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

STUDENTS' ITEM RESPONSE ANALYSIS REPORT ON THE FORM TWO NATIONAL ASSESSMENT (FTNA) 2022

ENGINEERING SCIENCE

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035 ENGINEERING SCIENCE

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FOREWORD

This report is about the Students' Item Response Analysis (SIRA) on the Form Two National Assessment (FTNA) 2022 in the Engineering Science subject. The FTNA marks the completion of two years of ordinary level of secondary education. It is a formative evaluation, which shows the effectiveness of the education system in general, and the education delivery system in particular. It also portrays what the education system was able or unable to offer to the students in their first two years of secondary education. Therefore, this report provides feedback to the students, teachers, parents, policy makers and public in general on the performance of the students and the challenges they faced when responding to the questions.

The performance of the students in the Engineering Science subject in FTNA 2022 was average as 855 (47.03%) of students passed. In 2021, the 897(53.62%) students scored above average. This suggests a decrease in the students' performance in FTNA 2022 by 6.59 per cent as compared to FTNA 2021.

In this report, analysis of each question has been done to identify factors that affected students' responses. The student who passed this assessment had good knowledge and skills on the assessed topics and they understood the requirement of the questions. In contrast, the students with weak performance faced various challenges including inadequate knowledge and skills on the assessed topics, lack of mathematical skills and failure to understand the requirement of the assessed questions. This report also highlights some recommendations which will help various education stakeholders, school managers, teachers, and students to identify appropriate methods to be taken in order to improve students' performance in future assessments.

The Council profoundly acknowledges the examination officers, examiners and other participants who prepared this report. Their best contribution is highly appreciated.

Dr. Said A. Mohammed
EXECUTIVE SECRETARY

1.0 INTRODUCTION

This report presents the analysis of the students' performance in the Form Two National Assessment (FTNA) 2022 in the Engineering science subject.The paper assessed the competences acquired by the students after completing two years of study in Ordinary Level of education based on the 2019 Engineering science syllabus for technical secondary schools From 1 to 4.

The Engineering Science assessment had three sections, A, B, and C. Section A had two objective questions. Question 1 had ten (10) multiple-choice items, each carrying 1 mark. Question 2 had five (5) matching items, each carrying 1 mark. Section B had seven (7) short answer questions, each carrying 10 marks. Section C had one structured question carrying 15 marks. Students were instructed to answer all questions.

The number of students who sat for the 2022 FTNA were 1818 out of which 855(47.03%) passed while 963 (52.97%) failed. In 2021, 1673 students sat for the assessments out of which 897 (53.62%) passed while 776 (46.38%) failed. This indicates that there is adecreaseof 6.59 percent of the students who passed examinations in the 2022 compared to the 2021. Appendix II summarise this performance.

The performance is considered good, average and weak if students' marks range between 65-100, 30-64, and 0-29 indicated by green, yellow and red colours respectively. Samples of students' responses are inserted as extracts to represents good and weak cases. In addition, graphs and charts have been used to summarise the students' performance in a particular question. In the last part of the report there is an appendix II and III which show a comparison of students' performance between the 2021 and 2022 FTNA and general students' performance grade-wise, which is presented in Appendix I.

The analysis presents the requirements of each question, students' strengths and weaknesses in their responses, the percentage of students' who attempted the question and the reasons for the performance in each group of scores. The analysis also indicates the sample of the students' script good responses and poor responses in each question. This information's will be useful to the education stakeholders, teachers, and students', since the recommendation given will serve to improve the teaching and learning process in engineering science subject.

2.0 ANALYSIS OF STUDENTS' RESPONSES IN EACH QUESTION

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

2.1 SECTION A: Objective Questions

Section A comprised two objective questions,1 and 2. Question 1 consisted of 10 multiple-choice items derived from the topics of *Linea*r *Motion*, *Measurements*, *Properties of Matter*, *Work, Energy and Power*, *Sound Waves*, *Light*, *Turning Forces* and *Simple Machines.* Each itemcarried a weight of 1 mark each. Question 2 consisted of five matching itemsset from the topic of *Fluid Mechanics*carried a weight of 1 mark each. Thus, this section carried a total of 15marks. The analysis on each question is as follows.

2.1.1 Question 1: Multiple Choice Question

This question had 10 items, (i) to (x). The students were asked to choose one correct response for each item by writing its letter in the box provided.

A total of 1818 (100%) students attempted this question, out of which166 (9.1%) scored from 0 to 2.0 marks; 1264 (69.5%) scored from 3.0 to 6.0 marks; and 388 (21.3%) scored from 7.0 to 10.0 marks. These scores suggest that the general performance in this question was good because 90.8 per cent of the students scored above average.The general students' performance is presented in Figure 1.

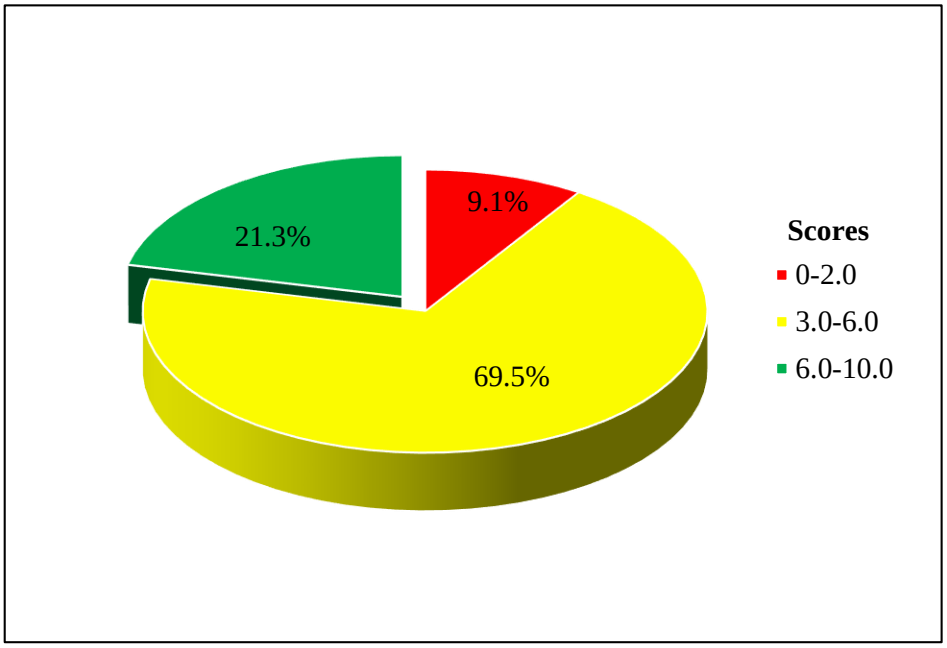


Figure 1: *The Students' Performance in Question 1*

Item (i) was composed from the topic of *Linear Motion*. It intended to measure students' ability to apply the third equation of linear motion, '$v^2 = u^2 + 2ah$' in solving the acceleration.The question asked:

A student threw upwards an apple of mass 'm' (kg) from his hands to a height of 'h' (m). If the acceleration is not 'acceleration due to gravity' owing to environmental location, what will be the acceleration of an apple during upward motion?

$A \quad \frac{v}{2h} \qquad B \quad \frac{v^2}{2h} \qquad C \quad -\frac{v^2}{2h} \qquad D \quad -\frac{mv^2}{2h}$

The correct alternative was D,$\frac{v^2}{2h}$. Students who chose the correct answer had a clear understanding on equations of linear motion particularly the third equation. In addition, they understood that for vertical upwards motion,the final velocity at maximum height is zero. In contrast, the students who chose alternatives A, B, and C failed to associate correctly the third equation of linear motion to identify the required acceleration.

Item (ii) was set from the topic of *Measurements*. It intended to measure students' ability to distinguish fundamental and derived quantities. The question asked:

In every aspect of engineering studies, physical quantities are divided into fundamental quantities and derived quantities. Which of the following quantities can be categorized under derived physical quantities?

A Weight, Length, Velocity and Pressure
B Length, Density, Pressure and Volume
C Velocity, Volume, Pressure and Density
D Volume, Pressure, Mass and Length

The correct alternative was C, *Velocity, Volume, Pressure and Density*. Students who chose the correct answer had an adequate knowledge of physical and derived quantities. However, some students overlooked the answer by confusing it with alternatives A, B and D. These studentsdid not understand that *mass* and *length* are fundamental quantities used to derive other quantities like weight, velocity density and other derived quantities. For example, weight (in Newton) is the product of mass (in Kg and the acceleration due gravity (m/s^2). Likewise, density (in kg/m^3) is obtained by dividing mass (in kg) by volume or cubic length (in m^3). Nevertheless, volume (in m^3) is obtained or derived from length (m) x length (m) x length (m), while pressure (in N/m^2) is obtained from (mass x length) ÷ ($time^2$ x $length^2$).

Item (iii) was set from the topic of *Properties of Matter*. It intended to test the students' competence in applying their knowledge on properties of matter in explaining the basic concepts applied in science and technology in daily life. The question was:

A student poured liquid L into a measuring cylinder and noticed that, it had concave meniscus. Which of the following is most likely to be in liquid L?
A Ethanol B Water C Soda D Mercury

The correct alternative was B, *water*. Students who chose the correct answer understood that in a glass vessel such as a measuring cylinder and water has 'concave meniscus', because of its adhesive property. The strong adhesive forces between water and glass pull the sides of water upwards along the glass forming a concave shaped meniscus. Moreover, the students who chose incorrect alternativesA, C, and D failed to apply the knowledge of properties of matter in determining the type of liquid, which forms the convex and concave meniscus. Most of them did not understand that when a liquid has 'concave meniscus'its surface is curved downwards while when a liquid has 'convex meniscus' its surface is curved upwards due to the actions of adhesive and cohesive forces.

Item (iv) was set from the topic of *Linear Motion.*It intended to measure students'ability to interpret the graphs of linear motion.The question asked:

A teacher threw a stone vertically upwards from the ground and presented a motion of the stone by a velocity-time graph as shown in figure 1. What is the correct statement regarding the velocity of the stone at different position in air?

