THE UNITED REPUBLIC OF TANZANIA
MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY
NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

CANDIDATES' ITEM RESPONSE ANALYSIS REPORT ON THE ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION (ACSEE) 2022

PHYSICS

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CANDIDATES' ITEM RESPONSE ANALYSIS REPORT ON THE ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION (ACSEE) 2022

131 PHYSICS

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FOREWORD

The Candidates' Item Response Analysis (CIRA) of the Advanced Certificate of Secondary Education Examination (ACSEE) 2022 in Physics subject is based on the performance of the candidates in their two years of Advanced Secondary School Education.

The analysis generally indicates that the performance was good since the majority of the candidates (97.5%) passed the examination. The analysis further indicates that the candidates had good performance in the topics of *Properties of Matter, Atomic Physics, Electromagnetism, Vibrations and Waves, Environmental Physics, Mechanics* and *Electronics*. However, four topics of *Electrostatics, Heat, Current Electricity* and *Fluid Dynamics* were averagely performed. There was no topic which was weakly performed.

In this report, the analysis of each question has been done to identify factors that affected the candidates' responses. The candidates with high performance provided the correct answers since they adhered to the requirement of each question and had enough knowledge of the subject matter. In contrast, the candidates who scored low marks faced various challenges in answering the questions. Such challenges include inadequate knowledge of the concepts tested, failure to describe the terminologies apply appropriate formulae and procedures in analysing different concepts, lack of skills in solving numerical problems and failure to abide by the given instructions to assemble the apparati when performing experiments and lack of drawing skills.

The National Examinations Council of Tanzania hopes that the feedback provided in this report will help various education stakeholders to take appropriate teaching and learning interventions so as to enable students master the required knowledge and skills in order to improve performance of the subject in future examinations.

Finally, the Council would like to express its sincere appreciation to all personnel who participated in the preparation of this report.

Athumani S. Amasi
EXECUTIVE SECRETARY

1.0 INTRODUCTION

This report analyses the performance of the candidates who sat for the Advanced Certificate of Secondary Education Examination (ACSEE) 2022 in Physics. The examination had three papers, namely 131/1 Physics 1, 132/2 Physics 2 and 131/3 Physics 3. Physics 1 and Physics 2 were theory papers whereas Physics 3 was the actual practical paper. The examination covered the topics stipulated in the 2010 Physics Syllabus for Secondary Education. The examination aimed to test the competences acquired by the candidates after two years of their study.

The Physics examination paper 1 comprised Sections A and B with a total of ten (10) questions. Section A had seven (7) short-answer questions, each carrying 10 marks while Section B consisted of three (3) structured questions, each carrying 15 marks. The candidates were required to answer all questions in Section A and any two (2) questions from Section B.

The Physics examination paper 2 had six (6) structured questions. The candidates were required to answer any five (5) questions. Each question carried 20 marks.

The Physics examination practical paper 3 had three alternative papers, namely 131/3A Physics 3A, 131/3B Physics 3B and 131/3C Physics 3C. Each alternative paper consisted of three questions. Question 1 carried 20 marks while questions 2 and 3 carried 15 marks each. The candidates were required to answer all questions in any of the three alternative papers.

School candidates who passed the ACSEE 2022 were 97.5 per cent whereas in ACSEE 2021, the school candidates who passed were 93.6 per cent. This suggests an increase in the candidates' performance in ACSEE 2022 by 3.9 per cent compared to ACSEE 2021. This significant increase in performance was contributed by the improvement of candidates' performance in four topics, which are *Atomic Physics, Environmental Physics, Electromagnetism* and *Electrostatics* as illustrated in Table 1.

Table 1: Candidates' Performance in 4 Topics in ACSEE 2021 and 2022

S/n	Topic	ACSEE 2021			ACSEE 2022		
		Number of Questions	Percentage of Candidates who Scored 35 % or Above	Remarks	Number of Questions	Percentage of Candidates who Scored 35 % or Above	Remarks
1.	Atomic Physics	1	28.70	Weak	1	79.90	Good
2.	Environmental Physics	1	25.20	Weak	1	74.40	Good
3.	Electromagnetism	1	21.30	Weak	1	74.20	Good
4.	Electrostatics	1	6.30	Weak	1	58.50	Average

Table 1 shows a comparison of candidates' performance in 4 topics between 2021 and 2022.

The following bar chart demonstrates the candidates' performance in grades for two consecutive years 2021 and 2022.

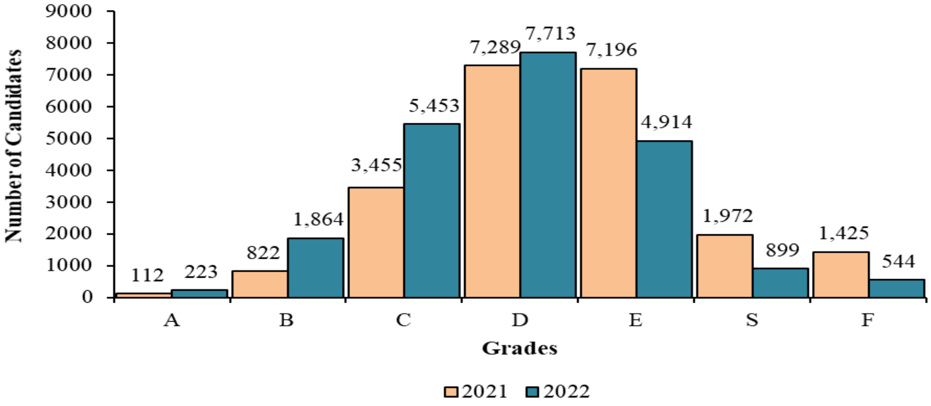


Figure 1

Figure 1: *Candidates' Performance in Terms of Grades*

Figure 1 shows that there was an increase in the number of candidates who scored grades A, B, C and D and a decrease in those who scored grades E, S and F compared to the previous year. This portrays a normal distribution curve across the grades.

This report provides a detailed analysis of the performance of the candidates in each question. The green, yellow and red colours are used to indicate good, average and weak performances when the percentage score of the candidates is 65-100, 30-64 and 0-29 respectively. The sample extracts of candidates' responses are inserted to justify the cases. Graphs and charts are used to summarize the candidates' performance on every question. The report also contains appendices I and II showing the candidates' performance in each question in the Physics theory paper and Physics practical paper respectively.

2.0 ANALYSIS OF CANDIDATES' PERFORMANCE IN EACH QUESTION IN 131/1 PHYSICS 1

This part describes the performance of the candidates in each question. The analysis covers the type of questions, topics from which the questions were constructed, demands of the questions as well as the performance of candidates in each question. The performance of the candidates has been graded as weak, average or good depending on the percentage of candidates who passed.

2.1 131/1 Physics 1

The Physics 1 examination paper consisted of ten (10) questions grouped into Sections A and B. Section A had seven (7) short-answer questions each carrying 10 marks. Section B had three (3) structured questions each carrying 15 marks. The candidates were required to answer all questions in Section A and any two (2) from Section B.

This paper examined six (6) topics. Four (4) topics were examined in Section A and two topics in Section B. The topics examined in Section A were *Rotational Dynamics*, *Mechanics*, *Heat* and *Environmental Physics* while two topics of *Current Electricity* and *Electronics* were examined in Section B. The analysis of each question is as follows:

2.1.1 Question 1: Measurement and Rotational Dynamics

The question comprised parts (a) and (b). In part (a), the candidates were required to (i) deduce the formula of the fractional error in 'g' from the relation of the period of oscillation of a simple pendulum, $T = 2\pi\sqrt{\frac{l}{g}}$ and (ii) identify the quantity which should be measured most accurately and give reasons for their choices. In part (b), they were required to calculate the speed of the body having the mass of 20 kg, radius of 0.2 m and moment of inertia of 0.4 kgm^2 at the foot of the slope as shown in Figure 1.

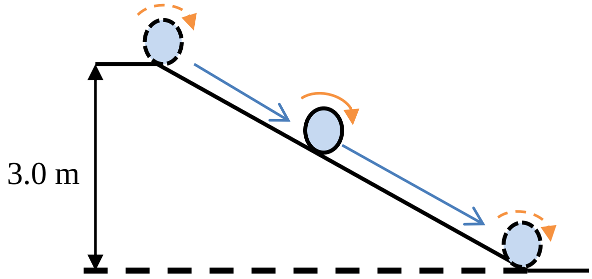


Figure 1

The question was attempted by 21,710 (100%) candidates whose scores were as follows: 39.4 per cent scored from 3.5 to 5.5 marks; 32.0 per cent scored from 6.0 to 10 marks and 28.6 per cent scored from 0 to 3.0 marks. Generally, candidates' performance in this question was good since 71.4 per cent of them scored from 5.5 to 10 marks. Figure 2 provides the graphical presentation of candidates' performance in question 1.

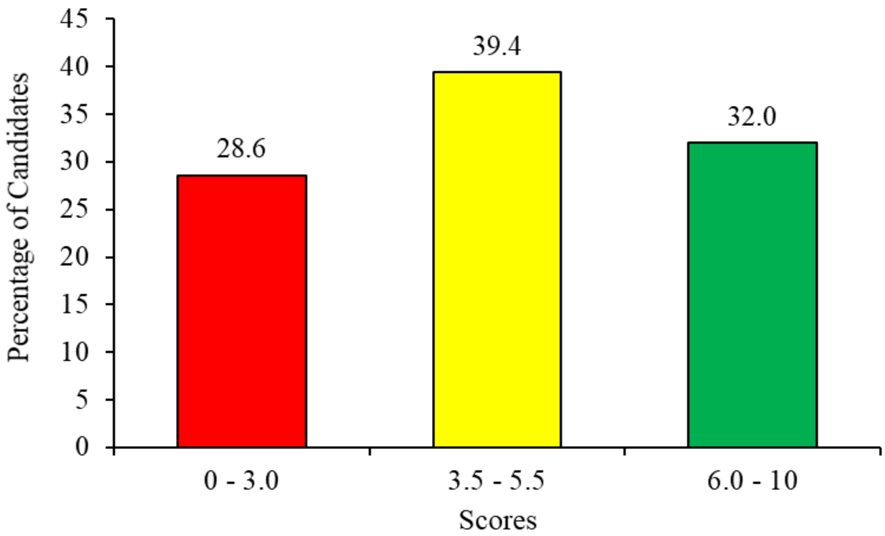


Figure 2: *The candidates' performance in Question 1 of Paper 1*

The candidates who performed well (71.4%) in this question deduced correctly the formula of the fractional error in 'g' from the given relation and identified the required quantity to be measured most accurately. They provided the reasons for their choices although few of them provided incorrect responses. In part (b), some of the candidates analysed correctly the energy change between the top and bottom of the slope which is given by loss in potential energy = gain kinetic energy of linear motion + gain of K.E of rotation motion. Finally, they applied the correct formula $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$ to determine the speed of the body rolling down the slope. Extract 1.1 is a sample of the candidates' correct responses to this question.

1. (a) from,

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$\frac{T}{2\pi} = \sqrt{\frac{l}{g}}$$

$$\frac{T^2}{4\pi^2} = \frac{l}{g}$$

$$g = \frac{4\pi^2 l}{T^2}$$

$$\ln g = \ln\left(\frac{4\pi^2 l}{T^2}\right)$$

$$\ln g = \ln 4 + \ln \pi^2 + \ln l - \ln T^2$$

$$\ln g = \ln 4 + 2\ln \pi + \ln l - 2\ln T$$

$$\frac{d(\ln g)}{dg} = \frac{d(\ln 4)}{d4} + 2\frac{d\ln(\pi)}{d\pi} + \frac{d(\ln l)}{dl} - 2\frac{d(\ln T)}{dT}$$

1 a)

$$\frac{\Delta g}{g} = \frac{\Delta l}{l} + 2\frac{\Delta T}{T}$$

Fractional Error in g; $\frac{\Delta g}{g} = \frac{\Delta l}{l} + 2\frac{\Delta T}{T}$

(ii) Periodic time (T) is the quantity which should measured more accurately because any error in time period is double when calculating error in g

(b) from,

Gain K.E = Loose in P.E

$$K.E_T = mgh$$

$$\text{but } K.E_T = K.E_r + K.E_T$$

$$K.E_r + K.E_T = mgh$$

$$\text{But, } K.E_r = \frac{1}{2} I \omega^2$$

$$K.E_T = \frac{1}{2} M V^2$$

$$\frac{1}{2} I \omega^2 + \frac{1}{2} M V^2 = mgh$$

$$\text{but, } \omega = \frac{V}{r}$$

$$\frac{1}{2} I \left(\frac{V}{r}\right)^2 + \frac{1}{2} M V^2 = mgh$$

$$\frac{1}{2} I \frac{V^2}{r^2} + \frac{1}{2} M V^2 = mgh$$

$$\frac{I V^2}{r^2} + m V^2 = 2mgh$$

$$\left(\frac{I}{r^2} + m\right) V^2 = 2mgh$$

$$V^2 = \frac{2mgh}{\frac{I}{r^2} + m}$$

$$V = \sqrt{\frac{2mgh}{I/r^2 + m}}$$

$m = 20\ kg$

$r = 0.2\ m$

$I = 0.4\ kgm^2$

$h = 3m$

$$V = \sqrt{\frac{2 \times 20 \times 9.8 \times 3}{\left(\frac{0.4}{(0.2)^2} + 20\right)}}$$

Velocity, $V = 6.26\ ms^{-1}$

$\therefore$ The speed of the body at the foot is $6.26 ms^{-1}$

Extract 1.1: *A sample of correct responses to Question 1 of Paper 1*

Extract 1.1 shows that, the candidate had adequate knowledge and mathematical skills about errors in measurement and conservation of energy and thus he/she provided the correct response.

On the other hand, more than a quarter of the candidates (28.6%) had inadequate knowledge of applying mathematical skills to solve the given question. Some candidates failed to deduce the fractional error in 'g' from the given formula. For example, one of the candidates failed to know that an error is always maximized, hence he/she wrote the fractional error in 'g' as $\frac{\Delta g}{g} = \frac{\Delta l}{l} - \frac{2\Delta T}{T}$ instead of $\frac{\Delta g}{g} = \frac{\Delta l}{l} + \frac{2\Delta T}{T}$. Others failed to recall that the periodic time varies directly proportional to the length of inextensible string. As a result, they failed to know that the quantity of time had to be measured most accurately because any error in period T causes a double error in the final answer. Most of them failed to interpret the energy changes of the object rolling down the inclined plane, as a result they failed to calculate the speed of the body. Extract 1.2 is a sample of a candidates' incorrect response to this question.

Q1. Solution.

(a)(i) $T = 2\pi\sqrt{\frac{L}{g}}$

Square both sides

$T^2 = (2\pi)^2\left(\sqrt{\frac{L}{g}}\right)^2$

$T^2 = \frac{4\pi^2 L}{g^2}$

(c) $g = \frac{2\pi}{T}\sqrt{L}$

apply ln both sides

$\ln g = \ln(2\pi) + \ln(\sqrt{L}) - \ln(T)$

$\ln g = \ln(2\pi) + \frac{1}{2}\ln(L) - \ln(T)$

Differentiate

$$\frac{\Delta g}{g} = 0 + \frac{1}{2}\frac{\Delta L}{L} + \frac{\Delta T}{T}$$

$$\frac{\Delta g}{g} = \frac{1}{2}\frac{\Delta L}{L} + \frac{\Delta T}{T}$$

ii) The quantity that should be measured most accurately is the acceleration due to gravity

Reason

This is because a small change in the acceleration due to gravity leads to a great change in the period.

Data given.

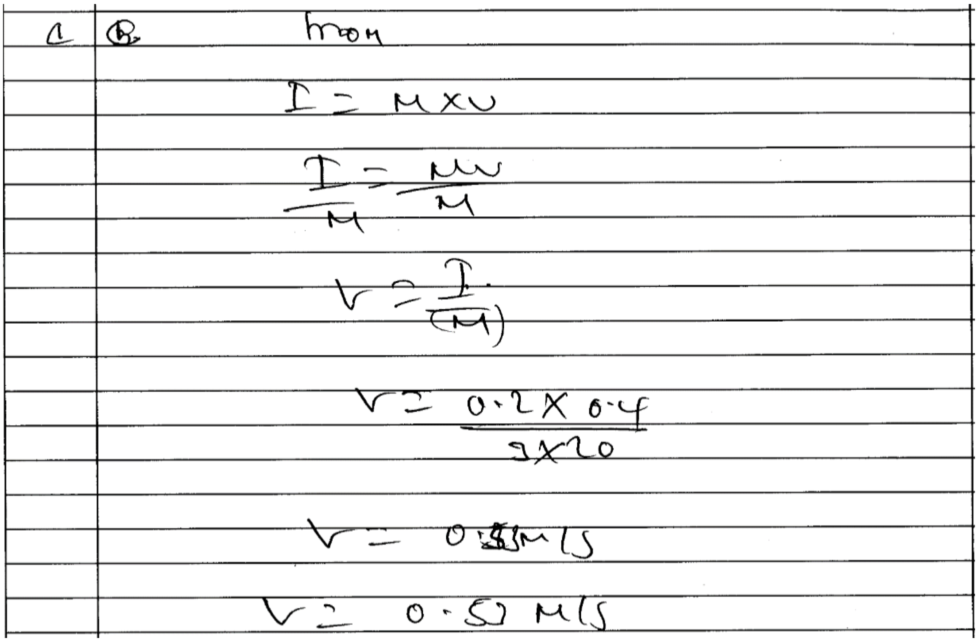
$M = 20\,kg$

$r = 0.2\,M$

Moment $= 0.4\,kg\,M^2$

$h = 3\,M$

but


a (b) mom

$I = M \times U$

$\frac{I}{M} = \frac{MU}{M}$

$V = \frac{I}{(M)}$

$V = \frac{0.2 \times 0.4}{3 \times 20}$

$V = 0.53 m/s$

$V = 0.53 m/s$

Extract 1.2: *A sample of incorrect responses to Question 1 of Paper 1*

Extract 1.2 indicates that the candidate applied a wrong formula and procedure to deduce fractional error in 'g' and the speed at the foot of the slope.

2.1.2 Question 2: Gravitation

The question had two parts, (a) and (b). In part (a), the candidates were required to (i) explain why bodies on the earth's surface do not move towards each other basing on Newton's law of universal gravitation, (ii) derive Kepler's third law using the law explained in a (i). In part (b), they were required to show that the moon would depart forever if its speed was increased by approximately 41%.

A total of 21,708 candidates attempted this question. The analysis of data as shown in Figure 2 indicates that almost a half of the candidates (50.5%) scored from 0 to 3.0 marks; 21.9 per cent scored from 3.5 to 5.5 marks and 27.6 per cent scored from 6.0 to 10 marks. This analysis indicates that the general performance of candidates in this question was average as 49.5 per cent of them scored from 3.5 to 10 marks. Figure 3 is a graphical presentation of the data.

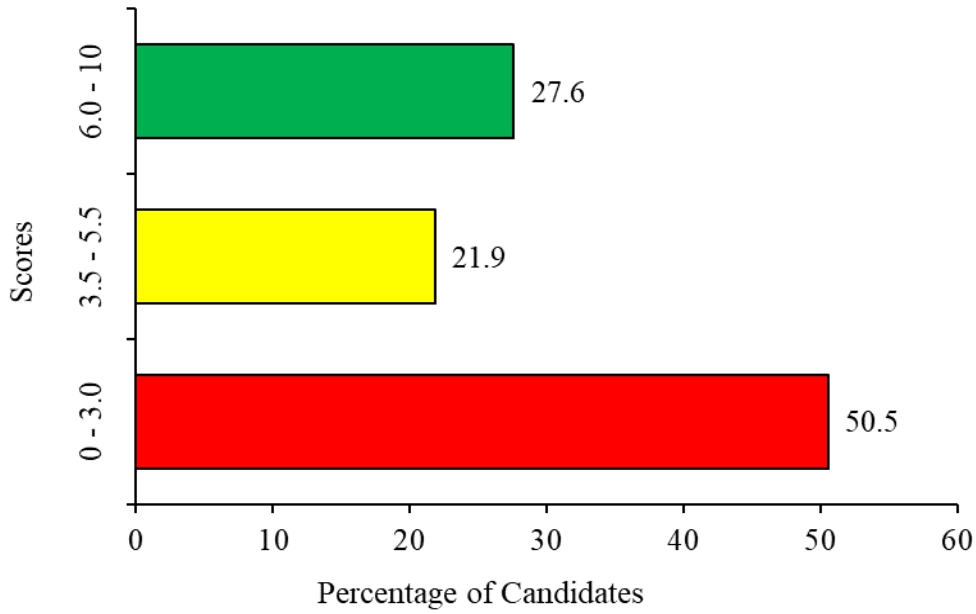


Figure 3: *The candidates' performance in Question 2 of Paper 1*

The candidates who performed averagely or above had adequate knowledge of gravitation. Some candidates used Newton's law of universal gravitation to explain why bodies on the earth's surface do not move toward each other. They knew that

> *"Due to very large mass of the earth, all the bodies lying on the surface are attracted towards the centre of the earth. However, the two bodies lying on the surface of the earth also attract each other. But owing to their small masses, they exert a force on each other, which is too small to cause any acceleration due to frictional force between the surface of the earth and the bodies"*.

Some candidates stated that centripetal force acting on the planet is provided by the sun's gravitational force on the planet. Then, they correctly used the Newton's law of universal gravitation to derive Keppler's third law. Those candidates used the relationship between centripetal force of the moon and the gravitation force of the moon to the earth to derive the formula of the escape velocity of the moon. A s a result, they correctly got the required percentage increase in velocity of moon as 41%. Extract 2.1 is a sample of the correct response to this question.

2 (a)(i) Bodies on the earth's surface do not move towards each other because have small mass so do not exert attraction forces compare to the heavinly body such as planets and sun or earth and sun it experience the gravitational force due to their large masses. This was explained by Newton's law of Universal gravitation which state that "every body in the universe attract to each other with the force which is directly proportional to the product of their masses and inversely proportional to the ~~dist~~ square distance between their Centres"

(ii) from

$$F \propto m_1 m_2$$

$$f \propto 1/r^2$$

$$F \propto \frac{m_1 m_2}{r^2}$$

$$F = \frac{K m_1 m_2}{r^2} \quad \text{where } K = G$$

$$F = \frac{G m_1 m_2}{r^2}$$

where m_1 = mass of the earth

m_2 = mass of the moon.

$$F = \frac{G m_1 m_2}{r^2}$$

$$F = \frac{M_2 v^2}{r}$$

$$\frac{M_2 V^2}{r} = \frac{G m_1 m_2}{r^2}$$

$$\frac{V^2}{r} = \frac{G m_1}{r^2}$$

2 (ii) (a)

$$v^2 = \frac{Gm_1}{r}$$

but $v = wr$.

$$(wr)^2 = \frac{Gm_1}{r}$$

$$w^2r^2 = Gm_1/r$$

$$w^2r^3 = Gm_1.$$

$$w^2r^3 = Gm_1$$

but $w = 2\pi/T$

$$\left(\frac{4\pi^2}{T^2}\right)r^3 = Gm_1.$$

$$4\pi^2r^3 = Gm_1T^2.$$

$$4\pi^2r^3 = Gm_1T^2$$

$$r^3 = \frac{Gm_1T^2}{4\pi^2}$$

$$\frac{Gm_1}{4\pi^2} = K$$

$$r^3 = KT^2.$$

$$T^2 \propto r^3.$$

Hence shown.

Keplers third law states that "The time period of the planet revolve around the sun is directly proportional to the radius of the cube". $T^2 \propto r^3$.

2 (b)

$$F = \frac{GM_EM_m}{R^2}.$$

$$\frac{M_mV^2}{R} = \frac{GM_EM_m}{R^2}$$

$$V^2 = \frac{GM_E}{R}$$

$$V = \sqrt{\frac{GM_E}{R}}$$

but $GM_E = gR^2$.

$$V = \sqrt{\frac{gR^2}{R}}$$

$$V = \sqrt{gR}$$

Orbital velocity $= v = \sqrt{gR}$.
escape velocity $v = \sqrt{2gR}$

$$\left(\frac{\sqrt{2gR} - \sqrt{gR}}{\sqrt{gR}}\right) \times 100\%$$

where $g = 9.8$ and $R = 6.4 \times 10^6$ m.

$$\frac{\sqrt{2 \times 9.8 \times 6.4 \times 10^6} - \sqrt{9.8 \times 6.4 \times 10^6}}{\sqrt{9.8 \times 6.4 \times 10^6}} \times 100$$

2 (b)

$$\frac{\sqrt{2 \times 9.8 \times 6.4 \times 10^6} - \sqrt{9.8 \times 6.4 \times 10^6}}{\sqrt{9.8 \times 6.4 \times 10^6}} \times 100\%$$

$$\frac{11200 - 7919.6}{7919.6} \times 100\% = 41.42$$

$$= \underline{41\%}$$

. Hence shown

Extract 2.1: *A sample of correct responses in Question 2 of Paper 1*

In Extract 2.1, the candidate got higher marks due to his/her ability of applying Newton’s law of universal gravitation. He/she derived correctly Keppler’s third law and showed that the moon would depart forever if its speed was increased by 41%.

On the other hand, the candidates who performed poorly failed to know that all the bodies lying on the earth’s surface are attracted towards the centre of the earth due to its larger mass but they exert a small force on each other due to their small masses. Few candidates recalled that the centripetal force acting on the planet is equal to gravitational force on the planet but they failed to apply it to derive Keppler’s third law. Most of the candidates derived the expression for velocity of the moon but failed to relate it to the escape velocity to obtain the percentage increase in velocity of the moon. For example, in equating the two forces, that is, centripetal force acting on the planet and gravitational force on the planet, one of the candidates substituted the acceleration in linear motion, $a = \frac{v}{t}$ instead of acceleration in circular motion, $a = \frac{v^2}{r}$, and thus failed to obtain the required expression. Extract 2.2 shows one of the incorrect responses to this question.

02. (a) (i) because the centripetal force balances with the force existing between bodies.

$$F_c = F_g.$$

$$\frac{mv^2}{r} = \frac{G m_e M}{r^2},$$

(ii) From the law which state that '' The force between two massive bodies is directly proportional to the product of their magnitude and inversely proportional to the square of the distance between their centre.

02 (a) (ii)

$$F \propto \frac{m_1 m_2}{r^2}.$$

$$F = \frac{G m_1 m_2}{r^2}.$$

$$F = \frac{G m_e M}{r^2}$$

where

F - is the force between two bodies,

Me - mass of the earth -

r^2 - is the distance of separation.

M - is the mass of a body.

Extract 2.2: *A sample of incorrect responses to Question 2 of Paper 1*

In extract 2.2, the candidate failed to apply Newton's law of gravitation and consequently got incorrect responses.

2.1.3 Question 3: Simple Harmonic Motion (S.H.M)

The question consisted of two parts, (a) and (b). In part (a), the candidates were required to (i) explain briefly the importance of energy interchange in simple harmonic motion and (ii) explain what would happen if the negative sign in the equation $a = -\omega^2 y$ is omitted as applied in simple harmonic motion. In part (b), they were required to calculate the maximum velocity and maximum potential energy of the object executing simple harmonic motion if it has a mass of 2 kg, frequency of 2 Hz and amplitude of 2.5 cm.

A total of 21,708 candidates answered this question. Among them, 22.4 per cent scored from 0 to 3 marks; 25.5 per cent scored from 3.5 to 5.5 marks; and 52.0 per cent scored from 6 to 10 marks. The performance was generally good as 77.6 per cent scored above 3.0 marks. Figure 4 is the graphical presentation of the candidates' performance in this question.

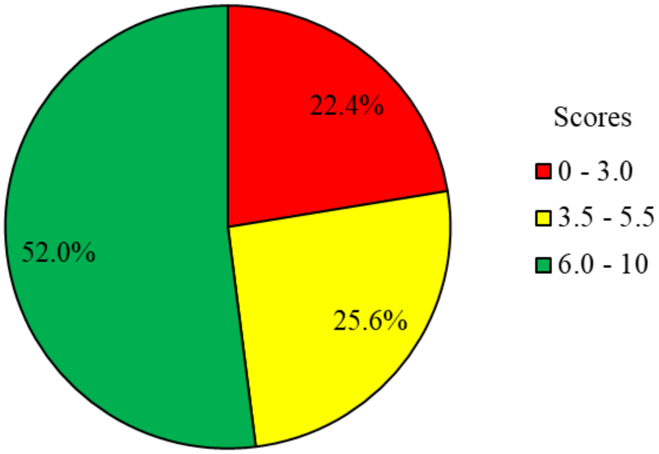


Figure 4: *The candidates' performance in Question 3 of Paper 1*

Most of the candidates who answered this question correctly explained correctly that the energy interchange in Simple Harmonic Motion produces and maintains oscillations of different nature. Some of the candidates understood the effect of omitting the negative sign in the equation $a = -w^2 y$ as applied in Simple Harmonic Motion. They explained that, *"if the negative sign is omitted the acceleration will increase in the direction of y and the object will then never return to its original position"*. They also recognised the positions where the maximum velocity and maximum height were attained by the body executing Simple Harmonic Motion. Thus, they applied their mathematical skills to compute correctly the maximum velocity and maximum potential energy. A total of 2,457 (11.3%) candidates who scored all marks allotted to the question provided the correct responses to all parts of the question. Extract 3.1 shows a sample of correct response from one of the candidates.

3 a)(i) Energy Interchange enables Conservation of total energy which inturn keeps a body in oscillatory motion between two extremes through an equilibrium position Hence a body Can execute S·H·M due to this energy Interchange.

ii) When negative Sign is omitted the equation will become. $a = \omega^2 y$. This means that the acceleration is directly to the displacement and both are in Same direction. This is against S·H·M. Hence a body will not execute S·H·M as acceleration is not directed towards equilibrium position.

b) Given; $m = 2kg$ $f = 2Hz$ $A = 2.5 \times 10^{-2} m$

$V_{max} = \omega A$ but $\omega = 2\pi f$

$= 2\pi f A$

$= 2\pi \times 2 \times 2.5 \times 10^{-2}$

$V_{max} = 0.314 ms^{-1}$

$\therefore$ Maximum Velocity, $V_{max} = 0.314 ms^{-1}$

$P.E_{max} = \frac{1}{2} kA^2$

but $k = m\omega^2$

$= m(2\pi f)^2$

$k = 4\pi^2 m f^2$.

$P.E_{max} = \frac{1}{2} \times 4\pi^2 \times 2 \times 2^2 \times (2.5 \times 10^{-2})^2$

$\therefore$ Maximum, $P.E_{max} = 0.0987 J$

Extract 3.1: *A sample of correct responses to Question 3 of Paper 1*

Extract 3.1 demonstrates how the candidate was competent in the concepts of Simple Harmonic Motion. He/she applied the formula of kinetic energy in solving the problems systematically and correctly.

Low achievers (22.4%) lacked knowledge of the Simple Harmonic Motion especially in part (a). Some of them failed to explain the importance of energy exchange in Simple Harmonic Motion. Others used wrong formulae to calculate the maximum velocity and maximum potential energy. Some of the candidates used $v_{max} = \omega^2 y$ instead of $v_{max} = \omega^2 A$ and potential energy = mgh instead of $P.E = \frac{1}{2}m\omega^2A^2$. Extract 3.2 shows a sample of incorrect responses.

03 (a)

(i) It help to return the body to the mean position, and keeping it oscillations.

(ii) The acceleration would move is opposite to the direction of displacement.

(b) Given,

Mass = 2kg.

Frequency = 2Hz.

Amplitude = 2.5cm = 2.5×10^{-2}m

From

$V_{max} = w^2y$.

but

$w = 2\pi f = 2\pi\times2 = 4\pi$.

$V_{max} = (4\pi)^2 \times 2.5\times10^{-2}$m.

$= 3.947841760$ m/s

$= 3.9478$ m/s.

$\therefore$ Maximum velocity = 3.9478 m/s.

03. (b)

Max. potential energy.

From.

Potential energy = mhg.

$= 2\,kg \times 2.5\times10^{-2} \times 9.8\,m/s^2$

$= 0.49$ Joules.

$\therefore$ Maximum potential energy $= 0.49$ Joules

Extract 3.2: *A sample of incorrect responses to Question 3 in Paper 1*

Extract 3.2 shows that the candidate lacked knowledge of SHM especially the interpretation of negative sign in the equation $a = -w^2 y$. He/she also used a wrong formula to determine the maximum velocity energy and potential energy.

2.1.4 Question 4: Newton's Laws of Motion and Projectile Motion

The question was comprised of two parts, (a) and (b). Part (a) required the candidates to (i) give reasons why the aircraft twists its wings as it prepares to land and (ii) give the effect on the horizontal range for a given projection of angle θ if its initial velocity is doubled. In part (b), they were required to show that $\frac{H}{R} = \frac{1}{4}\tan\beta$ whereas H, R and β are the maximum height, range and an angle above the horizontal respectively, for a projectile fired from the ground level.

This question was attempted by 100 per cent of the candidates. The results indicate that 11.7 per cent of the candidates scored from 0 to 3.0 marks; 39.4 per cent scored from 3.5 to 5.5 marks; and 48.9 per cent scored from 6.0 to 10 marks. The analysis shows that the general performance of the candidates in this question was good as 88.3 per cent performed well. Figure 5 summarizes the performance of the candidates in this question.

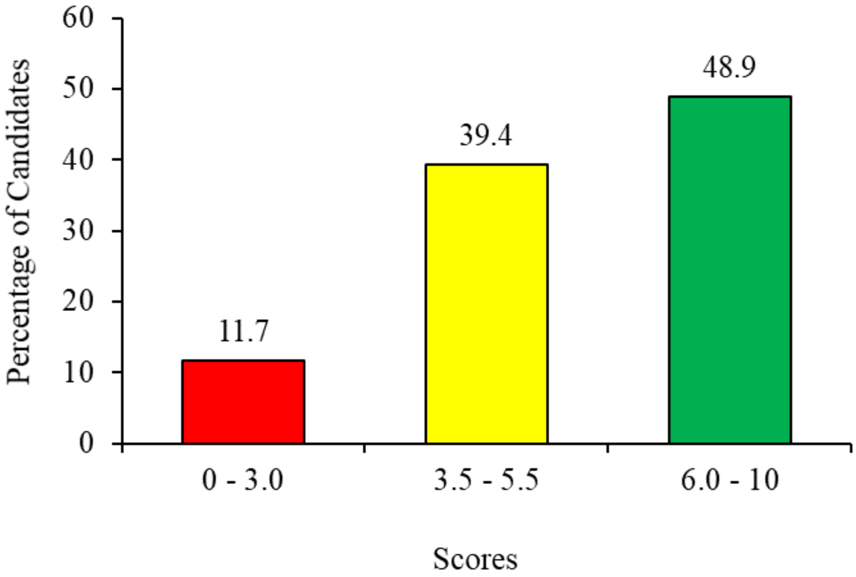


Figure 5: *The candidates' performance in Question 4 of Paper 1*

Candidates who performed well in this question were knowledgeable enough to give the correct responses. In part (a) (i), most of the candidates in this category correctly explained why the aircraft twists its wings as it prepares to land. In part (b) (ii), they provided the effect on the horizontal range for a given projection of angle θ if its initial velocity is doubled as *"if the initial speed v_o is doubled, the horizontal range will be four times its initial value. Note that θ and g are constant"*. Moreover, in part (b), they applied mathematical skills to deduce correctly the expressions for maximum height and horizontal range and then divided the two expressions to get $\frac{H}{R} = \frac{1}{4}\tan\beta$. Extract 4.1 is a sample of the correct response.

