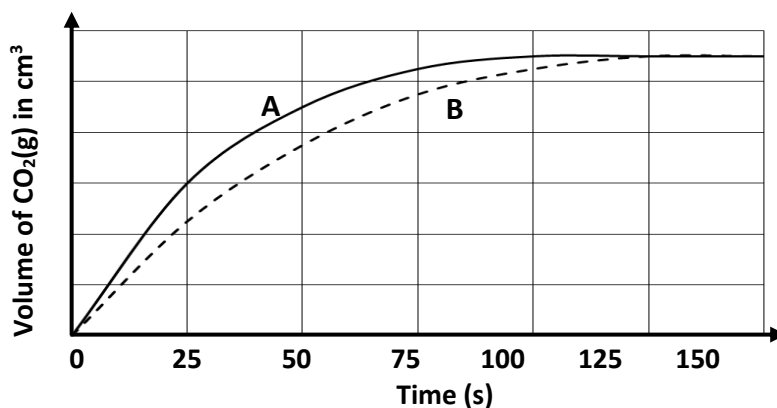
The balanced equation for the reaction is:



- 2.1 Define the term *reaction rate* in words. (2)

Graph **A** (solid line) below shows the volume of  $\text{CO}_2(\text{g})$  formed as a function of time.

**Graph of volume of  $\text{CO}_2(\text{g})$  formed versus time**

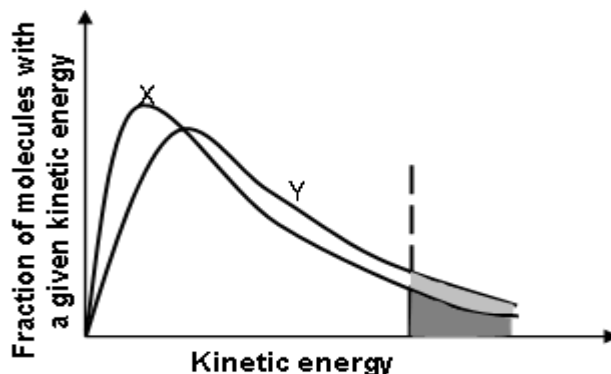


- 2.2 How long (in seconds) did the reaction represented by graph **A** take to reach completion? (1)
- 2.3 How does the reaction rate of the reaction represented by graph **A** at  $t = 5 \text{ s}$  compare to that at  $t = 25 \text{ s}$ ? Write down HIGHER THAN, LOWER THAN or EQUAL TO. Use the collision theory to explain the answer. (3)
- 2.4 Calculate the maximum volume of  $\text{CO}_2(\text{g})$ , in  $\text{dm}^3$ , that can be produced by this reaction at STP. (5)
- 2.5 The same reaction is now repeated using the same mass of  $\text{Na}_2\text{CO}_3$  and the same volume of the  $0,1 \text{ mol}\cdot\text{dm}^{-3} \text{ H}_2\text{SO}_4$ . The volume of  $\text{CO}_2(\text{g})$  formed as a function of time is represented by graph **B** above. Write down TWO possible changes that could have been made to the reaction mixture. (2)
- [13]**

### QUESTION 3

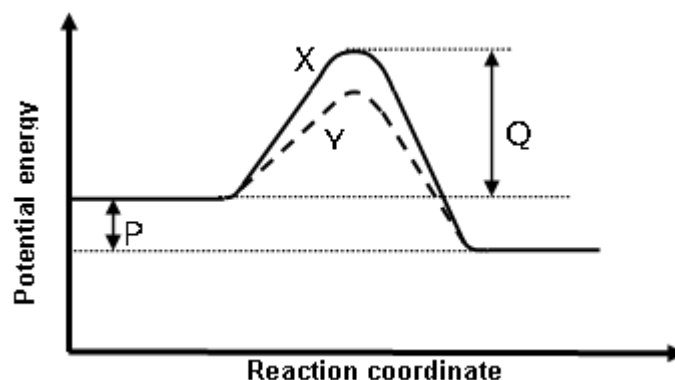
A learner investigates a way to increase the rate at which hydrogen gas develops in the reaction between zinc and hydrochloric acid.