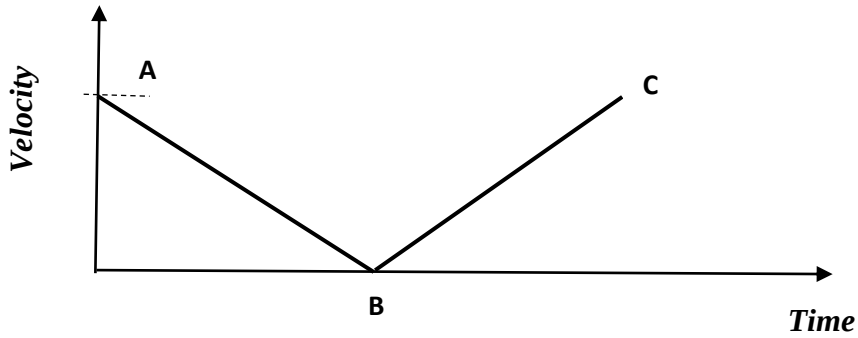


Figure 1

A *Velocity is maxir minimum at C*
B *Velocity is maximum at B and minimum at C*
C *Velocity is maximum at A and minimum at B*
D *Velocity is maximum at C and minimum at A*

The correct alternative for this item was C, *Velocity is maximum at A and minimum at B.* Students who chose the correct option had adequate knowledge on the concept of linear motion specifically on velocity-time graph as they managed to interpret the given graph and identify the correct answer. In contrast, those who opted for distractors A, B or D failed to interpret the velocity-time graph due to insufficient knowledge of linear motion. These students missed the concept on how acceleration due to gravity affects the velocity of a stone when thrown vertically upwards. In fact, when a stone is thrown vertically upward its velocity is high at **point A,** but it starts decreasing owing to the acceleration due to gravity, which is acting oppositely downwards and finally reaches **point B**. When the body reaches its greatest height in the air at **point B** its velocity becomes zero. The velocity **at point B** starts increasing gradually and strikes the ground at **point C** with the same velocity as that which was thrown upwards.

Item (v) was set from the topic of *Work, Energy and Power*. It intended to test the students' ability to apply various types of energy. The question asked:

An old ship burned charcoal in an engine room so as to manage the ship to sail. What type of energy transformation is this?

A *Heat energy to mechanical energy*
B *Chemical energy to heat energy*
C *Chemical energy to mechanical energy*
D *Heat energy to chemicalenergy*

The correct alternative for this item was A,*Heat energy to mechanical energy*.Students who chose this answer had adequate knowledge about the principle of conservation of energy. Most of them understood that when charcoal or any fuel is burned in the internal combustion engines, the heat produced is converted by engine into mechanical energy. Students who chose alternative B, *chemical energy to heat energy*, failed to discover the actual transformation, which gives the energy required for the ship to sail. Those who chose alternative C, *chemical energy to mechanical energy* did not understand that chemical energy stored in the charcoal could not transmitted directly to mechanical energy. However, those who chose alternative D, *heat energy to chemical energy* failed to understand that heat energy cannot be converted into chemical energy.

Item (vi) wascomposed from the topic of *Sound Waves*. It intended to measure students' ability to distinguish the effect of reflection of sound. The question asked:

Four Form Two girls; Bupe, Minja, Muza and Tutindaga were singing loudly while standing 10m in front of a tall building and found a closely reflected sound which gave them a problem to distinguish their sounds. They all argued about this problem as follows:

(a) *Bupe said, we can't distinguish our sound because it is too close to stand 10m from the building and be able to distinguish our sound, it is supposed to be 17 m.*
(b) *Minja said no Bupe, 10m and even 17m from the building is enough for us to distinguish our sound but the problem is the huge building.*
(c) *Muza said, we can't distinguish our sound because we are too far to the building. We were supposed to be not less than 10m from the building.*
(d) *Tutindaga said, 17m is correct for us to distinguish our sound because from the distance less than 17m we can't distinguish our sound.*

From their arguments who was right?

A	*(a) and (b).*	*B*	*(a) and (d).*
C	*(b) and (d)*	*D*	*(c) and (d).*

The correct response for this item was A,*(a) and (b)*. Students who chose the correct alternative had good understanding about the effects of sound reflection. They understood properly how echo and reverberation occurs when sound waves encounter obstacles. However, those who chose alternative B, C, or D, had inadequate knowledge of the subject matter particularly on properties of sound waves. These students had tounderstand thatecho and reverberation result from the reflection of sound at hard surfaces such as a wall, and that their main differences lie in the distances between the observer and the reflecting surface.

Item (vii) was set from the topicof *Light*. It intended to measure students' ability to verify the second laws of reflection of light.The question asked:

A form one student carried out an experiment to study the laws of reflection of light. The student directed a touch ray to the mirror through a small hole or a cardboard so that the reflected ray makes an angle 'S' with the plane mirror as shown in Figure 2. What observation will the student make while measuring angles P, Q R and S?

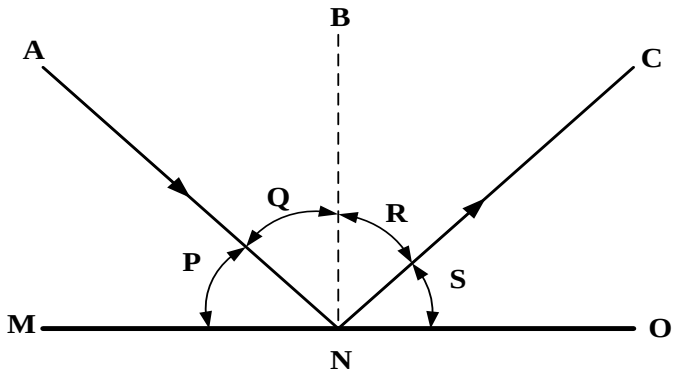


Figure 2

A	*Angle Q is less than angle R.*	*B*	*Angle Q is equal to angle R.*
C	*Angle P is less than angle S.*	*D*	*Angle P is equal to angle S.*

The correct alternative for this item was B,*Angle Q is equal to angle R.* Students who chosethe correct answer were competent with the laws of reflection of light.Most of them understood that according to the second law of reflection of light, the angle of incidence Q is equal to the angle of

reflection R. In addition, they realised that the angle between the normal line BN and the plane mirror MO is 90^{o}. However, some students chose distractors A, C, or D. These students had inadequate knowledge about the laws of reflection of light, as they did not understand that angle Q is equal to angle R according to the second law of reflection of light at plane surfaces.

Item (viii) was set from the topic of *Friction*. It intended to test students' competence in analyzing the factors on which friction depends. The question was as follows:

Students were arguing on parameter, which changes the coefficient of friction. The students' comments were as follows:

1. *If metals of different properties are replaced, the coefficient of friction is changed*
2. *Normal force and density of material can change the coefficient of friction*
3. *Area of contact and frictional force can change the coefficient of friction*
4. *Only material of metals in contact can change the coefficient of friction*

From their arguments, which statement is correct?

A	*1 and 3*	*B*	*2 and 4*
C	*1 and 4*	*D*	*2 and 3*

The correct response for this item was C,*1 and 4*. Students who chose the correct answer were able to identify the factors on which friction depends. They understood properly on howthe nature of the surface in contact,the physical properties of materials involved, and the normal force between the sliding surfaces affects the coefficient of friction. In contrast, the students who chose alternativesA, B or D failed to apply the laws of friction as they did not understand that friction does not depend on the area of the surfaces in contact.

Item (ix) was composed from the topic of *Turning Forces*. This question intended to measure the students' competence in explaining three types of equilibrium. The question asked:

Figure 3 shows the diagram with centre of gravity '**o**' *seated on horizontal as in (a). It was slightly tilted to rise up its centre of gravity as in (b). When*

was released after being tilted the object returned to its original position as in (c). In which state does the object in Figure 3 (a) is said to be?

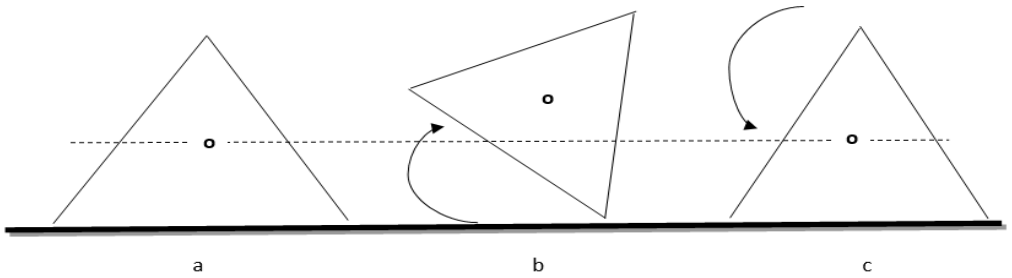


Figure 3

A	*At neutral equilibrium*	*B*	*At static equilibrium*
C	*At stable equilibrium*	*D*	*At unstable equilibrium*

The correct response for this item was alternative C, *at stable equilibrium*. Students who chose this alternative were able to differentiate the three types of equilibrium. In addition, they had adequate knowledge about the factors on which the stability of the body depends. Nevertheless, some of them who chose distractors A, B or D lacked knowledge on the concept of turning effect of forces as they failed to study and interpret the diagram correctly.

Item (x) was set from the topic of *Simple Machines*. It intended to measure the students' competences in applying various simple machines in daily life. The question asked:

A tailor uses a scissor for cutting clothes, people use wheelbarrow for carrying loads while a carpenter uses seesaw for cutting wood and masonry uses shovel for mixing concrete. Which activities is an application of a third class of lever?

A	*Cutting clothes*	*B*	*Carrying loads*
C	*Mixing concrete*	*D*	*Cutting wood*

The correct response for this item was alternative C, *mixing concrete*. The students who scored this question correctly had the ability to classify levers according to their three classes.This suggests that they had sufficient knowledge about the concept of simple machines. However, the students who chose distractors B, C, or D did not understand the concept of simple machines particularly in classes of levers. They failed to group wheelbarrow, pair of scissors, seesaw and shovel to their respective classes.

These students had to understand thatin the first class order, effort is between the fulcrum and the load, which includes levers such as seesaw and a pair of scissors. In the second-class of lever, the load is between the effort and fulcrum, which includes levers such as wheelbarrow while in the third class the effort is between the load and fulcrum, which is shovels.

2.1.2 Question 2: Matching Items

This question was set from the topic of *Fluid Mechanics*. It intended to test students' ability to apply various measuring instruments in real life. Students were required to match the fluid mechanics measurements in **List A** with the corresponding measuring instruments in **List B** by writing the letter of the correct answer. The question was as follows:

List A	***List B***
(i) Measures the pressure of a gas	*A Barometer*
(ii) Measures relative density of liquid	*B Bourdon gauge*
(iii) Measures the atmospheric pressure	*C Pressure gauge*
(iv) Measures the gauge pressure	*D Hydrometer*
(v) Measures the difference between the absolute pressure and atmospheric pressure	*E Hygrometer*
	F Manometer
	G Thermometer
	H Thermostat

A total of 1818 (100%) students attempted this question, out of which 417 (22.9%) scored from 0 to 1.0 marks; 996 (54.8%) scored 2.0 to 3.0 marks; and 405 (22.3%) scored 4.0 to 5.0 marks. These scores suggest that the general students' performance in this question was good as 76.79 per cent of the students scored above average. Figure 2 summarizes the scores.