4 (a) (i) Air craft twists its wings to reduce the surface area hence reduce the upward force (~~pressure~~) and thus allow it to land on the ground easily. This force is due to air resistance which is decreased necessarily for the craft to land.

(ii) soln

Horizontal Range $= \dfrac{U^2 \sin 2\theta}{g}$

If, $U_0 = 2U_0$

If U is doubled,

$$R = \frac{(2U_0)^2 \sin 2\theta}{g}$$

$$R_f = \frac{4U_0^2 \sin 2\theta}{g}$$

$$R_f = 4\left(\frac{U_0^2 \sin 2\theta}{g}\right)$$

But $\dfrac{U_0^2 \sin 2\theta}{g} = R_0$

$$R_f = 4R_0.$$

— Thus, if the initial velocity is doubled its Range will be four times its initial Range (horizontal range)

(b) soln

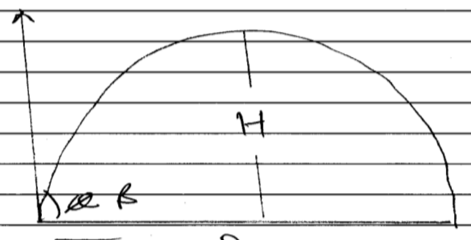
required to show $H/R = \frac{1}{4} \tan B$,

given,

H, — maximum height

R — range

B — angle, thus,



where $\theta = B$.

4. (b) from,

$$R = \frac{U^2 \sin 2\theta}{g} \quad \text{— (i)}$$

But

$$H = \frac{U^2 \sin^2 \theta}{2g} \quad \text{— (ii)}$$

Dividing the two equation (i) ÷ (ii)

$$R/H = \frac{U^2 \sin 2\theta}{g} \times 2g / U^2 \sin^2\theta$$

$$R/H = \frac{2 \sin 2\theta}{\sin^2\theta}$$

But $\sin 2\theta = 2 \sin\theta \cos\theta$

$$R/H = \frac{4 \sin\theta \cos\theta}{\sin^2\theta}$$

$$R/H = \frac{4 \cos\theta}{\sin\theta}$$

$$H/R = \frac{\sin\theta}{4\cos\theta}$$

$$H/R = \frac{\tan\theta}{4}$$

where $\theta = \beta$.

$$\therefore H/R = \frac{\tan\beta}{4}$$

Hence shown.

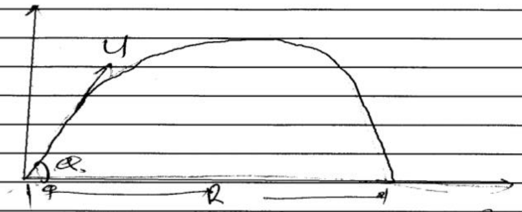
Extract 4.1: *A sample of correct responses in Question 4 of Paper 1*

In extract 4.1, the candidate met the requirements of the question by attempting all parts precisely and correctly.

Low achievers (11.7%) in this question were not knowledgeable of the effect of aircraft to twist the wings when preparing to land. They were not aware that when the aircraft prepares to land it twists its wings to reduce the pressure below its wings and hence, momentarily reduce the upthrust. Some of the candidates failed to interpret the expression for horizontal range for a projected body. As a result, they failed to explain that if the initial speed v_o is doubled, the horizontal range would be four times its initial value. Furthermore, they were unable to relate the equation for range for the projected body to its maximum height to get the required expression in part (b). Extract 4.2 shows a sample of incorrect responses from a candidate.

4(a)(i) The aircraft twists its wings in order to reduce the radius from the centre of the craft to the end point of the wings hence reducing the craft's moment of inertia (I) as Moment of inertia $(I) = MR^2$.

4(a)(ii)



From 2nd eqn of motion:

$s = ut + \frac{1}{2}at^2$.

$R = u_x t + \frac{1}{2}(0)t^2$.

$R = u_x t$.

But $u_x = u\cos\alpha$.

$R = u\cos\alpha \cdot t$.

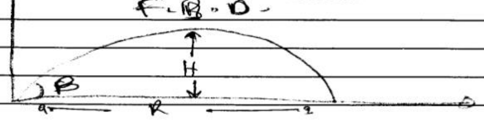
So, when $u' = 2u$

$R = u'\cos\alpha t$.

$R = 2u\cos\alpha t$.

When the initial velocity is double also the horizontal range is doubled.

4(b). Solution.



Thus

$$R = u_x t.$$

$$H = -\tfrac{1}{2} g t^2$$

$$\frac{H}{R} = \frac{\tfrac{1}{2} g t^2}{u_x t}$$

$$H/R = \frac{gt}{2u_x}$$

But; $u_x = u\cos\beta$

$$H/R = \frac{gt}{2u\cos\beta}$$

But $t = \dfrac{v_y - u_y}{2a_y} = \dfrac{\cancel{0} - u\sin\beta}{g}$

$$H/R = \frac{\dfrac{\cancel{g} \times -u\sin\beta}{2\cancel{g}}}{2u\cos\beta}$$

$$H/R = \frac{u\sin\beta}{4u\cos\beta}$$

$$H/R = \tfrac{1}{4}\tan\beta.$$

$$\therefore H/R = \frac{\tan\beta}{4}$$ Hence shown

Extract 4.2: *A sample of incorrect responses to Question 4 of Paper 1*

Extract 4.2 shows that the candidate lacked knowledge of the key concepts in projectile motion, specifically general formulae for range and maximum height.

2.1.5 Question 5: Heat and Thermodynamics

The question consisted of two parts namely (a) and (b). In part (a), the candidates were required to (i) with the aid of a relevant diagram give reasons, why lake water in very cold regions does not freeze completely into ice even if the temperature in it is far below the freezing point and (ii) give biological significance of the behaviour observed in part (a) (i). In part (b), they were required to calculate the time taken to raise the temperature of water to 100 ºC if one litre of pure water at 25 ºC was poured into an electric kettle of negligible heat capacity rated 2.5 kW when the electric kettle is switched on.

The analysis indicates that 21708 (100%) candidates attempted the question and their scores were as follows: 49.6 per cent scored from 0 to 3 marks; 22.5 per cent scored from 3.5 to 5.5 marks; and 27.9 per cent scored from 6 to 10 marks. The performance in this question was average as 50.4 per cent of the candidates were able to score above 3.5 marks or more. Figure 5 summarises the analysis of the candidates' performance in question 5.

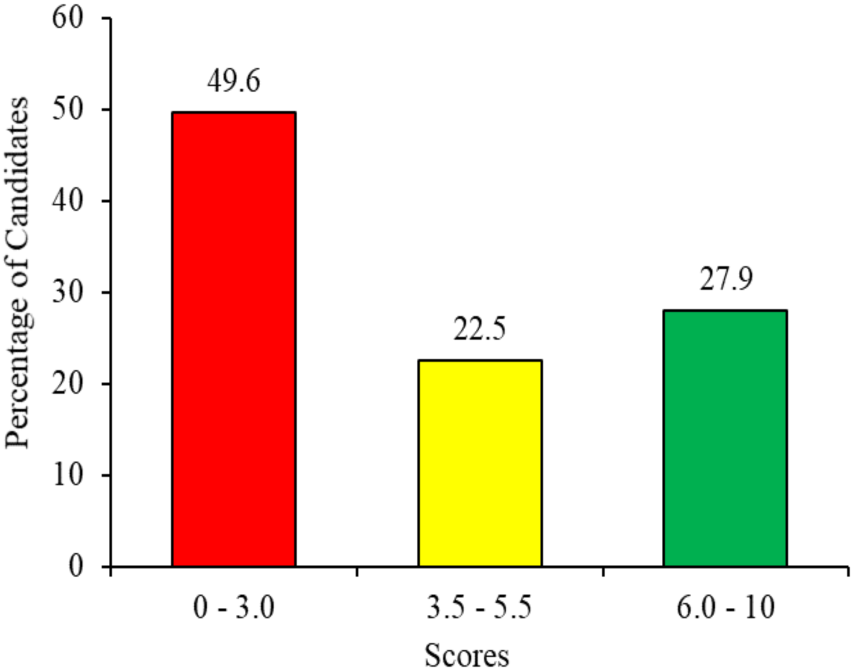
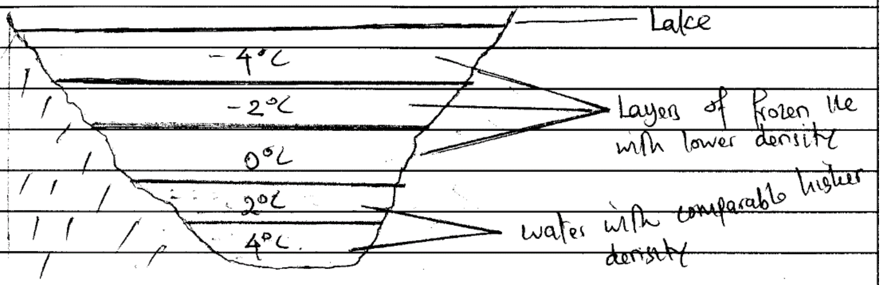


Figure 6: *The candidates' performance in Question 5 of Paper 1*

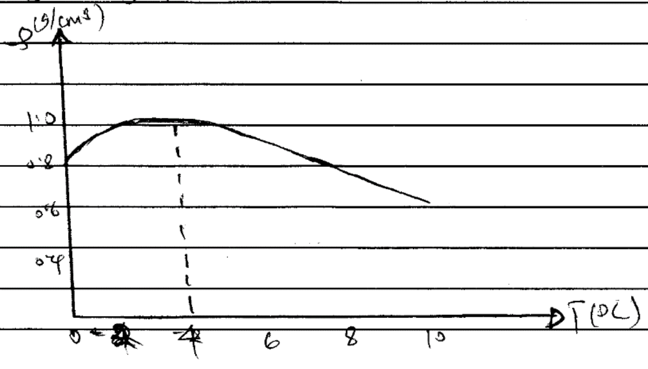
The candidates who scored high marks provided correct reason for water in very cold regions not to freeze completely into ice even if the temperature in it is far below the freezing point. Furthermore, they correctly stated the biological significance of the anomalous behaviour of water. Some were skilful enough to use the principle of conservation of energy to relate the electrical energy supplied by the electric kettle and heat energy that raised the temperature. Therefore, they computed correctly the time taken to raise the temperature of water. Extract 5.1 is a sample of a candidate's correct response.

5. a) i) This is because water at the bottom of the lake being at temperature of almost (4°C) has the highest maximum density hence settling at the bottom allowing the ice being having less density to float over the water hence the whole water cannot freeze. This occurs due to anomalous expansion of water whereby its density decreases as it is being cooled, and it is being frozen thus ice has lower density than water. Its density becomes maximum at 4°C and it then decreases when temperature is increased more. Consider the following diagram



⇒ from the diagram it shows clearly on how the various layers of ice increase in density as the temperature is increased.

The variation of density of water with temperature can be shown by the graph below



5. a) (ii) Anomalous expansion of water enhances the aquatic life by keeping fish and other aquatic animals alive during the seasons of very ~~lo~~ low temperature whereby they all go at lowermost depth of the lake where there is water and they can survive

b) soln

from

$H = mc\Delta T$

$\text{Power} = \frac{H}{t} = \frac{mc\Delta T}{t}$

$P = \frac{mc\Delta T}{t}$

$t = \frac{mc\Delta T}{P}$, $c = 4200 J kg^{-1} K^{-1}$

$\Delta T = (100-25)°C = 75°C$

$P = 2.5 kW = 2500 watts$

$m = \rho V = \frac{1}{1000} m^3 \times 1000 kg m^{-3}$

$m = 1 kg$

$t = \frac{1 kg \times 4200 J kg^{-1} K^{-1} \times 75 K}{2500 J/s}$

$= 126$ seconds

Time = 126 seconds

Extract 5.1: *A sample of correct responses to Question 5 of Paper 1*

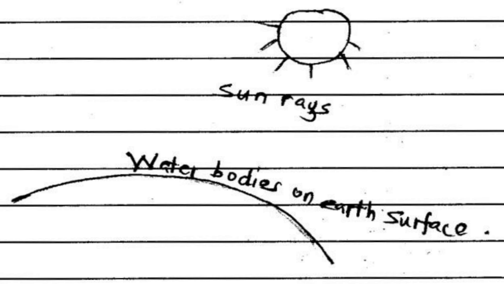
Extract 5.1 shows that the candidate had adequate knowledge of the anomalous expansion of water and the principle of conservation of energy that helped him/her to present the correct response to the question.

On the other hand, the candidates who performed weakly in this question lacked prior knowledge of thermal expansion of liquids. Some of the candidates in this category were not aware that lake water in cold regions does not freeze completely due to its anomalous behaviour. That means water does not expand between 0 ºC and 4 ºC, instead it contracts. It expands above 4 ºC where its density is maximum (water has maximum density at 4 ºC). For example, one of the candidates wrote:

> *"the water will being at triple point where it can be obtained in all three states of matter solid, liquids and vapour. This because, the deeper water will be hot the middle will be ice like and the upper will be vaporizing".*

These candidates failed to know that the triple point of water is the temperature and pressure at which a substance can exist in equilibrium in the liquid, solid, and gaseous states. They were supposed to explain that *when temperature falls, the top layer of water in a lake contracts, becomes denser and sinks to the bottom. A circulation is thus set up until the entire water in the lake reaches its maximum density at 4 °C".* Most of those candidates drew incorrect diagrams that resulted in giving incorrect reasons. In part (ii), they failed to know that anomalous expansion of water helps to preserve aquatic life during very cold weather. In part (b), some of the candidates used incorrect formulae due to failure to use the principle of conservation of energy to establish the relation between electrical energy supplied by the electric kettle and heat energy which raised the temperature. Extract 5.2 shows the response of a candidate who lacked knowledge of anomalous expansion of water.

5; (a) (i) Lake water at very high cold regions does not freeze completely in to ice even if temperature fall below freezing point because the sun rays its directed to the water surface therefore it lowers the water temperature so due to sun rays the water do not freezed.



(ii) The sun rays ~~...~~ which is directed to the water surface it lower the freezing temperature of the water so it helps to mantains constant body tempertures of some living organisms which lives in the water.

(b) Solution.

Temperature 25°C

$P = 2.5KW \Rightarrow 2500\ W$

Required time taken to raise temperature to 100°C

$C = 1$

from Mass of water = Density × Volume

$1000 Kgm^{-3} \times 1\times10^{-3} m^3$

mass of water = 1Kg.

from $\frac{power}{time} = m c \Delta T$

$time = \frac{power}{m c \Delta T}$

~~7~~ 9365

5; (b) $time = \frac{power}{mc\Delta T}$

$\frac{2500}{1 \times 1 \times (100-25)}$

$= 33.33$ seconds.

Extract 5.2: *A sample of incorrect responses to Question 5 of Paper 1*

In Extract 5.2, the candidate provided incorrect responses to all parts of the question. The candidate lacked knowledge of anomalous expansion of water. He/she applied a wrong formula to determine the time to raise the temperature of water.

2.1.6 Question 6: Heat and Thermodynamics

The question consisted of two parts, (a) and (b). In part (a), the candidates were required to calculate the external work done by the gas given that an ideal gas of volume 0.05 m^3 initially at $27\,^{\circ}C$ and pressure $1.0\times10^5 Pa$ was heated at constant pressure until its volume increased to 0.06 m^3. In part (b) the candidates were tasked to find the actual length of a steel rod having 5 cm longer than a copper rod if their difference in length was maintained constantly at any temperature.

A total of 21,707 candidates attempted this question and their scores were as follows: 31.4 per cent scored below 3 marks, including 21 per cent who scored 0; 30 per cent scored from 3.5 to 5.5 marks and 35.1 per cent scored from 6 to 10 marks. These scores suggest that the candidates' performance in this question was good as 65.1 per cent of them scored from 3.5 to 10 marks. Figure 7 presents a summary of the candidates performance.

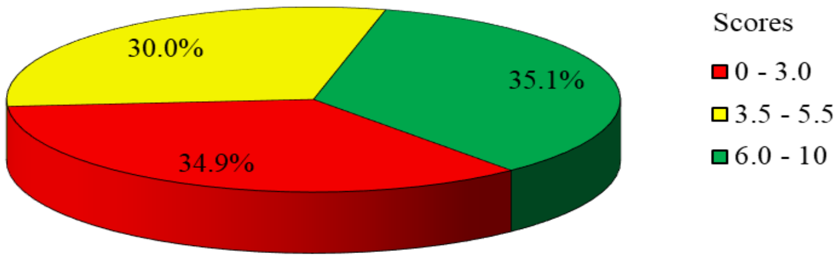


Figure 7: *The candidates' performance in Question 6 of Paper 1*

Most of the candidates who scored from 6 to 10 marks applied the concept of the first law of thermodynamics to organise the data and compute the external work done by the gas in part (a). In part (b), they were able to interpret the given task by formulating and equating two equations related to linear expansion of steel and copper when heated. Further, they applied the given values of coefficient of linear expansion of steel and copper to evaluate the actual lengths of two rods. However, some of the candidates who scored average marks failed to describe correctly the concepts tested. Extract 6.1 is a sample of the correct responses.

6 (a) Data given;

- Initial volume $(V_1) = 0.05 m^3$
- Initial temperature $(T_1) = 27°C$
  $= (273 + 27)K$
  $= 300K.$
- Pressure of a gas $(P) = 1 \times 10^5 Pa$
- Final volume $(V_2) = 0.06 m^3$

required; the external workdone by the gas.

from, Workdone $= P \times dV$

$W = P \, dV$

$W = P (V_2 - V_1)$

$W = 1 \times 10^5 Nm^{-2} \times (0.06 m^3 - 0.05 m^3$

$W = 1000J.$

∴ The amount of external work done by the gas is 1000J.

6(b) let, x be length of copper rod

y be length of steel rod.

given that, $y = 5cm + x$

required: to find the values of x and y.

6(b) also given, $\alpha_{copper} = 1.1 \times 10^{-5}\ K^{-1}$

$\alpha_{steel} = 1.7 \times 10^{-5}\ K^{-1}$

recall,

$$\alpha = \frac{\Delta L}{L_0 \Delta T}.$$

since $\frac{\Delta L}{\Delta T}$ = constant

$$\alpha_s y_0 = \alpha_c x_0.$$

$$\alpha_s (x_0 + 5cm) = \alpha_c x_0.$$

$$1.1 \times 10^{-5} (x_0 + 5cm) = 1.7 \times 10^{-5} x_0.$$

$$1.1 \times 10^{-5} x_0 + 5.5 \times 10^{-5} cm = 1.7 \times 10^{-5} x_0.$$

$$5.5 \times 10^{-5} cm = 0.6 \times 10^{-5} x_0$$

$$x_0 = 9.167\ cm\ (\text{copper}).$$

then $y_0 = 5cm + 9.167cm$

$y_0 = 14.167\ cm.$ (steel).

$\therefore$ The original (actual) length of steel rod = 14.167 cm and that of copper rod is 9.167cm.

Extract 6.1: *A sample of correct responses to Question 6 of Paper 1*

In Extract 6.1, the candidate applied the concepts of thermodynamic process and thermal expansion to obtain the correct responses to parts (a) and (b).

On the other hand, 4568 (21%) candidates who scored 0 lacked mathematical skills for analysing the examined concepts. Most of them faced challenges in describing the applications of thermal conduction in domestic and industrial activities as they failed to analyse the given tasks correctly. In addition, some of the candidates applied the concepts of the first law of thermodynamics and thermal expansion of solids interchangeably, and thus ended with incorrect responses. Extract 6.2 shows incorrect responses given by one of the candidates.

6(a) Given

$V_1 = 0.05\,m^3$

$V_2 = 0.06\,m^3$

$P = 1 \times 10^5\,Pa$

$T = 27^oC = 300K$

soln

from ideal gas equation

$PV = nRT$

$n = \frac{PV_1}{RT}$

$n = \frac{1 \times 10^5 \times 0.05 m^3}{8.314 \times 300K}$

$n = 2.0046$ moles

Workdone.

$W = nRT \ln\left(\frac{V_2}{V_1}\right)$

$= 2.0046 \times 8.314 \times 300 \times \ln\left(\frac{0.06}{0.05}\right)$

$W = 911.5KJ$

(b) Given

~~Lsteel = (5 + Lcu) cm~~

soln

$\cancel{\alpha = \frac{\Delta L}{L\Delta T}}$

6(b) $\alpha cu = \frac{\Delta Lcu}{Lcu \cdot \Delta T}$, $\alpha\, steel = \frac{\Delta Lsteel}{Lsteel \cdot \Delta T}$

$\Delta Lcu = \Delta Lsteel - 5$

$\alpha cu \cdot Lcu = (\alpha steel \cdot Lsteel) - 5$

$(\alpha steel \cdot Lsteel) - (\alpha cu \cdot Lcu) = 5$

$1.7 \times 10^{-5}(Lcu + 5) - 1.1 \times 10^{-5} Lcu = 5$

$1.7 \times 10^{-5} Lcu + 8.5 \times 10^{-5} - 1.1 \times 10^{-5} Lcu = 5$

$0.6 \times 10^{-5} Lcu + 8.5 \times 10^{-5} = 5$

$0.6 \times 10^{-5} Lcu = 4.99$

$Lcu = \cancel{833.319\,m}\ 8333.19m$

$Lsteel = Lcu + 5$

$= \cancel{833.319m + 0.05m}\ 8333.19 + 0.05$

$Lsteel = \cancel{833.369m}\ 8333.24m$

Extract 6.2: *A sample of incorrect responses to Question 6 of Paper 1*

In Extract 6.2, the candidate applied the ideal gas equation $PV = nRT$ and the formula $W = nRT \ln\left(\frac{V_2}{V_1}\right)$ instead of the correct formula Work done $= P\left(V_2 - V_1\right)$ to find the external work done. In part (b), he/she failed to equate correctly the two formulae in describing the coefficient of linear expansion of solid as a result they ended with incorrect lengths.

2.1.7 Question 7: Environmental Physics

The question consisted of two parts (a) and (b). In part (a), the candidates were required to (i) identify two principles on which the wind turbine operates to generate electrical energy and (ii) give reasons for renewable energy sources being regarded as environmental friendly by using two examples. Part (b) required the candidates to (i) state the influence of oxygen and carbondioxide gases to plant growth and (ii) explain the effect of rainfall on the renewal of soil air.

The question was attempted by 21,707 candidates whose scores were as follows: 25.8 per cent scored from 0 to 3 marks, 32.1 per cent scored from 3.5 to 5.5 marks and 42.1 per cent scored from 6 to 10 marks. These scores imply that the general performance in this question was good as 74.2 per cent scored from 3.5 to 10 marks. Figure 8 is a graphic representation of these scores.

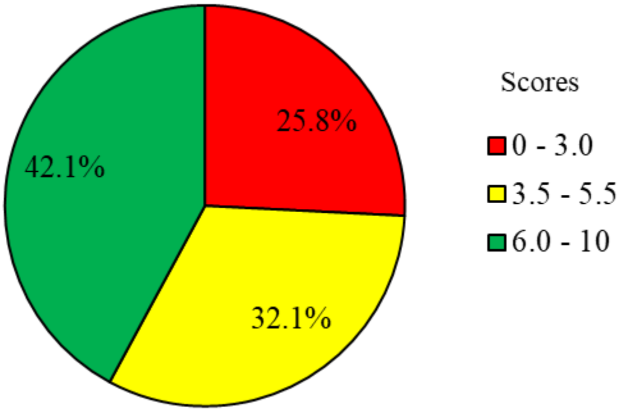


Figure 8: *Distribution of candidates' performance in Question 7 of Paper 1*

The analysis of candidates' responses reveals that those who scored high marks had good understanding of the principle on which wind turbine operates to generate electric energy. In addition, they provided enough reasons for renewable energy to be regarded as environmentally friendly. For example, one candidate wrote that *'Renewable energy sources (e.g. Biogas and Sunlight) are environmentally friendly because it releases few chemicals that can harm the environment i.e they have minimal adverse effect to environment'*. Such a response suggest that the candidate had sufficient knowledge about sources and types of pollutants in the environment. Furthermore, most of them were able to provide the role played by oxygen and carbondioxide in plant growth as well as the effect of rainfall on the renewal of soil air, as illustrated in Extract 7.1.

7 (a) Principles
(i) Principle of Conservation of energy
That is energy Can be transformed from kinetic energy of wind to electrical energy
(ii) Principle of electromagnetic induction, rotation of motor by turbines generated electric current

7 (ii) Renewable Source of energy are environmental friendly because
(i). They do not pollute environment or do not bring negative effects on environment.
Example
Solar energy and wind Wind energy
- Also renewable source of energy does not get exhausted over a time.

7 (b) • Positive influence of Oxygen to plant
— Oxygen is used for respiration which enable plants to obtain energy for growth. and metabolic activities.

Negative influence
— Oxygen Cause photorespiration which decrease plant yield and affect plant growth.
— Oxygen Cause decline in process of photosynthesis by inhibiting enzymes.

• Positive influence of Carbondioxide
— It is a raw material for photosynthesis hence it increase plant yield and growth.

(b)(ii) Rainwater fill the pores in the soil and replace air previously contained in a soil hence removed air is replaced by another thus it results into renewal of soil air.

Extract 7.1: *A sample of correct responses to Question 7 of Paper 1*

In Extract 7.1, the candidate identified the principles guiding how wind turbine operates to generate electrical energy. Consequently, to some extent, he/she explained correctly renewable energy sources, the role of oxygen and carbondioxide to plant growth and the effect of rainfall on the renewal of soil air.

However, those candidates who performed weakly lacked mastery of proper concepts in the topic of *Environmental Physics*. This made some of them fail to identify the principles on which the wind turbine operates. Consequently, they failed to recognise that renewable energy sources (e.g. Biogas and Sunlight) are regarded as environmentally friendly because they have minimal adverse effect to environment. Some of them failed to recall that oxygen is required for the respiration of plant roots, microbes and soil fauna (wildlife) while carbondioxide is essential for photosynthesis. They were also unable to argue that the entry of rain water into the soil causes movement of water in it, which results in the displacement of soil air from the pores. The water is subsequently displaced by fresh air resulting in the renewal of soil air. Extract 7.2 is the sample of a candidate's incorrect responses to the question.

7(a)	Renewable energy sources can be regarded as environmental friendly since can be recycled and stored for future uses.
-	Renewable energy
7(b)	
-	Oxygen is important since it acts as a requirement for manufacturing of food
-	Carbondioxide is important since it is used as an energy source for performing of various metabolic activities
(ii)	
-	Rainfall creates a porous environment such that cations essential for fertility are absorbed back by ionic exchange.
-	Rainfalls also improves the soil pH by balancing the pH when its too low or high.

Extract 7.2: *A sample of the incorrect responses to Question 7 of Paper 1*

In Extract 7.2, the candidate provided the incorrect responses to all parts of the question, showing that he/she lacked knowledge of environmental physics.

2.1.8 Question 8: Current Electricity

This question had three parts: (a), (b) and (c). Part (a) required the candidates to (i) explain how a fuse is used to protect electrical installations and (ii) why bulbs in a house became dim when high power heater is connected to the main supply. In part (b), they were required to (i) calculate the number of electrons passed through the filament bulb when a current of 0.5 A passes through a light bulb rated 40 W if the charge on electron is 1.6×10^{-19}C and (ii) use Kirchhoff's voltage law to determine the voltage between point 'a' and 'b' as shown in Figure 2.

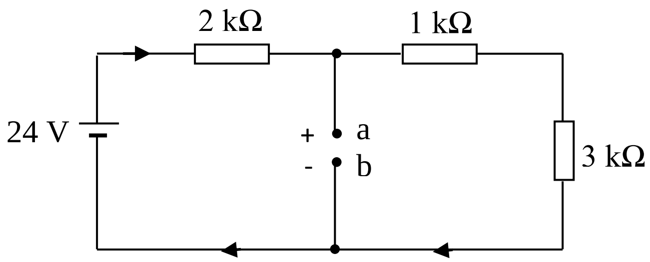


Figure 2

Part (c) required the candidates to study the circuit diagram in Figure 3 and then determine (i) the value of E such that a current of 0.5 A existed in 8 Ω resistor with a sense from 'a' and 'b' and (ii) the potential difference V_a-V_b.

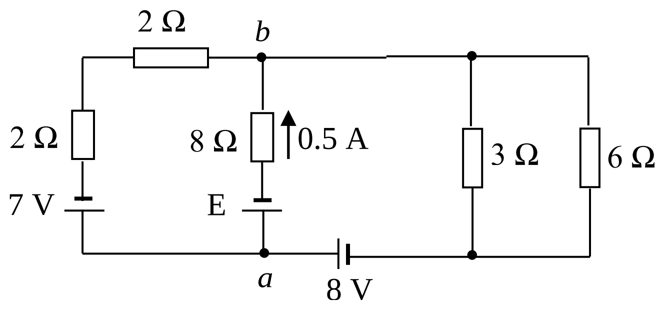


Figure 3

The question was answered by 4,418 candidates, which correspond to 20.3 per cent. The analysis reveals that 46.1 per cent of the candidates scored 0 to 5 marks; 33.4 per cent scored 5.5 to 8.5 marks and 20.5 per cent scored 9 to 15 marks. These data are summarised in Figure 9.

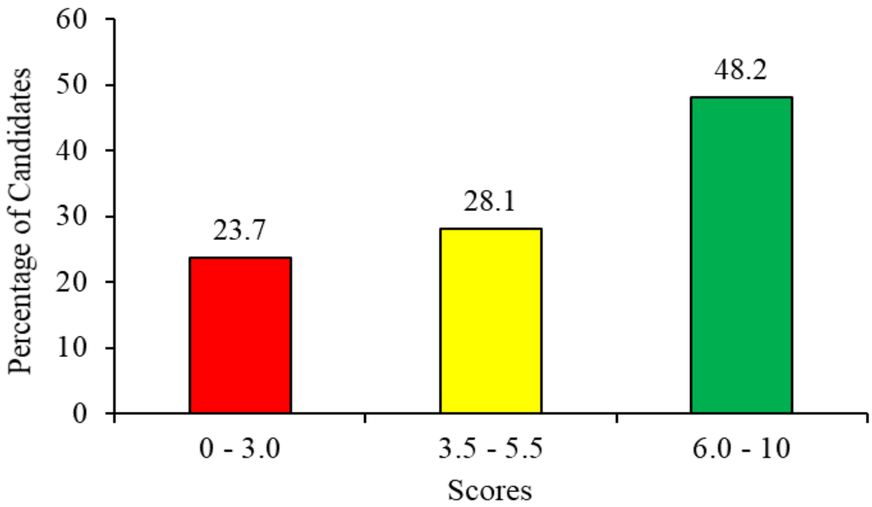


Figure 9: *Distribution of candidates' scores in Question 8 of Paper 1*

Figure 9 shows that the candidate's performance in this question was average since 53.9 per cent of the candidates scored 5.5 to 15 marks.

The candidates who scored high marks stated correctly the working mechanism of a fuse in protecting an electrical installation. They also provided the reason why bulbs in a house become dim when a high power heater is connected to the main supply. In addition, about 1.0 per cent corresponding to 44 candidates scored 14.5 to 15 marks. These candidates showed their mathematical skills in using Kirchhoff's laws of electrical networks to determine the values of electromotive force, E, voltage and potential difference V_a - V_b. Extract 8.1 illustrates a sample of the correct responses.

8. (a) (i). A fuse protect electrical installations by switching off current flow in the electrical installation once excessive current passes through it causing it to blow out. A fuse is designed to allow the passage of the maximum value (labelled value) and that below this but not above. In this way it protects electrical installation by limiting/preventing the passage of excess current by blowing out and cutting the current flow.

(ii). The bulb in a house become dim when high power heater is connected to the main supply since it has high wattage and therefore draws large current from the supply and therefore reducing the current through the bulb. Because the current reduces through the bulb it lights with dim light intensity.

(b) (i) Given

current (I) = 0.5A

power (P) = 40W

electron charge (e) = 1.6×10^{-19} C

Number of electron N = required.

from $I = \text{Quantity of charge } (Q) \times \frac{1}{\text{time}(t)}$

$$I = \frac{Ne}{t}$$

8 (b).(i).

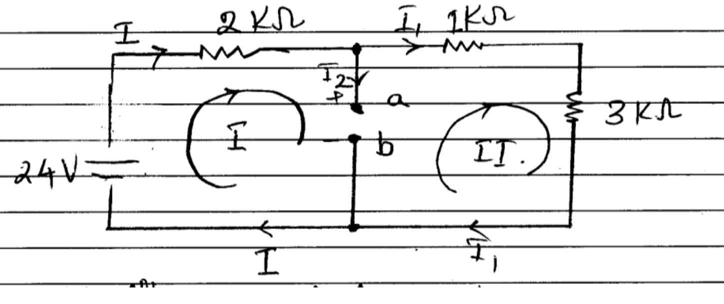
$$\frac{N}{t} = \frac{I}{e}$$

$$\frac{N}{t} = \frac{0.5\ A}{1.6 \times 10^{-19}\ C}$$

$$\frac{N}{t} = 3.125 \times 10^{18} \text{ electrons/second}$$

∴ 3.125×10^{18} electrons pass through the bulb in one second

(ii). Consider the diagram below



Kirchhoff's current law KCL:

$I = I_1 + I_2$

Applying Kirchhoff's voltage law KVL to loop I

$24V - 2000I - Va + Vb = 0$

$24 - 2000I_1 - 2000I_2 - Va + Vb = 0$ —(i)

Applying KVL to Loop II

$Va - 1000I_1 - 3000I_1 - Vb = 0$

$Va - Vb = 4000I_1$. —(ii)

8 (b) (ii). Total resistance $R = 2000\Omega + 1000\Omega + 3000\Omega$

$R = 6000\Omega$.

$\therefore I = \frac{24}{6000} A$

$I = 4 \times 10^{-3} A$.

Taking (ii) → (i)

$24 - 2000I_1 - 2000I_2 = 4000I_1$

or $6000I_1 + 2000I_2 = 24$ —(a)

Also $I_1 + I_2 = 4 \times 10^{-3}$ —(b)

solving (a) and (b) simultaneously we have

$I_1 = 4 \times 10^{-3}$ A

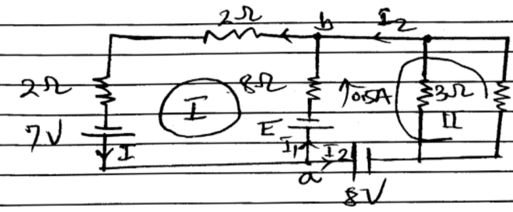
$I_2 = 0$ A.

$Va - Vb = 4000 \times 4 \times 10^{-3} V$

$Va - Vb = 16 V$

The potential difference between points a and b is 16V

8 (c). consider the circuit diagram below



equivalent resistance on the right

$R = \frac{3 \times 6}{3+6} \Omega = 2\Omega.$

By KCL:

$I = I_1 + I_2$

$I = 0.5 + I_2$

Applying KVL to loop I:

$7 - E - 8 \times 0.5 - 2I - 2I = 0$

$3 - E - 4I = 0$

$3 - E - 2 - 4I_2 = 0$

$1 - E - 4I_2 = 0 \Rightarrow E + 4I_2 = 1$ —(i)

Applying KVL to loop II:

$E - 8 - 2I_2 + 8 \times 0.5 = 0$

$E - 2I_2 = 4$ —(ii)

solving simultaneously we have.