- 3.1 By changing one reaction condition she obtains the graph below, in which:
- Curve X denotes the initial condition.
  - Curve Y denotes the changed condition that produced a higher reaction rate



- 3.1.1 Which reaction condition did the learner change? (2)

- 3.1.2 Apply the collision theory and explain why the changed condition results in a higher reaction rate. (3)
- 3.2 She then changes another condition in which the effect is represented by the graph below. Once again:
- Curve X represents the initial condition.
  - Curve Y represents the changed condition that resulted in a higher reaction rate

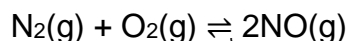


- 3.2.1 Which reaction condition did the learner change? (2)
- 3.2.2 What is the name of the energy value represented by the following:
- P (1)
- Q (1)
- [9]

## 5 Chemical Equilibrium

### QUESTION 1

A chemical engineer studies the reaction of nitrogen and oxygen in a laboratory. The reaction reaches equilibrium in a closed container at a certain temperature, T, according to the following balanced equation:



Initially, 2 mol of nitrogen and 2 mol of oxygen are mixed in a 5 dm<sup>3</sup> sealed container.

The equilibrium constant ( $K_c$ ) for the reaction at this temperature is  $1,2 \times 10^{-4}$ .

- 1.1 Is the yield of NO(g) at temperature T, HIGH or LOW? Give a reason for the answer. (2)
- 1.2 Calculate the equilibrium concentration of NO(g) at this temperature. (8)
- 1.3 How will each of the following changes affect the YIELD of NO(g)? Write down only **INCREASES**, **DECREASES** or **REMAINS THE SAME**.
- 1.3.1 The volume of the reaction vessel is decreased at constant temperature. (1)
- 1.3.2 An inert gas such as argon is added to the mixture. (1)

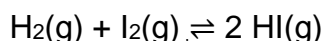


- 1.4 It is found that  $K_c$  of the reaction increases with an increase in temperature. Is this reaction exothermic or endothermic? Explain the answer.

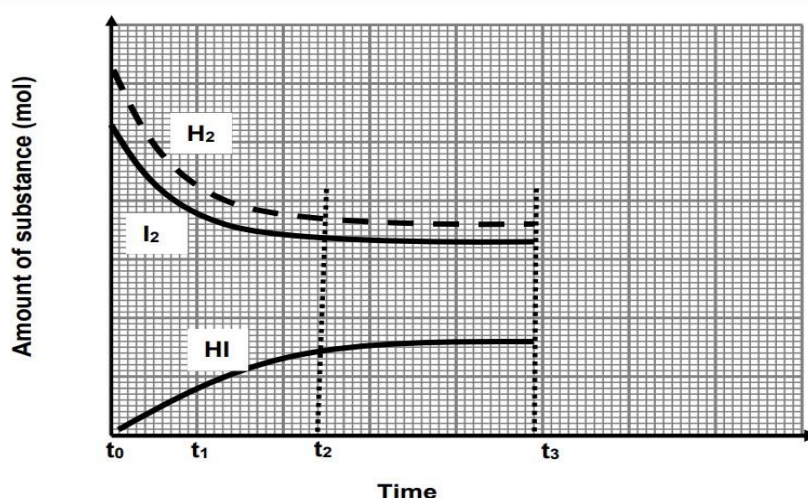
(3)  
[15]

## QUESTION 2

Consider the reversible reaction taking place in a closed container:



- 2.1 Define the term reversible reaction. (2)  
The graph below shows the changes in the amount of the substances  $\text{H}_2$ ,  $\text{I}_2$  and  $\text{HI}$  from the moment the reactants are pumped into an empty container.



- 2.2 Which reaction (FORWARD or REVERSE) has a HIGHER rate of reaction during the interval  $t_0$  to  $t_1$ ? (1)  
2.3 Did the chemical reaction stop during the interval  $t_2$  to  $t_3$ ? Write only YES or NO. Give a reason for the answer. (3)  
2.4 At time  $t_3$  the pressure on the equilibrium system is increased by decreasing the volume at constant temperature. How will the increase in pressure affect the following? Write down only INCREASES, DECREASES or REMAINS THE SAME.  
2.4.1 Rate of reaction (1)  
2.4.2 Number of moles of  $\text{HI}$ . (1)  
2.4.3 Concentration of  $\text{HI}$ . (1)  
2.4.4 Explain the answer to QUESTION 2.4.3 above. (2)  
2.5 The table below shows the equilibrium constants,  $K_c$  values for the reaction at different temperatures.

TEMPERATURE ( $^{\circ}\text{C}$ )	$K_c$
448	50.3
227	129

- 2.5.1 Is there a HIGH or LOW YIELD at  $227^{\circ}\text{C}$ ? Give a reason for the answer. (3)

2.5.2 Is the forward reaction EXOTHERMIC or ENDOTHERMIC?

Explain the answer by referring to Le Chatelier's principle (4)

- 2.6 The reaction is started by placing hydrogen gas ( $\text{H}_2$ ) and iodine gas ( $\text{I}_2$ ) into an empty  $0,5 \text{ dm}^3$  container which is then sealed and heated.