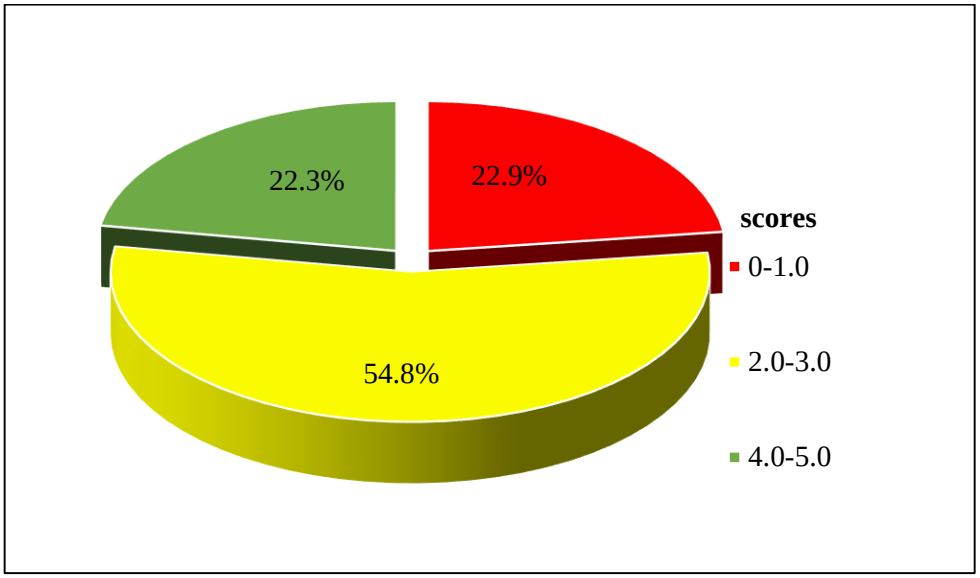


Figure 2: *The Students' Performance in Question 2*

In Item (i), the students were required to identify the response, which matches with the statement; *Measures the pressure of a gas.* The correct response was F, *manometer.*Most of the students were able to match this item correctly except a few of them who matched it with inappropriate responses particularly A, *Barometer*. These failed tounderstand that barometer is used to measure atmospheric pressure.Some of them matched it with alternative C,*gauge pressure,* suggesting that they lacked skills on measuring tools used in fluid mechanics.

Item (ii) required the students to identify an instrument used to *Measure relative density of liquid.* The correct response was D, *Hydrometer*. Students who matched this item correctly had adequate knowledge on the concept of relative density. However, a few students chose option E, *Hygrometer* as they failed to distinguish hydrometer from hygrometer. This might be due to how these two terms sound. In fact, hygrometer is used to measure the amount of water vapour in air.

In item (iii), students were required to identify an instrument used to *measure the atmospheric pressure.* The correct answer was A, *Barometer*. Majority of the students got this item correctly. This suggests that they had good knowledge about barometers. Most of students matched it wrongly by choosing H, *Thermostat*. These students might have misconception that resulted from the fact that thermostat is a device that automatically regulates temperature, or activates a device when the temperature reaches a certain point.

In item (iv), students were required to identify an instrument used to *measure the gauge pressure.* The correct response was B, *Bourdon gauge.* Most of the students matched this item incorrectly, as they lacked knowledge of Bourdon gauge. Distractor *C, gauge pressure* attracted them due to the presence of the word gauge. In practice, that gauge pressure measures the difference between absolute pressure and atmospheric pressure.

In item (v), students were required to identify an instrument used to*measure the difference between absolute pressure and atmospheric pressure.* The correct answer was *C, gauge pressure*. Most of students matched correctly this item showing that they had adequate skills of measuring devices. However, a few of them matched it incorrectly with a response A, *barometer*. These students had insufficient knowledge about the concept of fluid mechanics especially on devices used to measure different quantities.

2.2 SECTION B: Short Answer Questions

This section comprised of seven (7) questions, which were set from the topics of *Measurement Friction, Linear Motion, Turning Forces, Simple Machine, Heat and Electricity*. Each question carried 10 marks, making a total of 70 marks.

2.2.1 Question 3: Measurements

The question intended to test students' competence in measuring volumes and densities of irregular objects. Students were instructed to write steps to be followed when measuring the density of an irregular object. The question asked:

With the aid of sketches, write down the steps you will follow while measuring the density of irregular object.

A total of 1818 (100%) students attempted this question whose scores were as follows: 838 (46.1%) scored from 0 to 2.5 marks; 579 (31.8%) scored from 3.0 to 6.0 marks; and 401 (22.1%) scored from 6.5 to 10.0 marks. The general performance in this question was average, because 54.7 per cent of the students scored above average. Figure 3 summarizes this performance.

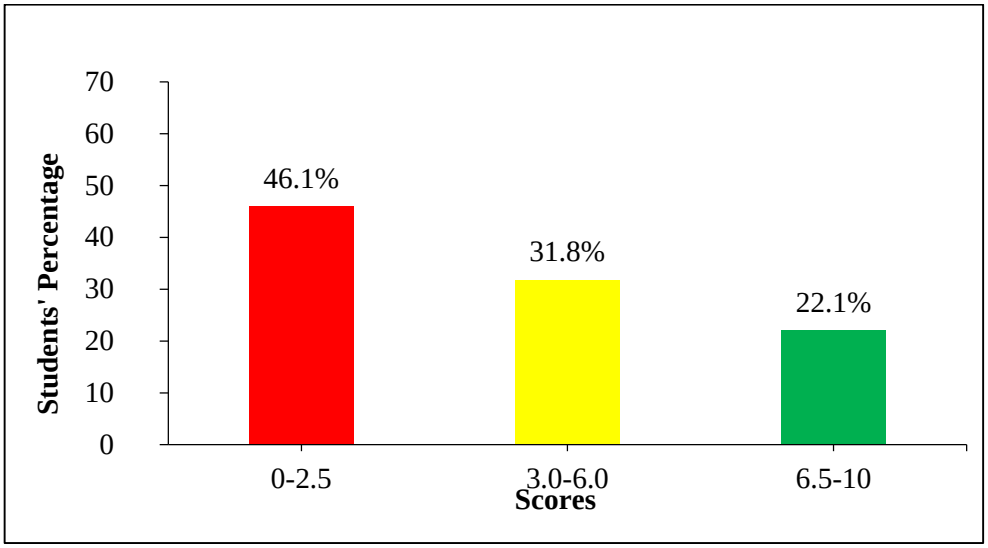
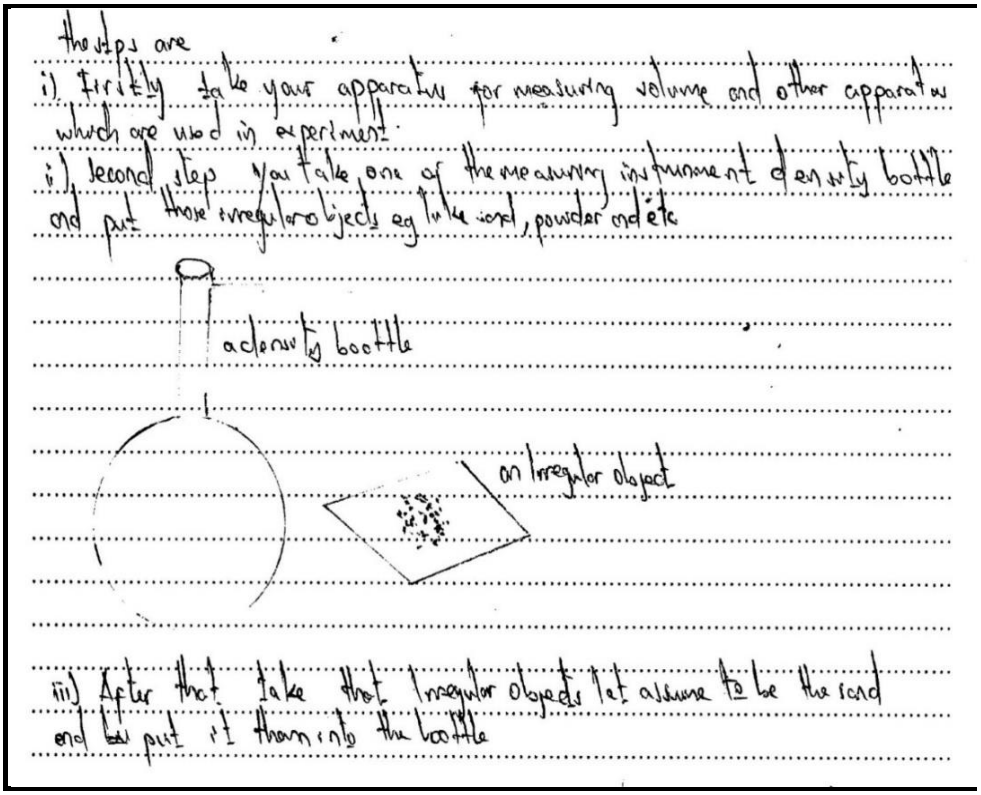


Figure 3: *The Students' Performance in Question 3*

The analysis shows that 529 (29.1%) students scored 0 mark. Further analysis on students' scripts reveals that most of them lacked the skills of measurements as they failed to write at least one-step to measure the density of irregular object. In addition, they failed to sketch any relevant measuring instrument such as an over-flow can, measuring cylinder, beaker, and an irregular object such as stone being tied on a string. For example, one student wrote: *follow rules which are required in the place where measures of density of irregular object is obtain*. This student insisted to follow the rules required during measurement instead of writing the steps required in measuring irregular objects. He/she also failed to provide sketches in each step. Another student wrote: *measuring spring, Centre of gravity, a scissor for cutting clothes* showing that he/she did not understand the demand of the question. He/she also lacked drawing skills.However, students who scored low marks (0.5 to 2.5) provided one to two correct steps used in measuring irregular objects while some drew correctsketches but failed to write the required steps. Extract 3.1 shows the sample of incorrectresponses from the student's script.



Extract 3.1: A sample of the students' poor responses to Question 3

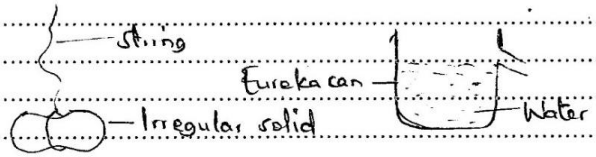
In Extract 3.1, the studentdrew an irrelevant sketch of measuring instrument and irregular object. He/she wrote *take the apparatus* without mentioning the name of that apparatus. He/she also wrote: *take one of the measuring instrument and insert the irregular object* instead of specifying the type of instrument used in measuring the volume.