$E = 3V$, $I_2 = -0.5A$

∴ The value of E is 3V.

8 (c). (ii). $V_a - E - 8 \times 0.5 - V_b = 0$

$V_a - V_b = 3 + 8 \times 0.5$

$V_a - V_b = 7V$

∴ The potential difference $V_a - V_b = 7V$

Extract 8.1: *A sample of correct responses to Question 8 of Paper 1*

In Extract 8.1, the candidate correctly and systematically described the mechanism of fuse and applied Kirchhoff's laws to obtain the correct responses in parts (b) and (c) of the question.

Nevertheless, 46.1 per cent of the candidates scored below 5.5 marks. The analysis on the responses of those who scored 0 (3.7%) shows that they had inadequate knowledge of current electricity. Specifically they failed to describe the mechanism of electric conduction in metals. They faced difficulties in explaining how a fuse plays an important role in protecting electrical installations. Moreover, those who scored low marks provided the reason why bulbs in a house become dim when a high power heater is connected to the main supply. However, some of them lacked mathematical skills for using Kirchhoff's laws to analyse electrical networks. Extract 8.2 illustrates an example of incorrect responses.

8 a. i) The fuse protect the electrical installation, since it ~~#~~ is a semiconductor devices, so it have high input impedence and hence low voltage can enter the circuit and hence protect it from deformation, Fuse mostly is made up common emitter amplifier which have high input impedence and low output impedence.

ii) The bulbs in house become dim when high power heater is connected to the main supply, this is because heater is made up of secondary and primary coils, so as to start the secondary coil ~~has~~ greater amount of ~~fur~~ voltage is required so that is why the ~~light~~ bulbs in house dim first and after then continues with the flow.

b i) Solution

Data given

Current $(I) = 0.5\,A$

Power $(P) = 40\,W$

Charge $(q) = 1.6 \times 10^{-19}\,C$

Number of electrons $(N) = ?$

From the formula

$$Q = It$$

also

$$P = IV$$

8 b i/ $P = IV$

$I = Q/t$

$I = \frac{Ne}{t}$

$P = Q/t\,V$

$V = P/I = \frac{40}{0.5} = 80V$

$t = \frac{1.6 \times 10^{-19} \times 80}{40}$

$t = 3.2 \times 10^{-19}$

Then

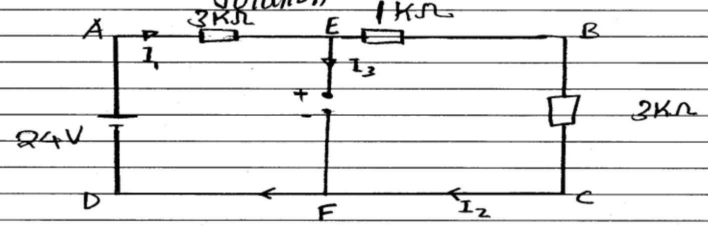
$N = \frac{It}{e}$

$N = \frac{3.2 \times 10^{-19} \times 0.5}{e}$

$N = 1$ electron.

$\therefore$ The number of electron = 1 electron

8 b ii) Solution



Conside the loop A E F D A

$24 + 3I_1 \cancel{3}\ V = 0$

Extract 8.2: *A sample of incorrect responses to Question 8 of Paper 1*

In Extract 8.2, the candidate provided incorrect responses to all parts of the question. He/she failed to recall and apply Kirchhoff's laws, and consequently obtained incorrect values of potential difference between terminals.

2.1.9 Question 9: Electronics

This question was divided into parts (a), (b) and (c). Part (a) required the candidates to (i) state the meaning of semiconductor based on energy band theory of solids and (ii) provide three distinctions between intrinsic and extrinsic semiconductor. In part (b), they were required to (i) identify the property of a semiconductor diode which permits it to be used as a rectifier and (ii) calculate the collector current in a common base connection if the emitter current $I_E = 1mA$ and collector current $I_C = 0.95$ mA when the transistor is connected in common emitter with base current of 0.005 mA. In part (c), they were required to (i) distinguish between breakdown voltage and knee voltage as applied to PN-junction and (ii) give reasons why the conductivity of intrinsic semiconductor increases with the increase in temperature while that of metals decreases.

The analysis of data reveals that 20,060 (92.4%) candidates who attempted this question, had the following scores: 24.6 per cent scored from 0 to 5 marks; 29.9 per cent scored from 5.5 to 8.5 marks and 45.5 per cent scored from 9 to 15 marks. These scores suggest that the candidates' performance in this question was good because three quarters of them scored the pass mark or above. These data are summarised in Figure 10.

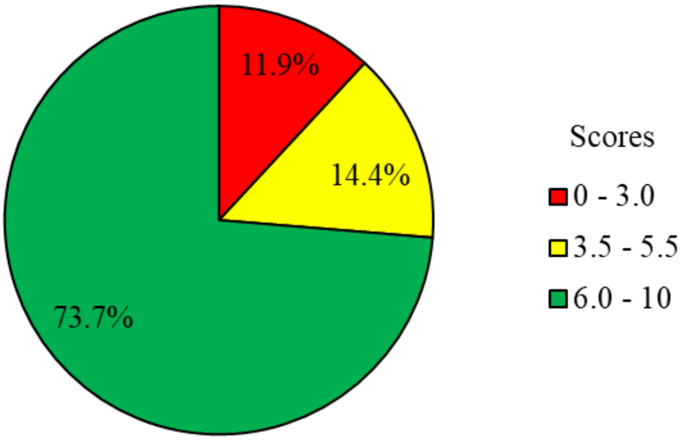


Figure 10: *Distribution of candidates' performance in Question 9 of Paper 1*

According to the analysed responses from the scripts, the candidates who scored high marks (45.5%) stated correctly the meaning of semiconductor based on energy band theory of solids and the distinctions between intrinsic and extrinsic semiconductors. Most of these candidates showed their ability to analyse the effect of temperature on conduction of electricity in solids and to interpret transistor characteristics to determine the collector current. Extract 9.1 is one of the correct responses to the question.

9\. (a)(i) Semiconductor refers to the solid material whose conduction band and valance band are separated by a narrow forbidden gap as compared to insulator materials, for example silicon and Germanium

(a)(ii)

	Intrinsic semiconductor	Extrinsic semiconductor
(i)	They are pure semiconductors.	They are impure semiconductors obtained by doping of intrinsic semiconductor
(ii)	They have Lower conductivity of electricity	They have greater conductivity due to free charge carriers
iii	The Number of Holes is equal to the number of electrons.	The Number of Holes is not equal to the number of electrons and depends on doping

(b)(i) Semiconductor diode allow the flow of current through it in only one direction hence used as rectifier

(b)(ii) Given

$I_E = 1mA$.

$I_c = 0.95mA$.

$I_B = 0.05mA$.

required I_c in common emitter

From

$$\alpha = \frac{I_c}{I_E}$$

$$= \frac{0.95mA}{1mA}.$$

$$\alpha = 0.95.$$

Then

$$\beta = I_c/I_B.$$

$$\alpha = \frac{I_c}{I_B + I_c}$$

$$\frac{1}{\alpha} = \frac{I_B}{I_c} + I_c/I_c$$

$$\frac{1}{\alpha} = \frac{1}{\beta} + 1$$

$$\frac{1}{\alpha} - \frac{1}{1} = \frac{1}{\beta}$$

$$\frac{1}{\beta} = \frac{1-\alpha}{\alpha}$$

$$\beta = \frac{\alpha}{1-\alpha}$$

$$\beta = \frac{0.95}{1-0.95}$$

$$\beta = 19.$$

Then

$$\beta = I_c/I_B$$

$$I_c = \beta \times I_B$$

$$= 19 \times 0.05mA$$

$$= 0.95mA.$$

9.	(c)(i) Breakdown voltage refers to the voltage required to break the coordinate bonds on the PN junction under reverse bias, leading to a sharp increase of reverse current as a result of strong field.
	while.
	• Knee voltage refers to the voltage at which the PN junction exhibits a sharp increase in forward current due to elimination of depletion layer.
	(c)(ii) • For intrinsic semiconductors, increase in temperature excites the electrons from the valence band crossing the forbidden gap to the conduction band hence increasing conductivity
	• For metals, increase in temperature increases the random motion of electrons which in turn result to an increase in the collision frequency of electrons, as the collision increases also the resistance to the flow of current increases leading to lower conductivity. (conductivity decreases)

Extract 9.1: *A sample of correct responses to Question 9 of Paper 1*

In Extract 9.1, the candidate presented the correct responses by describing the concepts, and he/she applied the correct formula and procedure to determine the collector current.

In contrast, 24.6 per cent of the candidates scored 0 to 5 marks. These candidates had inadequate knowledge of semiconductors and transistors. They failed to identify the significance of femi level and energy gap in solids. In addition, most of them faced difficulties to identify the differences properties between intrinsic and extrinsic semiconductors and assess the effect of temperature on transistor circuits.

Moreover, those who scored 0 used wrong concepts to answer the question. Similarly, in parts (b) and (c), they faced more challenges to deduce transistor characteristics. For example, some of them wrote the formula for the transfer ratio/current gain of common base transistor $\alpha = \frac{I_C}{I_E}$ and that of common emitter transistor amplifier $\beta = \frac{I_C}{I_B}$ interchangeably. Those candidates failed to establish the relationship between α and β due to lack of mathematical skills, and they finally obtained incorrect values of collector current. Extract 9.2 is a sample of incorrect responses.

9. (a)(i) Semiconductor is the device which is used to conduct electric current (electricity).

Intrinsic semiconductor	Extrinsic semiconductor
(i) Involves the adding of impurities inside the semiconductor	— involves no addition of impurities because is conducted outside the conductor
(ii) ~~Hote~~ Have hollow	— have no hollows
(iii) contain NPN junction	— contain PNP junction.

9 (b) (ii) solution

Given

emitter current $I_E = 1mA$

Collector current $I_C = 0.95mA$

$I_B = 0.05mA$

Required $I_C = ?$

from

$I_C = I_B + I_E$

$I_C = 0.05 + 1 = 1.05mA$

$I_E = I_B + I_C$

$I_E - I_B = I_C$

$I_E = 1 - 9$

9 (c) (i) Voltage breakdown These are breakdown of voltage in which pn junction is obtained and get to concentrate at PN junction, whereas knee junction is the type of junction in which positive is concentrated than negative junction in PN junction.

(ii) Because when adding impurities to intrinsic semiconductor the conductivity increases in temperature while that of metal decreases because metals obtain conductivity only at high temperature but if temperature decreases and the metal has less conductivity.

Extract 9.2: *A sample of incorrect responses to Question 9 of Paper 1*

In Extract 9.2, the candidate wrongly provided the distinction between intrinsic and extrinsic semiconductor. He/she also applied incorrect formula and concepts to present incorrect responses.

2.1.10 Question 10: Electronics

Parts (a) of this question required the candidates to (i) explain why the NAND (or NOR) gates are known as digital building blocks and (ii) draw the logic symbol and give the name of the gate obtained from the combination of the gates shown in Figure 4.

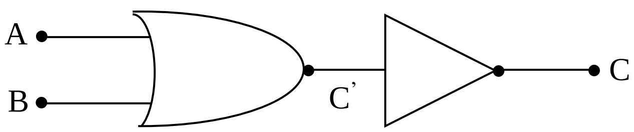


Figure 4

In part (b), they were required to (i) explain why the current gain in common base transistor amplifier is always less than one and (ii) identify three main properties of operational amplifier. Part (c) required the candidates to (i) give two advantages of digital circuits over analogue circuits and (ii) with the help of illustrative diagram state the condition necessary for the transistor to behave as an open switch.

A total of 18,932 candidates equivalent to 87.2 per cent attempted this question. Their scores were as follows: 42.8 per cent scored below 5.5 marks including 3.3 per cent who scored 0; 42 per cent scored from 5.5 to 8.5 marks and 15.2 per cent scored from 9 to 15 marks. Figure 11 illustrates the candidates performance in this question.

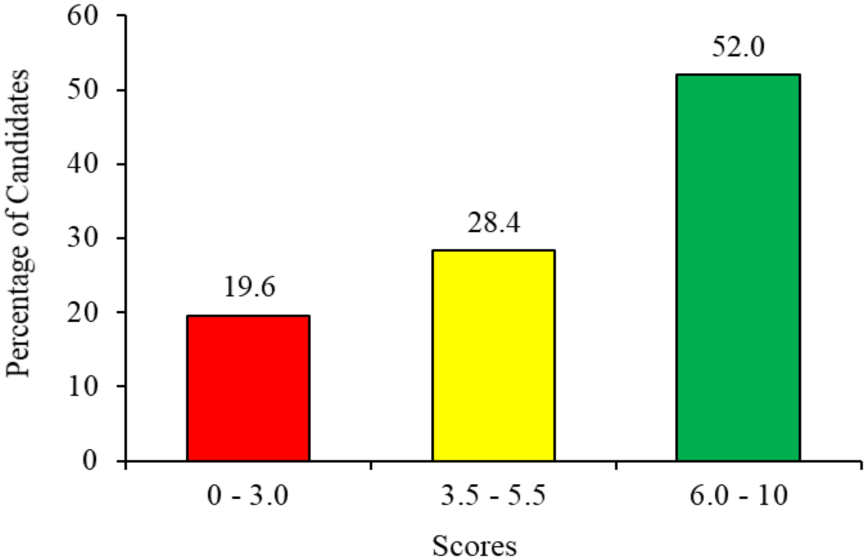


Figure 11: *Distribution of candidates' scores in Question 10 of Paper 1*

The analysis of data reveals that the overall performance in this question was average as 57.2 per cent of the candidates scored the pass mark or above. The candidates who scored high marks had a good understanding of basic types of logic gates as they were able to draw the logic symbol and name the gate obtained from the combination of gates. Most of those candidates competently applied Boolean Algebra to analyse logic gates, design and construct basic transistor switching circuits. However, some of those who scored 5.5 to 8.5 marks failed to describe the properties and mode of action of operational amplifiers and to state the condition for a transistor to act as an open switch. Extract 10.1 shows the correct responses to the question.

10 (a) (i) Because NAND or NOR gate can form the three basic gates which are AND, NOT and OR gate.

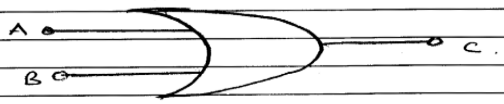
(ii) Soln.

TRUTH TABLE.

A	B	C'	C
0	0	1	0
0	1	0	1
1	0	0	1
1	1	0	1

Name of gate obtained OR GATE

Logic symbol



10 (b) (i) Because the emitter current is the sum of base current and collector current since gain obtained by ratio of collector current (I_C) and emitter current (I_E) hence gain will be less than one.

Current gain (α) = I_C / I_E = $\frac{I_C}{I_C + I_E}$

10 (b) (i)

$$\alpha = \frac{I_C}{I_E} = \frac{I_C}{I_C + I_B}$$

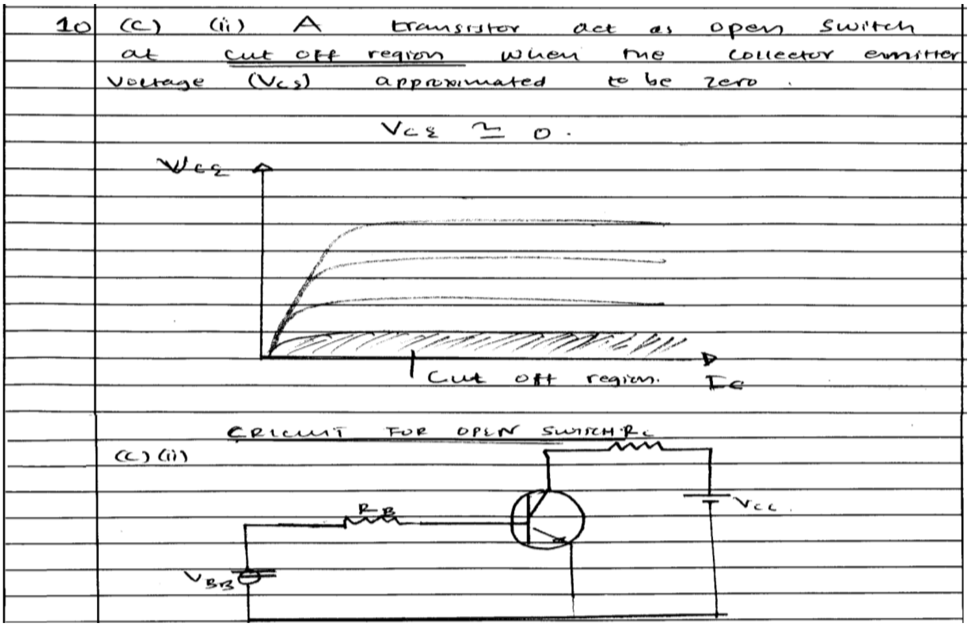
Hence gain will be less than one.

(ii) Properties of operational amplifier.

- It has high open loop gain to about 1×10^5
- It has low output impedence.
- It has high input ~~gain~~ Impedence

(c) (i) Advantages of digital circuit.

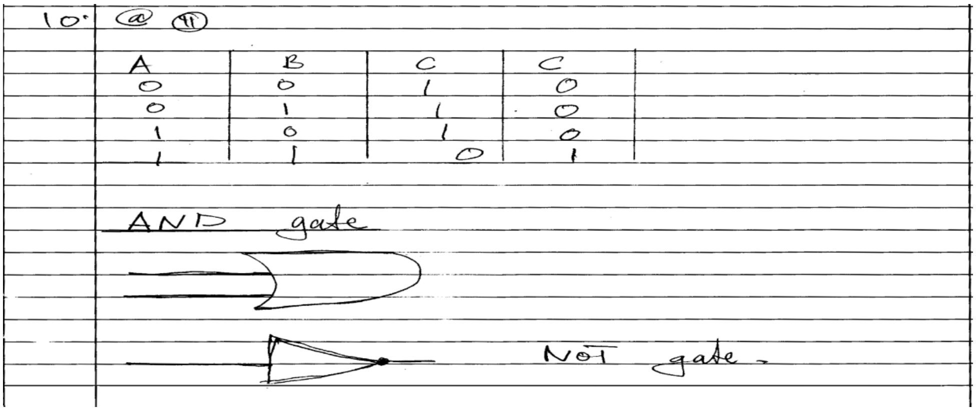
- It easily to store information
- It less affected by noise hence produce high quality output.
- It has a minimum power loss.



Extract 10.1: *A sample of correct responses to Question 10 of Paper 1*

In Extract 10.1, the candidate correctly applied the concepts of electronics to answer all parts of the question. He/she was able to identify the basic logic gates and describe the working principle of transistors.

Among the 42.8 per cent of the candidates who scored 0 to 5 marks; 633 candidates, corresponding to 3.3 per cent, scored 0. These candidates had inadequate knowledge of digital circuits, operational amplifier and transistor circuits. They failed to interpret the circuit of the combined logic gates, consequently thereafter they obtained the incorrect truth table and wrong logic gates. As a result, they provided insufficient conditions necessary for a transistor to act as an open switch. Extract 10.2 presents a sample of the incorrect responses to the question.



10 (c) (i) Digital circuits has high out put than in put.

(ii) It is simple and easily to use.

(b) The current gain in common base transistor amplifier is always less that one so as to allow electrons to passing.

Extract 10.2 *A sample of incorrect responses to question 10 of Paper 1*

In Extract 10.2, the candidate failed to clarify basic types of logic gates, interpret transistor characteristics and describe properties and mode of action of operational amplifier.

3.0 ANALYSIS OF CANDIDATES' PERFORMANCE IN EACH QUESTION IN 131/2 PHYSICS 2

The 131/2 Physics 2 paper contained six (6) questions, which were set from six topics. The topics included *Fluid Dynamics*, *Vibrations and Waves*, *Properties of Matter*, *Electrostatics*, *Electromagnetism* and *Atomic Physics*. Each question carried 20 marks. The pass mark for each question was 5.5 or above. The analysis of each question is as follows:

3.1 Question 1: Fluid Dynamics

This question had parts (a), (b) and (c). Part (a) required the candidates to (i) give the importance of coefficient of viscosities of liquids in daily life activities and (ii) identify the assumptions made in deriving Poiseuille's equation for the flow of a liquid through a narrow tube. In part (b), they were required to (i) determine how much would the pressure difference between the ends of the constricted pipe increase to maintain the constant flow rate if the radius of a pipe carrying liquid gets decreased by 8% and (ii) describe the mode of action of Pitot-static tube and apply Bernoulli's equation to obtain the formulae used to measure the velocity of a flowing liquid. Part (c) required the candidates to (i) state the circumstances at which Torricelli's theorem applies and (ii) calculate the diameter of circular hole needed at the base of the tank to discharge water at the rate of $26.4\ m^3$/minute if water is maintained at a height of 10 m.

The question was attempted by 19,315 candidates, equivalent to 89 per cent. The distribution of their scores is shown in Figure 12.

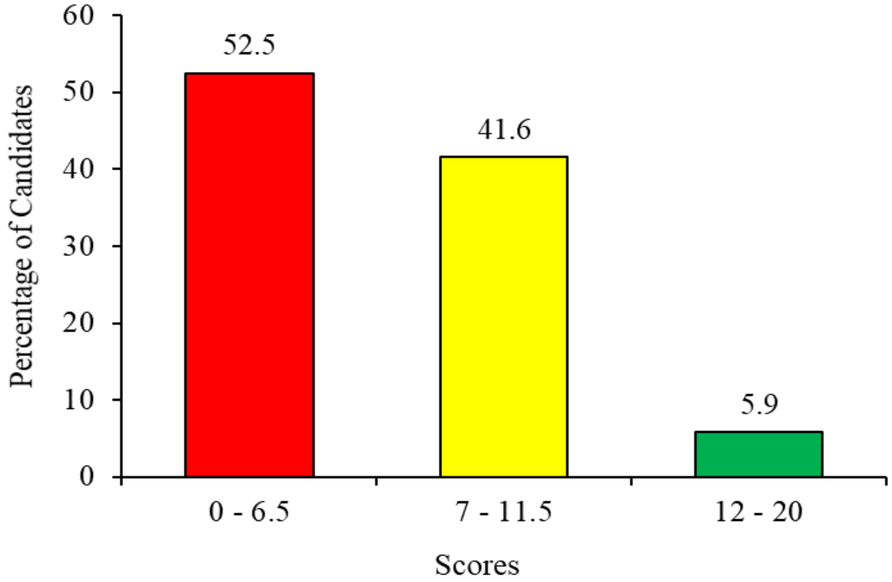


Figure 12: *The candidates' performance in Question 1 of Paper 2*

Figure 12 shows that 52.5 per cent of the candidates scored from 0 to 6.5 marks; 41.6 per cent scored from 7 to 11.5 marks while only 5.9 per cent scored marks ranging from 12 to 20 marks.

The data analysis reveals that the general performance in this question was average because more than a half (52.5%) of the candidates scored below the pass mark (< 7 mark). However, 47.5 per cent scored from 7 to 20 marks. The candidates who scored high marks correctly stipulated the importance of coefficient of viscosities of liquids in daily life activities. Subsequently, they made assumptions in deriving the Poiseuille's equation for the liquid flow through a narrow tube. Most of them successfully applied Poiseuille's equation, $V = \frac{\pi P r^4}{8\eta l}$ to determine the pressure difference between the ends of the constricted pipe that increases in order to maintain constant flow rate. They also stated the circumstances under which Torricelli's theorem apply. Some of them applied the theorem in calculating the diameter of a circular hole at the base of the tank to discharge water at the given rate. However, some candidates failed to describe the mode of action of a Pitot static tube. Those candidates faced difficulties to apply Bernoulli's equation to obtain the formulae used to measure the velocity of a flowing liquid and therefore scored average marks. Extract 11.1 is a sample of candidates' correct response.

Qn.1 (a) i) Importance of coefficient of viscosities of liquid

- Help In applying brakes

- Help in selecting good liquid to be used as lubricant in machine parts.

- used in measuring the rate of flow of blood.

(a) ii) Assumptions in deriving Poiseuille's equation

- The liquid is considered as incompressible

- The velocity of liquid flow is constant that means a flow consider to be steady

(b) i) solution

Given

let Original radius be r

new radius $= r - \left(\frac{8r}{100}\right) = r - 0.08r = 0.92r$

Original pressure difference be "P"

new pressure be P'

from Poiseuilles theorem

$$Q = \frac{\pi P r^4}{8\eta l}$$

$$P = \frac{8\eta l Q}{\pi r^4}$$

$$P \propto 1/r^4$$

Qn. 1 (b) i)

$$\frac{P'}{P} = \frac{r^4}{(0.92r)^4}$$

$$P' = \left(\frac{r}{0.92r}\right)^4 . P$$

$$P' = \left(\frac{1}{0.92}\right)^4 . P$$

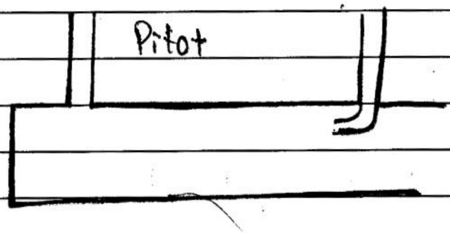
$$P' = 1.396 . P$$

$$P' = 1.396 P$$

∴ This means that the pressure difference will increase by 1.396 times.

ii) Mode of action of Pitotic - static tube.

_ Pitotic - static tube refers to the horizontal tube consisting two tubes whereby one is stationary in terms of position and pressure of water and other is dynamic. consider.



- The pitot-static tube is closed as one end where there is stationary tube

- When water flowing tending to cause static pressure at the pitot tube (stationary) while in the dynamic tube there is changing in Pressure due to changing in velocity.

Qn.1 (b) ii) - At the pitot tube the velocity of water is zero, so causing static pressure.

According to Bernoulli's theorem

$P_1 + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$

But in Pitot-static tube $h = 0$

$P + \frac{1}{2}\rho v^2 = \text{Constant}$

so

The total pressure in Pitot-static tube is maintained Constant

where

$P_T = P + \frac{1}{2}\rho v^2.$

where

P is static pressure

$\frac{1}{2}\rho v^2$ is Dynamic pressure

P_T is total pressure.

So

$\frac{1}{2}\rho v^2 = P_T - P$

$v^2 = \frac{2(P_T - P)}{\rho}$

$v = \sqrt{\frac{2(P_T - P)}{\rho}}$

$\therefore$ The velocity of flowing liquid is $v = \sqrt{\frac{2(P_T - P)}{\rho}}$

Qn.1 (c) ii)

$$Q = a \times V$$

$$Q = \frac{\pi d^2}{4} \times V$$

$$d^2 = \frac{4Q}{\pi V}$$

$$d = \sqrt{\frac{4Q}{\pi V}}$$

$$d = \sqrt{\frac{4 \times 0.44\, m^3/s}{\pi \times 14\, m/s}}$$

$$d = \sqrt{\frac{4 \times 0.44\, m^3/s}{3.14 \times 14\, m/s}}$$

$$d = 0.2\, m$$

∴ The Diameter of a circular hole is 0.2m.

Extract 11.1: *A sample of correct responses to Question 1of Paper 2*

In Extract 11.1, the candidate was able to describe and evaluate the concepts of Bernoulli's equation and pitot static tube, as a result he/she managed to provide the correct responses.

Although the candidates' performance in this question was average, 52.5 per cent scored low marks (0 - 6.5). These candidates had inadequate knowledge on the topic of *Fluid Dynamics*. Most of them failed to explain how the coefficient of viscosities of liquids play an important role in daily life activities. They also failed to identify the assumptions made in deriving the Poiseuille's equation. A further loss of marks was observed among those who were not able to deduce Bernoulli's principle as one of the basic concepts used in this topic. They failed to express correctly the application of Bernoulli's principle in describing the mode of action of a Pitot static tube. However, some of the candidates applied Torricelli's theorem to determine the diameter of the circular hole at the base of the tank even though they failed to identify the circumstance under which Torricelli's theorem applies. Extract 11.2 is a sample of incorrect responses.

1 (a) (i) Importance of Coefficient of Viscosities of Liquid in daily Life such as:-

(i) it used to measure the height of the Liquids in a substances

(ii) it used in the hospital to know the drugs and Volume of the drugs required so is very importance.

(iii) Coefficient of Viscosities is used to determine the Pressure of the Liquid in the objects.

1 a (ii) Assumption of ~~Viscosities~~ Made in deriving the Poiseuille's equation for the flow of the Liquid through narrow tube such as:-

(i) The Pressure of The Liquid are negligible to the Container.

(ii) The temperature of Liquid does not Considered in deriving the Poiseuille's equation.

b (i). Given,

Decreasing of Radius = 8%
Required the Pressure difference between the End of the Constricted pipe.
from,

$$\text{Radius Decreasing} = \frac{8}{100} = 0.08$$

$$\text{The Pressure} = F/A.$$

$$\text{But } A = \pi r^2.$$

$$\text{Force} = mg.$$

$$\text{Pressure} = \frac{mg}{\pi r^2}.$$

$$\text{Pressure} = \frac{9.8}{3.14 \times (0.08)^2}$$

$$= 487.7 \ N/m^2.$$

$\therefore$ Pressure difference between the end = 487.7 N/m^2.

1 b(ii) Required the Mode of Action of a Pitot-static tube

Pitoti-static tube Are the tube which are Used to Measure the Velocity of the flowing Liquids.

the Pitotic-static are Very Importance. are require the high Vapour Pressure of the Liquid, Containe a tube also Must have the Volume of the Liquid Maximum also the Cross-sectional areas.

when the Pressure is applied of first the Container and the Velocity B already been Measured from the Point.

The Applying Bernoulli's equation to obtain the formulae used to Measure the Velocity of flowing Liquids.

from the Equation'

$P_1 + h_1\rho g = P_2 + h_2\rho_2 g$,

then

formulae become.

$P_1 + h_1\rho g + P_2 + h_2\rho_2 g$ ..

c ①. Torricell's theorem apply when:—

(i) There are Presence of the atmosphere Pressure.

(ii) Applied When there are Presence of the height or Radius of an object.

(ii) Given,

Height of the Tank = 10m.

Rate of Water discharge = $26.4 m^3$/Minutes.

Required the diameter of the Circular hole.

From.

~~C~~ Area = ~~4~~ πr^2,

But Radius = $d/4$.

Area = $3.14 \times (10)^2$.

Area = ~~3.14m²~~ ~~3.1~~ 314m².

But

Area = $d^2/4$.

$\sqrt{d^2} = \sqrt{4 \times 314}$.

$d = \sqrt{4 \times 314}$,

$d = 35.4$ m

diameter of the circular hole = 35.4 m.

Extract 11.2: *A sample of incorrect responses to Question 1 of Paper 2*

In extract 11.2, the candidate used inappropriate concepts and applied incorrect formula to describe the Bernoulli's equation. For instance, in part (c) (ii), he/she wrote an incorrect relation between diameter and radius as $r = \frac{d}{4}$ instead of $r = \frac{d}{2}$.

3.2 Question 2: Vibrations and Waves

Part (a) of this question required the candidates to (i) give a concrete reason behind a straight line propagation of light irrespective of its wave nature and (ii) calculate the distance of separation between the fringes in a Young's double slit experiment if the green light of mercury of wavelength $0.54\ \mu m$ was used with a pair of parallel slits of separation 0.6 mm when the fringes were observed at a distance of 40 cm from the slit. In part (b), they were required to (i) identify two cases in which there is no Doppler effect in sound and (ii) calculate the change in pitch of the note as heard by observer Q when a car sounding a horn which produces a note of frequency 500 Hz approaches and then passes a stationary observer Q at steady speed of $20\ m/s$. Part (c) required the candidates to (i) identify two properties of a medium responsible for propagation of a wave through it and (ii) determine the distance between successive crests of the wave motion if a horizontal stretched elastic string of length and mass of 3.0 m and 12 kg respectively is subjected to a tension of 1.6 N, given that a transverse wave of frequency 40 Hz was propagated down the string.

A total of 17,390 candidates, equivalent to 80.1 per cent attempted this question and their scores were as follows: 25.7 per cent scored below 7 marks, including 3.8 per cent who scored 0; 39.3 per cent scored from 7 to

11.5 marks and 35 per cent scored from 12 to 20 marks. These scores suggest that the candidates' performance in this question was good as 74.3 per cent of them scored from 7 to 20 marks. Figure 13 is illustrative.

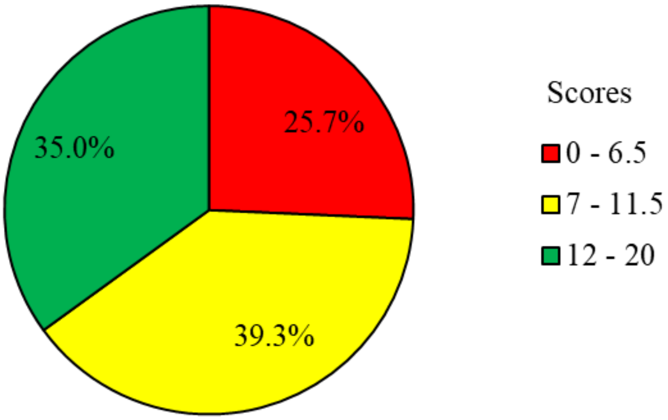
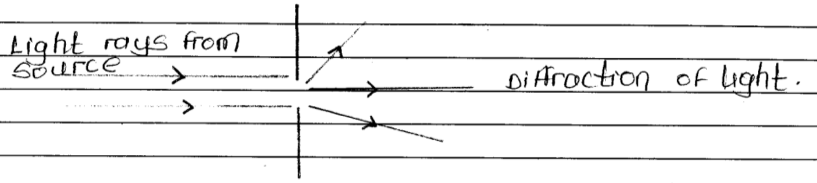


Figure 13: *The candidates' performance in Question 2 of Paper 2*

The analysis of candidates' responses indicates that those who scored from 12 to 20 marks had sufficient knowledge of vibrations and waves specifically on the respect of *interference, wave motion* and *Doppler effect*. They were able to explain the necessary conditions for diffraction of light to occur. Most of them responded correctly by providing a concrete reason behind the straight line propagation of light irrespective of its wave nature. About 0.4 per cent of them who scored (18 to 20) marks proved their competence by applying the concept of Young's double slit experiment to determine fringe separation $y = \frac{\lambda D}{a}$. Further, they were neat and precise in deducing expressions of apparent frequency for approaching $f' = \left(\frac{c}{c - v_s}\right) f$ and apparent frequency for receding $f'' = \left(\frac{c}{c + v_s}\right) f$ to determine the change in pitch, $\Delta f = f' - f''$ of the note as heard by a stationary observer Q. However, the candidates who scored average marks (7 - 11.5) faced difficulties in part (c) to identify the properties of a medium that are responsible for propagation of wave. Moreover, they failed to apply the formulas $c = \sqrt{\frac{Tl}{m}}$ and $\lambda = \frac{c}{f}$ to determine the distance between two successive crests of a wave (wavelength) where T, m, l, λ, c and f are tension, mass, length of a string, wavelength, speed of a wave and frequency respectively. Extract 12.1 is a sample of a candidate's correct responses.

2\. (a) (i) → Light propagates in a straight line and this is evidenced by property of light to bend when passing a narrow aperture.

→ This phenomenon is called diffraction of light. Diffraction of light is the splitting of light when pass through a narrow aperture.



(ii) solution.

from.

$nd = \frac{yd}{D}$.

but..

$y = \frac{Dn d}{d}$.

$y_1 = \frac{D n d}{d}$.