When the reaction reaches equilibrium at  $448^\circ\text{C}$  it is found that the concentration of  $\text{H}_2$  and  $\text{I}_2$  are  $0,46 \text{ mol.dm}^{-3}$  and  $0,39 \text{ mol.dm}^{-3}$  respectively.

The value of the equilibrium constant,  $K_c$  is equal to 50,3 at  $448^\circ\text{C}$ .

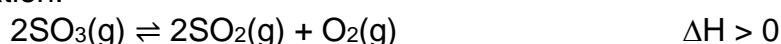
Calculate the:

- 2.6.1 Concentration of HI at equilibrium

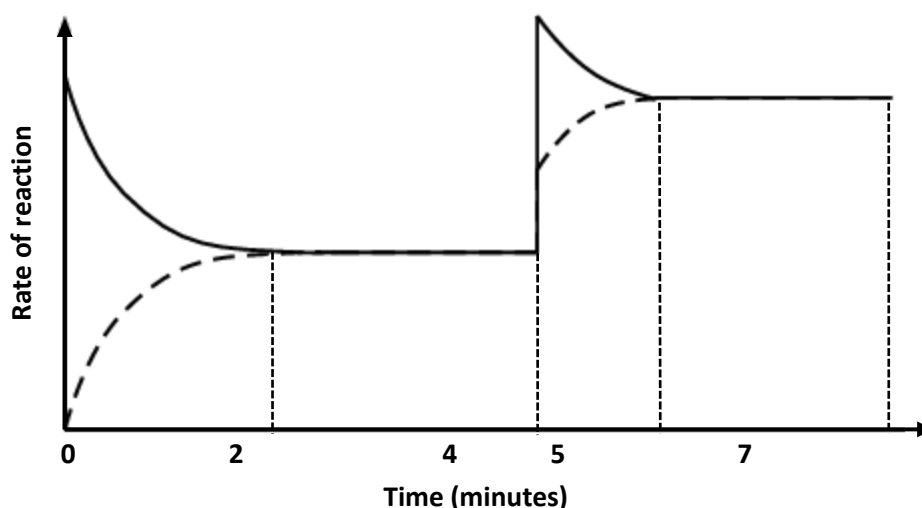
(4)  
[22]

### QUESTION 3

12 moles of  $\text{SO}_3(\text{g})$  are sealed in an empty  $2 \text{ dm}^3$  container at 700 K. It decomposes into  $\text{SO}_2(\text{g})$  and  $\text{O}_2(\text{g})$  and equilibrium is reached at 700 K according to the following balanced equation:



- 3.1 Define the term *reversible reaction*. (2)  
3.2 If 5,0 moles of  $\text{O}_2(\text{g})$  are present at equilibrium, calculate the equilibrium constant,  $K_c$ , for this reaction at 700 K. (7)  
3.3 The graph below shows the changes in the rate of the reaction over 7 minutes from the time that the 12 moles of  $\text{SO}_3(\text{g})$  were sealed in the container.

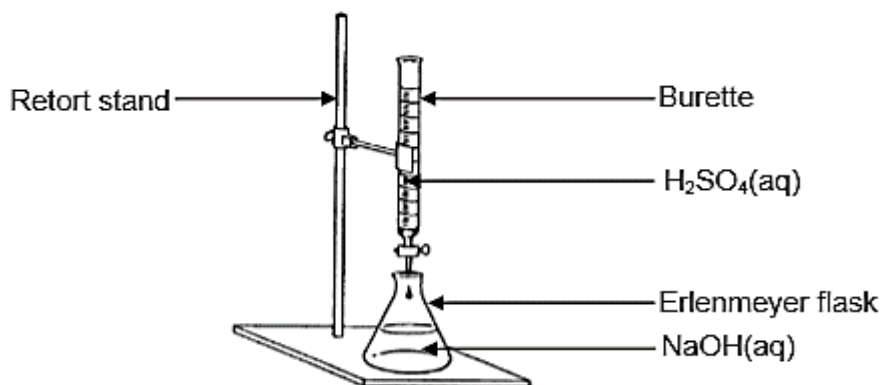


- 3.3.1 Write down the balanced equation for the reaction that is represented by the broken line. (1)  
3.3.2 Give a reason for the decrease in reaction rate represented by the solid line between  $t = 0$  minutes and  $t = 2$  minutes. (1)  
3.3.3 State the change that was made to the equilibrium mixture at  $t = 4$  minutes. Fully explain how you arrived at the answer. (4)