On the other hand, 579 (31.8%) students who scored from 3.0 to 6.0 marks were able to write some of the correct steps to follow when measuring the density of an irregular object. A few number of them failed to provide the formula $'Density = \frac{Mass}{Volume}$of finding density of liquid while others provided correct sketches without labeling.

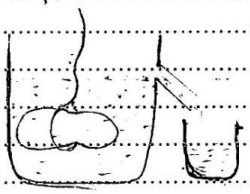
However, 401(22.1%) students who scored marks (6.5-10.0) understood the requirement of the question. These students had adequate skills on measuring the volume of irregular objects as well as using the sketch in writing the required steps while measuring its volume. In addition, some of them presented their responses very precisely though they had some errors, which lead to lose some marks. A sample of the students' good responses is shown in Extract 3.2

While measuring the density of irregular object.
- Prepare the following instruments, Measuring cylinder, Beam balance, Eureka can, Beaker, irregular object (stone), string, water.

→ Measure the mass of the irregular object given, using a beam balance. And then record its mass.
→ Put some water in the Eureka can until at its spout level.
→ Tie the irregular object with a string tightly.



→ Slowly, immerse the solid in the Eureka can and ensure that the water displaced is tapped in a beaker.



→ Take the liquid (water) that is collected in the beaker and measure its volume using a measuring cylinder and then record its volume.

Then use the following formula,

$$\text{Density of substance} = \frac{\text{Mass of substance}}{\text{Volume of substance}}$$

$$\text{Density of irregular solid} = \frac{\text{Mass of irregular solid}}{\text{Volume of irregular solid}}$$

Extract 3.2: A sample of the students' good responses to Question 3

In Extract 3.2, the student was very systematic in identifying tools used for measuring the volume, providing the correct sketches and steps required when measuring the volume of irregular object.

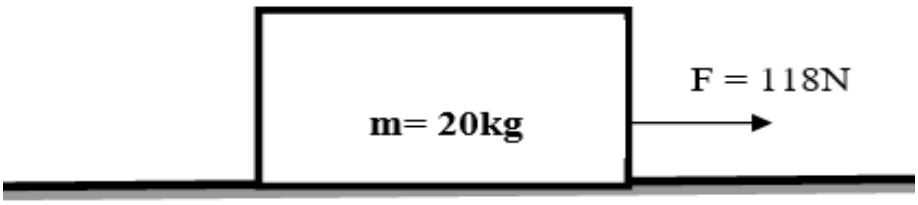
2.2.2 Question 4: Friction

This question had two parts part (a) and (b) set from the topic of 'Friction'. It measured students' ability to explain the laws of static and kinetic friction. The question asked:

(a) A Coca Cola company experiences an excessive consumption of electrical power due tovarious frictions developed on the mechanical

drives. What are the four laws which both static friction and kinetic friction depend on?

(b) *The figure below shows a box of 20 kg, which is pushed by a student on a horizontal surface by using a force of 118N. Calculate the coefficient of friction between the two surfaces in contact.*



Number of students who attempted this question was 1818 (100%). The data shows that 1008 (55.4%) scored from 0 to 2.5 marks; 463 (25.5%) scored from 3.0 to 6.0 marks; and 347 (19.1%) scored from 6.5 to 10.0 marks. The general performance in this question was averagebecause 44.6 per cent of the students scored above average. Figure 4 presents this performance.

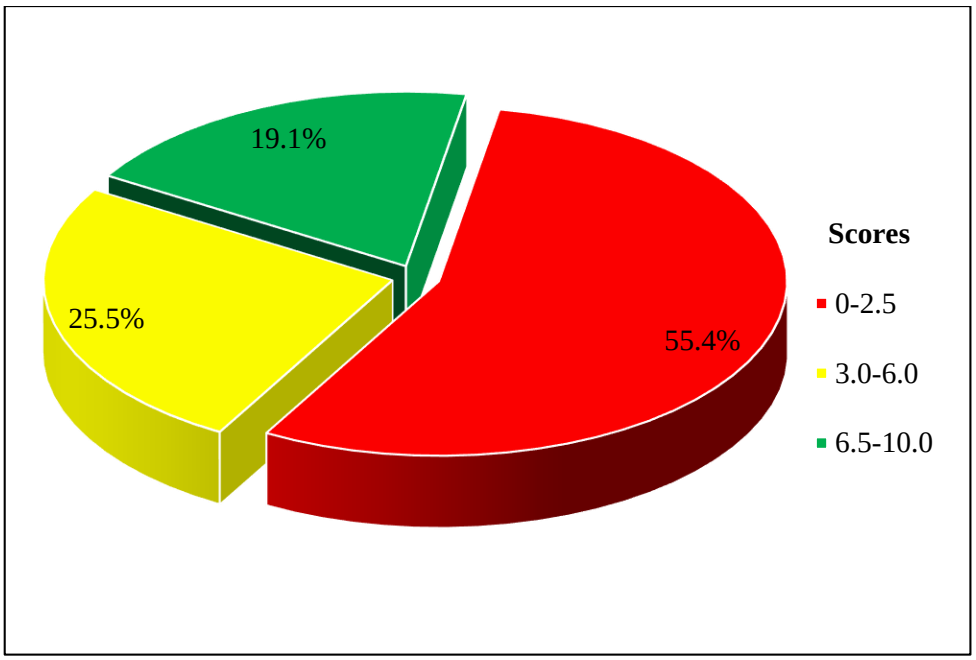
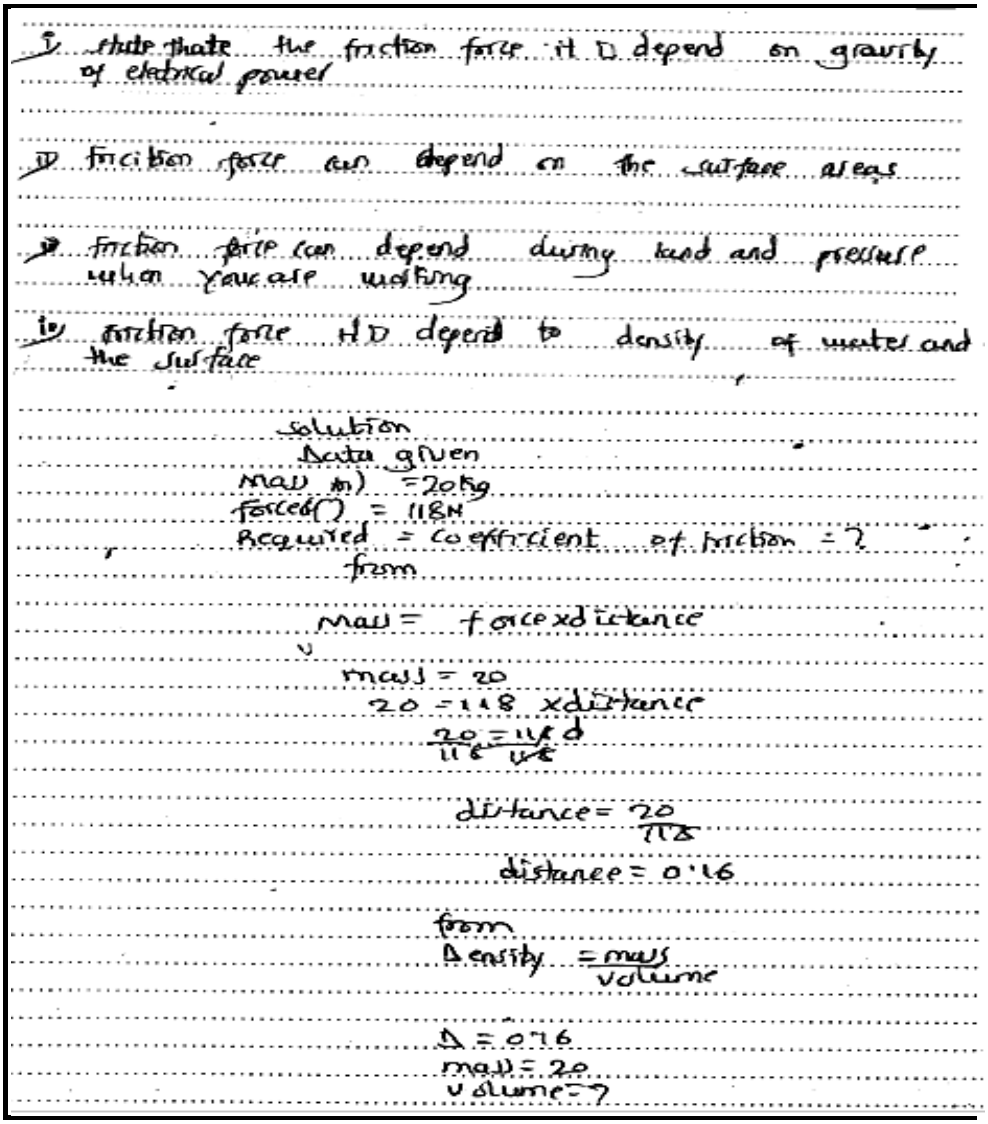


Figure 4: *The Students' Performance in Question 4*

Almost 41.1 per cent of the students out of those who scored low marks scored 0. These students failed to state the laws of friction and apply the

equation $F = \mu R$ to compute the coefficient of friction in part (a) and (b) respectively. Other students did not understand the demand of the question as they provided irrelevant answers. For example, in part (a) one student copied the question in part (b) such as *figure four shows a box of 20 kg, which is pushed by a student on horizontal surface instead of writing the four laws*, as demanded. In part (b), when calculating the coefficient of friction he/she wrote *V=20, M=118, F=118, N=1, 0=2,?=0* ended with incorrect answer *365*. Another student in part (a) just copied the physical quantities as appeared in question 2 such as *measures the pressure of a gas, measure the gauge pressure.* In part (b) the student used the formula *force/mass =41.20 m/s* instead of applying $\mu = \frac{F}{mg}$ to compute the coefficient of friction. All these misconceptions suggest that most of them lacked knowledge on the concept of friction specifically about the effects occurred when an object is moving relative to the surface in contact. Extract 4.1 portrays a sample of a script of a student's poor responses.