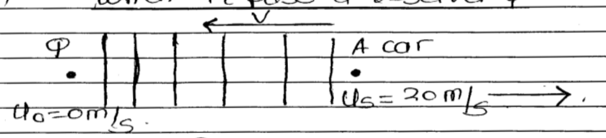
$y_2 = \frac{D}{d} \cancel{\lambda} d\,(n+1)$

$\Delta y = y_2 - y_1$.

$\Delta y = \frac{D}{d} d\,(n+1) - \frac{D}{d} nd$.

$\Delta y = \frac{dD}{d}$.

2\. (b) (ii) when it pass a observer Q.



from.

$F'' = \left(\frac{V}{V+u_s}\right) \times F$.

$F'' = \left(\frac{340\,m/s}{340\,m/s + 20\,m/s}\right) \times 500\,Hz$.

$F'' = 472.22\,Hz$.

change in pitch $= F' - F''$

$\Delta F = F' - F''$

$\Delta F = 531.25\,Hz - 472.22\,Hz$.

$\Delta f = 59.03\,Hz$.

∴ change in pitch of note $= 59.03\,Hz$.

(c) (i) The properties of a medium which are responsible for a propagation of a wave throught it are

→ Density of the material medium.

→ Modulous of the material medium.

2. (c) (ii) solution.

$L = 3m$

$m = 12kg$

$T = 1.6N$

$F = 40Hz$

$d = ?$

from

$v = \sqrt{T/\mu}$

but

$\mu = m/L = \dfrac{12kg}{3m}$

$\mu = 4kg/m$

$v = \sqrt{\dfrac{1.6N}{4kg/m}}$

$v = 0.632 m/s$

from

$v = dF$

$d = v/F$

$d = \dfrac{0.632 m/s}{40Hz}$

$d = 1.581 \times 10^{-3} m$

$\therefore$ Distance between succesive crests $= 1.581 \times 10^{-3} m$

Extract 12.1: *A sample of correct responses to Question 2 of Paper 2*

Extract 12.1 shows that the candidate correctly applied the concepts of vibrations and waves to answer the question. He/she stated the correct reason of a straight line propagation of light and demonstrated enough competence on Young's double slit experiment, the concepts of Doppler effect in sound waves and vibration of strings.

In contrast, 25.7 per cent of the candidates scored below 7 marks including 3.8 per cent who scored 0. These candidates demonstrated poor knowledge of *Vibrations and Waves*, particularly on the concepts of *sound, diffraction of waves, interference* and *Doppler Effect*. They failed to describe the application of mechanical vibrations and waves. Consequently, they failed to deduce the formula for calculating apparent frequency for a moving source and a stationary observer. For example, one candidate explained that *'a moving source was approaching a stationary observer by apparent frequency given by* $f' = \left(\dfrac{u+v}{v}\right)f$ *instead of* $f' = \left(\dfrac{c}{c-v_s}\right)f$. The candidate failed to associate the speed of sound relative to a stationary observer, Q with a steady speed to determine the apparent frequency. Further loss of marks was also observed in part (a) where they failed to find out how diffraction effect depends upon the size of the aperture relative to the wavelength of the wave. Accordingly, they were not able to give a concrete reason behind a straight line propagation of light. In addition, most of them lacked mathematical skills for using the concept of Young's double slit method to deduce the fringe separation. Extract 12.2 is a sample of incorrect responses from a candidate.

02. (a) (i) The straight line propagation of light lies within wave-particle matter duality, as it transform (propagates) with both wave and particle properties such as amplitude, velocity, frequency and wavelength.

(ii) solution.

Data given.

wavelength $\lambda, = 0.54\,\mu m$,

Separation distance $D = 0.66mm$.

Distance from slits, $d = 40\,cm$.

then

from ~~§~~ Young's double slit experiment

$$\frac{xd}{D} = n\lambda$$

all symbols carry their usual meanings

then $D = \frac{xd}{n\lambda}$

Distance of separation of fringes

= Fringe width

$$= \frac{\lambda D}{d}$$

$$= \cancel{\frac{0.54\times10^{-6} \times 0.66\times10^{-3}}{40\times10^{-2}}}$$

$$= \cancel{\frac{3.564\times10^{-10}}{0.4}}$$

$$= \cancel{8.91\times10^{-10}}$$

$$= \frac{0.54\times10^{-6} \times 40\times10^{-2}}{\cancel{3.5}\ 0.66\times10^{-3}}$$

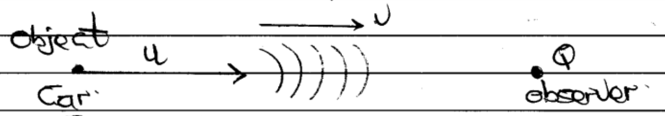
$$= 3.273\times10^{-4}\,m = 0.327\,mm$$

$\therefore$ Distance of separation between fringes is $0.327\,mm$.

02. (b) (i) — Doppler effect is not possible in vacuumed medium
— In place with no medium of sound travelling.

(ii) Solution.

Consider illustration below



From above
apparent frequency of sound heard by an observer Q

$$f' = \left(\frac{u+v}{v}\right) f$$

$f' =$ ~~20~~ +

Given u = velocity of car $= 20\,ms^{-1}$
v = velocity of sound $= 340\,ms^{-1}$
f = frequency ~~of~~ of horn sound $= 500\,Hz$

then

$$f' = \left(\frac{20+340}{340}\right) \times 500\,Hz$$

$$= \frac{500 \times 18}{17}\,Hz$$

$$f' = 529.412\,Hz.$$

change in pitch of note heard by Q

$$\Delta f = f' - f$$

$$= (529.412 - 500)\,Hz$$

$$\Delta f = 29.412\,Hz.$$

There fore

Pitch heard by Q is 529.412Hz and change in pitch of note heard is 29.412 Hz.

Q2. (c) (i) – Medium should be ~~contain~~ at least particles ~~of pro~~ for easy propagation of wave

–Medium should be with pressure and temperature variations (not necessarily).

(ii) Solution.

Data given:

Mass of string $m = 12kg$

length of ~~t~~ $L = 3.0m$

Tension, $T = 1.6N$

frequency, $f = 40Hz$.

from: $V = \frac{1}{2\pi}\sqrt{\frac{T}{\mu}}$

but $\mu = \frac{m}{L}$

$= \frac{1}{2\pi}\sqrt{\frac{mT}{L}}$

$= \frac{1}{2\pi}\sqrt{\frac{12 \times 1.6}{3}}$

$v = 0.403 ms^{-1}$.

from. $f = \frac{nv}{2L}$

also $V = \frac{f}{\lambda}$

$\cancel{V = f.\lambda}$ $\lambda = \frac{V}{f}$

$\cancel{\lambda = 40Hz \times}$

$\lambda = \frac{0.403 ms^{-1}}{40 s^{-1}}$

$\lambda = 10.075 \times 10^{-3} m$.

$\lambda = 10.075 mm$.

∴ Distance between successive crest is $10.075mm$.

Extract 12.2: *A sample of incorrect responses to Question 2 of Paper 2*

In Extract 12.2, the candidate failed to describe correctly the concepts of vibrations and waves specifically interference and Doppler effect. He/she wrongly substituted the data and the applied incorrect formula $v = \frac{1}{2\pi}\sqrt{\frac{T}{\mu}}$ instead of $v = \sqrt{\frac{T}{\mu}}$ to obtain the velocity of a vibrating string.

3.3 Question 3: Properties of Matter

This question had parts (a), (b) and (c). Part (a) required the candidates to (i) state the meaning of the angle of contact between the liquid and solid as used in properties of matter and (ii) outline four factors on which the value of angle of contact depends. In part (b), they were required to (i) give a qualitative distinction between surface tension and surface energy of a liquid and (ii) determine the pressure inside the air bubble when a small air bubble of radius 0.1 mm was situated just below the water surface, if the atmospheric pressure is 1.013×10^5 N/m. Part (c) required the candidates to (i) stipulate four practical applications of capillarity in daily life activities and (ii) compute the height at which water will rise in another capillary tube whose radius is $\frac{1}{3}$ of the first tube in which water raised to a height of 2.0 cm.

A total of 21,134 candidates equivalent to 97.4 per cent, attempted this question and their scores were as follows: 17.9 per cent scored from 0 to 6.5 marks, 34.3 per cent scored from 7 to 11.5 marks and 47.8 per cent scored from 12 to 20 marks. These scores indicate that the candidates' performance in this question was good as 82.1 per cent of them scored from 7 to 20 marks. Figure 14 presents a summary of the candidates performance.

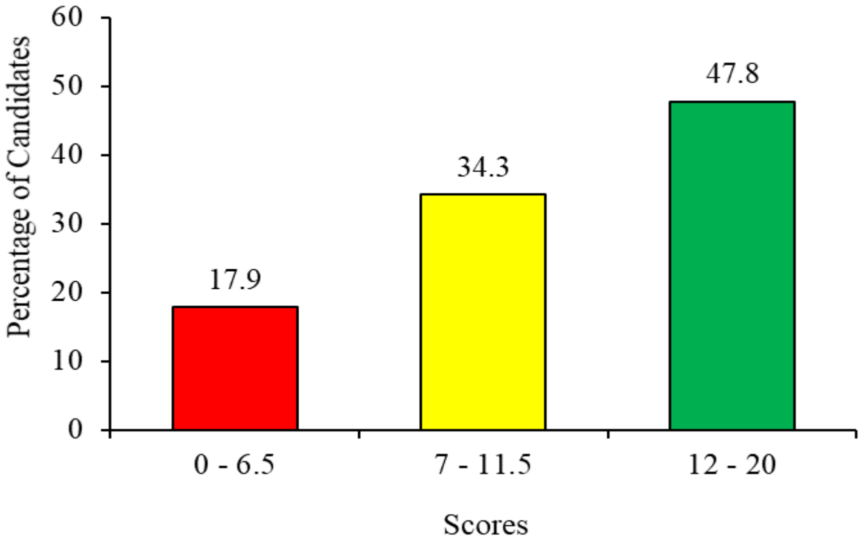
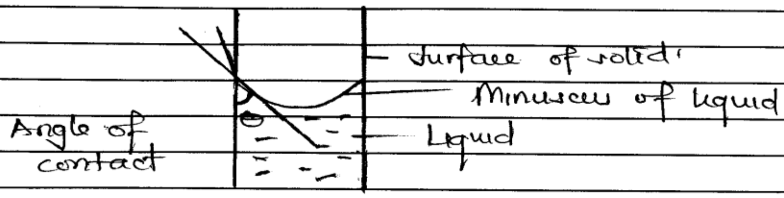


Figure 14: *The candidates' performance in Question 3 of Paper 2*

The analysis reveals that the candidates who scored from 12 to 20 marks described correctly various phenomena regarding surface tension. They stated correctly the angle of contact and factors on which its value depends. In part (b), most of them were able to deduce qualitative distinction between surface tension and surface energy of a liquid. They further demonstrated their competence by applying the correct formula and procedure to determine the pressure inside the air bubble. However, some of the candidates (34.3%) who scored averagely faced difficulties to identify practical applications of capillarity in daily life and to determine the height at which water raised in a capillary tube. Extract 13.1 presents an example of a good response to the question.

3(a) (i) Angle of contact between the liquid and solid is the angle between the minuscus of the particular and the surface of solid ~~water~~ liquid contact with.

Consider diagrammatical representation.



3(a) (ii) Factor affecting the angle of contact.

- (i) Nature of liquid. The nature of liquid interact with particular solid surface determine the angle of contact.

(ii) Presence of contaminating or impurities in the solution; impurities lower angle of contact.

(iii) Temperature at which liquid exert affecting the angle of contact; temperature as increase the angle of contact.

(iv) The nature of medium at which the minuscus surrounded by.

3(b)	(i) Surface tension is the tendency at which the liquid at rest by virture ~~3tre~~ behave like
3 (b)	(i) Surface tension is the tendency at which the liquid at rest by virture behave like stretched skin or membrane on it surface.
	Where as
	Surface energy is the workdone against the increase of surface of area of liquid at isothermal.
3(b)	(ii) Solution.
	Atmosphere pressure, $P_a = 1.013 \times 10^5 N/m^2$.
	Radius of air bubble; $r = 0.1mm$
	$= 1 \times 10^{-4} m$.
	The excess pressure in air bubble, $\Delta P = \frac{2T}{r}$
	$\Delta P = \frac{2T}{r}$.
	$\Delta P = P - P_a$
	P - Pressure inside the air bubble.
	$P - P_a = \frac{2T}{r}$.
	$P = \frac{2T}{r} + P_a$
	Surface tension of water, $0.072 Nm^{-1}$.

3(b) (ii)

$$P = \frac{2 \times 0.072 Nm^{-1}}{1 \times 10^{-4} m} + 1.013 \times 10^5 Pa.$$

$$P = 102740 \text{ Pa}.$$

$\therefore$ The pressure inside the air bubble is 102740 Pa.

3(c) (i) Application of Capillarity.

1. It is used in wick of lamp so as to raise kerosene on the wick.

2. It is used in towel, since fine thread of towel acts as the narrow tube to raise water and hence enable dry the body.

3. It is used in plants to raise water through xylem from the soil in the root, stem to upper part of plant. This called capillary action.

4. It is used raise ink chinese pens, when dipped in the ink the pole through it enable the ink to raise.

3 (c) (ii) Solution.

height of first tube, $h_1 = 2$ cm.

let the radius of first tube, be R_1.

the radius of second tube be R_2.

3b(ii) But $R_2 = \frac{R_1}{3}$.

From $h = \frac{2T\cos\theta}{Rg\rho}$.

$hr = \frac{2T\cos\theta}{g\rho}$

$hr = \text{constant}$.

$hr = k$

$h_1R_1 = h_2R_2$.

$h_2 = \frac{h_1R_1}{R_2}$, $R_2 = \frac{R_1}{3}$

$h_2 = h_1R_1 \div \frac{R_1}{3}$.

$h_2 = h_1R_1 \times \frac{3}{R_1}$

$h_2 = \frac{3h_1R_1}{R_1}$

$h_2 = 3h_1$

$h_2 = 3 \times 2\text{cm}$

$h_2 = 6\text{cm}$.

∴ height of another capillary tube is 6cm.

Extract 13.1: *A sample of correct response to Question 3 of Paper 2*

In Extract 13.1 the candidate provided correct responses to the parts which required explanations as well as precise calculations for the parts which required computations.

On the other hand, 17.9 per cent of the candidates who scored 0 to 6.5 failed to describe correctly surface tension in terms of molecular theory. They faced difficulties to analyse surface tension in terms of surface energy. The analysis of their responses reveals that, some of them provided incorrect explanations about the angle of contact and failed to identify the factors which affect its value and to determine the pressure inside the air bubble. In addition, they lacked knowledge of the concepts of capillary rise and fall and mathematical skills to relate height and radius from the relation

$h = \dfrac{2T\cos\theta}{r\rho g}$ to compute the height at which water raised in a capillary tube.

Extract 13.2 portrays a sample of incorrect response to this question.

3. (a)(i) Are the angle of contact:

→ Is the degree to which surface of liquid is perpendicular to the solid body.

(ii) Angle of contact depend on.

→ Density of the liquid.

→ Surface tension.

→ Cohesion and adhesion forces between liquid and solid body,

→ Viscousity (Nature of the liquid),

(b) (i) Differences Between Surface energy and Surface Tension:

Surface energy	Surface tension;
(i) It is the Surface tension times area, distance.	It is ability of liquid to behaves like a stretched membrane skin.
(ii) It's SI unit is Newton (N)	It is SI unit is Newton/m ehe square (N/m^2).
(iii) It is given by $E_s = \gamma \cdot A$.(Area x Surface tension).	It is given by. Surface tension (γ) = Surface energy / distance

3. (b)(ii) pressure inside the air bubble is 9

$= 9.986 \times 10^3$.

(c)(i) Application of capillarity in our daily activities:

- ~~To rise water in~~
- House water system it use the capillarity
- Mode of action (lighting) of Spirit lamp.
- In Irrigation by using (irrigation pipe).
- When water are raised or poured by the vertical ~~to~~ pipe in the tank.

(ii) Soln

Height $(h_1) = 2cm.$, $r = r_1$

radius is $r_2 = \frac{1}{3} r_1$

From:

$$h_1 A_1 \rho g = F_1.$$

$$F_1 = F_2$$

$$h_1 A_1 \cancel{\rho g} = h_2 A_2 \cancel{\rho g}.$$

$$h_1 A_1 = h_2 A_2.$$

But:

$A = \pi r^2$

$$h_1(\pi r_1^2) = h_2(\pi r_2^2).$$

$$h_1 r_1^2 = h_2 r_2^2$$

$$h_2 = \frac{h_1 r_1^2}{r_2^2} = h_1\left(\frac{r_1}{r_2}\right)^2$$

3. (c)(ii) $h_2 = h_1\left(\frac{r_1}{r_2}\right)^2.$

$$= 2cm\left(\frac{r_1}{\frac{1}{3} r_1}\right)^2.$$

$$= 2cm\,(3)^2$$

$$= 18cm.$$

$\therefore$ Height at which water will rise is 18cm.

3. (b) (ii) Soln.

Data given:

Radius (R) = 0.1mm = 0.1×10^{-3} m.

Surface tension of water (γ) = 0.072N/m

Pressure atmosphere: P_1 1.013×10^{5} N/m^2

From:

$$P = \frac{2\gamma}{R}$$

$$P = \frac{2\times0.072}{0.1\times10^{-3}}$$

$$P_2 = 1440\ N/m^2 = 1.44\times10^{3}\ N/m^2$$

Then:

Pressure inside = ΔP

$$\Delta P(\text{inside}) = P_1 - P_2.$$

$$= 1.013\times10^{5} - 1.44\times10^{3}$$

$$= 9.986\times10^{4}\ N/m^2$$

3. (c) (ii) $h_2 = h_1\left(\frac{r_1}{r_2}\right)^2$

$$= 2cm\left(\frac{r_1}{\frac{1}{3}r_1}\right)^2$$

$$= 2cm\,(3)^2$$

$$= 18cm.$$

$\therefore$ Height at which water will rise is 18cm.

Extract 13.2: *A sample of incorrect response to Question 3 of Paper 2*

In Extract 13.2 the candidate provided incorrect explanations in most parts of the question. In part (c), he/she applied a wrong formula $h_2 = h_1\left(\frac{r_1}{r_2}\right)^2$ instead of $h' = \frac{3hr}{r} = 3\times h$ to find the height at which water raised in a capillary tube.

3.4 Question 4: Electrostatics

This question was comprised of parts (a), (b) and (c). In part (a), the candidates were required to (i) state the Coulomb's law and (ii) calculate the time of fall of proton of mass 1.673×10^{-27} kg if it falls through a distance of 1.5 cm in uniform electric field of magnitude 2.0×10^4 NC^{-1}, given that air resistance and acceleration due to gravity is neglected. Part (b) required the candidates to determine the force of an electron in a field, which was connected to 100 V battery terminals through two large and parallel plates which are 2 cm apart when the field in the region between the plates is nearly uniform. In part (c), the candidates were required to use part 4 (b) given that an electron is released from rest from the upper plate inside in the field to determine (i) the velocity with which an electron will hit the lower plate and (ii) kinetic energy and the time it will take for the whole journey.

This question was attempted by 15,889 candidates, which corresponds to 73.2 per cent. The analysis of data reveals that 41.5 per cent of the candidates scored from 0 to 6.5 marks; 20.6 per cent scored from 7 to 11.5; while 37.9 per cent scored from 12 to 20 marks. Figure 15 shows the graphic presentation of the candidates' performance in question 4.

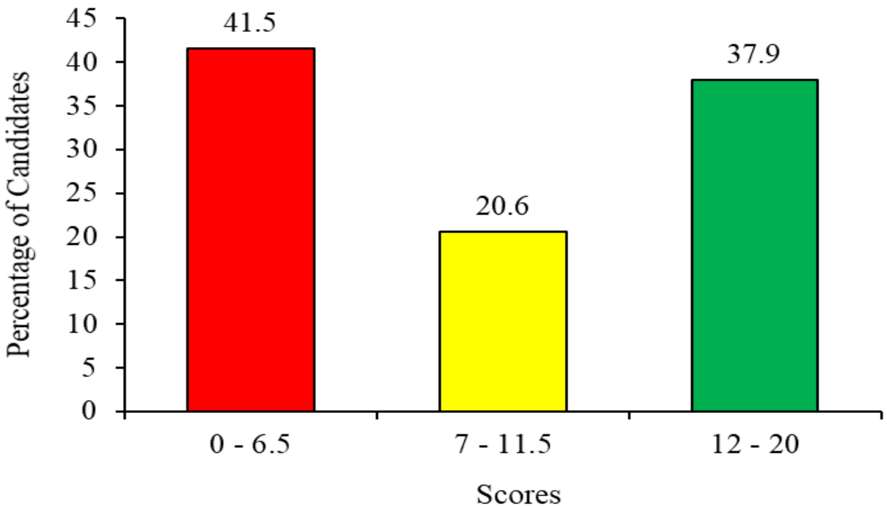


Figure 15: *Distribution of candidates' performance in Question 4 of Paper 2*

Most of the candidates who scored low marks failed to state the Coulomb's law. For example, one candidate incorrectly stated the law as "*the electrostatic force of attraction between two charged particles is directly proportional to the magnitude of their charge and inversely proportional to square distance apart"*. The candidate was supposed to know that *the force of attraction or repulsion of two charges is proportional to the product of the magnitude of the two charges*. In addition, some of the candidates failed to find the time of fall of proton in an electric field by using the concept of net force on a point charge due to electric field. These forces are due to weight of a proton (mg), electric force (F_e) and upthrust forces (F_u). The candidates were not aware that when these forces are added up, they must balance with the net force (ma) which in turn can be used to determine the time of proton to fall. In part (b), some of them confused the force due to electric field with that of magnetic field. One of the candidates used the $F = BqV$ instead of electrostatic force, F_e = Ee to determine the force on the electron in the electric field. Consequently, in part (c), they failed to determine the velocity with which the electron will hit the lower plate, the kinetic energy and the time an electron takes for the whole journey. Extract 14.1 shows the incorrect response from one of the candidates.

04. (a) (i) Columb's law state that
" The electrostatic force of attraction between two charged particle is directly propotional magnitude of their charge and inversely propotional to the square distance apart

(ii) Data given
mass of proton 1.673×10^{-27} kg
distance of plate is 1.5 cm $= 1.5 \times 10^{-2}$ m
$\beta = 2.0 \times 10^4 NC^{-1}$

fm,

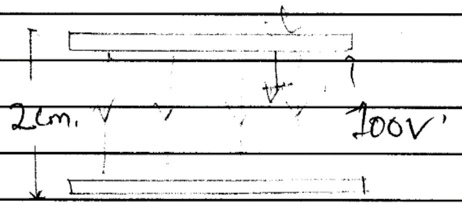
$\frac{Mv^2}{r} = \cancel{qBV}$ ~~9×10^7~~

$\frac{Mv^2}{r} = q\cancel{B}$

$\frac{\cancel{M}v}{\cancel{M}} = \frac{\beta q r}{M}$

$v = \frac{2.0 \times 10^4 NC^{-1} \times 1.5 \times 10^{-2} \times 1.6 \times 10^{-19}}{1.673 \times 10^{-27}}$

$V =$ ~~$228.4016 \times 10^{\ldots} m/s$~~
$V = 2.869097 \times 10^{10} m/s$

04	(ii) speed = $\frac{\text{distance}}{\text{time}}$
	$\frac{\text{distance}}{\text{speed}} = \frac{\cancel{\text{speed}} \times \text{time}}{\cancel{\text{speed}}}$
	$\text{time} = \frac{1.5 \times 10^{-2}}{2.86909743 \times 10^{10}}$
	$\text{time} = 5.228125 \times 10^{-13}$ sec
	∴ The time of fall will be 5.228125×10^{-13} sec
	(b) Data given
	Potential difference between two parallel plate apart 100V
	Separation distance = 2cm.
	If the electric field of the requires require to
	require to deflect force electrons
	
	$f = \cancel{Bqv}$.
	$f = \frac{k\,q^2}{r^2}$
	but
	$f = Bqv$.

04. (c) (i)

$$\sqrt{V^2} = \sqrt{\frac{k q_1 q_1}{Mr}}$$

$$V = \sqrt{\frac{9\times10^{9}\times(2.22\times10^{-10})^2}{9.11\times10^{-31}\,kg}}$$

$V = 2.206556441\times10^{10}\,m/s$

∴ The velocity which will hit the lower plate is $2.206556\times10^{10}\,m/s$

(ii)

$K.E = \frac{1}{2} m v_e^2$

$K.E = \frac{1}{2}\times 9.11\times10^{-31}\,kg \times (2.20655\times10^{10})^2$

$K.E = 2.21778\times10^{-10}\,J$

∴ The kinetic energy will be $2.21778\times10^{-10}\,J$

(iii) time for whole journey

speed of electron takes for electron to hit the lower journey

$$speed = \frac{distance}{t}$$

$$\frac{distance}{speed\ of\ electron} = \frac{speed\ electron \times time}{speed\ of\ electron}$$

$$time = \frac{2\times10^{-2}}{2.206556\times10^{10}\,m/s}$$

Extract 14.1: *A sample of incorrect responses to Question 4 of Paper 2*

Extract 14.1 shows that the candidate was not competent in the topic of electrostatic, particularly the Coulomb's law and the concepts of motion of charged particles in electric field. He/she also used incorrect formulas in his/her calculations.

However, in part (a), majority (58.5 per cent) of the candidates stated correctly the Coulomb's law and used the appropriate formula to calculate the time an electron takes to fall. In part (b), the candidates used appropriate formula to determine the force on the electron in the electric field. In part (c), they related correctly the net force (ma), electrostatic force, (F_e) and Newton's 3rd equation of motion to determine the velocity and kinetic energy of the electron. Extract 14.2 is a sample of a correct response.

4 (a) i) Coulomb's law states that
" Electrostatic force is directly proportional to the magnitude of product between two charges and inversely proportional to their squared separation distance.

$$Fe \propto Q_1 Q_2.$$

$$Fe \propto \frac{1}{r^2}$$

so,

$$Fe = \frac{KQ_1Q_2}{r^2}.$$

ii) Data given

Mass of proton $= 1.673 \times 10^{-27}$ kg.

Distance (d) $= 1.5 \times 10^{0}$ cm $= 1.5 \times 10^{-2}$ m

Electric field (E) $= 2.0 \times 10^{4}$ N/C.

Required: Time of fall of a proton.

solution

$$E = F/q$$

$$F = Eq$$

but also, $F = ma$.

$$Eq = ma.$$

$$a = \frac{Eq}{m} = \frac{2 \times 10^4 N/C \times 1.60 \times 10^{-19} C.}{1.673 \times 10^{-27} kg.}$$

$$a = 1.915 \times 10^{12} m/s^2.$$

But from Newton's law 2nd ~~of motion~~ equation. Given by.

$$S = ut + \frac{1}{2}at^2.$$

4 (a) ii) Required ! Time (t)

$d = \frac{1}{2}at^2$ fut.

but ~~a~~ = 0m/s.

$2 \times d = \frac{1}{2}at^2$

$\sqrt{\frac{2d}{a}} = \sqrt{t^2}$.

so,

$t = \sqrt{\frac{2 \times 1.5 \times 10^{-2} (m)}{1.9153 \times 10^{12}\ m/s^2}}$.

$t = 1.2515 \times 10^{-7}$ seconds.

∴ A proton will take 1.252×10^{-7} seconds to fall. while moving in an electric field.

(b) Data given.

potential difference (p.d) = 100v

Distance (L) = 2 cm = 2×10^{-2}m.

Required : force of an electric field.

solution

From

Electric fied (E) = $\frac{\text{Potential difference (V)}}{\text{Distance (m)}}$

$= \frac{100\ V}{2 \times 10^{-2} m}$.

$E = 5000 Vm^{-1}$.

Then required ! force.

but

$E = \frac{\text{Force (F)}}{\text{Electronic charge (e)}}$

4 (b) $E = F/e$.

So

$F = eE$.

But $e = 1.6 \times 10^{-19}$ C.

$F = 1.6 \times 10^{-19} C \times 5000 N/C$

$F = 8.01 \times 10^{-16} N$.

∴ Force on an electron in this field is $8 \times 10^{-16} N$.

(C) If an electron is from rest. ($V_{initial} = 0 m/s$).

Then.

i) Required: Find velocity it will hit lower plate (V_f)

solution.

$V_i = 0 m/s$.

$F = 8.0 \times 10^{-16} N$ $m_e = 9.11 \times 10^{-31} kg$.

$E = 5000 Vm^{-1}$

$e = 1.6 \times 10^{-19} C$

Required: Final velocity (V_f).

From

$F = ma$

$ma = F$.

$a = \frac{F}{m} = \frac{8.01 \times 10^{-16} N}{9.11 \times 10^{-31} kg}$.

Then.

$a = 8.792 \times 10^{14} m/s^2$.

from

4 (c) i) $v^2 = u^2 + 2as$

Given, S (distance) $= 2 \cdot \times 10^{-2}$ m.

$u = 0$ m/s^2.

$a = 8.78 \times 10^{+14}$ m/s^2.

Then,

$v^2 = 0 + 2as$.

$v^2 = 2as$.

$v = \sqrt{2as}$.

$v = \sqrt{2 \times 8.78 \times 10^{14} \text{m/s}^2 \times 2 \times 10^{-2} \text{m}}$

$= 5.93 \times 10^6$ m/s.

∴ Velocity of electron will be 5.93×10^6 m/s from upper plate to hit the lower plate.

ii) Required: Kinetic energy and time.

From

$KE = \frac{1}{2} Mv^2$.

$= \frac{1}{2} \times 9.11 \times 10^{-31}$ kg $\times (5.93 \times 10^6)^2$.

$KE. = 1.60 \times 10^{-17}$ Joule.

∴ Kinetic energy is 1.60×10^{-17} J.

Time taken

From

$V = u' + at$ since $u = 0$ m/s

$V = at$

$t = \frac{V}{a} = \frac{5.93 \times 10^6 \text{m/s}}{8.78 \times 10^{14} \text{m/s}^2}$

time (t) 6.75×10^{-9} seconds.

Therefore,

Time for whole journey is 6.75×10^{-9} seconds.

Extract 14.2: *A sample of correct responses to Question 4 of Paper 2*

In Extract 14.2, the candidate correctly stated the Coulomb's law. He/she applied appropriate computing skills and formulas to provide the correct solutions.

3.5 Question 5: Electromagnetism

This question had three parts: (a), (b) and (c). Part (a) required the candidates to (i) explain why magnetic lines of force always form closed loop and (ii) calculate the angle between the wire and the field lines if a force of 0.025 N experienced by a test wire of length 0.05 m is placed in magnetic field of strength 0.2 T carrying a current of 2.5 A. In part (b), the candidates were required to (i) identify two classes of magnetic materials which are weakly affected by magnetic field and (ii) determine their magnetizing force and magnetic flux density when a toroid in a wire with an air core, carries a current of 0.15 A as a min circumference of 50 cm and 500 turns. Part (c) required them to (i) briefly explain the cause of earth's magnetic field and (ii) determine the potential difference induced between one wing tip and the other if an aircraft is flying horizontally at 860 km/hr in a region where vertical component of the earth's magnetic field is 6.0×10^{-5} and its wing span is of 50 m.

The analysis reveals that 14,644 (67.5%) candidates attempted this question. Among them, 25.6 per cent scored from 0 to 6.5 marks; 34.2 per cent scored from 7 to 11.5 marks; and 40.2 per cent scored from 12 to 20 marks. Generally, these scores imply that the candidates' performance in this question was good as 79.9 per cent of the candidates scored from 7 to 20 marks. Figure 16 summarizes the analysis of the candidates' performance in this question.

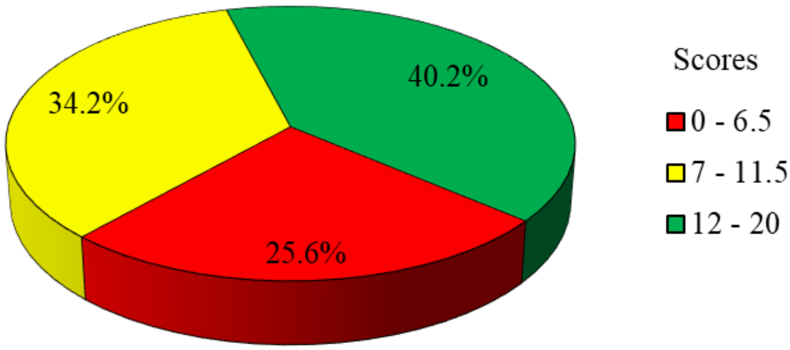


Figure 16: *Distribution of candidates' performance in Question 5 of Paper 2*

Further analysis shows that the candidates who scored high marks explained correctly why magnetic lines of force form a closed loop. Moreover, some of the candidates demonstrated their skills in calculating the angle between the wire and the field lines. In part (b), some of them identified the classes of magnetic field lines which are weakly affected by magnetic field as *diamagnetic* and *paramagnetic* materials. Additionally, they used correct the formulae $H=\frac{NI}{L}$ and $B = \mu_0 H$ to calculate the magnetizing force and magnetic flux density respectively. In part (c), they explained the cause of the earth's magnetic field. Furthermore, they determined the potential difference induced between one wing tip and the other. They also applied the correct formula and procedure to determine the angle between the wire and field, magnetizing force, magnetic flux density and induced potential difference. Extract 15.1 is the sample of a candidate's correct responses.

5. (a) (i) - One of the properties of magnetic lines of force is that, they tend to move from the North pole to wards the south pole of a magnet.
- While tracing their path from North to south pole, they tend to contract in Length and Expand Latellaly hence forming closed Loops.

5. (a) (ii) — Soln

$F = 0.025N$

$L = 0.05M$

$B = 0.2T$

$I = 2.5A$

Soln.

From

$$F = BIL\sin\theta$$

$$\sin\theta = \frac{F}{BIL}$$

$$= \frac{0.025}{0.2 \times 2.5 \times 0.05}$$

$\sin\theta = 1.$

$\theta = \sin^{-1} 1$

$\theta = 90^\circ$

$\therefore$ Angle between Wire and field lines

$\theta = 90^\circ$

5. (b)(i) • Diamagnetic materials. Example oxygen

• Paramagnetic materials. Example Aluminium

5. (b)(ii) soln.

$I = 0.15A$

$L = 50cm$

$N = 500$ turns

case I, Magnetising force

From

$H = nI$, $n = \frac{N}{L}$

$H = \frac{NI}{L}$

$H = \frac{500 \times 0.15}{50 \times 10^{-2}}$

$H = 150\ Am^{-1}$

$\therefore$ Magnetising force $= 150\ Am^{-1}$

	case II, Magnetic flux density
	From
	$B = \mu_0 nI$.
	$B = \mu_0 H$.
	$B = 4\pi \times 10^{-7} \times 150$
	$B = (4 \times 3.14) \times 10^{-7} \times 150$
	$B = 1.884 \times 10^{-4} T$
	$\therefore$ Magnetic flux density $= 1.884 \times 10^{-4} T$
	• The Magnetising force $= 150 Am^{-1}$ and
	• The Magnetic flux density $= 1.884 \times 10^{-4} T$
5.	(c) (i) Causes of Earths magnetic field.
	• Rotation of the earth.
	• Motion of rock layers and molten material
	s in the earths crust
	• Motion of charged and ionized particles
	in the earths Atmosphere resulting to
	creation of earths magnetic field.
5.	(c) (ii) Soln.
	$V = 860 \ km/hr$
	$B_v = 6.0 \times 10^{-5} T$.
	$L = 54 m$

5. (c) (ii) ... required, E.m.f induced,

From

$$E.m.f = BLV$$

$$= B_v \times L \times V$$

Given

$$V = 860\ km/hr = 238.89\ m/s$$

Then

$$E = 6.0 \times 10^{-5} \times 54 \times 238.89$$

$$E = 0.774\ V$$

∴ The potential difference induced between one wingtip and the other is $E = 0.774\ V$

Extract 15.1: *A sample of correct responses to Question 5 of Paper 2*

In Extract 15.1, the candidate provided the correct responses because he/she applied a correct formula and appropriate procedure in performing calculations.