- 3.3.4 How does the value of the equilibrium constant ( $K_c$ ) for the reaction at  $t = 5$  minutes compare to that at  $t = 2$  minutes? Write down GREATER THAN, SMALLER THAN or EQUAL TO. (1)
- 3.3.5 Explain the answer to QUESTION 5.3.4. (2)
- [18]**

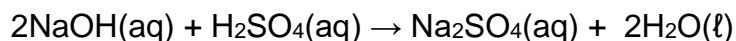
## 6 Acids and Bases

The reaction between a sulphuric acid ( $\text{H}_2\text{SO}_4$ ) solution and a sodium hydroxide ( $\text{NaOH}$ ) solution is investigated using the apparatus illustrated below.



- 1.1 Write down the name of the experimental procedure illustrated above. (1)
  - 1.2 What is the function of the burette? (1)
  - 1.3 Define an acid in terms of the Arrhenius theory. (2)
  - 1.4 Give a reason why sulphuric acid is regarded as a strong acid.
  - 1.5 Bromothymol blue is used as indicator. Write down the colour change that will take place in the Erlenmeyer flask on reaching the endpoint of the titration. Choose from the following: (1)
- BLUE TO YELLOW      YELLOW TO BLUE      GREEN TO YELLOW

During the titration a learner adds  $25 \text{ cm}^3$  of  $\text{NaOH(aq)}$  of concentration  $0,1 \text{ mol}\cdot\text{dm}^{-3}$  to an Erlenmeyer flask and titrates this solution with  $\text{H}_2\text{SO}_4(\text{aq})$  of concentration  $0,1 \text{ mol}\cdot\text{dm}^{-3}$ . The balanced equation for the reaction that takes place is:



- 1.6 Determine the volume of  $\text{H}_2\text{SO}_4(\text{aq})$  which must be added to neutralise the  $\text{NaOH(aq)}$  in the Erlenmeyer flask completely (4)
- 1.7 If the learner passes the endpoint by adding  $5 \text{ cm}^3$  of the same  $\text{H}_2\text{SO}_4(\text{aq})$  in excess, calculate the pH of the solution in the flask. (7)

**[17]**

## QUESTION 2

Learners prepare a solution of known concentration by dissolving 2 g pure sodium hydroxide crystals, NaOH, in water in a 250 cm<sup>3</sup> volumetric flask.

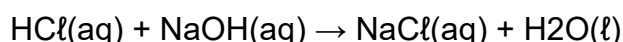
2.1 Write down the term for the underlined phrase (1)

2.2 Calculate the:

2.2.1 Concentration of the sodium hydroxide solution (4)

2.2.2 pH of the solution (4)

The learners now react 1,5 g of pure CaCO<sub>3</sub> with 50 cm<sup>3</sup> dilute HCl of unknown concentration. The EXCESS HCl is neutralised with 25 cm<sup>3</sup> of the NaOH solution that they prepared. The balanced equations for the reactions are:



2.3 Calculate the initial concentration of the dilute HCl(aq). (8)  
[17]

## QUESTION 3

3.1 A monoprotic acid HY ionises completely when dissolved in water. The hydroxide ion concentration [OH<sup>-</sup>] in the solution is 1 x 10<sup>-11</sup> mol·dm<sup>-3</sup>.

3.1.1 Define an acid in terms of the Brønsted-Lowry theory (2)

3.1.2 Define the term monoprotic acid. (2)

3.1.3 Is acid HY a WEAK or a STRONG acid? Give a reason for your answer. (2)

3.2 Calculate the following:

3.2.1 The concentration of hydronium ions [H<sub>3</sub>O<sup>+</sup>] in the solution. (3)

3.2.2 The pH of the solution (3)

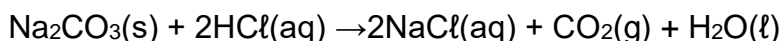
3.3 A sample of sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>) is dissolved in water.

Write down:

3.3.1 Equation for the hydrolysis of the carbonate ion (CO<sub>3</sub><sup>2-</sup>) in water (3)

3.3.2 Formula of the conjugate acid of the carbonate ion (CO<sub>3</sub><sup>2-</sup>) (1)

4,24 g of sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>) is dissolved in water. The solution is neutralised by 250 cm<sup>3</sup> of a hydrochloric acid (HCl) solution according to the following balanced equation:



3.4 Calculate the concentration of the HCl solution (6)  
[17]