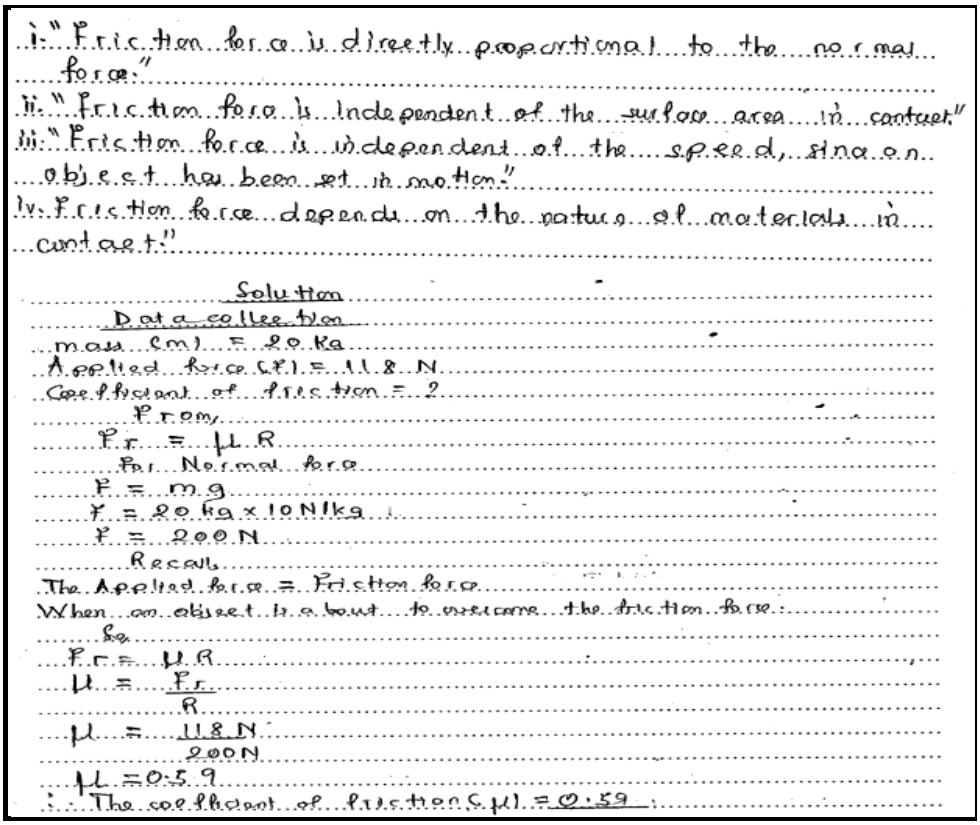


Extract 4.1: A sample of the students' poor responses to Question 4

In extract 4.1, the student provided incorrect laws on which both the static and kinetic friction depends. In part (b), he/she analysed the given data but failed to write and apply the correct formula to find the coefficient of friction.

On the other hand, 463 (25.5%) students scored from 4.5 to 6.0 marks. These students had partial knowledge on the concept of friction. Most of them were able to write the laws of friction in part (a) and the equation $F = \mu R$ but failed to convert the units of mass into weight using the equation $R = mg$. Other students in part (a) stated correctly one or two laws of friction but missed some parts.

Moreover, 41 (2.3%) students scored all 10 marks allotted to this question. These studentshad good understanding on the subject matter. In part (b), they were able to calculate correctly the normal reaction force by applying required formula and procedures in calculating the coefficient of friction. In addition, they managed to provide the laws of friction as required by part (a) of this question. Extract 4.2 shows a sample of a good response from of a student's script.


i. "Friction force is directly proportional to the normal force."
ii. "Friction force is independent of the surface area in contact"
iii. "Friction force is independent of the speed, since an object has been set in motion."
iv. Friction force depends on the nature of materials in contact."

Solution

Data collection

mass (m) = 20 kg

Applied force (F) = 11.8 N

Coefficient of friction = ?

From

$F_r = \mu R$

For Normal force

$F = mg$

$F = 20\,kg \times 10\,N/kg$

$F = 200\,N$

Recall,

The Applied force = Friction force

When an object is about to overcome the friction force.

So

$F_r = \mu R$

$\mu = \frac{F_r}{R}$

$\mu = \frac{11.8\,N}{200\,N}$

$\mu = 0.59$

∴ The coefficient of friction (μ) = 0.59

Extract 4.2: A sample of the students' good response to Question 4

In Extract 4.2, the student correctly provided four laws on which both static and kinetic friction depend. In part (b), he/she applied the correct formula to find the coefficient of friction.

2.2.3 Question 5: Linear Motion

This question was set from the topic of *'Linear Motion'*. It intended to measure students' ability to apply the equations of linear motion to solve real life problems. The question asked:

When a body travels in a straight line with an initial velocity 'u' m/s accelerates uniformly by 'a' m/s^{2}until it reaches a final velocity of 'v' m/s at a time 't' and cover a distance 's'. Prove that $s = ut + \frac{1}{2}at^2$.

There were 1818 (100%) students attempted this question and their scores were as follows: 1088 (59.8%) scored from 0 to 2.0 marks; 436 (24.0%) scored from 3.0 to 6.0 marks; and 294 (16.2%) scored from 7.0 to 10.0 marks. The general performance in this question was average, because 40.2 per cent of the students scored above average. Figure 5 presents a summary of students' performance.

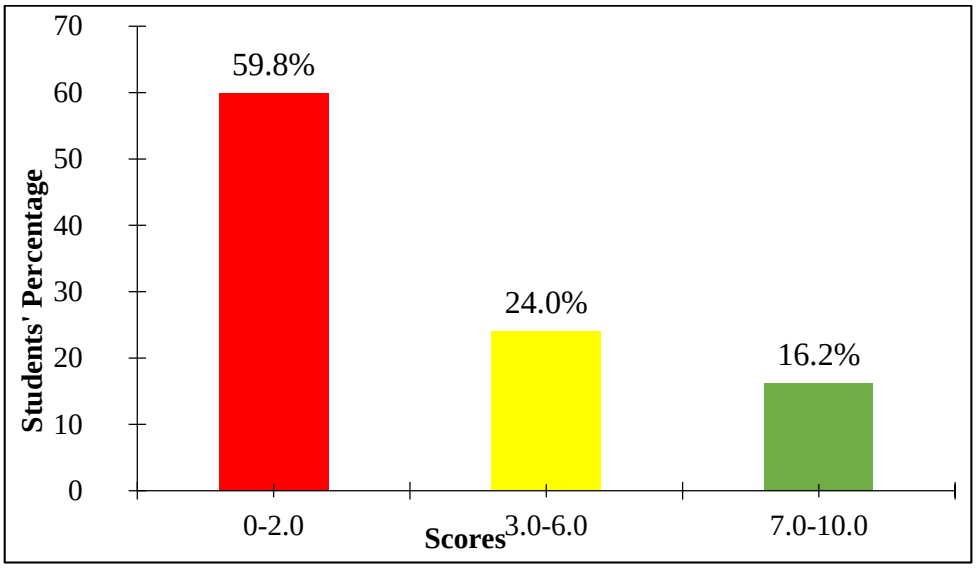
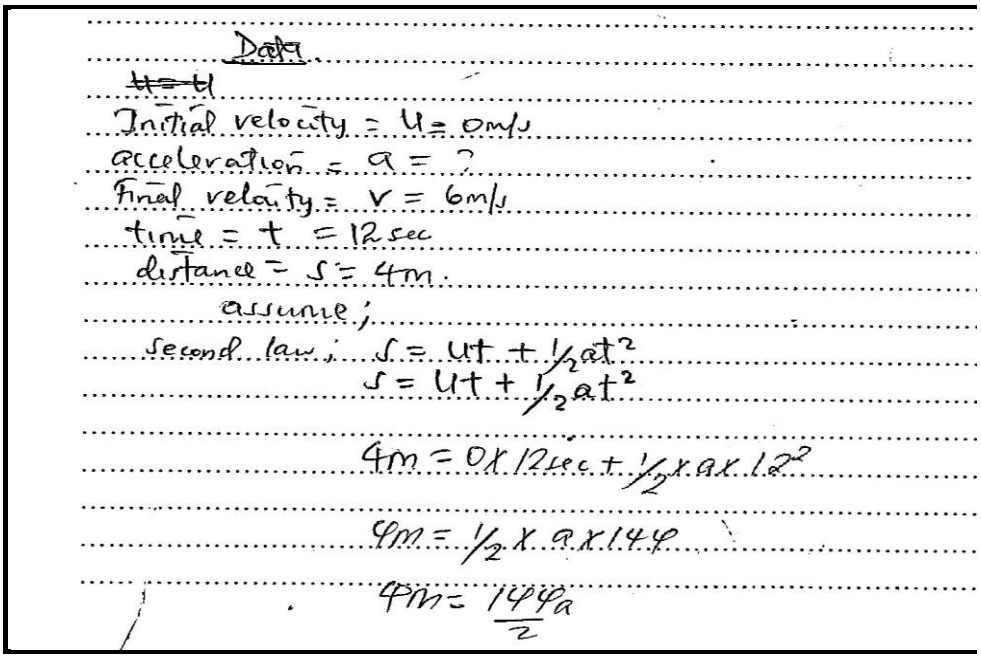


Figure 5: *The Students' Performance in Question 5*

The analysis shows that 641 (35.0%) of the students scored 0 mark. These students lacked the knowledge of linear motion as they failed to write the first equation of motion $v = u + at$. Students had to substitute this equation into an expression, $\frac{s}{t} = \frac{u+v}{2}$, to produce $s = ut + \frac{1}{2}at^2$. For example, one students listed the given values, but failed to write any formula based on linear motion. Another student copied the formula such as $s = ut + \frac{1}{2}at^2$ then substituted the given units in the question to obtain $s = \frac{m}{s}xs + \frac{1}{2}m/s^2\, xs^2$ and finally $s = m + \frac{1}{2}m$. However, those who scored 1.0 to 2.0 marks wrote the correct equation $v = u + at$ but failed to remember that, an average velocity *'v_a'* may be obtained from either $v_a = \frac{s}{t}$ *or* $v_a = \frac{u+v}{2}$. This suggests poor mastery of the subject matter to most

of the students as they failed to apply the first equation of motion to analyse the concept and obtain the required expression. Extract 5.1 shows a sample of response from of a student's script.