On the other hand, the candidates who scored low marks had inadequate knowledge of the examined concept. In part (a) most of the candidates failed to explain why magnetic lines of force always form a closed loop. The reason behind was that *magnetic poles always exist in pairs. Therefore, magnetic lines of force run from N-pole to S-pole outside the magnet and from S-pole to N-pole inside the magnet. As a result, magnetic lines of force form a closed loop*. Some of the candidates failed to relate magnetic force with magnetic flux density, current and length of a conductor, as a result, they failed to calculate the angle between the wire and the field lines. In part (b), some candidates failed to demonstrate their competences to classify magnetic materials. They also failed to determine the magnetizing force and magnetic flux density because they lacked knowledge of electromagnetic induction. In part (c), some of them failed to explain the cause of the earth's magnetic field. They were not aware that *when the earth rotates about its axis the charged fluid in the core also rotates. This gives rise to circular electric current inside the core of the earth. This electric current is responsible for earth's magnetic field.* Moreover, some of them used incorrect formula and procedure to determine the induced potential difference between one wing tip and the other. Extract 15.2 is a sample of incorrect responses from one of the candidates.

5. a) (i) Magnetic lines of force always form a closed loops this is due to magnetic lines of force always they have strong attractive force that why they ~~force~~ form closed loops.

(ii) $F = 0.025\,N$
$L = 0.05\,m$
$B = 0.2\,T$
$I = 25\,A$.
$\theta = ?$

b) (i) - Ferromagnetic materials.
- Diamagnetic materials.

(ii) $I = 0.15\,A$.
$r = 50\,cm = 50 \times 10^{-2}$
$N = 500$
$f_m = ?$
but $A = \pi r^2$
$A = \pi \times (50 \times 10^{-2})^2$
$A = 0.785\,m^2$
Magnetic flux density $(B) = NIA$.
$B = NIA$.
$B = 500 \times 0.15 \times 0.785$
$B = 58.9\,T$
$\therefore$ Magnetic flux density B 58.9T.

5. a) (ii) $F = BIL\cos\theta$.

$\cos\theta = \frac{F}{BIL}$

$\cos\theta = \frac{0.025}{0.2 \times 2.5 \times 0.05}$

$\cos\theta = \frac{0.025}{0.025}$

$\cos\theta = 1$

$\theta = \cos^{-1}(1)$

$\theta = 0°$

∴ The angle between the wire and the field lines is $0°$.

b) (i) - Ferromagnetic materials.

- Diamagnetic materials.

(ii) $I = 0.15A$.

$r = 50cm = 50 \times 10^{-2}$

$N = 500$

$fm = ?$

but $A = \pi r^2$

$A = \pi \times (50 \times 10^{-2})^2$

$A = 0.785 m^2$

Magnetic flux density $(B) = NIA$.

$B = NIA$.

$B = 500 \times 0.15 \times 0.785$

$B = 58.9T$

∴ Magnetic flux density B 58.9T.

5. a) (ii) $P.d = \frac{Bd}{V}$ ~~$\frac{Vd}{B}$~~

~~$= \frac{860 \times 10^{-3} \times 60 \times 60 \times 54m}{6.0 \times 10^{-5}}$~~

$P.d = \frac{BV}{d}$

$= \frac{860 \times 10^{-3} \times 60 \times 60 \times 6.0 \times 10^{-5}}{54m}$

$P.d = 3.44 \times 10^{-3}$ V

∴ Tho potontial differenos induced betwon one wire tip end the other is 3.44×10^{-3} V

5. b) (ii) Demagnotizing force (fm) = BAN.I

fm = BANI

fm = 58.9 x 0.785 x 500 x 0.15

Fm = 3467.7N.

∴ Demagnotizing force is 3467.7N.

c) (i) Causo of Magnetic field.

Nature of tho material.

- Due to nature of materials some of material acquire magnetic characteristic which can be weak, strong or weakest. Duo to nature this can couse highly attracted of the materal and cause magnetic field.

Rotation of the bodies.

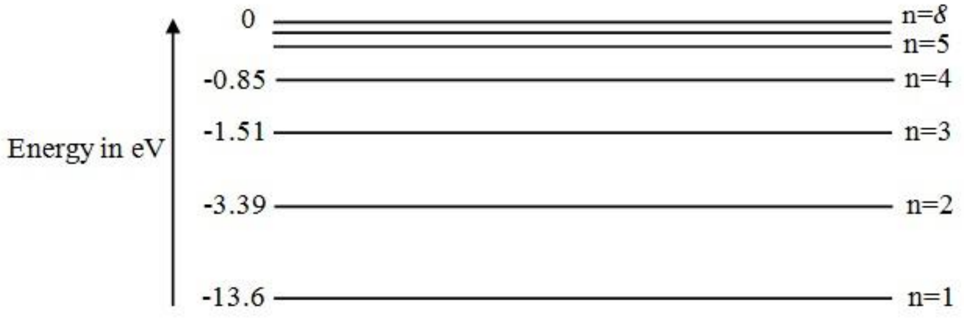
- Due to some bodies of Universal have highly attraction foro they couse eletric magnetic with other bodies which couse attraction of tho bodies in earth's magnotic field. This is tho couso of earth's magnotic field.

Extract 15.2: *A sample of incorrect responses to Question 5 of Paper 2*

In Extract 15.2, the candidate lacked the basic concepts of electromagnetism. For example, he/she applied an incorrect formula $F = BIL\cos\theta$ instead of $F = BIL\sin\theta$ to determine the angle between the wire and field lines.

3.6 Question 6: Atomic Physics

This question had three parts (a), (b) and (c). Part (a) required the candidates to (i) give the meaning of energy level and (ii) explain how ionization energy differs from excitation energy. In part (b), they were required to (i) explain why the Thomson's model fail (ii) identify the applications of cathode ray oscilloscope and (iii) calculate the wave length of the most energetic x–rays produced by a tube operating at 1.5×10^5. Part (c) required them to study the following figure of energy level for hydrogen atom.



By using the given figure the candidates were required to (i) calculate the frequency and the wavelength of the radiation emitted as a result of electron transmission from n = 3 to n = 2 and (ii) determine the energy at the level where n = 5.

A total of 20084 (92.6%) candidates attempted this question and their scores were distributed as follows: 20.1 per cent scored from 0 to 6.5 marks; 49.6 per cent scored from 7 to 11.5 marks; and 30.3 per cent scored from 12 to 20 marks. This indicates that the general performance in this question was good since 79.9 per cent of the candidates scored from 7.0 to 20 marks. Figure 17 describes the performance in this question.

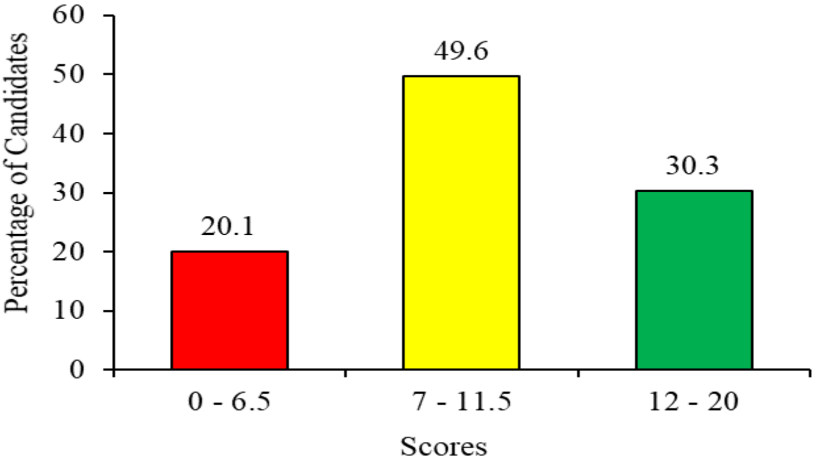


Figure 17: *Distribution of the candidates' scores in Question 6 of Paper 2*

The candidates' good performance in this question was attributed to their ability to understand the requirements of the question. In part (a), the candidates provided the correct meaning of the term energy level. Moreover, most of them were able to differentiate ionization energy from excitation energy. In part (b), some of the candidates explained the failure of Thompson's model as *the model failed to explain the scattering of* α *particle through large angle in Rutherford's* α *scattering experiment. It also failed to explain the existence of the nucleons.* Additionally, most of them mentioned correctly the applications of cathode ray oscilloscope (C.R.O). In part (c), some of the candidates studied the diagram for hydrogen atom and answered the given question by using the required formula and procedures to compute the frequency, wavelength of the radiation emitted and the energy level. Extract 16.1 is a sample of the correct responses.

6 (a)(i) Energy level is energy possessed by electrons in an orbital

(ii) Ionization energy is the energy required to remove electron from the ground state of an atom to infinity (energy required to remove electron completely from its ground state).

While

Excitation energy is the energy required to move electron in atom from one energy level, usually lower energy level to another energy level, usually higher energy level.

(b) (i) (i) Thompsons modal failed due to following reasons

(i) It did not agreed with Rutharford Scattering experimant

(ii) Failed to explain stability of an atom.

(ii) (i) It is used to display wave form

(ii) It is used to measure phase difference

(iii) It used to measure time

(iv) It is used to measure Voltage.

6:(b) (iii) Energy, $E = eV$

$E = 1.6\times10^{-19} \times 1.5\times10^{5}$

$E = 2.4\times10^{-14}J.$

from, $E = hf$,

$$E = \frac{hc}{\lambda}$$

$\cancel{\lambda = h}$

$$E = hf$$

$$f = \frac{E}{h} = \frac{2.4\times10^{-14}J}{6.63\times10^{-34}}$$

$f = 3.62\times10^{19}\ Hz$

$$f = \frac{c}{\lambda}$$

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{3\times10^{8}}{3.62\times10^{19}}$$

$\lambda = 8.287\times10^{-12}m$

∴ Wavelength of most energetic x-ray is $8.287\times10^{-12}m$

Q(c) (i) $\Delta E = E_3 - E_2$

$\Delta E = {}^{-}1.51 - {}^{-}3.39$

$\Delta E = 1.88eV$

$\Delta E = 1.88 \times 1.6 \times 10^{-19} J$

$\Delta E = 3.008 \times 10^{-19} J$

from,

$\Delta E = hf.$

$f = \frac{\Delta E}{h}$

$f = \frac{3.008 \times 10^{-19}}{6.63 \times 10^{-34}}$

$f = 4.537 \times 10^{14} Hz$

$\therefore$ frequency is $4.537 \times 10^{14} Hz$

from,

$f = \frac{c}{\lambda}$

$\lambda = \frac{c}{f}$

$\lambda = \frac{3 \times 10^8}{4.537 \times 10^{14}} = 6.61 \times 10^{-7} m$

$\therefore$ Wavelength is $6.61 \times 10^{-7} m.$

6: (c) (ii) from,

$$E = \frac{-13.6\,eV}{n^2}$$

$$E = \frac{-13.6eV}{5^2}$$

$$E = -0.544eV$$

$\therefore$ the energy at the level $n = 5$ is $-0.544eV$

Extract 16.1: *A sample of the correct responses to Question 6 of Paper 2*

In Extract 16.1, the candidate applied the knowledge of atomic physics and arithmetic skills of Bohr's parameters to determine the frequency, wavelength and energy of the electrons.

On the other hand, the candidate who failed to answer correctly this question lacked knowledge of basic concepts of atomic physics. Most of them were incompetent on the parameters of Bohr's atomic model such as frequency, wavelength and energy of the electrons in different levels. In part (a), some of the candidates failed to give the correct the meaning of energy. They also failed to differentiate ionization energy from excitation energy. For example, one candidate differentiated ionization energy from excitation energy as *ionization in alpha particle and gamma is higher while in excitation energy is not.* Another candidate wrote that *ionization energy is the energy acquired by alpha, beta and gamma particles while excitation energy is the energy that does not acquired by nuclear particles*. These candidates were supposed to state that *ionization energy is the minimum amount of energy required to ionize an atom which is in its ground state* or *is the energy required to remove an electron completely from the lowest level to infinity while excitation energy is the amount of energy required to promote electrons to higher energy levels*. In part (b), most of the candidates failed to explain the failure of the Thompsons's model. They were also unable to identify the application of cathode ray oscilloscope. Moreover, they used incorrect formulas to calculate the wavelength of the most energetic x-rays. In part (c), most of them were unable to interpret the given figure, as a result, they failed to calculate the frequency, wavelength of the emitted radiation and the energy of an electron transition from one level to another. Extract 16.2 is a sample of incorrect responses to the question.

06. a (i) Energy level refer to the levels of Energy in which an electron reach when being excited or absorb the radiant of energies.

06 a (ii). The ~~Ionization energy differ from excitation energy because an electron~~

06 (ii) Ionization energy means the minimum energy required to excite an electron. The Ionization energy differ from the excitation energy, due to the distance from the nuclear, the larger the distance ~~the lower it~~ from the nuclear the lower the Ionization energy, and also the near the distance from the nuclear the higher the ionization ~~lower~~ energy have,

06 b. The reason for the failure of the ~~Tom~~ Thomson's model,

i/ The model fail to explain about existance of the hydrogen spectrum

ii/ The model fail to explain about the motion of an electron around the nuclear of an atom

iii/ The model fail to explain the stability of the electrons and proton in an atom

ii/ Application of the Cathode ray oscilloscope

i/ Used in securities

ii/ Used in X-rays activities

iii/ Used in treatment of cancer like skin cancer

iv/ Used in manufacturing of nuclear bombs.

06.b(iii) Data given;

$\lambda = ?$ (required)

$f = 1.5 \times 10^5 v.$

From;

$$f = \frac{c}{\lambda}$$

$$\lambda = \frac{c}{f}.$$

but $c = 3 \times 10^8 m/s$.

$$\lambda = \frac{3 \times 10^8}{1.5 \times 10^5}$$

$$\lambda = 2.0 \times 10^3 \ m$$

$\therefore$ The wave length of the most energetic X-rays produced is ~~about~~ $2.0 \times 10^3 m$.

06.c. Required;

frequency = ?

wavelength = ?

$n_1 = 2$

$n_2 = 3$

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

06'c. $\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$

but $R_H = 1.1 \times 10^7 m^{-1}$

$\frac{1}{\lambda} = 1.1 \times 10^7 \times \left(\frac{5}{36}\right)$

$\frac{1}{\lambda} = 1.527 \times 10^6.$

$\lambda = \frac{1}{1.527 \times 10^6}$

$\lambda = 6.545 \times 10^{-7} m.$

Then: from: $f = \frac{c}{\lambda}$

$f = \frac{3.0 \times 10^8}{6.545 \times 10^{-7}}$

$f = 4.583 \times 10^{14} Hz$

∴ i) The frequency of radiation emitted is $4.583 \times 10^{14} Hz$

ii) The wavelength of the radiation emitted is $6.545 \times 10^{-7} m$

From; $E = \frac{-13.6\,eV}{n^2}$

$E = \frac{-13.6\,eV}{5^2}$

$E = \frac{-13.6 \times 1.6 \times 10^{-19}}{25}$

$= -8.71 \times 10^{-20}$ Joule

$\therefore$ The Energy was -8.7×10^{-20} Joule

Extract 16.2: *A sample of incorrect responses to Question 6 of Paper 2*

In Extract 16.2, the candidate provided irrelevant responses which do not meet the requirements of the question. For instance, in part (c), he/she wrongly interpreted the figure of energy levels and ended up with incorrect values of frequency, wavelength and energy.

4.0 ANALYSIS OF CANDIDATES' PERFORMANCE IN EACH QUESTION IN 131/3 PHYSICS 3

Physics Paper 3 had three alternatives of Actual Practical Papers which are 131/3A Physics 3A, 131/3B Physics 3B and 131/3C Physics 3C. Each alternative paper comprised three questions. Question 1 carried 20 marks while questions 2 and 3 carried 15 marks each. Question 1 was set from the topic of Mechanics, question 2 was set from Heat while question 3 was set from Current Electricity.

4.1 Question 1: Mechanics

This part consisted of three questions derived from the topic of Mechanics. It is a collection of questions from each alternative papers. The analysis of each question is as follows:

4.1.1 Physics 3A, 3B and 3C

A total of 21,697 candidates attempted this question. Among them, 62.6 per cent scored from 0 to 6.5 marks; 30.4 per cent scored from 7 to 11.5; and 7.0 per cent scored from 12 to 20 marks. Only three (3) candidates scored all 20 marks. The analysis reveals that the general performance in this question was weak. Figure 18 summarizes the performance.

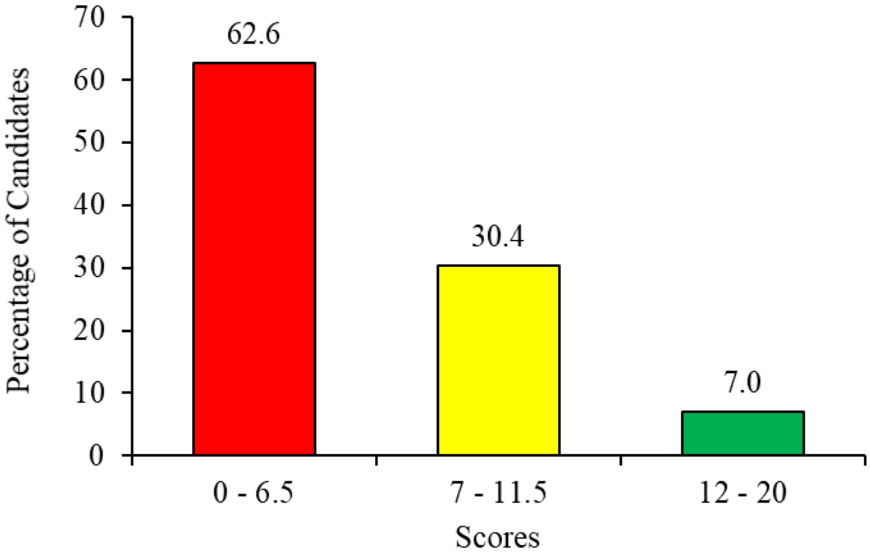


Figure 18: *Distribution of candidates' performance in Question 1*

4.1.1.1 Physics 3A

The candidates were provided with a wire W (Constantan wire SWG 26), meter rule, two cork pads, test tube, micrometre screw gauge, slotted mass of 20 g, retort stand with its accessories, masking tape and optical pin.

The candidates were required to:

(a) measure and record the length l and diameter d of the wire W.

(b) wind the whole length of the wire W tightly on the test tube such that the turns are as close as possible but not overlapping.

(c) measure the length x of the coil made as shown in Figure 1 and count the number of turns.

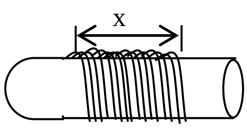


Figure 1

(d) remove the coil from the test tube; straighten the first and the last coil. Clamp one end on the retort stand while bending the other end to make a hook. Count the number of complete turns (n) remaining and measure the distance h_1 between the ends of the coil as shown in Figure 2.

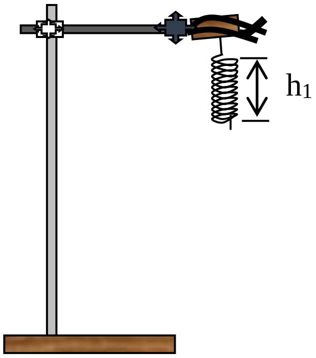


Figure 2

(e) load a 20 g mass on the other end of the coil and arrange as shown in Figure 3. Measure and record the distance h_2 between the ends of the turns.

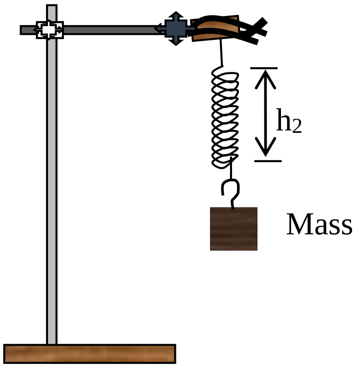


Figure 3

(f) remove the mass, reduce the number of turns by straightening three turns of the coil from the upper end and adjust the point of suspension of the coil. Record the number of turns *(n)* remaining and measure the distance h_1. Load 20 g mass of the coil and then measure and record distance h_2.

(g) repeat the procedures in 1 (f) so as to obtain the other three readings to make a total of five readings for n, h_1 and h_2.

Questions

(i) Record the values of n, h_1 and h_2 and find extension *e* as shown in the following table:

Number of turns n **remaining**						
Distance h_1(cm)						
Distance h_2(cm)						
Extension, *e* = (h_2- h_1)(cm)						

(ii) Plot the graph of extension, *e* against the number of turns, n.

(iii) Determine the slope S of the graph.

(iv) Compute the value of constant G from the equation; $\frac{1}{n} = \frac{Gx}{de}$.

Most of the candidates who scored high marks had enough skills to wind the whole length of the wire W tightly on the test tube to make a coil with reasonable minimum separation and number of turns. Some of the candidates obtained the correct value of x, which helped them to collect the correct data, as a result they plotted the correct graph. They correctly interpreted the plotted graph to get the slope which in turn helped them to obtain the value of the constant G. Extract 17.1 is a sample of the correct responses.

1 REPORT

Length of wire = 95cm

Diameter of wire = 0·44mm

TABLE OF RESULTS.

(i)

Number of turns (n) remaining	15	12	9	6	3	
Distance h_1 (cm)	10	9	7	5	2	
Distance, h_2 (cm)	15·1	13	10	7	3	
Extension e $(h_2 - h_1)$ (cm)	5·1	4	3	2	1	

no of turns = 19.

Length x of the coil = 1cm.

(iii) from the graph.

Slope = $\frac{\Delta e}{\Delta n}$.

Slope = $\frac{3·35 - 1·5}{10 - 4·5}$

Slope = 0·3364 cm

1 (iv) from the equation

$$\frac{1}{n} = \frac{qx}{de}.$$

$$\frac{de}{nx} = q.$$

Given

$d = 0.244mm = 0.0244cm.$

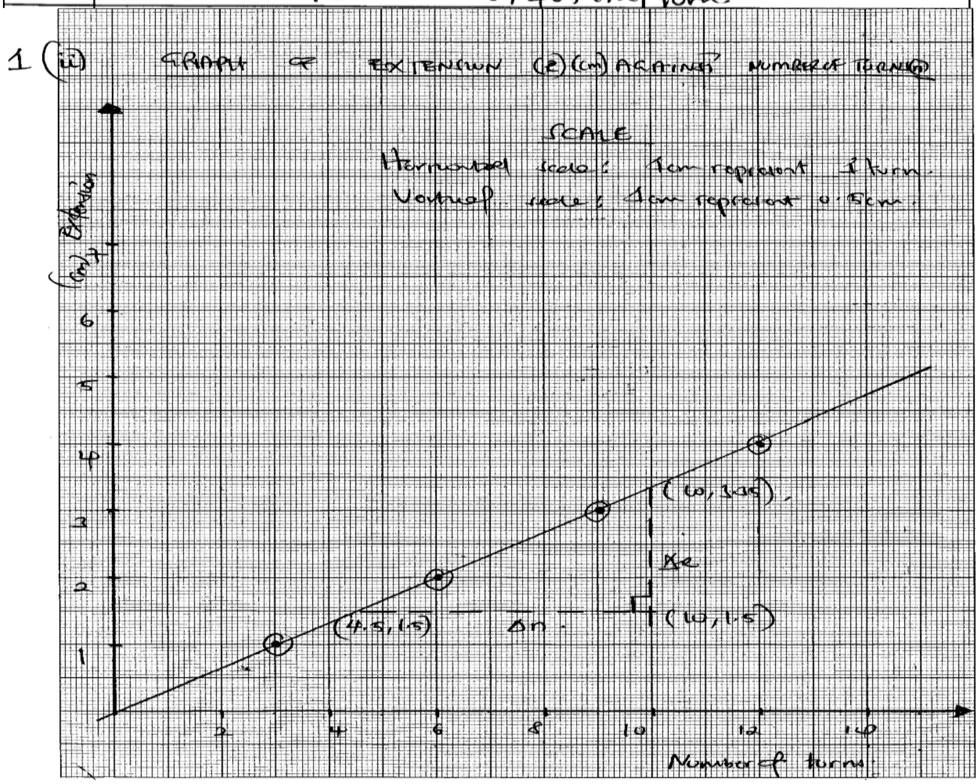
$x = 1cm.$

$n = \cancel{75}\ 12$

$e = 4cm.$

$$q = \frac{0.0244cm \times 4cm}{12 \times 1cm}.$$

$q = 0.01467 cm/turn.$



Extract 17.1: *A sample of correct responses to Question 1 of Paper 3A*

In Extract 17.1, the candidate correctly collected the data and manipulated the data to obtain the required values.

However, the candidates who scored low marks in this question did not have enough skills and knowledge of practical aspect of Physics. The analysis shows that most of the candidates faced the challenges in winding the wire W tightly on the test tube to get the minimum separation. Some of them obtained large value of x and smaller number of turns which would not give the expected value. Failure to get the required value of x led them to collect wrong data and plot incorrect graphs. Most of graphs drawn lacked basic features such as title of the graph, labels of the axes, proper scales and best lines. Some of the candidates lacked knowledge of how to determine the slope of the graph and thus failed to provide the correct answers to the other parts of the question. For example, some candidates did not draw the graph which was a necessary step to compute the slope, instead, they just used the data which they collected from the experiment to determine the slope, contrary to the requirement of the question. Extract 17.2 is a sample of incorrect responses.

01. i/ TABLE OF VALUES.

Number of turns remaining.	18	15	12	9	6
Distance h_1 (cm)	29	24.2	19.3	14.5	9.67
Distance h_2 (cm)	61	73	82	91	97
Extension $e(h_2 - h_1)$ cm.	32	48.8	62.7	~~96~~.5	87.3.

b). length of wire (L) = 101 cm.
Diameter of wire (d) = 0.24 mm.

c) The length x = 6 cm.
Number of turns were ~~21~~ 20 Turns.

(d) The height h_1 = 24 cm.

e) The height h_2 = 61 cm.

iii/ For the slope of the graph

$S = \frac{\Delta e}{\Delta n}$

$= \left(\frac{80.07 - 35.7}{5.69 - 18}\right) \frac{cm}{n}$

$= -3.6.$

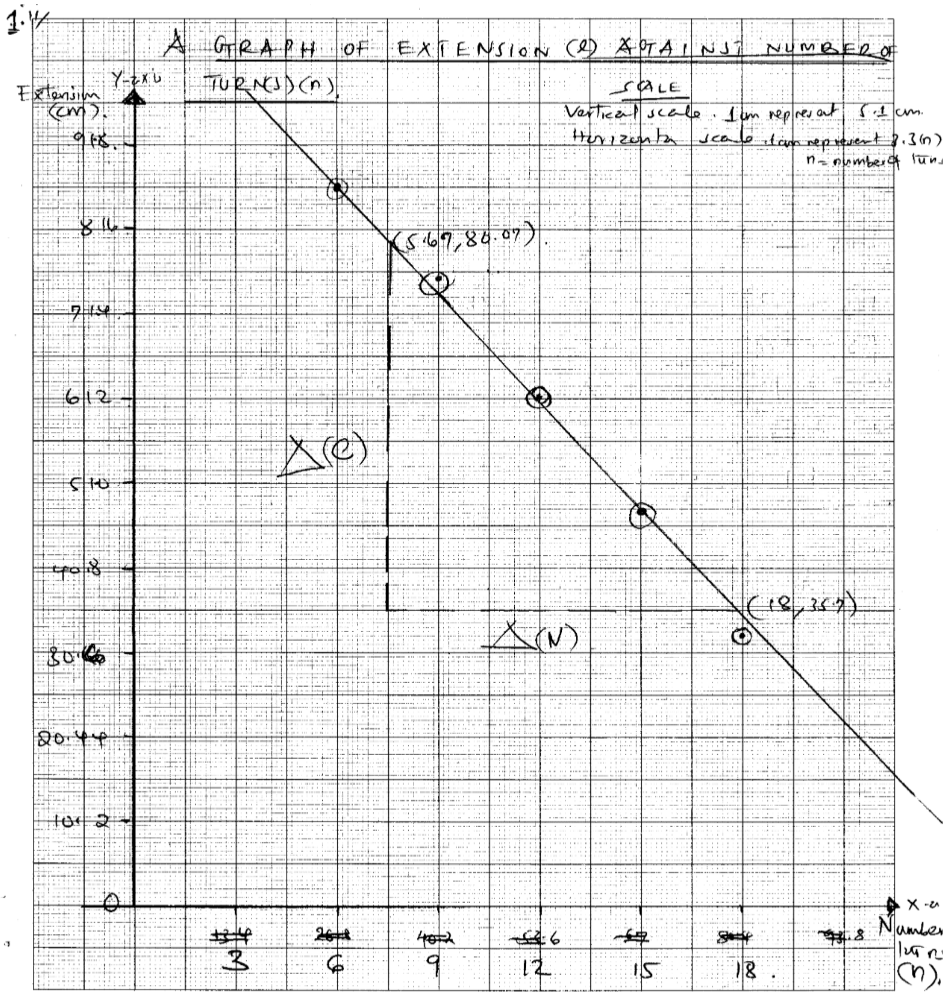
$\therefore$ slope $= -3.6\ cm\,n^{-1}$

iv/ From the equation

$\frac{1}{n} = \frac{Gx}{de}.$

01	iv) $\frac{G_T X}{d} = \text{slope.}$
	$-3.6 = \frac{G_T X}{d}$
	$-3.6 = \frac{G_T X \; 6\,cm}{0.024\,cm.}$
	$G_T = \frac{0.024 \times -3.6}{6\,cm.}$
	$G_T = -1.44 \times 10^{-4}\,cm.$
	$\therefore$ The value of constant $G_T = -1.44 \times 10^{-4}\,cm.$

01.	iv/ $\frac{1}{n} = \frac{G_T X}{de}$
	$nG_T X = de$
	$e = \frac{nG_T X}{d.}$
	$e = \frac{G_T X}{d}\,n$
	$\downarrow$ $\downarrow$ $\downarrow$
	y $\ \ 1/m$ $\ \ x$
	$m = \text{slope}$



Extract 17.2: *A sample of incorrect responses to Question 1 of Paper 3A*

Extract 17.2 shows the work of a candidate who did not measure the diameter of the wire correctly. He/she got 0.24 mm instead of 0.46 mm. He/she also failed to wind the given wire appropriately, as a result he/she obtained the incorrect length of the coil.

4.1.1.2 Physics 3B

In this question, it was assumed that the weighing balance at the school is not working properly. The candidates were required to determine the mass of the empty glass beaker as follows:

(a) Using the masking tape to firmly wrap the thread on the beaker and suspend it to the lower end of the spring as shown in Figure 1 where an optical pin is bent into 'S' shape.

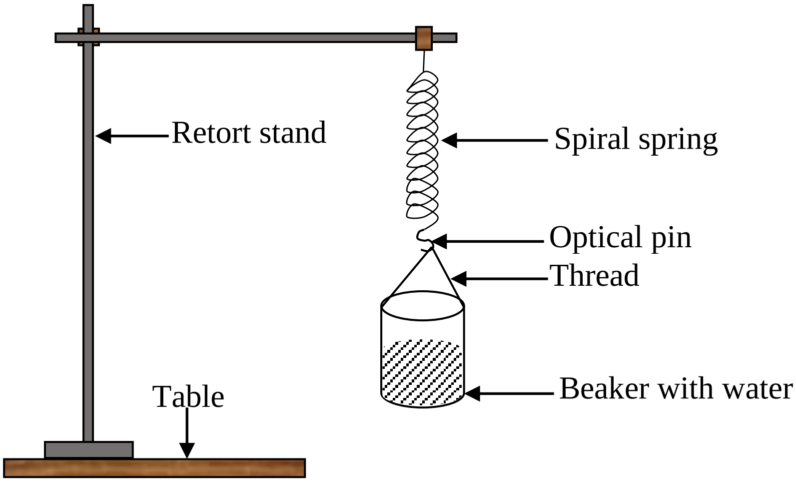


Figure 1

(b) Measure the volume V = 25 cm^3 of water and pour it into the suspended beaker. Gently pull the beaker a small distance downward and release it so that it performs vertical oscillations. Measure and record time t (s) for 30 oscillations and determine periodic time, T.

(c) Repeat the procedure in 1 (b) for V = 60 cm^3, 100 cm^3, 150 cm^3 and 200 cm^3.

Questions

(i) Tabulate your results including the values of T^2 (s^2).

(ii) Plot a graph of V (cm^3) against T^2 (s^2).

(iii) Establish the equation governing this experiment.

(iv) Use the graph and the equation obtained in 1 (iii) to determine the mass of an empty glass beaker.

(v) What will happen to the floating object if it is put in oscillating beaker at the bottom position of its oscillation? Briefly explain.

The candidates who scored high marks in this question had sufficient knowledge to perform the experiment correctly. Most of them tabulated the correct results and followed the required procedure to plot the graph. Some of the candidates were competent enough to interpret the graph and they applied the formula $T = 2\pi\sqrt{\frac{m + M}{k}}$ to establish the equation $V = \frac{k}{4\pi^2\rho}T^2 - \frac{M}{\rho}$ which obeys the experimental results. Some of those candidates used the information from the graph and the equation obtained to determine correctly the mass of an empty glass beaker. However, few candidates faced difficulties to explain what happens to a floating object if it is in oscillating beaker at the bottom position of its oscillation. They did not realise that the object will not oscillate relative to water surface because water and beaker were oscillating together. Extract 18.1 is a sample of the correct responses.

Q1. A TABLE OF RESULTS.