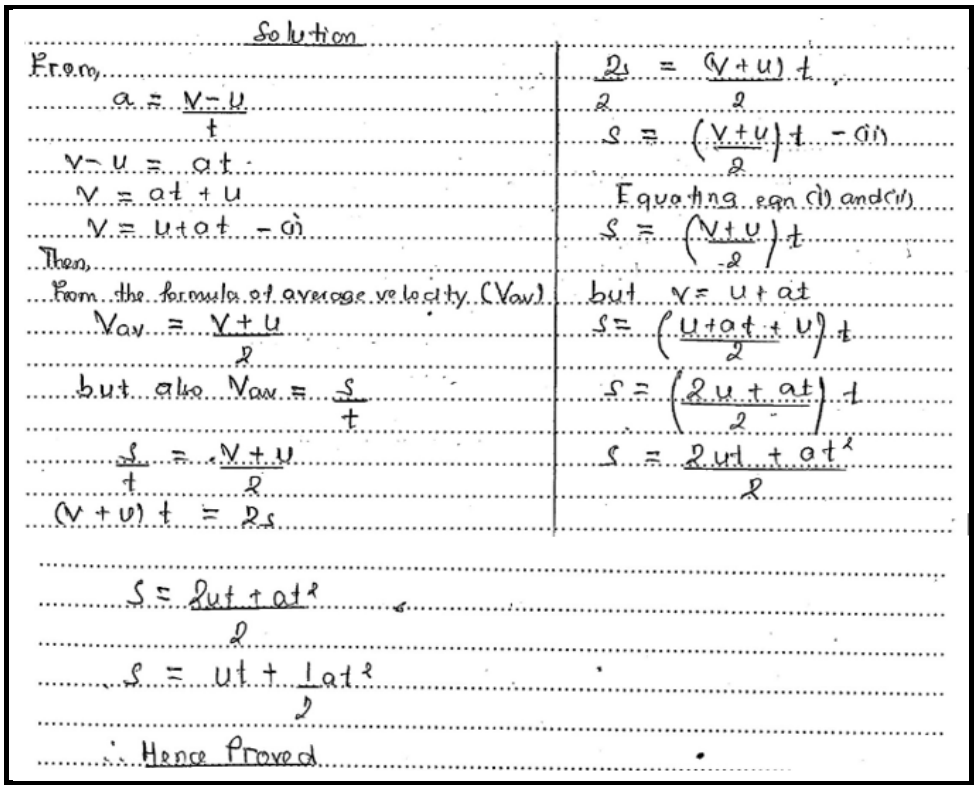


Extract 5.1: A sample of the students' poor responses to question 5

In extract 5.1, the student listed the incorrect values of velocities, acceleration, time and distance thensubstituted it in the equation $s = ut + \frac{1}{2}at^2$. However, in this question, those values were not given but students were required to use the knowledge of linear motion to prove the second equation of motion.

On the other hand, 24.0 per cent of the students who scored from 3.0 to 6.0 marks were able to correctly write one of equations of linear motion necessary to derive the second equation of motion, but failed to substitute the necessary information to reach the conclusion. For example, one student wrote: $a = \frac{v-u}{t}$. This student missed some marks since he/she failed to write the two formulas of finding average velocity which are $= \frac{v+u}{2}$ and $= \frac{\text{displacement(s)}}{time(t)}$ respectively.

On the contrary, some students (16.2%) provided relevant responses to most parts of the question. They demonstrated their competence by applying the equations of linear motion to prove the given equation. Extract 5.2 shows a sample of good responses.


Solution

From,

$a = \frac{v-u}{t}$

$v - u = at$

$v = at + u$

$v = u + at \quad -(i)$

Then,

From the formula of average velocity (V_{av})

$V_{av} = \frac{v+u}{2}$

but also $V_{av} = \frac{s}{t}$

$\frac{s}{t} = \frac{v+u}{2}$

$(v+u)t = 2s$

$\frac{2s}{2} = \frac{(v+u)t}{2}$

$s = \left(\frac{v+u}{2}\right)t \quad -(ii)$

Equating eqn (i) and (ii)

$s = \left(\frac{v+u}{2}\right)t$

but $v = u + at$

$s = \left(\frac{u+at+u}{2}\right)t$

$s = \left(\frac{2u+at}{2}\right)t$

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

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

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

∴ Hence Proved

Extract 5.2: A sample of the students' good responses to Question 5

In Extract 5.2, the student applied the laws of linear motion by writing the correct formulatoprove the second equation of linear motion

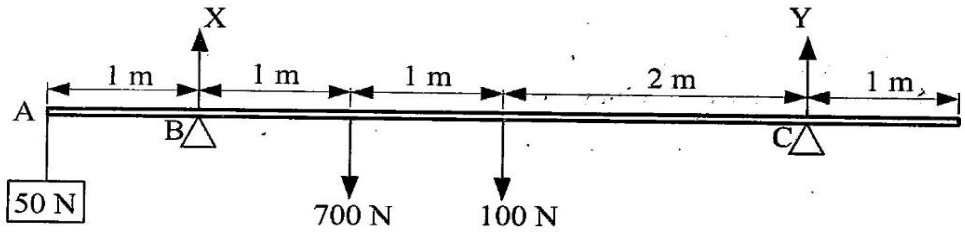
2.2.4 Question 6: Turning Forces

This question had two parts, (a) and (b). It intended to measure students' competence in solving real life problems involving turning forces. The question was as follows*:*

A uniform scaffold plank 6 m long and weight 100 N rests on supports at B and C as shown in the figure below. A man of weight 700 N stands 2 m from end A where there is a hanged weight of 50 N.

(a) Calculate the reaction X and Y at the supports.

(b) What additional weight at A would make the plank just tilt about B thus endangering the safety of the man?



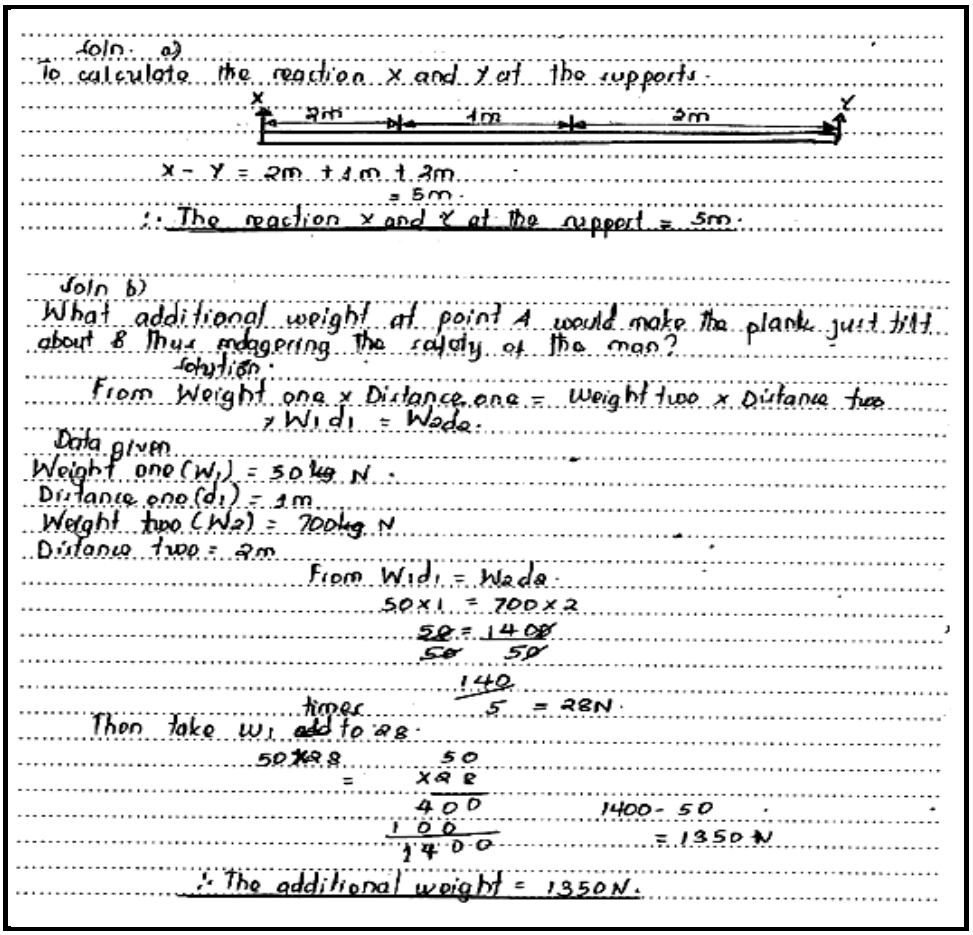
The analysis revealed that 1818 (100%) students attempted this question, out of whom 1670 (91.9%) scored from 0 to 2.5 marks; 73 (4.0%) scored from 3.0to 6.0 marks; and 75(4.1%) scored from 6.5to 10.0 marks. Generally, students' performance in this question was weak, because 91.9 per cent of the students scored below average.Table 1 summarises this performance.

Table 1: *The Students' Performance in Question 6*

General Grade	Percentage Range	Description	Number of Students	Percentage
0-2.5	0 – 29	Unsatisfactory	1670	91.9
3.0-6.0	30 – 64	Average	73	4.0
6.5-10.0	65 – 100	Good	75	4.1
Total			**1818**	**100**

The analysis indicates that about 91.9 per cent of the students had weak performance, where 45 per cent scored 0. These students lacked knowledge of *Turning Forces* as they failed to apply the two conditions for equilibrium when a number of parallel forces acts upon a body. The analysis done in students' responses reveal that, most of them failed todraw the free force diagram showing how the forces balance. For example, one student added the value of length given in a scaffold such as *1m+1m+1m+2m+1m=6m*. Then he/she added the sum of all forces in the scaffold such as *50N+700N+100N=12+700*. Another student calculated the reaction at Y by writing the formula of moment such as $F_1 \times D_1 = F_2 \times D_2$ then substituted the value of F_1 *as 100N,* D_1 *as 2m, D2 as 1m,* without performing any further calculations. These students had little knowledge on equilibrium as they failed to recall and apply the principle of moment into a given scaffold plank to resolve moments at A, B and C and finally to find

reactions X and Y. Also in part (b) most of them failed to calculate the weight that must be added at A to make the plank tilt about B. These students did not understand that for the plunk to tilt about B, the reaction Y must be zero. Extract 6.1shows a sample of the poor responses from the student script.