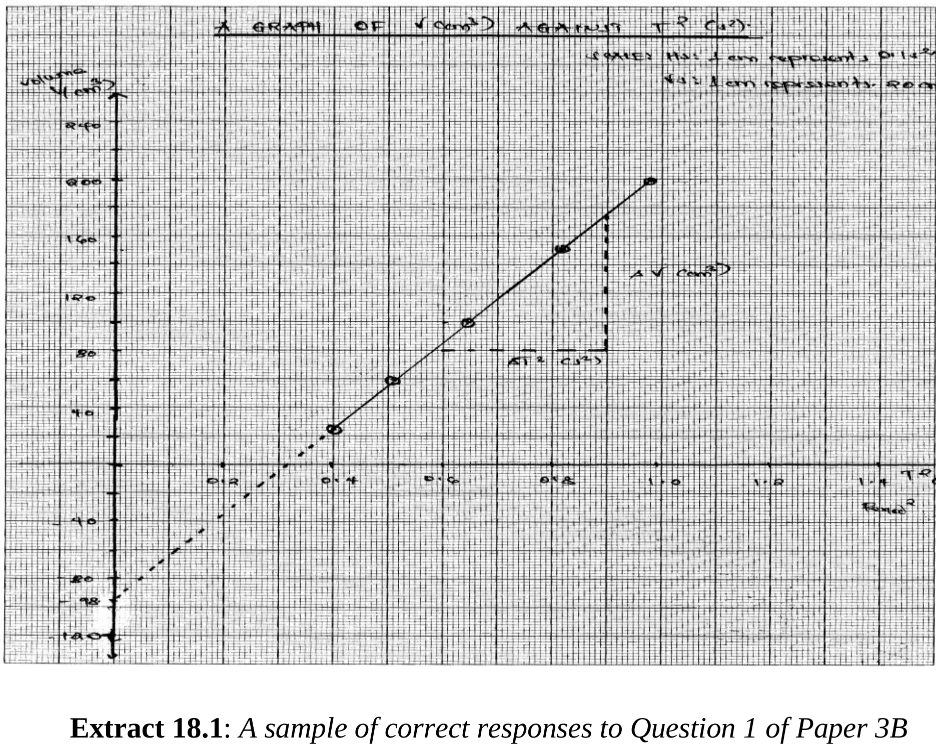
Volume V (cm^3)	Time t (sec)	Periodic time T (s)	T^2 (s^2)
25	19.12	0.6363	0.4049
60	21.60	0.7209	0.5198
100	24.21	0.8070	0.6513
150	27.10	0.9081	0.8155
200	29.70	0.9898	0.9798

(ii)	Required to plot a graph of V (cm^3) against T^2 (s^2).
	From The graph
	The Value of Y-intercept is $\underline{-98.24}$ cm^3
	$\text{slope} = \dfrac{\text{change in Volume}}{\text{change in } T^2}$
	$= \dfrac{(176 - 80)cm^3}{0.9 - 0.58\ s^2}$
	$\therefore$ slope = $\underline{304.39\ cm^3/s^2}$

1 (iii)	Required The equation governing the experiment
	so
	consider
	$T = 2\pi\sqrt{\dfrac{m_w + M_b}{k}}$
	$T^2 = 4\pi^2\left(\dfrac{M_w}{K} + \dfrac{M_b}{K}\right)$
	But Mass of water = ρ_{water} × Volume,
	so
	$T^2K = 4\pi^2(\rho V + M_b)$
	$\dfrac{T^2K}{4\pi^2} = \rho V + M_b$
	$\rho V = \dfrac{T^2K}{4\pi^2} - M_b$
	$\cancel{\rho} V = \dfrac{T^2K}{4\pi^2\rho} - \dfrac{M_b}{\rho}$
	Therefore
	$V = \dfrac{T^2K}{4\pi^2\rho} - \dfrac{M_b}{\rho}$
	$Y = mx - c$
	where V = Volume of water
	M_b = Mass of empty beaker
	ρ = Density of water
	k = Spring constant
	$\therefore$ The relation governing the experiment
	is
	$V = \dfrac{T^2K}{4\pi^2\rho} - \dfrac{M_b}{\rho}$

1 iv	From the graph drawn above the value of Y-intercept
	= − 98.24
	So consider the relation of the experiment.
	$V = \frac{T^2 K}{4\pi^2 \rho} - \frac{M_b}{\rho}$
	So $+\frac{M_b}{\rho} = +98.24$
	Mass of beaker = 98.24 × density of water
	= 98.24 × 1g/cm³
	∴ Mass of the beaker = 98.24g
1(v)	When a floating object is put in an oscillating beaker being at the bottom position of its oscillation it will Experience No viscous force than when being at the top of its oscillation since at the bottom there is no reaction force acting on a floating body.

01



Extract 18.1: *A sample of correct responses to Question 1 of Paper 3B*

Extract 18.1 shows how the candidate collected the data correctly, and drew the required graph. The candidate had enough skills to deduce the necessary equations although he/she was not aware that the object will oscillate together with water and beaker.

On the other hand, the candidates who scored low marks faced challenges to record the time t (s) for 30 oscillations, as a result they incorrectly determined the periodic time, T and failed to represent the data graphically. Some of them were not aware of the important features to be include when drawing graphs. They drew the graphs without indicating the title, axis, scales used and the slope indication. In addition, most of the candidates failed to analyse the information from the graph, hence they failed to deduce the intended equation. Furthermore, they computed incorrectly the mass of an empty beaker. Finally, most of the candidates failed to explain correctly the last part of the question. For example, one of the candidates explained that *the period of oscillation will decrease due to addition of floating object*. The candidate failed to recall that *adding the object to an oscillating system would decrease its frequency, leading to the increase in period* though this was not the requirement of the question. Extract 18.2 is one of the incorrect responses.

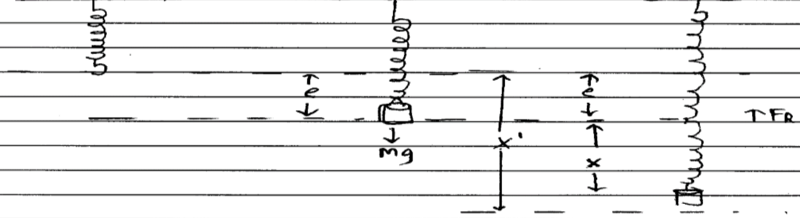
1 (i) Table of results

Volume (cm^3)	time "t" (s)	Period T (s)	Period T^2 (s^2)
25	21.34	1.40	1.96
60	24.44	1.23	1.51
100	27.03	1.11	1.23
150	30.13	0.99	0.98
200	32.78	0.92	0.85

(ii) Graph.

(iii) The equation governing the experment consider diagrams

without mass   with addition of mass M   with addition of f. Force



• On addition of mass M to a spring the spring increas length by e

From hooke's law $F \propto e$

$F = ke$ Put Here $F = Mg$

Hence $Mg = ke$ - - - - i

• When the system is set to oscillate the it will move with SHM due to restoring Force FR

$F_{net} = F_R - Mg$

1 (iii) $\cancel{F_R} =$

$$Ma = F_R - Mg \qquad F_R = Kx' \qquad x' = (x+e)$$

$$\cancel{Ma} = \qquad\qquad Mg = Ke$$

$$Ma = K(x+e) - Ke$$

$$Ma = Kx + Ke - Ke$$

$$Ma = Ke$$

$$a = \frac{Ke}{M}$$

But for SHM $a = \omega^2 A$
where A = Amplitude

$$\omega^2 A = \frac{Ke}{M} \qquad \omega = \frac{2\pi}{T}$$

$$\left(\frac{2\pi}{T}\right)^2 A = \frac{Ke}{M}$$

$$\frac{4\pi^2 A}{T^2} = \frac{Ke}{M} \qquad \text{for maximum } A = e$$

Equation:

$$T^2 = \frac{4\pi^2 m}{K} \qquad \text{Also } M = \rho \times V$$

$$T^2 = \frac{4\pi^2 \rho V}{K}$$

where
V = Volume of water
ρ = Density of water
K = Spring constant
T = Period T(s)

1 (iv) from the graph

$$\text{Slope } M = \frac{\Delta V}{\Delta T^2}$$

$$M = \frac{100 - 70}{1.23 - 1.65}$$

$$M = \frac{30}{-0.42} - 71.42.$$

From

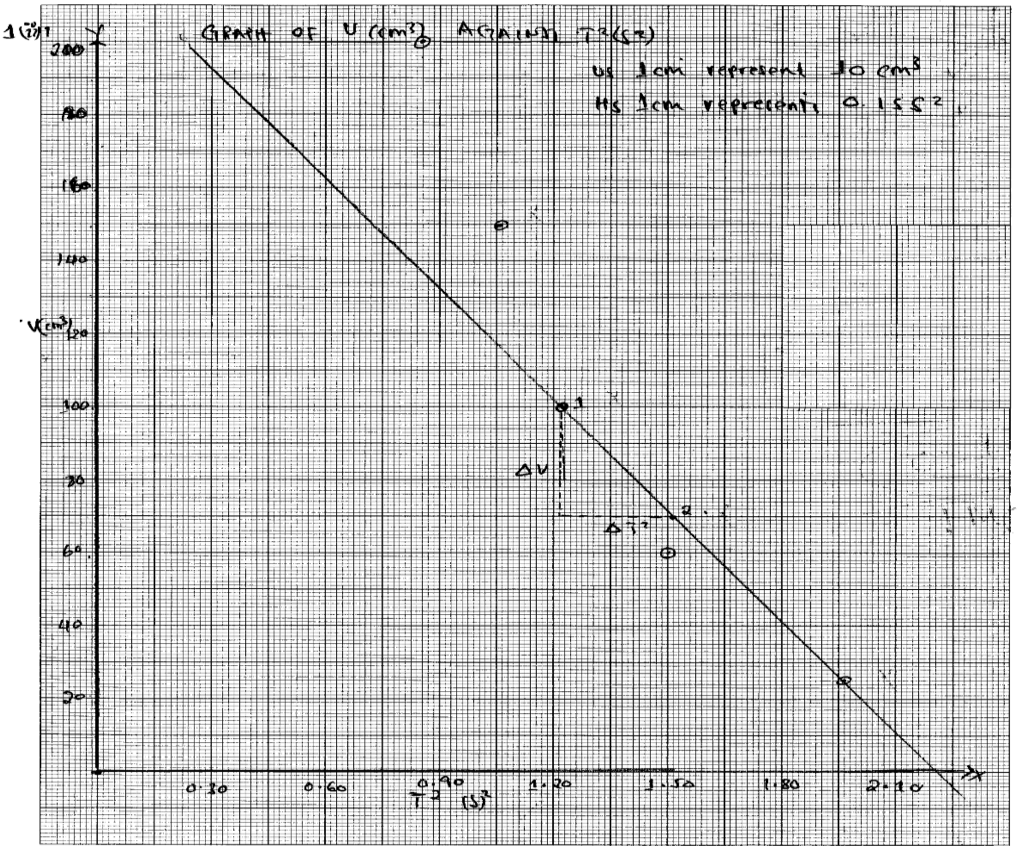
$$T^2 = \frac{4\pi^2 m}{K}$$

$$T = 2\pi\sqrt{\frac{M}{K}} \qquad \because M = m_{beaker} + M_{water}$$

$$\text{Also} \quad Mg = Ke$$

$$\frac{M}{K} = \frac{e}{g}$$

(v) When floating object is put in oscillating beaker at the bottom of its oscillation the time period for the oscillation or the time for regaining original position will increase.



Extract 18.2: *A sample of incorrect responses to Question 1 of Paper 3B*

Extract 18.2 shows how the candidate failed to collect the correct data and ended up drawing a graph with negative slope instead of positive slope. He/she also failed to derive the required equation.

4.1.1.3 Physics 3C

In this question the candidates were provided with a wire **W**, a meter rule, cork pads, a test tube, a micrometre screw gauge, five masses each having 10 g a retort stand with its accessories, an optical pin (pointer), a string of 20 cm, masking tape and a light plastic scale pan.
Then, they were required to:

(a) Measure and record the length, L (m) and diameter d (m) of the wire, W provided.

(b) Wind tightly the whole length of the wire on the test tube provided, making sure that turns are as close as possible but do not overlap.

(c) Remove the coil from the test tube, straighten the first and last turns of the coil made, then bend one end of the coil to make a hook.

(d) Arrange the apparatus as shown in Figure 1.

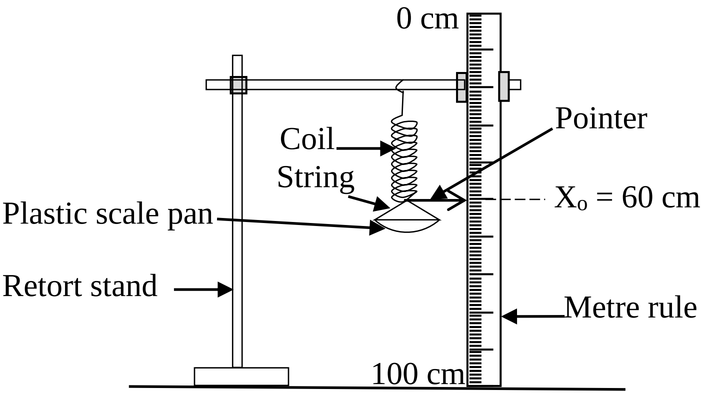


Figure 1

(e) With the help of a masking tape, insert a pointer at X_o when there is no mass placed on a plastic scale pan.

(f) Place 10 g mass on a plastic scale pan, measure the new length, X when the spring is extended and calculate the extension.

(g) Without removing the first mass, add another mass weighing 10 g on the scale pan to make a total of 20 g and measure the new length and calculate its extension.

(h) Repeat the procedure in 1 (g) by adding 10 g mass until you get a total mass of 50 g while measuring new length and extension in each case.

Questions

(i) Tabulate your results including the values of load as F (N) and extension, e (m), where; 100 g = 1 N.

(ii) Plot a graph of extension (m) against load (N).

(iii) Give comment on the relationship between the load and extension in 1 (ii).

(iv) Determine the slope, K of the graph.

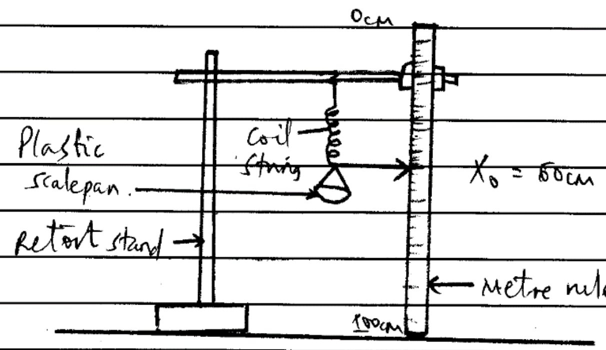
(v) Use the value obtained in 1 (iv) to calculate the value of ρ from the equation, $K = \frac{4L}{\pi d^2 \rho}$.

(vi) What is the physical meaning of the value obtained in 1 (v)?

The candidates who scored high marks in this question demonstrated the required skills in performing the experiment. Most of them were competent in analysing, evaluating and applying mathematical skills to obtain the solution to the problem. They used the collected data and followed the required procedure to plot the graph of extension (M) against the load (N). Moreover, they interpreted the graph and found that from the first three points of the graph, extension is directly proportional to the load (the graph obeys Hooks law). Furthermore, they used correctly the ratio of change of extension to the change of load to determine the slope, K of the graph. Finally, they used the slope obtained and the equation given to compute the value of ρ as a longitudinal stress *or* tensile stress. Extract 19.1 is a correct response given by a candidate who scored high marks.

1. EXPERIMENTAL REPORT.

a) Experimental diagram.



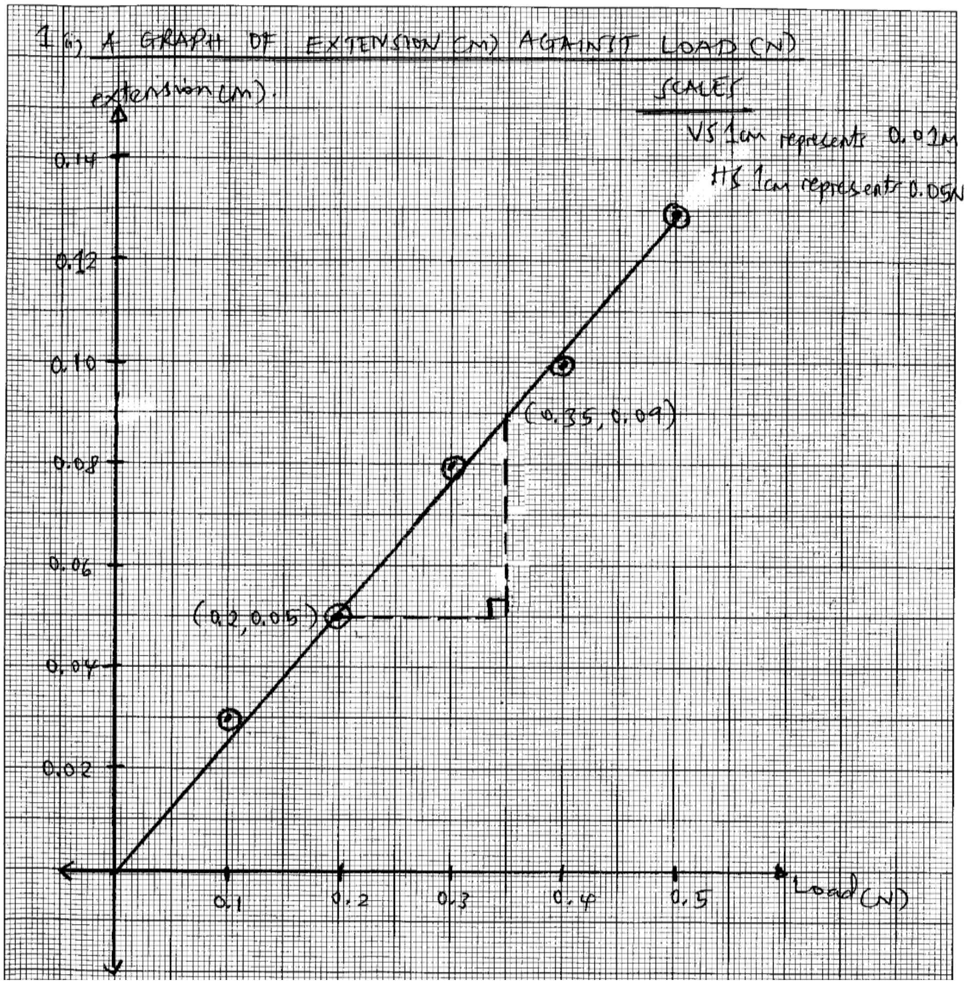
i) Table of results.

Mass (g)	X_0 (cm)	X (cm)	extension, (cm)	Load, F(N)
10	60	63	0.03	0.1N
20	60	65	0.05	0.2
30	60	68	0.08	0.3
40	60	70	~~1.00~~ 0.10	0.4
50	60	73	~~1.30~~ 0.13	0.5

then,

iii) from the graph.

1	iv) slope $= \frac{\Delta e \ (m)}{\Delta F \ (N)}$
	$K = \frac{(e_2 - e_1), m}{(F_2 - F_1), N}$
	$K = \frac{(0.09 - 0.05) m}{(0.35 - 0.2) N}$
	$K = \frac{0.04 \ m}{0.15 \ N}$
	$\therefore$ slope, $K = \underline{\underline{0.267 \ m/N}}$
	iii) From the graph, load(N) is directly proportional to extension (m).
	v) from,
	$K = \frac{4L}{\pi d^2 f}$
	where, $K = 0.267 \ m/N$
	Then,
	$f = \frac{4L}{\pi d^2 K}$
	$= \frac{4 \times 1m}{\pi \times (0.45 \times 10^{-3} m)^2 \times 0.267 \ m/N}$
	$= \frac{4 \ m}{1.6985 \times 10^{-7} \ m^3/N}$
	$f = 2.355 \times 10^7 \ N/m^2$
	$\therefore$ The value of f is $\underline{\underline{2.355 \times 10^7 \ N/m^2}}$
	vi) The physical meaning of f is $\underline{\underline{\text{Young's modulus}}}$.



Extract 19.1 *A sample of correct responses in Question 1 of Paper 3C.*

Extract 19.1 shows the responses of a candidate who performed the question correctly but failed to identify the physical meaning of the value calculated. He/she stated it as Young's modules instead of longitudinal stress *or* tensile stress.

Some of the candidates who scored low marks (0 to 6.5 marks) did not collected the data correctly because they failed to wind the wire on the test tube to obtain a spring with a reasonable minimum separation. In data collection, some them failed to convert gram into Newton although they were given that 100 g = 1 N. They just multiplied by 9.8 N/kg and used the extension in centimetre (cm) instead of meter (m). Most of the candidates were not aware of the features of a good graph. They drew the graphs without indicating the title, axes, scales, best line and slope. Some of candidates transferred the data incorrectly and failed to choose the points for slope calculation. So, they failed to comment on the relationship between load and extension and to determine the slope K of the graph. Additionally, they lacked skills to calculate the value of ρ from the equation, $K=\frac{4L}{\pi d^2 \rho}$, and thus failed to state its physical meaning. Extract 19.2 is the sample of incorrect responses.

1 (i) TABLE OF RESULTS

Mass (g)	Length (m)	Extension (m)	Load (N)
10	60	8.16×10^{-15}	0.098
20	65	1.67×10^{-15}	0.03
30	70	2.5×10^{-15}	0.03
40	75	3.3×10^{-15}	0.04
50	80	4.16×10^{-15}	0.05

(ii) A graph of extension (m) against Load (N) has been plotted on the graph paper given

(iii) Load and extension obey's hooke's Law, that is as the Load increase the extension also increase.

(iv) from

$$slope = \frac{\Delta y}{\Delta x}$$

$$slope = \frac{\Delta \text{ Extension (m)}}{\Delta \text{ Load (N)}} = \frac{8.16\times10^{-15} - 4.16\times10^{-15}}{0.098 - 0.05}$$

$$slope = 1.2\times10^{13} \ m^{-}N$$

(v) From the equation

$$K = \frac{4L}{\pi d^2 y}$$

$$y = \frac{4L}{\pi d^2 K}$$

Where $L = 98cm = 0.98M$

$d = 0.46mm = 0.46\times10^{-3} M$

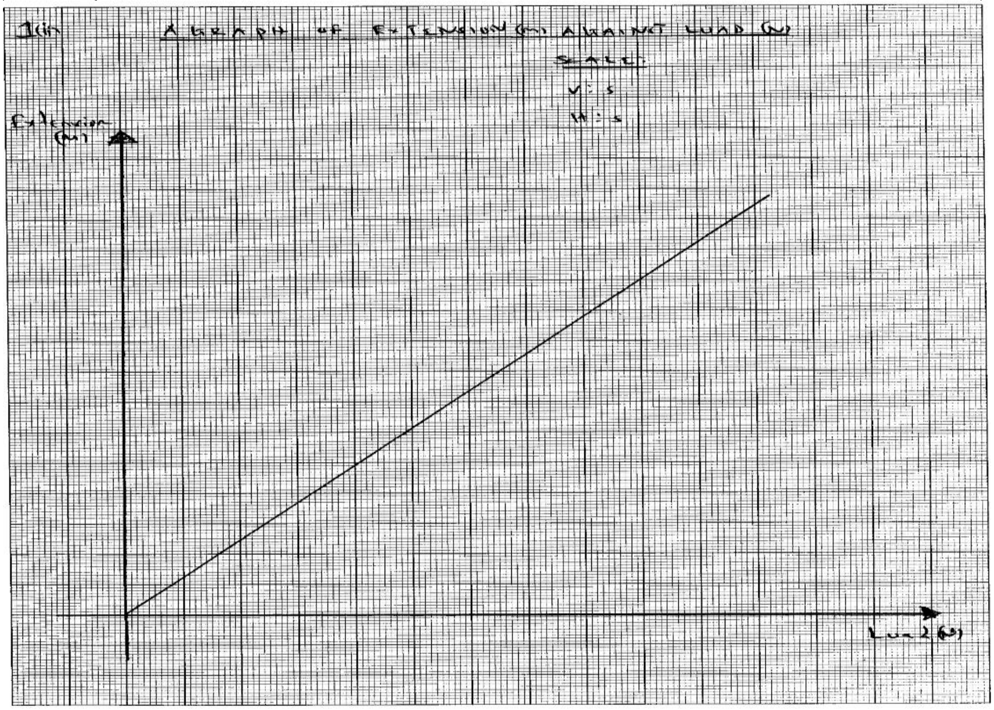
$K =$

1 (v) Therefore

$$y = \frac{4 \times 0 \cdot 98}{3.14 \times (0 \cdot 46 \times 10^{-3})^2 \times 1 \cdot 2 \times 10^{3}}$$

$y = 4 \cdot 9 \times 10^{-7}\ \Omega m$

(vi) The value obtained is resistivity of the wire



Extract 19.2: *A sample of weak responses to Question 1 of Paper 3C*

Extract 19.2 shows the solution of a candidate who lacked knowledge of the concept of mechanics, particularly the strength of materials. The candidate was not able to set up the experiment correctly, as a result he/she failed to record the correct data. In addition, he/she lacked skills of using proper scales to transfer the data into the graph and show the slope indication.

4.2 Question 2: Heat

This part comprised three questions derived from the topic of Heat. It is a collection of questions from physics 3A, 3B and 3C papers. The analysis of each question is as follows:

4.2.1 Physics 3A, 3B & 3C

The question was attempted by 21,697 candidates, out of which 45.7 per cent scored from 0 to 5 marks; 33.2 per cent scored from 5.5 to 8.5 marks and 21.1 per cent scored from 9 to 15 marks. This shows that the candidates' performance in this question was average since 54.3 per cent of them scored the pass mark (5.5 marks) or above. Figure 19 presents a summary of candidates' performance.

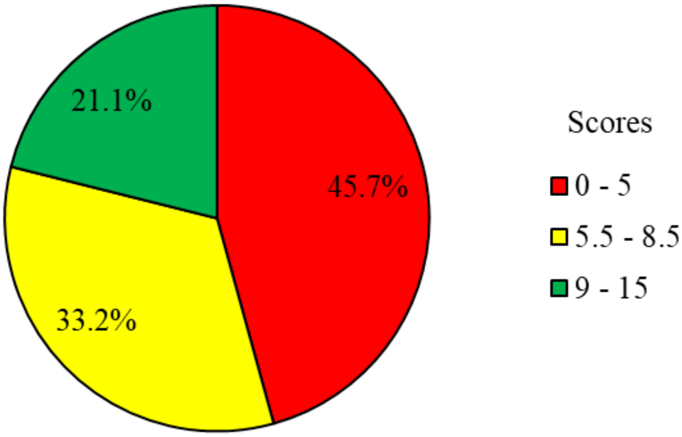


Figure 19: *Percentage of candidates' performance in Question 2*

4.2.1.1 Physics 3A

In this question it was given that, *Form Five Physics students were debating on whether hot objects made with the same materials but having different masses have the same rate of cooling or not*. The candidates were required to conclude their debate by performing the experiment using the following procedures:

(a) Measure the mass of empty calorimeter provided.

(b) Fill the calorimeter with hot water of 90 °C to three quarters and then cover the calorimeter with a lid.

(c) While fanning hard board, record the time (t) in seconds for every 5°C drop of temperature of water starting from the temperature of 80 °C to 55°C.

(d) Record the mass of the calorimeter with water.

(e) Repeat procedure (c) to (d) when the calorimeter is half filled with hot water.

Questions

(i) Tabulate the results obtained in (c) and (e).

(ii) Determine the mass of water m_1 and m_2 as obtained from procedures in (a) and (e) respectively.

(iii) Plot the graph of time obtained in (c) against that in (e).

(iv) Determine the slope of the graph plotted in (iii).

(v) Determine the ratio of the masses m_1 and m_2.

(vi) Use the slopes and the ratio of masses obtained from the experiment to conclude the debate of the students.

The candidates who scored average marks (5.5 - 8.5) had clear understanding of the concept of heat transfer. They applied the basic skills in setting and carrying out an experiment to determine the mass of water m_1 and m_2. Moreover, they followed the procedure of collecting the data and tabulating the results hence they plotted the cooling graph for both experiments. However, some of them faced challenges in locating the tabulated values when plotting the graph.

The data analysis reveals that 21.1 per cent of the candidates who scored high marks (9 - 15) had enough knowledge of performing an experiment regarding the rate of heat flow. Most of them demonstrated the skills of collecting the data at a reasonable range and correctly used a table of values to plot the graphs. In the graphs, they indicated the following important aspects: The title of the graph including their units; the scale (vertical and horizontal scales), the axes (vertical and horizontal axes) with their respective SI units; transfer of points; best line and slope indication. In addition, they used points at the slope indication to determine the slope by using the formula: $\text{Slope} = \dfrac{\Delta t_{\frac{3}{4}}}{\Delta t_{\frac{1}{2}}}$. They also used the relation $\dfrac{m_1}{m_2}$ to determine the ratio of masses m_1 and m_2, and then compared its value with the slope. Finally, most of them clearly concluded that mass is proportional to the time taken by the body to cool, provided that other factors such as nature of the material, room temperature and temperature of the surrounding are kept constant. This implies that, the objects with small mass will cool faster than the one with large mass. Extract 20.1 is a sample of a candidates' correct response.

REPORT.

2. Mass of an empty calorimeter M = 37.7g.

Mass of calorimeter with water M_{11} = 112.7g.

Mass of calorimeter with water M_{22} = 88.7g.

Room temperature = 16°c.

2 (i) TABLE OF RESULTS FOR CALORIMETER WITH WATER THREE QUARTERS-FULL

Temperature. θ °C	Time. t_1 (seconds)
80	0
75	85
70	197.
65	320
60	464.
55	630.

TABLE OF RESULTS FOR CALORIMETER WITH WATER HALF FULL

Temperature θ°C	Time t_2 seconds.
80	0
75	61
70	120
65	195
60	280
55	400.

2 (iii) Mass of Water M_1

$M_1 = M_{11} - M.$

$= 112.7g - 37.7g.$

$M_1 = 75g.$

Mass of water M_2.

$M_2 = M_{22} - M.$

$= 88.7g - 37.7g$

$M_2 = 51g.$

∴ Mass of water M_1 and M_2 are 75g and 51g respectively.

(iv) Slope of the graph.

$$\text{Slope} = \frac{\Delta t_1 \text{ (sec)}}{\Delta t_2 \text{ (sec)}}$$

$$= \frac{(500 - 240)\text{sec}}{(315 - 150)\text{sec}}$$

Slope = 1.575

∴ Slope of the graph = 1.575.

v) Ratio of the masses.

$$M' = \frac{M_1}{M_2}$$

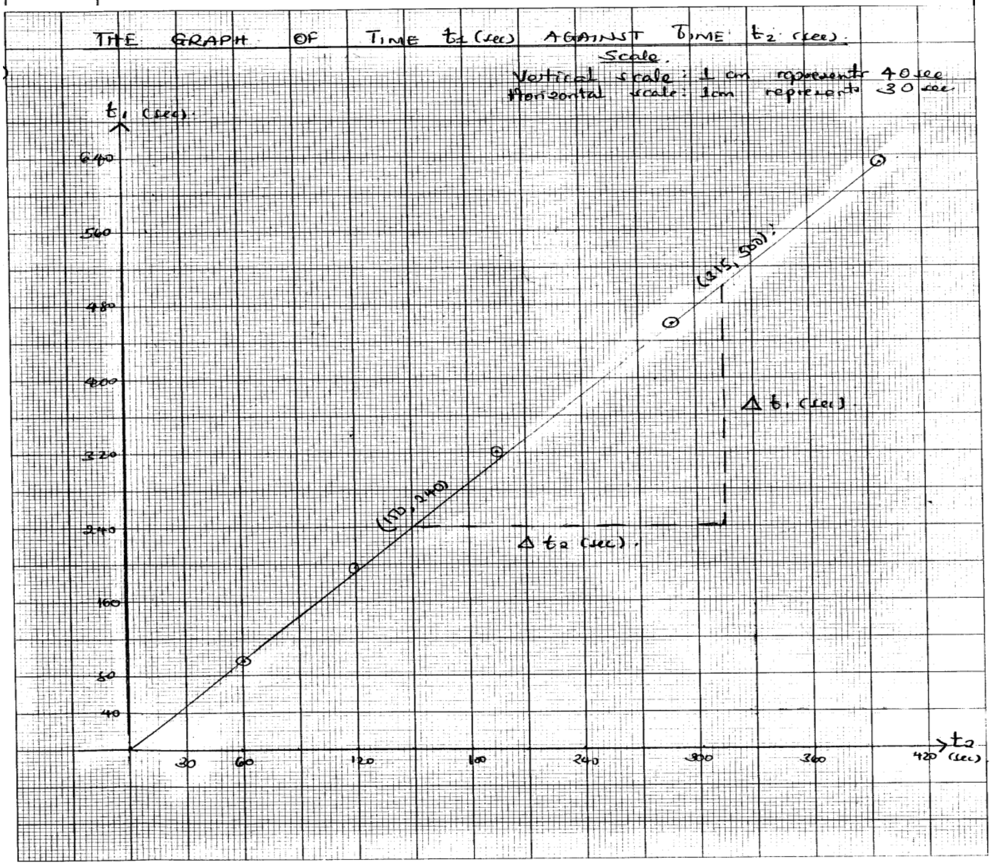
$$= \frac{75\,g}{51\,g}$$

2(v) ∴ $M' = 1 \cdot 5$.

∴ Mass ratio of M_1 and $M_2 = 1 \cdot 5$.

(vi) Conclusion of the experiment.

- Different masses of liquid will have different rate of cooling
Since when the calorimeter was 3/4 full it took much time than when the calorimeter was 1/2 full.



Extract 20.1: *A sample of good responses to Question 2 of Paper 3A*

In Extract 20.1 the candidate was competent in collecting the data, plotting the graph and determining the slope and ratio of masses correctly.

However, 45.7 per cent of the candidates who scored low marks (0 - 5) lacked enough knowledge and skills for carrying out heat experiments. Most of these candidates recorded incorrect data while other candidates recorded time in minutes instead of seconds. They also faced difficulties in using beam balance and thermometers because the obtained results of mass and temperature were out of range. Another observed challenge was failure to analyse the concept to address the important aspects like title of the graph, scales, axis, transfer of points and slope indication when plotting the graph. Consequently, they failed to draw a conclusion based on the significance of the experiment. Extract 20.2 is a sample of candidates' incorrect responses to the question.

2. a) mass of an empty calorimeter was 0.029 kg

The room temperature $\theta_R = 28°C$

at three quarter

b) i/

Temperature (θ) °C	Time (min)
80	0.00 ~~2.5~~ 2.5
75	2.50
70	5.29
65	8.42
60	12.02
55	16.22

i) d/ The mass of calorimeter with water = 0.097 kg

i/d) at half filled water

Temperature °C (θ)	Time (min)
75	1.17
70	2.46
65	3.93
60	5.60
55	7.56

The mass of calorimeter with half filled water = 0.084 kg

2\. iii/ the mass of water (m_1)

= mass of water with calorimeter − mass of empty calorimeter

= 0.097 kg − 0.029 kg

The mass of water (m_1) = 0.068 kg

The mass of water (m_2) = ~~0.087kg~~ 0.084kg − 0.029kg

The mass of water (m_2) = 0.055 kg

iv/ the slope of the graph from (1.8, 4) to (4.5, 10)

$$\text{Slope} = \frac{\Delta T \text{ in } 2(c)}{\Delta T \text{ in } 2(e)}$$

$$= \frac{10 - 4}{4.5 - 1.8}$$

$$= 6/2.7$$

Slope = 2.222

2\. v/ The ratio of masses m_1 and m_2.

$$m_1/m_2 = \frac{0.068 \text{ kg}}{0.055 \text{ kg}}$$

$$m_1/m_2 = 1.236$$

vi/ The slope and the ratio of masses from this experiment it show that the hot objects have the same rate of cooling.

Extract 20.2: *A sample of incorrect responses to Question 2 of Paper 3*

In Extract 20.2, the candidate recorded the data which were out of range. He/she failed to draw a graph correctly and apply the formula to obtain the required values of slope and the ratio of masses.

4.2.1.2 Physics 3B

In this question it was given that a hotel owner heats water for his customers every morning using electric heaters and has noticed that heat is lost because sometimes customers do not take bath. Therefore, he was aiming to use heat obtained from the heated water for other purposes. The candidates were required to perform an experiment to prove to him that the heated water can also be used to heat other liquids by using the following procedures:

(a) Fill the beaker with 100 ml of hot water of about 90 °C.

(b) Pour 50 ml of normal water (at the room temperature) into a calorimeter.

(c) Insert the calorimeter containing normal water into a beaker with hot water of 85 °C placed on a wooden block. Quickly close the beaker with lid as shown in Figure 2.

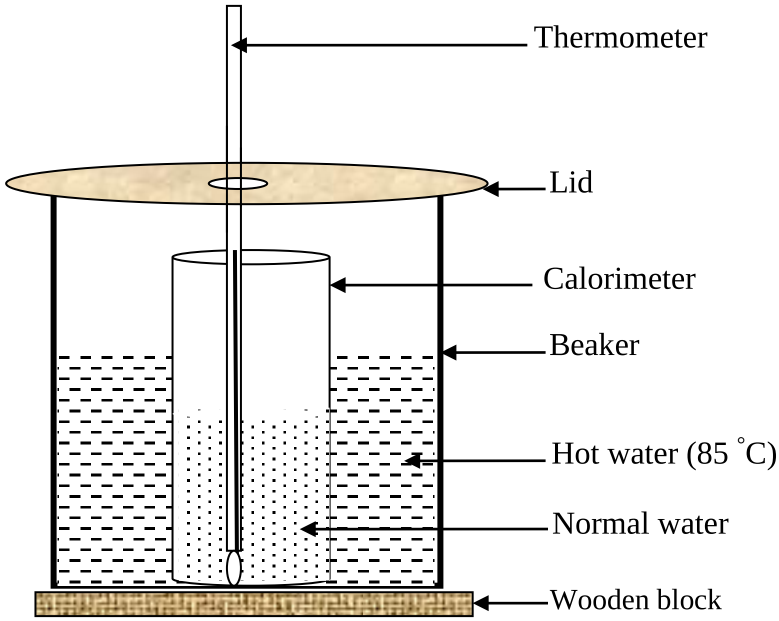


Figure 2

(d) Read and record the temperature of water in the calorimeter for every half minute until the thermometer records about 55 °C.

(e) Empty the calorimeter and the beaker.

(f) Repeat the procedure from (a) to (d) by filling the calorimeter with 50 ml of liquid L.

Questions

(i) Tabulate your results.

(ii) Plot the graph of temperature against time for water and liquid L on the same axes.

(iii) Determine the rate of temperature rise (°C/minute) for water and liquid L at 42 °C.

(iv) Suggest any two improvements that will result into increase in the temperature gained by liquid L.

The average performance of the candidates in this question was contributed by their ability to arrange the given apparati and analyse heat experiments under forced convection. Those candidates measured accurately the mass of calorimeter when it is half full and when it is two third full of water. However, some of them had problems with reading stopwatch when recording time after every 5^0C drop of temperature as instructed. They also failed to choose a proper scale for drawing the graph and determining its slope.

Those who scored 9 to 15 marks were knowledgeable about the concept of heat transfer particularly in investigating the factors that affect the rate of cooling. They made an experimental set up to collect and analyse the data in a tabular form. Moreover, they drew a correct conclusion by making comparison between the slope of the graph and the ratio between two masses. Extract 21.1 is a sample of the responses from a candidate who scored high marks.

2. Aim: To prove that heated water also can be used to heat other liquids.

(a) Experiment was done.
(b) Experiment was done
(c) Experiment was done

(d) Table of results of water

Room temperature
$\theta_1 = 28°C$
$\theta_2 = 28°C$
Average room temperature
$$\theta = \frac{t_1 + t_2}{2}$$
$$= \frac{28°C + 28°C}{2}$$
$$\theta = 28°C$$

$\therefore$ Room temperature was 28°C

2. (i) Table of results

- For water liquid

Time (min)	Temperature (°C)
0.0	28
0.5	40
1.0	49
1.5	52
2.0	54.5
2.5	55.5

- For liquid L

Time (min)	Temperature (°C)
0.0	28
0.5	44
1.0	51
1.5	56

(ii) A graph was plotted.

(iii) For water,
The rate of Temperature rise, $\Delta\theta/\Delta t$

now

$$\frac{\Delta\theta}{\Delta t} = \frac{45°C - 39°C}{(0.925 - 0.575)\ \text{min}}$$

$$\Delta\theta/\Delta t = 17.14\ °C/\text{min}$$

⇒ At 42°C the rate of Temperature rise were 17.14°C/min

2 (iii) For liquid L

$\frac{\Delta\theta}{\Delta t}$ at 42°C

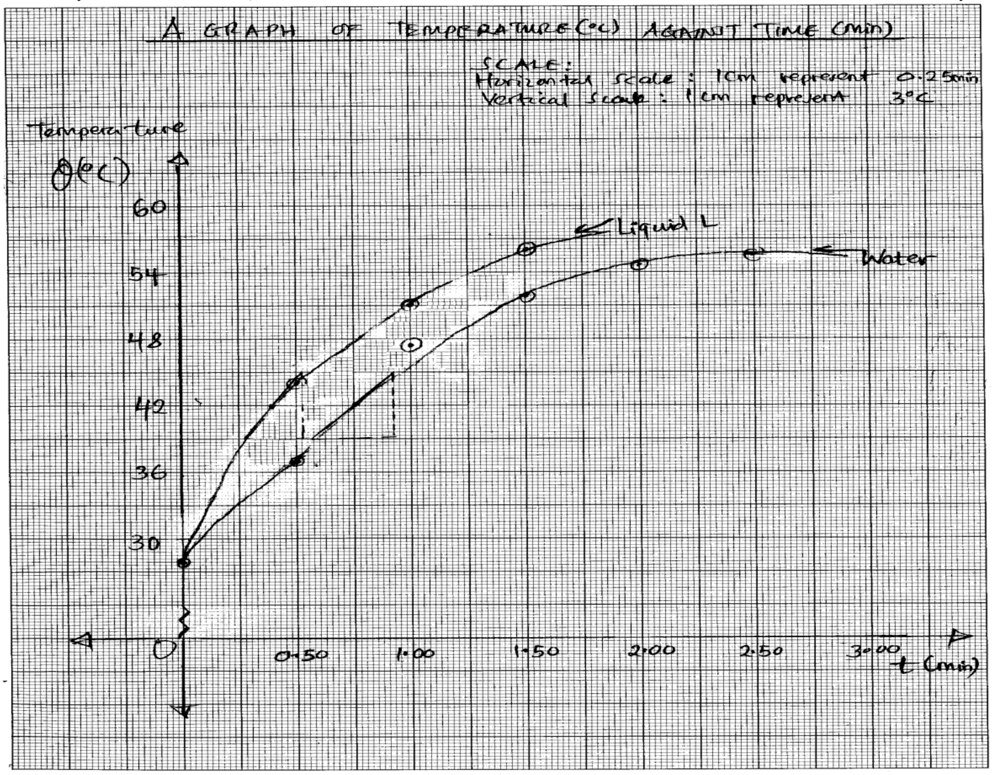
$$\frac{\Delta\theta}{\Delta t} = \frac{45^\circ C - 39^\circ C}{(0.525 - 0.275)\ \text{min}}$$

$$\frac{\Delta\theta}{\Delta t} = 24^\circ C/\text{min}$$

∴ The rate of temperature rise at 42°C was 24°C/min

(v) Ways of Improvement

1. Using of lagging materials such as cotton wool
2. Covering well of a top of a liquid surface



Extract 21.1: *A sample of correct responses to Question 2 of Paper 3B*

In Extract 21.1, the candidate prepared a table of values but failed to get reasonable values of time. However, he/she plotted a graph and determined the mass of calorimeter and slope of the graph, and finally made a correct conclusion.

On the other hand, the candidates who scored 0 to 5 marks in this question faced different challenges including reading a stopwatch. They tabulated the results of time which were out of range. It seemed that they failed to estimate the starting and stopping time of reading a stopwatch as instructed. Some of them misinterpreted the question as they drew a cooling curve instead of a heating curve. Moreover, their graphs were inverted such that they had incorrect rates in calculating slopes which led to incorrect suggestions. Generally, it was noted that, most of the candidates in this group had inadequate knowledge of conducting and analysing heat experiments. Extract 21.2 is a sample of incorrect responses.

2 Soln

The room temperature 30°C

The table of result of experiment number (2)

Time sec	0	30	60	90	120	150	180
water °C	85	76	71	65	60	56	53
liquid L °C	85	80	75	70	67	60	57

ii/ From the graph

Slope of water = $\frac{\Delta T °C}{\Delta T\ sec}$

$M = \frac{47-62}{100-60}$

$= \left(\frac{-15}{40}\right) \frac{°C}{sec}$

$M \simeq -0.4$

∴ Slope of water curve is ≃ 0.4°C s⁻¹

iii/ From the graph

For water

$\frac{\Delta T}{\Delta t} = \frac{85-42}{118\ sec} = \frac{43°C}{118\ sec} \simeq 0.4°C/sec$

$= 21.86$ °C minutes

For liquid L

$\frac{\Delta T}{\Delta t} = \left(\frac{85-42}{148}\right)$ °C sec⁻¹

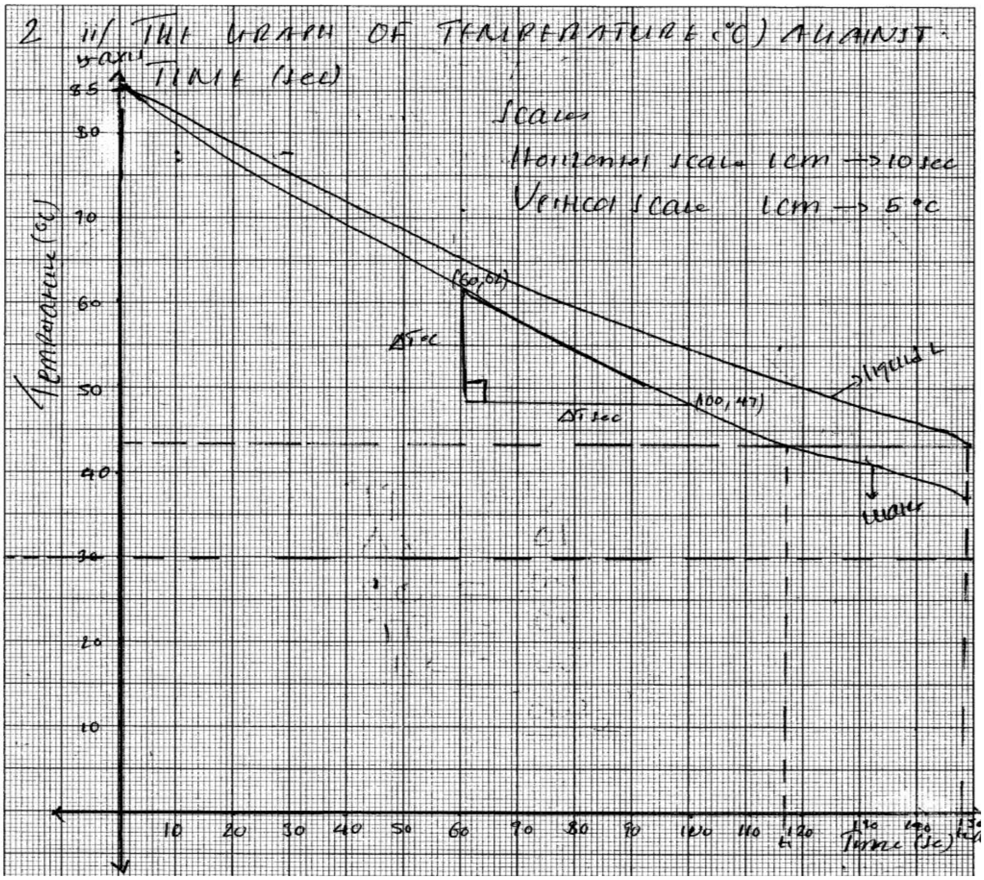
2 iii/ $\frac{\Delta T}{\Delta t} = \left(\frac{43}{148}\right)$ °C sec⁻¹ $= 0.29$ °C sec⁻¹

$\frac{\Delta T}{t} = 17.43$ °C/minutes

∴ Rate of the temperature of raise in water is 21.86 °C/minutes and for liquid was 17.43 °C/minutes

2 iv/ - Decrease impurities in liquids

- Through decreases of ~~rate of~~ loss of temperature



Extract 21.2: *A sample of incorrect responses to Question 2 of Paper 3B*

In Extract 21.2, the candidate recorded the time in minutes instead of seconds as instructed. He/she further collected incorrect data and ended up with incorrect graph.

4.2.1.3 Physics 3C

The candidates were provided with the following information: *A hotel with ten floors and 100 rooms has installed a solar heater at the top of the building. Copper pipes were used for distributing heated water from the heater to bathrooms. However, it has been noticed that there was a temperature drop as water flows from the heater to the outlets in the bathrooms*. They were required to diagnose experimentally on how heat is lost in the pipes by proceeding as follows:

(a) Pour hot water into the calorimeter so that it is $\frac{3}{4}$ full and set the apparati as shown in Figure 2.

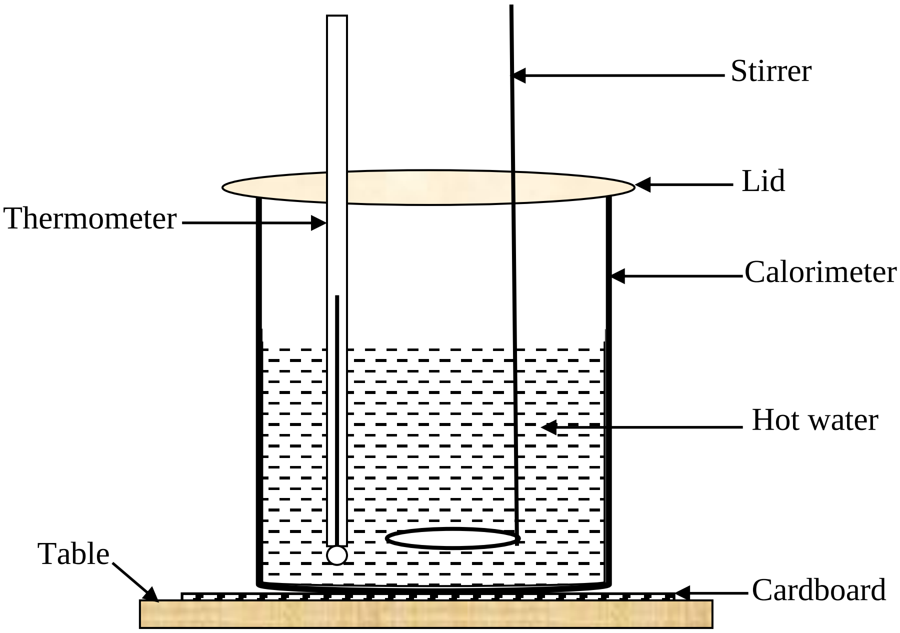


Figure 2

(b) Record the room temperature, θ_R.

(c) While stirring start with the temperature 65 °C in the calorimeter, record the temperature θ of water in the calorimeter as it cools at an interval of 2 minutes for 16 minutes.

Questions

(i) Record your results in a tabular form including the values of $(\theta - \theta_R)$ and $\log(\theta - \theta_R)$.

(ii) Plot the graph of $\log(\theta - \theta_R)$ against time, (t) in minutes.

(iii) Relate the slope of a graph plotted in (ii) to the water flowing from the heater to the outlet in the bath rooms.

(iv) Deduce the temperature of the surroundings, θ_s from the equation, $\theta_s = 65 - \log^{-1} C$ where, C is the vertical intercept of the graph.

(v) What can you conclude on the values of room temperature, θ_R and surrounding temperature, θ_s obtained in this experiment?

The analysis of candidates' responses reveals that, those who scored high marks in this question recorded correctly the room temperature under forced convection. They demonstrated their competence in using thermometer and stopwatch to read and record the temperature and time respectively. Consequently, they plotted the graph to determine the slope and temperature of the surroundings θ_s using the equation $\theta_s = 65 - \log^{-1}C$ where C is the vertical intercept of the graph. Finally, they concluded that the room temperature and the surrounding temperature θ_s obtained experimentally are almost the same. Extract 22.1 is a sample of candidates' correct response.

2 Room temperature, $\theta_R = 25°C$

(i) TABLE OF RESULTS

Time, t (min)	θ(°C)	$\theta - \theta_R$(°C)	$\log(\theta - \theta_R)$
0	65	40	1.60
2	64	39	1.59
4	62	37	1.56
6	60	35	1.54
8	58	33	1.52
10	56	31	1.49
12	54.9	29.9	1.48
14	53	28	1.45
16	52	27	1.43

(ii) The graph of $\log(\theta - \theta_R)$ against time in minutes

(iii) $$\text{Slope} = \frac{\Delta \log(\theta - \theta_R)}{\Delta \text{Time}}$$

$$= \frac{(1.50 - 1.56)}{(10 - 4)\,\text{min}}$$

$$= -0.01\ \text{min}^{-1}$$

~~Sot~~ slope $= -0.01\ \text{min}^{-1}$

The rate of heat loss from the heater to the bathroom is antilogarithm of excess temperature of 0.01

2 per minute

(iv) Vertical intercept, $C = 1.6$

from

$Q_s = 65 - \log^{-1}(C)$

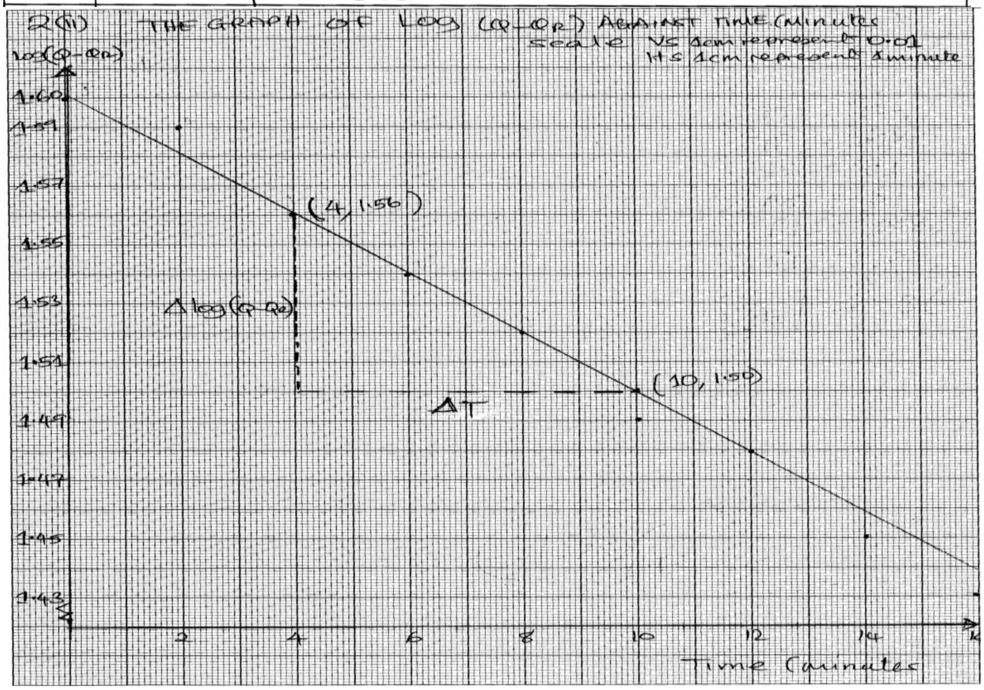
$Q_s = 65 - \log^{-1}(1.6)$

$= 65 - 39.81$

$= 25.2\ °C$

∴ The temperature of surrounding is 25.2°C

(v) The value of room temperature ~~and~~ (25°C) ~~ex~~ surrounding temperature (25.2°C) are almost similar (are same). in this experiment.



Extract 22.1: *A sample of good responses to Question 2 of Paper 3C*

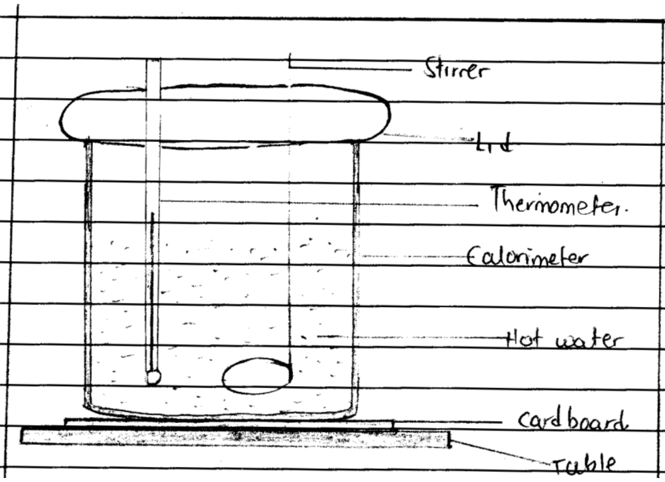
In Extract 22.1, the candidate measured and recorded correctly the values of temperature and time. He/she also used the collected data to plot the correct graph and determine the slope as well as the rate of heat loss.

On the contrary, some of the candidates who attempted this question scored low marks because they had little knowledge of the concepts of heat transfer. It seemed they faced difficulties in reading thermometers and stopwatches because they obtained the data which were out of range. They failed to examine the factors on which the rate of cooling of a substance depends. Another challenge that the candidates faced was lack of drawing and mathematical skills. Most of the candidates failed to employ the correct formula to analyse the concepts. Moreover, the graphs they plotted lacked some important features such as title, scales and slope indication. Extract 22.2 is illustrative.

2. Apparatus used ~~are~~
- Calorimeter
- Thermometer
- Cardboard
- Lid
- Stirrer
- Hot water

Aim of experiment
- How heat is lost in the pipes.

Set up of experiment.



2(i) Table of results.

$Q_R = 28°c$.

Time (T)	Q	$(Q - Q_R)$	$\log(Q - Q_R)$
2	85.44°c	57.44.	1.76
4	82.10°c	54.10	1.73
6	78.95°c	50.95	1.71
8	75.98°c	47.98	1.68
10	73.19°c	45.19	1.66
12	70.56°c	42.56	1.63
14	68.08°c	40.08.	1.60
16	65.75°c.	37.75	1.58

$Q_R = 28°c$

$$Q = 28 + 61e^{-0.03t}$$

$$Q = 28 + 61e^{-0.06}$$

$Q = 85.44 \rightarrow t = 2$

$Q = 82.10 \rightarrow t = 4$

$Q = 78.95 \rightarrow t = 6$.

$Q = 75.98 \rightarrow t = 8$.

$Q = 73.19 \rightarrow t = 10$.

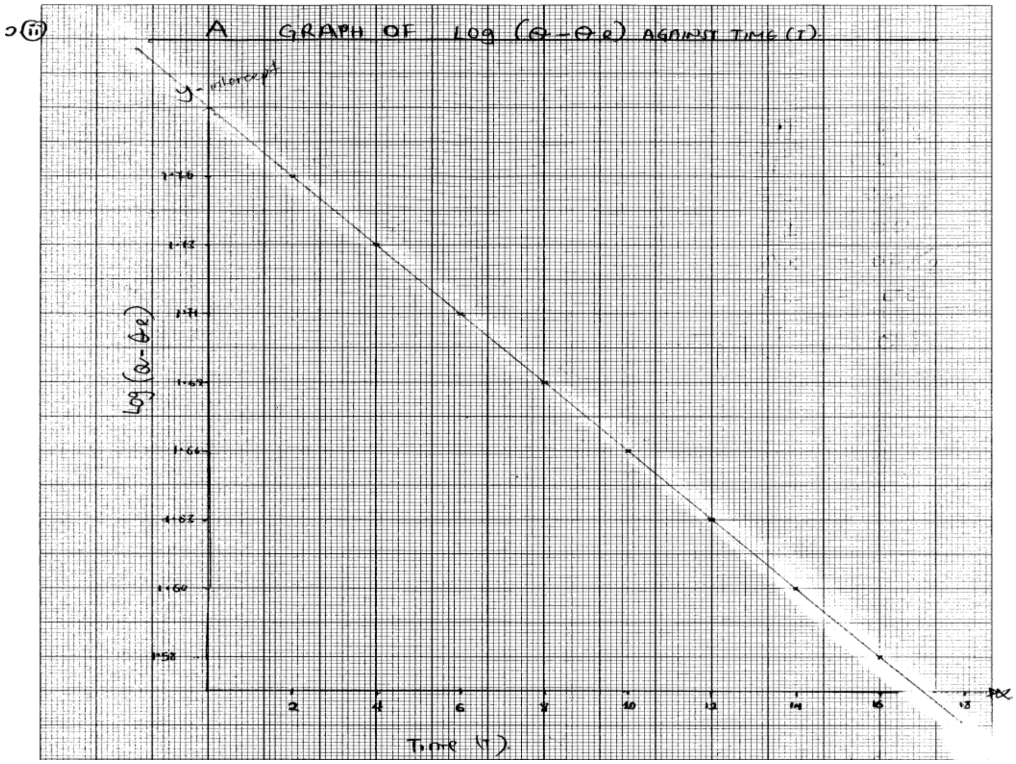
$Q = 70.56 \rightarrow t = 12$.

$Q = 68.08 \rightarrow t = 14$

$Q = 65.75 \rightarrow t = 16$.

2(iii) As the time increases the temperature drops. So the time is inversely proportional to the temperature of the water.

$$\cancel{t} \quad T \propto 1/\theta$$



Extract 22.2: *A sample of incorrect responses to Question 2 of Paper 3C*

In Extract 22.2, the candidate provided incorrect table of values and a wrong graph. He/she used mathematical method instead of experimental method to generate the data.

4.3 Question 3: Current Electricity

This part contains three questions from three alternative papers derived from the topic of Current Electricity. The analysis of each question is as follows:

4.3.1 Physics 3A, 3B & 3C

The question was attempted by 21,697 (100%) candidates, of which 61.8 per cent scored from 0 to 5 marks; 23.0 per cent scored from 5.5 to 8.5 marks; and 15.2 per cent scored from 9 to 15 marks. This suggests that the general performance of candidates in this question was average as only 38.2 percent scored above 5.0 marks. Figure 20 presents the analysis of these data.

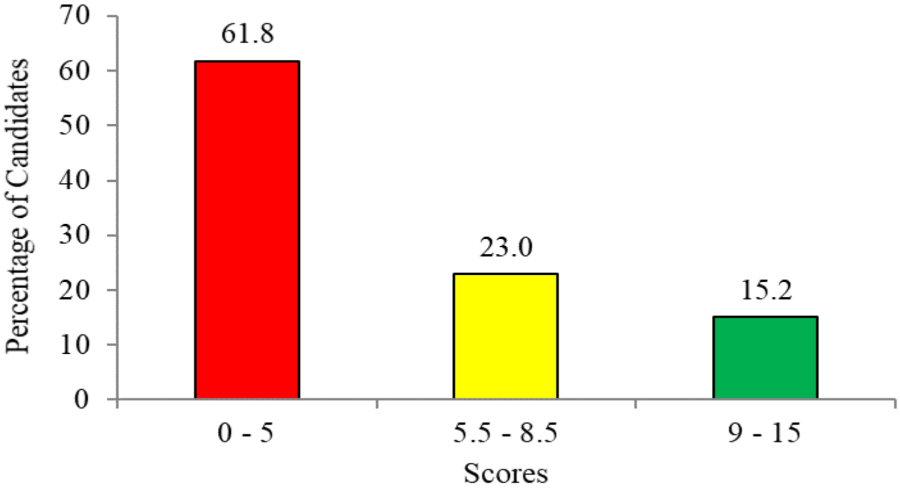


Figure 20: *Distribution of candidates' scores in Question 3*

4.3.1.1 Physics 3A

The candidates were provided with a meter bridge, a standard resistor of 2 Ω, a dry cell, a 100 cm wire of unknown specifications, a zero centred galvanometer, a switch, a micrometre screw gauge, a meter rule and several pieces of connecting wires. Then, they were required to perform an experiment to obtain the specifications of the wire using the following procedures:

(a) Measure and record the diameter of the wire.

(b) Connect a 2 Ω resistor in the right hand gap and in the left hand gap connect the wire at length x = 15 cm. Close the switch and quickly determine the balancing point. Record the balance length L on the metre bridge located on the left hand side of the jockey of the galvanometer, then open the switch.

(c) Repeat procedures in 3 (b) by connecting the wire at lengths x = 25 cm, 40 cm, 50 cm and 65 cm. In each experiment, record the corresponding values of L.

Questions

(i) Draw a clearly labelled circuit diagram of this experiment.

(ii) Tabulate your results including the values of x (m), $\frac{1}{L}$ (m^{-1}), L (m) and $\frac{1}{x}$ (m^{-1}).

(iii) Plot a graph of $\frac{1}{x}$ (m^{-1}) against $\frac{1}{L}$ (m^{-1}).

(iv) Determine the slope and the intercept of the graph in 3 (iii).

(v) Determine the average value of unknown resistivity of the wire from the results in 3 (iv).

(vi) If a customer wants to buy a piece of this wire, what will be the length of the wire required to make a resistance equivalent to 10 Ω?

High achievers in this question were knowledgeable of the concept tested. They connected the circuit properly, which enabled them to collect the correct data. Those candidates had abilities to draw a clearly labelled circuit diagram which they connected. Some of the candidates were aware of the requirements of the graph. They plotted correct graphs of $\frac{1}{x}$ (m^{-1}) against $\frac{1}{L}$ (m^{-1}) and determined correctly the slope and the intercept of the graph. Moreover, they had good computational skills to establish the required equations and relate them to compute the average value of resistivity of the wire. Finally, some of the candidates calculated the value of e correctly and the length of the wire required to make a resistance equivalent to 10 Ω. Extract 23.1 shows the sample of the correct response provided by a candidate.

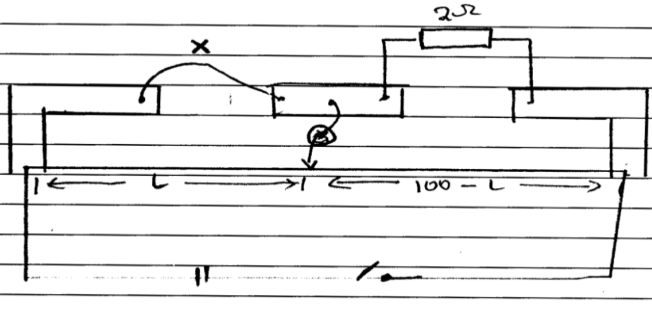
3 (a) Diameter = 0.37 mm

(b) ~~L = 97.0 cm~~

L = 24cm

(c)

(i)



ii

x (m)	$1/x$ (m^{-1})	L (m)	$1/L$ (m^{-1})
0.15	6.27	0.24.	4.2
0.25	4	0.340	2.94
0.40	2.5	0.467	2.14
0.50	2	0.512	1.95
0.65	1.5	0.577	1.73

3. (iv) $$\text{Slope} = \frac{\Delta\, 1/x\ (m^{-1})}{\Delta\, 1/L\ (m^{-1})}$$

$$= \frac{6 - 3.5}{3.9 - 2.7}$$

$$\text{Slope} = 2.083$$

intercept.

$\Rightarrow$ $1/L$ intercep. $= 1.2\ (m^{-1})$

$\Rightarrow$ $1/x$ intercept $= -2.2\ (m^{-1})$

(V) fru Resistance $\propto$ length

$$\frac{R_1}{L_1} = \frac{R_2}{L_2}$$

$$\frac{R_x}{L} = \frac{2}{1-L}$$

$$\frac{1-L}{L} = \frac{2}{R_x}$$

$$\frac{1}{L} - 1 = \frac{2}{R_x}$$

but $R_x = \frac{\rho \cancel{L}x}{A}$

$$\frac{1}{L} - 1 = \frac{2A}{\rho x}$$

$$\frac{1}{L}\left(\frac{\rho}{2A}\right) - \left(\frac{\rho}{2A}\right) = \frac{1}{x}$$

$$\frac{1}{x} = \left(\frac{\rho}{2A}\right)\frac{1}{L} - \frac{\rho}{2A}$$

From the equation of line.

$$\text{Slope} = \frac{\rho}{2A}$$

But $A = \frac{\pi d^2}{4}$

$$= \frac{\pi (0.37 \times 10^{-3})^2}{4}$$

$$A = 1.075 \times 10^{-7}\ m^2$$

$$\rho_1 = 2A(\text{Slope})$$
$$= 2 \times 1.075 \times 10^{-7} \times 2.083$$
$$= 4.48 \times 10^{-7}\ \Omega m$$

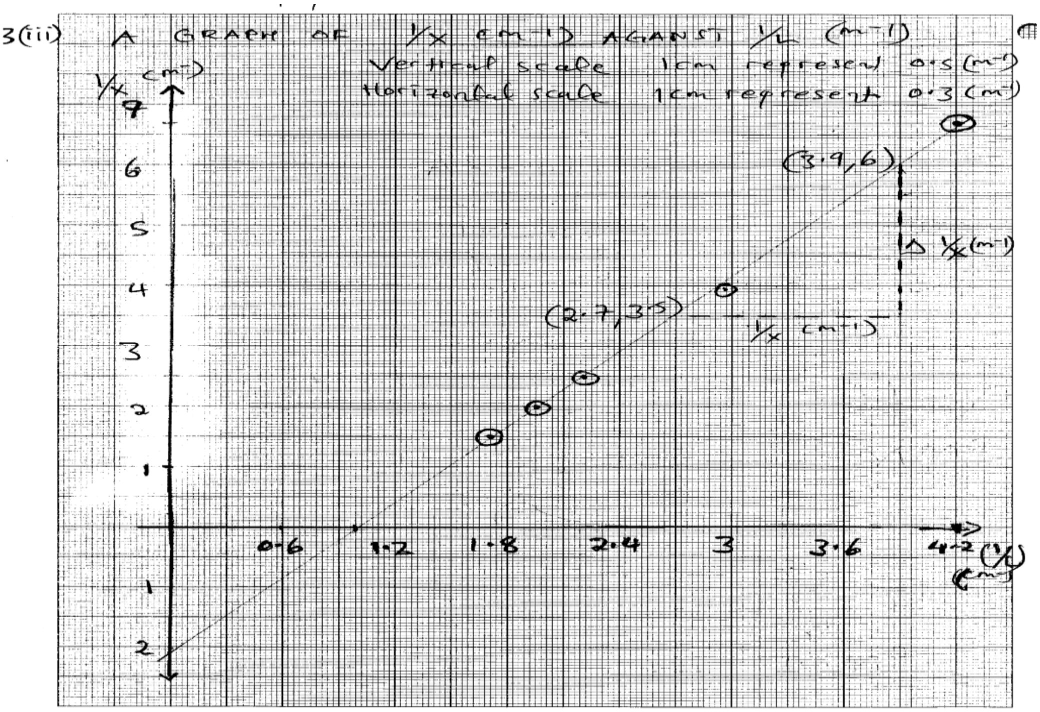
$$\text{intercept} = -2.2 = \frac{-\rho_2}{2A}$$

$$\rho_2 = 2A \times 2.2$$
$$= 4.4 \times A$$
$$= 4.4 \times 1.075 \times 10^{-7}$$
$$= 4.73 \times 10^{-7}\ \Omega m$$

$$\text{Average resistivity } (\rho) = \frac{\rho_1 + \rho_2}{2}$$

$$= \frac{4.48 \times 10^{-7} + 4.73 \times 10^{-7}}{2}$$

$$= 4.605 \times 10^{-7}\ \Omega m$$



Extract 23.1 *A sample of correct responses to question 3 of Paper 3A*

The responses in Extract 23.1 show that the candidate know how to use a micrometre screw gauge as a result he/she measured the diameter of the wire correctly. He/she also demonstrated enough skills to use mathematical equations to determine the required quantities.