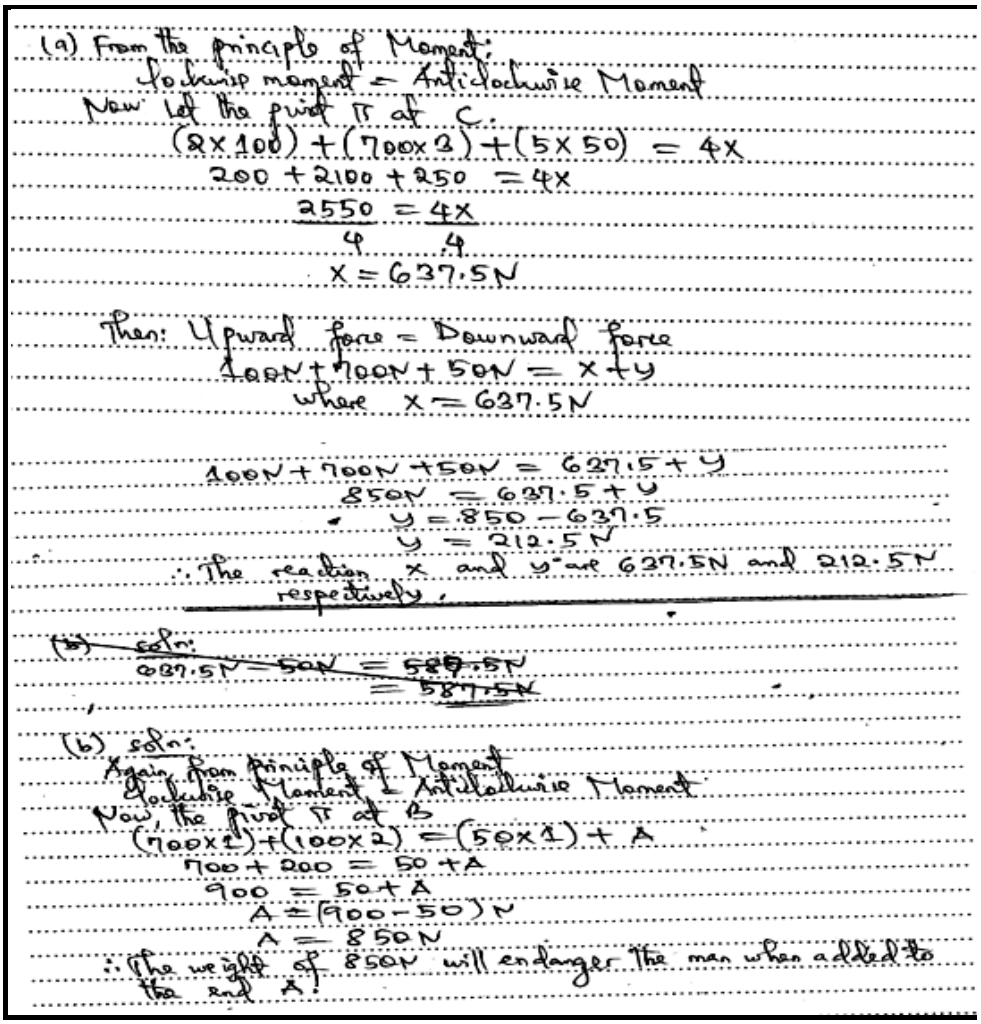


Extract 6.1: A sample of the students' poor responses to Question 6

Extract 6.1 shows how the student wrongly calculated the reaction forces X and Y in units of distance. He/she also failed to prove the acquired competence in other parts of the question.

However, few students (4.1%) scored from 6.5 to 10 marks. These students demonstrated competence in solving problems extracted from turning forces. They were able to apply the two conditions for equilibrium of parallel forces in solving the value of X and Y. In part (b),most of them calculated the weight W that must be added at A for the plank to tilt at B.

However, some of them failed to score full marks due to lack of accuracy in substituting data in the formulas. Extract 6.2 shows a sample of good responsesfrom a script of a student.


(a) From the principle of Moment:
Clockwise moment = Anticlockwise Moment
Now let the pivot π at C.
(2×100) + (700×3) + (5×50) = 4X
200 + 2100 + 250 = 4X
2550 = 4X
4 4
X = 637.5N

Then: Upward force = Downward force
100N + 700N + 50N = X + Y
where X = 637.5N

100N + 700N + 50N = 637.5 + Y
850N = 637.5 + Y
Y = 850 − 637.5
Y = 212.5N
∴ The reaction X and Y are 637.5N and 212.5N respectively.

(b) soln:
637.5N − 50N = 589.5N
= 587.5N

(b) soln:
Again from principle of Moment
Clockwise Moment = Anticlockwise Moment
Now, the pivot π at B
(700×1) + (100×2) = (50×1) + A
700 + 200 = 50 + A
900 = 50 + A
A = (900 − 50)N
A = 850N
∴ The weight of 850N will endanger the man when added to the end A.

Extract 6.2: A sample of the students' good responses to question 6

In extract 6.2, the student correctly applied the required conditions at equilibrium to obtain the correct reaction forces X and Y, and the weight W.

2.2.5 Question 7: Simple Machines

The question was composed from the topic *'Simple Machine'*. It intended to test students' competence in evaluating simple machines. The question was as follows:

A group of students was assigned to put a load of 5000 N into the vehicle at a height of 2m above the ground by using an inclined plane. The efforts required to haul the load was 50N. The students were required to select inclined plane to be used for a job with lengths 5m or 7m respectively. Which inclined plane would you advise the students to use with consideration to their efficient?

The question was attempted by 1818(100%) students' out of whom 992 (54.6%) scored from 0 to 2.5 marks; 505 (27.8%) scored from 3.0 to 6.0 marks; and 321(17.7%) scored from 6.5 to 10.0 marks. These data are summarised in Figure 6.

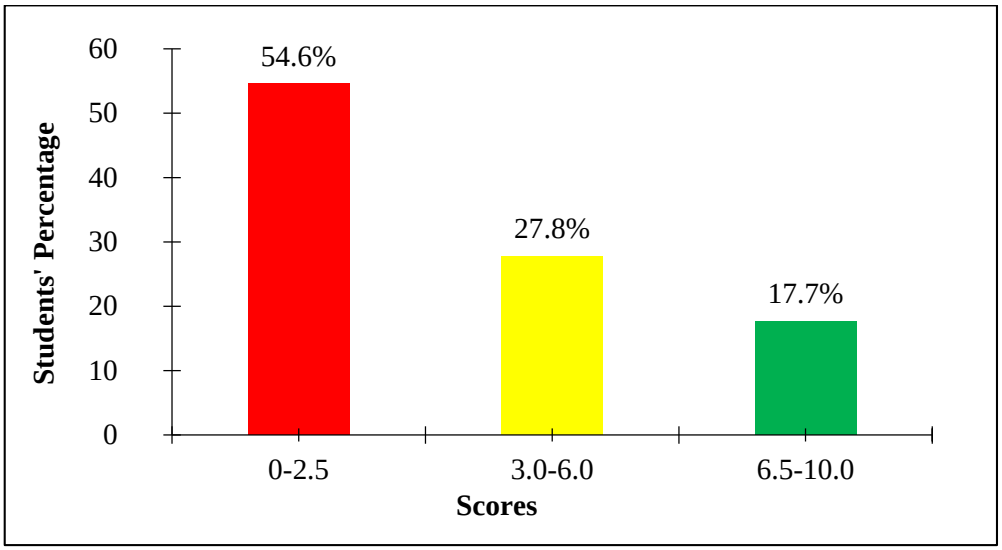


Figure 6: *The Students Performance in Question 7*

Figure 6 reveals that the general students' performance in this question was average because 45.5 per cent of the student scored above average.

The analysis show that (35.1%)of students scored 0 mark. These students failed to apply the principles of simple machines in solving problems by using different formula. Further analysis on students' scripts shows that most of them failed to applythe equations:

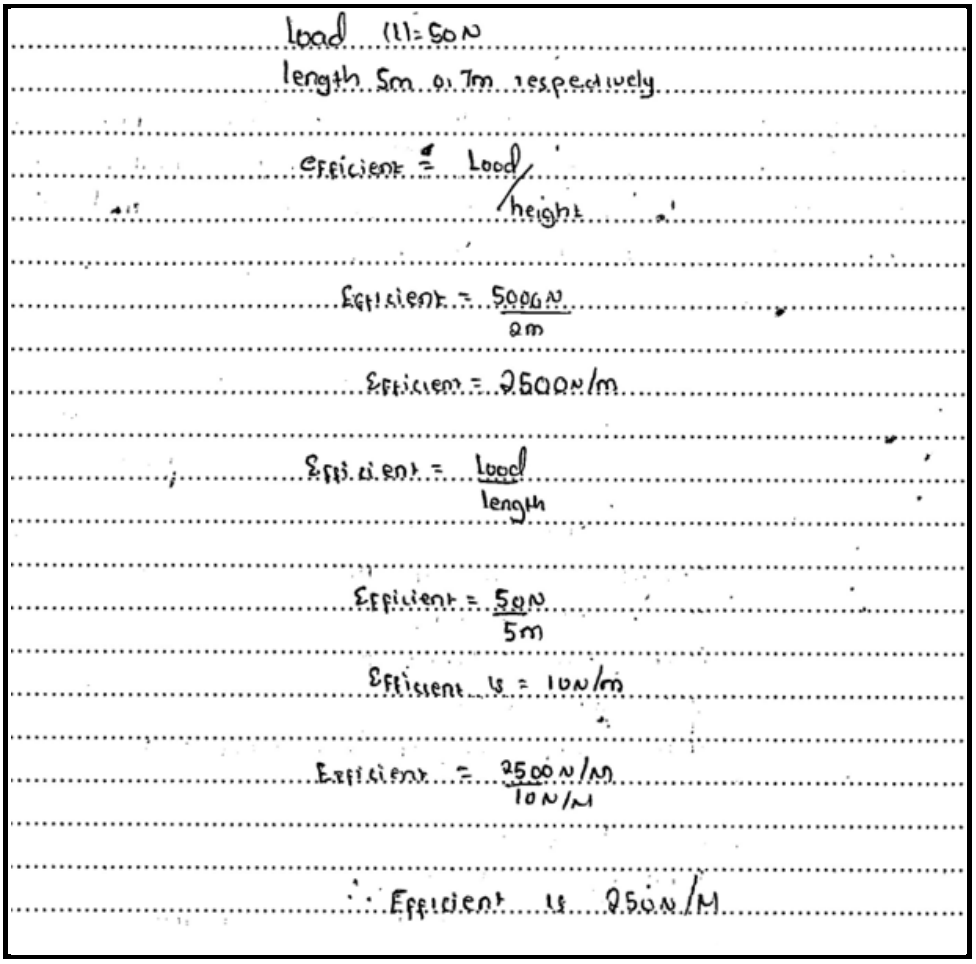
$$M.A = \frac{Load}{Effort}, V.R = \frac{Effort\ Distance}{load\ Distance}, and$$

$$Efficiency = \frac{Effort\ x\ Effort\ Distance}{Load\ X\ load\ Distance} x100\%\ or$$

$Efficieny = \frac{Work\ Output}{Work\ Input}\ x\ 100\% = \frac{M.A}{V.R}\ x\ 100\%$.These equations were useful in calculating the mechanical advantage (M.A), velocity ratio (V.R)

and efficiency(η) of the inclined plane. For example, one student wrote the value of load and height given, but failed to provide the formula for computing the question. Another student wrote *force$_2$-force$_1$=500-50=450N∴450Nx7m=3150N/m* as the inclined plane. This student lacked the mathematical skills as he/she failed to write the correct SI unit when multiplying force and distance. Another student just selected one of a length from the question without performing any calculation and wrote:*I can advise them to use inclined plane of 5m*. In addition, some students did not understand the demand of the question as they provided irrelevant responses. For example, one student wrote incorrect formula such as $\frac{l}{h}=\frac{5000x50x5x5}{7}=1.5$, then concluded that *this is a group of student were assigned to put a load of 1.5*. Another student provided the sketch of a person lifted the load into the vehicle in an inclined plane but failed to provide the formulas for calculating the efficiency in order to select the correct length of a given inclined plane. All these students' misconceptions indicate that most of them had insufficient knowledge on applications of inclined plane.