In contrast, most of the candidates who scored low (0 - 5) marks had inadequate knowledge of the concepts of current electricity specifically the metre bridge. Some of those candidates connected inappropriate electrical circuits, which led them to obtain incorrect data. The candidates had limited drawing skills as they drew improper electric circuits. Most of them did not draw proper graphs because of incorrect data they had obtained. In addition, they were not familiar with the requirements of the graphs. Some of them lacked computation skills as they failed to determine the correct value of slope and the intercept of the graph. Failure to obtain the values of slope and the intercept led them to provide incorrect answers to the rest of the examined items. For example, some of the candidates used the ratio slope = $\frac{\Delta X}{\Delta L}$ instead of slope = $\frac{\Delta(\frac{1}{X})}{\Delta(\frac{1}{L})}$. Others used the correct formula

$\rho = \dfrac{AR}{L}$ but they substituted wrong data to calculate the resistivity of the wire. Furthermore, some of the candidates had inadequate skills in measurement instruments. They failed to use properly the micrometre screw gauge, as a result, they obtained incorrect diameter of the wire. For example, one of the candidates obtained the value of the diameter as 0.29 mm instead of 0.37 $\pm$ 0.02 mm. Extract 23.2 shows the sample of incorrect response provided by one of the candidates.

3 a) Diameter of the wire = 0.29mm

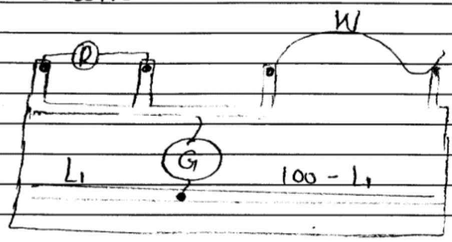


TABLE OF RESULTS

ii)

X(cm)	X (m)	L (m)	$1/X$ (m^{-1})	$1/L$ (m^{-1})
15	0.15	98.89	6.67	0.0101
25	0.25	96.97	4.00	0.0103
40	0.40	92.59	2.50	0.0108
50	0.50	88.89	2.00	0.011
65	0.65	82.56	1.54	0.012

DATA ANALYSIS

From the theorem

Ratio of Resistance = Ratio of Length

$$\frac{R_s}{R_w} = \frac{L_1}{100 - L_1}$$

but

from: $\rho_w = \dfrac{A_w R_w}{L_w}$

$$R_w = \frac{\rho_w L_w}{A_w}$$

$$\frac{R_s A_w}{\rho_w L_w} = \frac{L_1}{100 - L_1}$$

from

$$\frac{\frac{R_s}{A_w R_w}}{L_w} = \frac{L_1}{100-L_1}$$

but $100 - L_1 = L_2$

$$\frac{\frac{R_s}{A_w R_w}}{L_w} = \frac{L_1}{L_2}$$

but $L_w = X$

$$\frac{R_s \times x}{A_w R_w} = \frac{L_1}{L_2}$$

$$\frac{R_s}{A_w R_w} = \frac{L_1}{L_2 x}$$

divide by L_1 both side

$$\frac{R_s}{A_w R_w L_1} = \frac{1}{x L_2}$$

multiply L_2 both side

$$\frac{1}{x} = \frac{R_s L_2}{A_w R_w L_1}$$

$$\frac{1}{x} = -\left(\frac{R_s L_2}{A_w R_w}\right) \cdot \frac{1}{L}$$

3 iv)

$$Slope = \frac{\Delta \frac{1}{x}}{\Delta \frac{1}{L}}$$

$$= \frac{6.67 - 2.00}{0.0101 - 0.011}$$

$$= \frac{4.67}{-0.010}$$

$$= -9 \times 10^{-04}$$

$$Slope = -9 \times 10^{-04}$$

Intercept of the graph $= 0.015$

v Required the average value unknown resistivity

from

$$\rho = \frac{AR}{L}$$

$$= \frac{\frac{\pi d^2}{4} \times R}{L}$$

$$= \frac{3.14 \times 0.29 \times 10^{-4} \times 6.67 (\Omega m^2)}{4 \times 98.89 m}$$

Resistivity of unknown $= 4.9 \times 10^{-7} \Omega m$

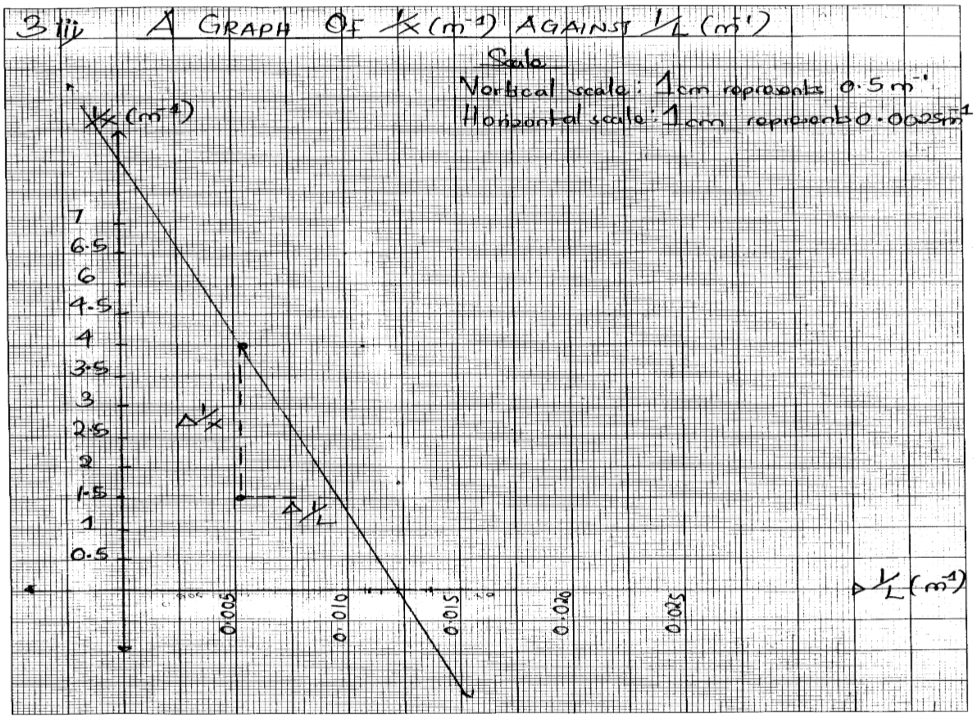
vi) From, $\frac{R_1}{R_2} = \frac{L_1}{100-L_1}$

$$\frac{2\Omega}{10\Omega} = \frac{L_1}{100-L_1}$$

$2(100-L_1) = 10L_1$

$200 - 2L_1 = 10L_1$

$200 = 12L_1$ $\therefore L_1 = 16.7 cm$



Extract 23.2: *A sample of incorrect responses to Question 3 of Paper 3A*

Extract 23.2 shows the responses of a candidate who obtained wrong data and ended up with incorrect answers. He/she also drew an incorrect graph with negative slope, contrary to the requirement of the question.

4.3.1.2 Physics 3B

In this question the candidates were required to investigate the value of the unknown resistance, R which was coupled parallel to a wire labelled W by means of wheatstone meter bridge. In order to achieve the task, the following instructions were given:

(a) Connect the standard resistance of 2 Ω in the left hand gap of the Wheatstone meter bridge. The unknown resistance R is connected parallel to the wire labelled W and placed in a right hand gap as shown in Figure 3.

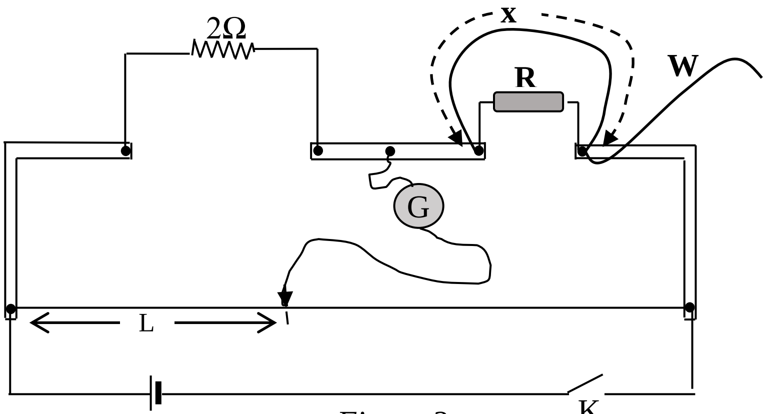


Figure 3

(b) With x = 1.0 m close the switch, K and find the balance point L, then determine the equivalent resistance R_e.

(c) Repeat the procedure in 3(b) using x= 0.8 m, 0.6 m, 0.4 m and 0.2 m, determine the corresponding equivalent resistance R_e in each case.

Questions

(i) Tabulate your results in (b) and (c) including the values of $\frac{1}{x}\left(m^{-1}\right)$ and $\frac{1}{R_e}\left(\Omega^{-1}\right)$.

(ii) Plot a graph of $\frac{1}{x}\left(m^{-1}\right)$ against $\frac{1}{R_e}\left(\Omega^{-1}\right)$.

(iii) Determine the slope S.

(iv) Deduce an equation that governs this experiment.

(v) Compute the value of unknown resistance, R.

(vi) Determine the specific resistance of a wire, W.

The candidates who scored high marks in this question had adequate knowledge of metre bridge theory. They acquired skills in setting the given apparati to perform the experiment. The data analysis reveals that most of the candidates tabulated the table of results correctly and applied them in plotting the graph of $\frac{1}{x}\left(m^{-1}\right)$ against $\frac{1}{R_e}\left(\Omega^{-1}\right)$. They further, deduced an equation governing this experiment to determine slope, unknown resistance and specific resistance of the given wire. Extract 24.1 provides an example of a correct response from one of the candidates.

3

(c)

(i)

X (m)	L (m)	R_e (Ω)	$1/X$ (m^{-1})	$1/R_e$ (Ω^{-1})
1	0.707	0.83	1	1.20
0.8	0.714	0.80	1.25	1.25
0.6	0.727	0.75	1.67	1.33
0.4	0.749	0.67	2.5	1.49
0.2	0.803	0.49	5	2.04

(ii) ON GRAPH PAPER

(iii) Slope from graph

$$\text{Slope} = \frac{\Delta\, 1/x \ (m^{-1})}{\Delta\, 1/R_e \ (\Omega^{-1})}$$

$$= \frac{4.54 - 0.63}{1.92 - 1.12}$$

Slope = 4.8875 ~~Ωm~~ Ω/m.

$\therefore$ Slope; r = 4.8875 Ω/m.

(iv) for the equation of the experiment:-

$R_e = \dfrac{R \times R_w}{R + R_w}$; R_e = Effective resistance of the Right Hand gap.

$R_w = \dfrac{\rho}{A}\,x$

ρ/A = specific resistance of wire W

let $\rho/A = r$.

$R_e = \dfrac{R \times rx}{R + rx}$.

3c)

(ii) Reciprocating

$$1/Re = \frac{R}{Rrx} + \frac{rx}{Rrx}.$$

$$1/Re = 1/rx + 1/R.$$

$$1/rx = \frac{1}{Re} - \frac{1}{R}.$$

$$\frac{1}{X} = (r)\frac{1}{Re} - r/R.$$

$$y = m\ x - c.$$

Also:-

$$2/L = Re/100 - L$$

$$Re = 100 - L/L \times 2.$$

$$Re = \left(100 - L/L\right)2.$$

$$Re = \frac{200 - 2L}{L}$$ when L is in cm

$$Re = \frac{2 - 2L.}{L}$$ when L is in metres

3 (v). from:-

The intercept of $1/x$ – axis.

$1/x$ – intercept, $c = -r/R$.

But:-

r = slope = $4.8875 / \Omega m$.

$1/x$ - intercept from graph $= -4.977\ m^{-1}$

hence:-

$$R = \frac{-r}{c}$$

$$R = \frac{-4.8875}{-4.977}$$

$$R = 0.98$$

$$\simeq 1$$

∴ The value of unknown resistance is equal to 1.

(vi) specific resistance of given wire W is equal to the value of slope

slope = r, specific resistance

$= 4.8875$

$\simeq 4.9$.

∴ Specific resistance of wire W $= 4.9\ \Omega/m$

Extract 24.1: *A sample of correct responses to Question 3 of Paper 3B*

Extract 24.1 shows that the candidate was competent in presenting, analysing and evaluating the data to obtain the correct responses.

In contrast, the candidates who scored low marks in this question failed to describe the mechanism of electric conduction in metals. The responses given by those candidates revealed that they failed to make proper connection of the metre bridge circuit. Consequently, they recorded incorrect values of the required quantities. The wrong data resulted into incorrectly plotted graphs as well as slopes. Another remarkable challenge to most of the candidates was lack of mathematical skills to deduce the equation that governs the experiment. Due to this most of them got incorrect values of unknown resistance and specific resistance of the wire. Extract 24.2 is a sample of an incorrect response to this question.

03. (i) Table of results

x	$1/x$	R_e	$1/R_e$
0.8	1.25	0.75	1.333
0.6	1.67	1	1.00
0.4	2.50	1.5	0.670
0.2	5	3	0.333
0.1	10	6	0.167

(iii) slope (s) = $\dfrac{\Delta\, 1/x}{\Delta\, 1/R_e}$

$= \dfrac{10 - 3}{0.84 - 0.07}$

$s = 9.09\, m^{-1} / \Omega^{-1}$

(iv) from

$\cancel{\dfrac{R}{x} = \dfrac{R_s}{100 - x}}$

$\cancel{R(100 - x) = xR_s}$

$\cancel{100R - Rx = xR_s}$

$1/x + s/R = s(1/R_e)$

$1/x = s(1/R_e) - (s/R)$

$1/y = m\, x + c$

3. (v) from $\cancel{s/ = \dots}$

from the graph

$1/R_e$ intercept $= 1\Omega^{-1}$

from the equation of the graph

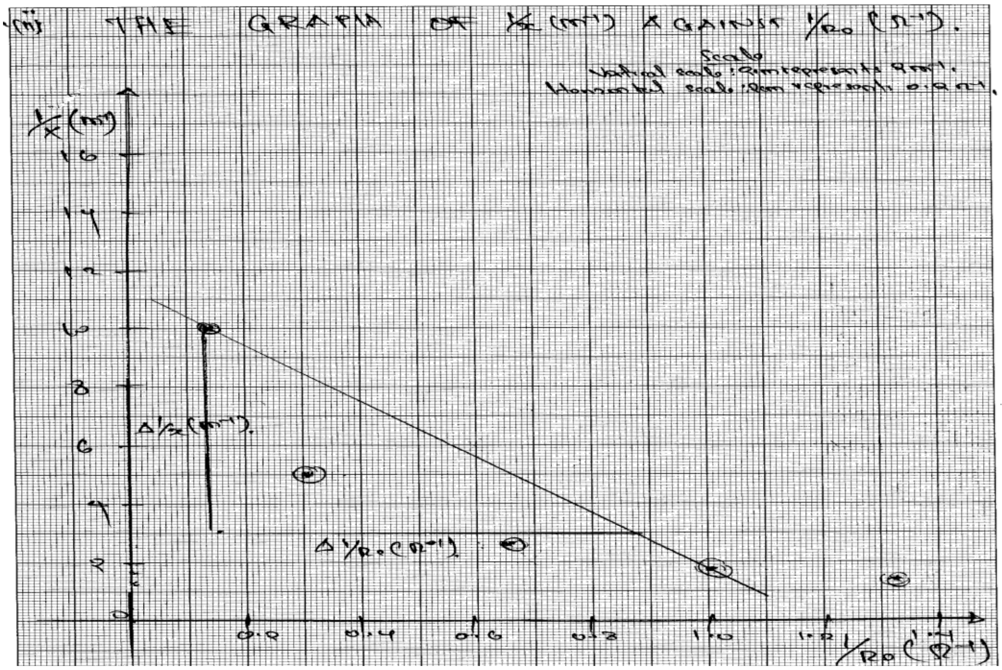
$1/x = s(1/R_e) - (s/R)$

$1/R_e$ ~~intopd~~ intercept $= 1/R$.

thus

$1/R = 1\, \Omega^{-1}$

$R = 1\, \Omega$



Extract 24.1: *A sample of incorrect responses to Question 3 of Paper 3B.*

Extract 24.2 indicates how the candidate analysed the tested concepts by producing incorrect responses due to the use of wrong data. The candidate prepared the table of results without indicating the units of all variables. In addition, he/she derived an equation governing the experiment as $\frac{1}{x} = s\left(\frac{1}{R_e}\right) - \left(\frac{s}{R}\right)$ instead of $\frac{1}{x} = \frac{\rho}{A}\left(\frac{1}{R_e}\right) - \left(\frac{\rho}{AR}\right)$ and ended up with incorrect slope, resistance and specific resistance of the wire.

4.3.1.3 Physics 3C

In this question the candidates were given a series that a car manufacturing industry used electroplating technique to paint car parts whereby a selected part of the body of a car becomes one electrode and the second electrode was a selected metal. In order to paint these parts, the resistance of the electrodes must be known before introducing a current through them. They were provided with an aluminium foil (30 cm × 2 cm), 1 Ω standard resistor, resistance box, dry cell, switch and two crocodile clips. Then, they were required to proceed as follows:

(a) Connect the meter bridge circuit in a usual manner with the aluminium foil in parallel with the given 1 Ω standard resistor. Use crocodile clips to fix the foil in its position. The resistance box should be connected in a right hand gap of the meter bridge.

(b) With the resistance box set at R = 5 Ω, close the switch, K and find the balancing length, L on the bridge wire on the side where aluminium foil is fixed.

(c) Repeat the procedure in 3(b) for the values of R = 4 Ω, 3 Ω, 2 Ω and 1 Ω.

Questions

(i) Draw a circuit diagram of your experimental set up.

(ii) Tabulate your results including the values of $\frac{1}{L}$.

(iii) Derive the equation governing this experiment.

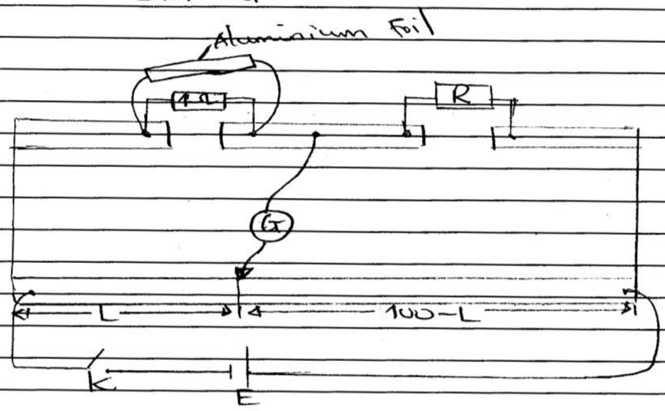
(iv) Plot a graph of $\frac{1}{L}\left(m^{-1}\right)$ against R (Ω).

(v) Determine the gradient of the graph in (iv).

(vi) Estimate the resistance of aluminium sheet of the surface area of $30\ m^2$ to be used as an electrode.

Few candidates who scored high marks in this question demonstrated their competence in performing this experiment. They connected the circuit properly which enabled them to obtain the correct data. In addition, they had enough skills in drawing a circuit diagram of the experimental set up as well as the graph of $\frac{1}{L}\left(m^{-1}\right)$ against R (Ω). Moreover, they demonstrated good computational skills to establish relevant mathematical equations in analysing the concept by computing the slope of the graph and estimating the resistance of aluminium sheet. Extract 25.1 is a sample of the candidates' correct response.

3(i) A CIRCUIT DIAGRAM OF THE EXPERIMENTAL SET UP



ii) The table of results

$R(\Omega)$	L (cm)	$1/L$ (cm^{-1})
5	7.6	0.13
4	9	0.11
3	11	0.09
2	14	0.07
1	22.6	0.04

iii) Required: Equation governing the experiment

From

$$\frac{R_e}{L} = \frac{R}{100-L}$$

Where;

3(iii) R_e = Effective resistance

Then

$$R_e = \frac{R_F \times 1}{1 + R_F}$$

Where R_F = Resistance of aluminium foil.

$$\frac{R_e}{R} = \frac{L}{100 - L}$$

$$(100 - L)R_e = RL$$

$$100R_e - R_eL = RL$$

$$R_eL + RL = 100R_e$$

$$L(R_e + R) = 100R_e$$

$$R_e + R = \frac{100R_e}{L}$$

$$\frac{1}{L} = \frac{R_e + R}{100R_e}$$

$$\frac{1}{L} = \frac{R}{100R_e} + \frac{1}{100}$$

From $R_e = \frac{R_F}{1 + R_F}$

Then

$$\frac{1}{L} = \frac{R}{100\left(\frac{R_F}{1+R_F}\right)} + \frac{1}{100}$$

3(iii)

$$\frac{1}{L} = \frac{R}{\frac{100R_F}{1+R_F}} + \frac{1}{100}$$

$$\frac{1}{L} = \left(\frac{1 + R_F}{100R_F}\right)R + \frac{1}{100}$$

∴ The equation governing the experiment is $\frac{1}{L} = \left(\frac{1 + R_F}{100R_F}\right)R + \frac{1}{100}$.

3(v) Req: The gradient of the graph in 3(iv)

from

$$\text{Gradient } (m) = \frac{\Delta \frac{1}{L}}{\Delta R}$$

$$m = \frac{0.1 - 0.06}{3.5 - 1.5}$$

$$m = \frac{0.04}{2}$$

$$m = 0.02\ m^{-2}\Omega^{-1}$$

∴ The gradient of the graph is $0.02m^{-2}\Omega^{-1}$

3(v) Req: Resistance of aluminium sheet

from

$$\frac{1}{L} = \left(\frac{1+R_f}{100R_f}\right)R + \frac{1}{100}$$

Then $y = mx + c$

Then:

$$m = \frac{1+R_f}{100R_f}$$

but $m = 0.02\,m^2\Omega^{-1}$

$$0.02 = \frac{1+R_f}{100R_f}$$

$$0.02 \times 100R_f = 1+R_f$$

$$2R_f = 1+R_f$$

$$2R_f - R_f = 1$$

$$R_f = 1\,\Omega^{-1}m^{-2}$$

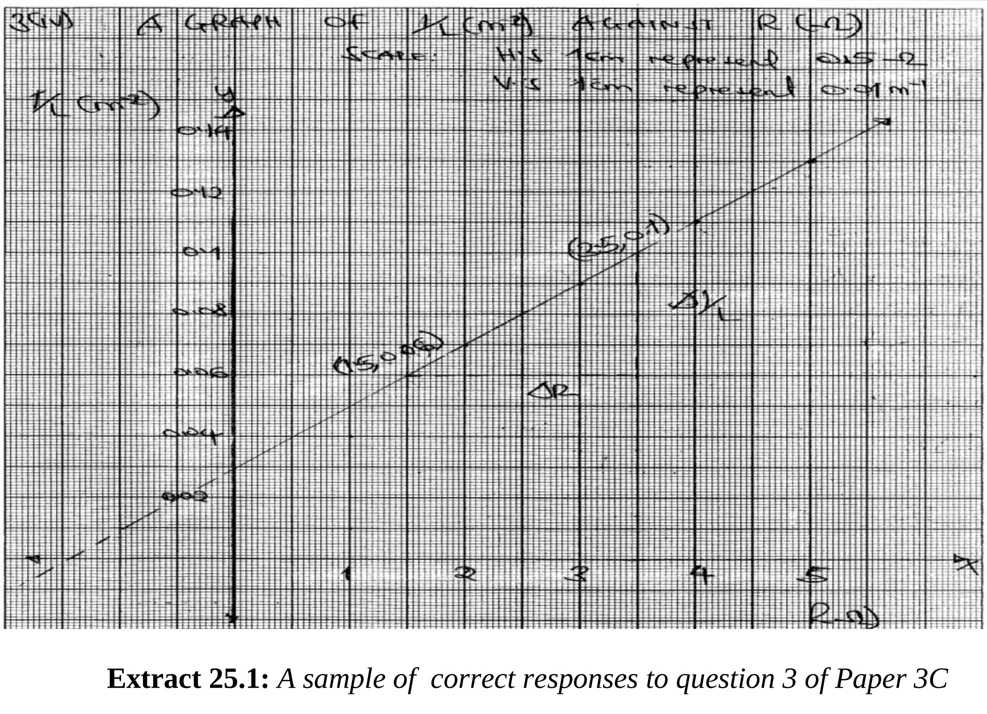
Given $A = 30m^2$

Then:

$$R_f = 1\,\Omega\,m^2 \times 30m^2$$

$$R_f = 30\,\Omega.$$

$\therefore$ The resistance of aluminium sheet of surface area $30m^2$ is $30\,\Omega$.



Extract 25.1: *A sample of correct responses to question 3 of Paper 3C*

Extract 25.1 shows that the candidate was competent in presenting, analysing and evaluating the data, which enabled him/her to get the correct answers of the tested concepts.

However, the candidates who scored low marks had insufficient knowledge of meter bridge theory. Most of them failed to interpret the given instructions in drawing the circuit diagram of experimental set up. Failure to design a proper circuit led them to obtain incorrect data. Further analysis reveals that, the candidates faced challenge in selecting a suitable scale in drawing graphs and points on the best line to determine the slope. Another significant shortcoming was lack of mathematical skills for applying meter bridge theory in deducing an equation governing the experiment. Consequently, they obtained incorrect resistance of aluminium sheet. Extract 25.2 presents a candidate's incorrect responses to this question.

2 v) Solution

The values of room temperature θ_R is approximately equal to the values of surrounding temperature.

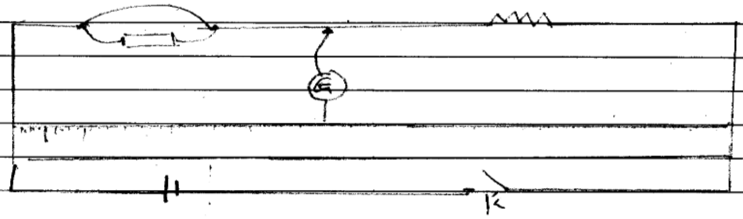


Table of results

$R (\Omega)$	L/m	$1/L\ m$	$1/L^2\ m^{-2}$
5	12.86	0.078	6.084×10^{-3}
4	16.61	0.06	3.6×10^{-3}
3	23.45	0.043	1.849×10^{-3}
2	39.81	0.025	6.25×10^{-4}
1	132.5	7.55×10^{-3}	5.7×10^{-5}

3iv. Solution: from the graph.

$$M = \frac{2.6\times10^{-3} - 6.084\times10^{-3}}{0.06 - 0.078} = \frac{2.484\times10}{0.018}$$

$$M = \cancel{0.338}\,m^2$$

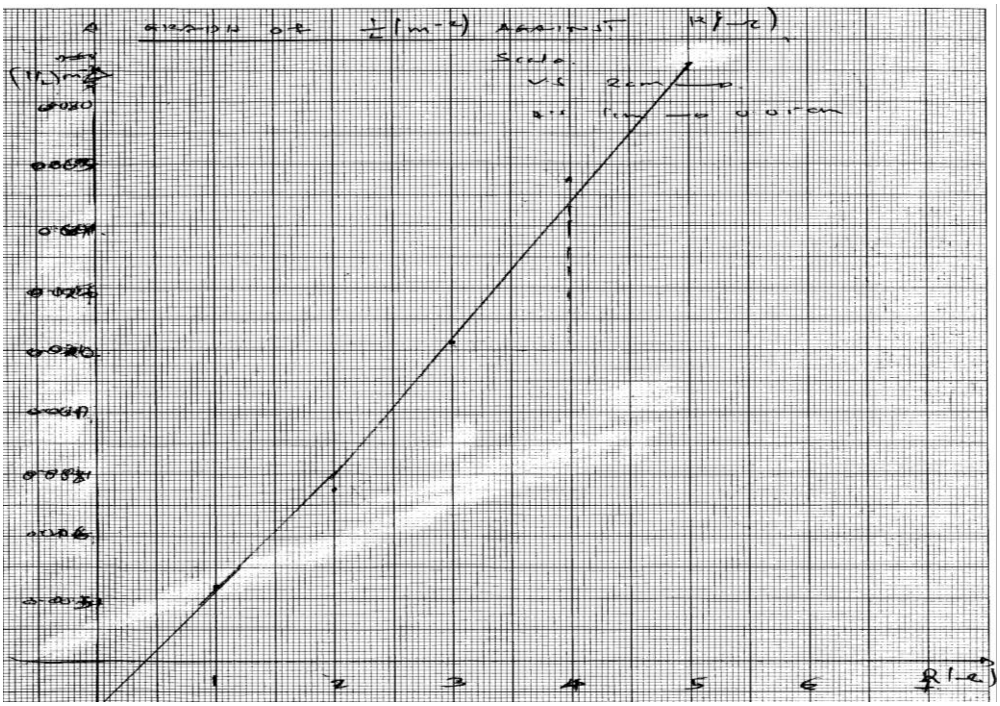
$$M = \frac{2.484\times10^{-3}}{2m}$$

$$M = 2.484\times10^{-3}\,m^{-2}/\Omega$$

3vi solution.

$A = 30m^2$

$$R = \frac{\rho L}{A}.$$



Extract 25.2: *A sample of incorrect responses to Question 3 of Paper 3C*

In Extract 25.2, the candidate presented irrelevant responses due to use of incorrect data. The obtained data resulted in incorrect graph with a negative slope.

5.0 ANALYSIS OF CANDIDATES' PERFORMANCE IN EACH TOPIC

The Physics Paper 1 had ten (10) questions extracted from five (5) topics. The topics include *Mechanics; Heat, Environmental Physics, Current Electricity* and *Electronics.* The Physics Paper 2 comprised six (6) questions derived from six (6) topics, which were *Fluid Dynamics, Vibrations and Waves, Properties of Matter, Electrostatics, Electromagnetism* and *Atomic Physics*. Physics Paper 3 had three equivalent actual practical papers (131/3A Physics 3A, 131/3B Physics 3B and 131/3C Physics 3C) each consisting of three questions. The questions were set from the topics of *Mechanics, Heat* and *Current Electricity*.

The data analysis reveals that the candidates had good performance in seven (7) out of eleven (11) topics that were tested in both Physics Paper 1 and 2. Those topics were *Properties of Matter (82.1%), Atomic Physics (79.9%), Electromagnetism (74.4%), Vibrations and Waves (74.3%), Environmental Physics (74.2%), Mechanics (71.7%)* and *Electronics (66.3%)*. The candidates had average performance in four (4) topics of *Electrostatics (58.5%), Heat (57.75%), Current Electricity (53.9%)* and *Fluid Dynamics (47.5%)*. Those candidates demonstrated their competence in the subject matter as they correctly analysed the examined concepts. However, some of them had insufficient knowledge and lacked computational skills for applying the correct formulae to perform calculations.

In Physics Paper 3, three topics of *Mechanics, Heat* and *Current Electricity* were averagely performed. The reasons for average performance include poor mastery of the subject matter especially in the examined concepts, misconceptions when presenting the ideas, lack of analytical skills, failure to describe and analyse the concepts to draw conclusion, lack of drawing skills and failure to follow instructions when assembling apparati in performing experiments. The summary of the candidates' performance in each topic is shown in Appendices I and II.

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Generally, the candidates' performance in Physics examination paper was good. Analytically, it was observed that adequate knowledge of the content and good mastery of the subject matter were among the major reasons for good performance. In this perspective, many candidates provided relevant responses which met the requirements of the questions.

Further analysis revealed that, mastery of computational skills was another reason that contributed to good performance among most of the candidates, especially in questions that involved the use of formulae and procedures to obtain the required answer. However, some of the candidates lacked mathematical skills. Consequently, they scored low marks. The case in point is question 1 of Physics Paper 2, which was averagely performed but more than a half (52.5%) of the candidates scored low marks $\left(0-6.5\right)$. These candidates lacked numerical skills to interpret and analyse the examined concepts.

In addition, most of the candidates were consistent, neat and precise in providing their responses with very few grammatical errors due to good mastery of the English language. For instance, in question 7 of Physics Paper 1, which required a brief explanation of the tested concepts, 74.2 per cent of the candidates provided detailed responses which enabled them to score the pass mark or above.

Another factor that led to good performance was the skills to interpret diagrams. Most of the candidates proved their competence in studying the given figures by applying the relevant formulae and procedure to analyse different concepts. For example, in question 6 of Physics Paper 2, more than three quarters (79.9%) of the candidates scored from 7 to 20 marks.

However, although a significant number of candidates had good performance, some of the candidates faced difficulties in attempting the questions. They provided inappropriate responses due to misconceptions of ideas. Lack of numerical skills affected most candidates in this group. They failed to think critically and to establish and apply proper formula and procedure when performing calculations. It was also observed that some candidates attempted few parts of the questions incorrectly, especially the structured questions, and skipped other parts.

Moreover, poor mastery of drawing skills contributed to candidates' average performance, especially in Physics Paper 3 of which, questions 1, 2 and 3 required the candidates to plot graphs. Most of them ignored the important aspects to consider when drawing graphs. They also faced difficulties in providing the title of the graphs, their units, the axes with their respective S.I units, the scales used, the transfer of points, the best line or curve and the slope indication which could help them score high marks. Furthermore, they failed to prepare the table of results, interpret the plotted graph and analyse the data to make conclusion.

6.2 Recommendations

For future improvement of the candidates' performance in Physics examination, teachers are advised to:

(a) guide students in groups to discuss and demonstrate the application of Bernoulli’s principle in *pitot-static tube, jets and nozzles, aerofoils* and *venture meter*.

(b) guide students to describe various concepts of *Electrostatics*, particularly the force between two charged bodies, electric field of a point charge and electric field intensity as well as to analyse the motion of a charged particle in a uniform electric field.

(c) assist students in groups to examine the mechanism of electric conduction in metals, and to deduce and apply Kirchhoff's laws for electrical networks.

(d) help students to deduce the Newton's law of cooling and investigate the factors that affect the rate of cooling.

(e) demonstrate to students the proper way of preparing the table of results and technique used in plotting graphs.

(f) apply participatory methods to guide students to conduct experiments as stipulated in Physics Syllabus and instruct them the proper ways of writing reports.

(g) help students acquire drawing skills by providing them with more assignments during practical sessions.

(h) encourage students to be critical and analytical when attempting the questions. This will help them to be neat and precise in evaluating the tested concepts.

(i) promote students' attitude of reading different textbooks and reference books in order to promote their knowledge of different concepts, theories and laws of Physics.

APPENDIX I

The Candidates' Performance in Each Topic in Physics 1 & 2 in ACSEE 2022

S/n.	Topic	2022 EXAMINATION PAPER		
		Number of Questions	Percentage of Candidates who Scored an Average of 35 Percentage or Above	Remarks
1.	Properties of Matter	1	82.10	Good
2.	Atomic Physics	1	79.90	Good
3.	Electromagnetism	1	74.40	Good
4.	Vibrations and Waves	1	74.30	Good
5.	Environmental Physics	1	74.20	Good
6.	Mechanics	4	71.70	Good
7.	Electronics	2	66.3	Good
8.	Electrostatics	1	58.50	Average
9.	Heat	2	57.75	Average
10	Current Electricity	1	53.9	Average
11	Fluid Dynamics	1	47.50	Average

APPENDIX 1I

The Candidates' Performance in Each Topic in Actual Practical Papers 3A, 3B and 3C in ACSEE 2022

S/n.	Topic	Number of Questions	Percentage of Candidates who Scored an Average of 35 Percentage or Above	Remarks
1.	Heat	1	54.30	Average
2.	Current Electricity	1	38.20	Average
3.	Mechanics	1	37.40	Average