Students who scored from 0.5 to 2.5 marks managed to provide one or two correct formulas applied in simple machines, but they failed to use the correct data in performing calculations, hence scored low marks. Extract 7.1 shows the weak response from the students' script.



Extract 7.1: A sample of the students' poor responses to Question 7

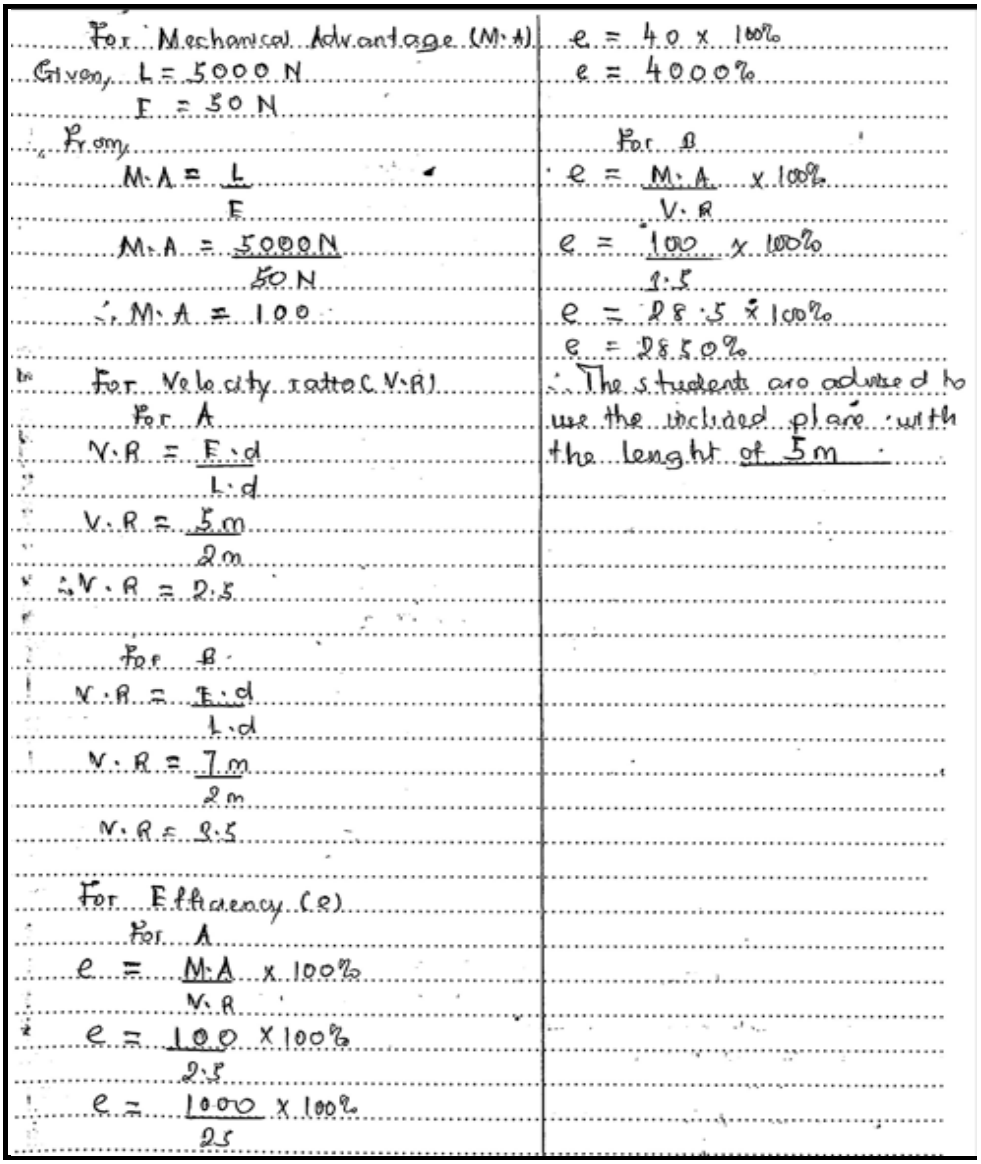
In extract 7.1, student wrote incorrect formula to find the efficiency. He/she ended up providing incorrect answer, thus failed to draw conclusion.

However, 27.8 per cent ofstudents were able to write one of the formulas used in simple machine to calculate either the velocity ratio or mechanical advantage, but they failed to apply them in finding the efficiency of the inclined plane. For example, one student calculated just the velocity ratio of inclined plane at a distance of 7m such as:

$$\text{V.R} = \frac{\textit{slant dis}\tan\textit{ce}}{\textit{vertical dis}\tan\textit{ce}} = \frac{7m}{2m} = 3.5.$$

On the other hand, the students who scored good marks (6.5 -10.0) applied the equations of simple machines to calculate *M.A, V.R* and *efficiency* of the inclined plane. These students were competent with the tested topic, as

they were able to apply the two formulas to obtain the required efficiency. Most of them drew conclusion by providing an advice about the inclined plane suitable to be used based on the obtained values of efficiency. Extract 7.2 shows the good responses from a student's script.


For Mechanical Advantage (M.A)
Given, L = 5000 N
E = 50 N
From,
M.A = L / E
M.A = 5000N / 50N
∴ M.A = 100
For Velocity ratio (V.R)
For A
V.R = E.d / L.d
V.R = 5m / 2m
∴ V.R = 2.5
For B
V.R = E.d / L.d
V.R = 7m / 2m
V.R = 3.5
For Efficiency (e)
For A
e = M.A / V.R x 100%
e = 100 / 2.5 x 100%
e = 1000 / 25 x 100%
e = 40 x 100%
e = 4000%
For B
e = M.A / V.R x 100%
e = 100 / 1.5 x 100%
e = 28.5 x 100%
e = 2850%
∴ The students are advised to use the inclined plane with the lenght of 5m

Extract 7.2: A sample of the students' good responses to Question 7

In Extract 7.2, the student applied the correct formula of mechanical advantage and velocity ratio in calculating the efficiency of the inclined plane. He/she was able to select the correct size of inclined plane depending on the obtained values of efficiency.

2.2.6 Question 8: Heat

This question was divided into two parts (a) and (b). It intended to measure students' competence in applying the concepts of heat in solving problems in real life. The question asked:

(a) A laboratory technician heated a piece of wire by 1^{o}C and it increased in length by 1 unit.Then, he heated a small piece of rectangular sheet by 1^{o}C and it increased in length by 1 unit. How would you differentiate the increment between both scenarios?

(b) You are given an iron tyre of diameter 50cm at 15^{o}C to shrink it on a wheel of diameter 50.35cm. To what temperature will you heat the tyre so that it will slip over the wheel with a radial gap of 0.5mm? (Linear expansivity of iron is 0.000012/K).

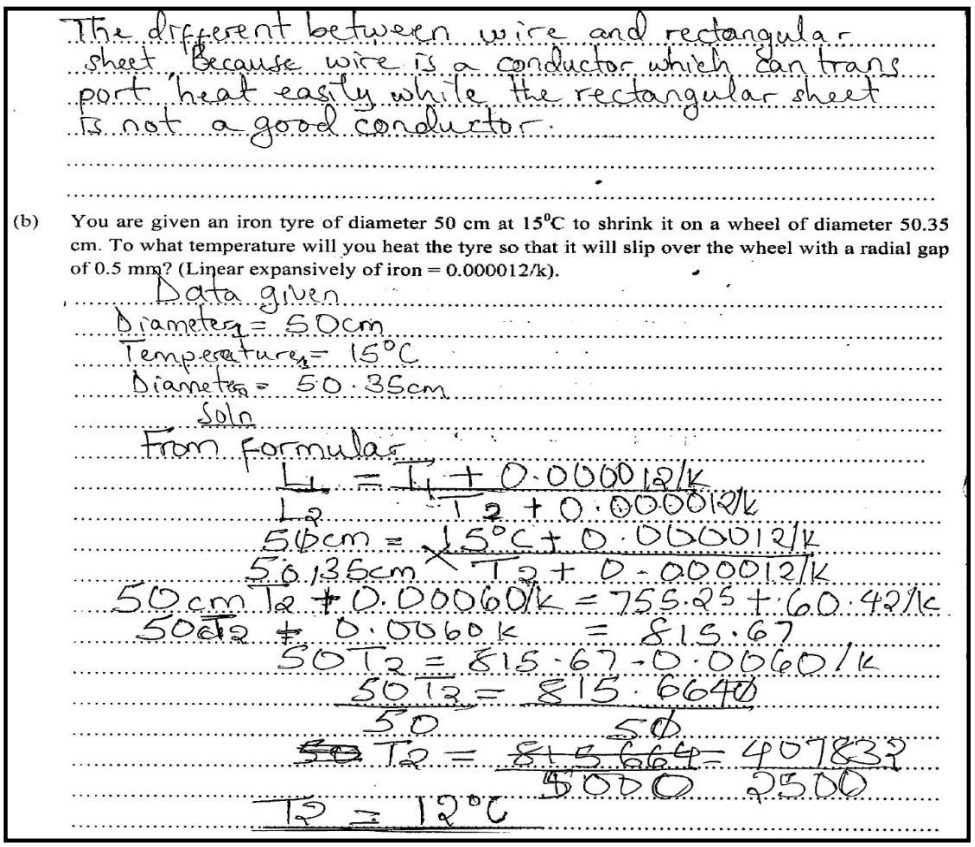
A total of 1818 (100%) students attempted this question. Among them 1654 (91.0%) scored from 0 to 2.5 marks; 161(8.9%) scored from 3.0 to 6.0 marks; and 3 (0.2%) scored from 7.0 to 8.5 marks. Generally, the students' performance in this question was weak because 91.9 per cent of the studentsscored below average. Table 2 summarizes this performance.

Table 2: *The Students Performance in Question 8*

Grade General	Percentage Range	Description	Number of students	Percentage
0-2.5	0 – 29	Unsatisfactory	1670	91.9
3.0-6.0	30 – 64	Average	161	8.9
7.0-8.5	65 – 100	Good	3	0.2
Total			**1818**	**100**

Further analyses on this question reveal that most of the students scored low marks, 48.8% scoring 0. Most of the students did not understand the meaning of *linear expansion* and *areal expansionor superficial expansion* as well. Consequently, they failed to differentiate between the small increment between the piece of wire and the small piece of rectangular sheet when the temperature was raised by 1^{o}C. They did not understand that the increment in a piece of wire by 1 unit was linear expansion and the increment in a small rectangular sheet was superficial or areal expansion. For example, in part (a), one student wrote that *the piece of wire is get heat very fast than piece of sheet so piece of wire can increase fast than piece of rectangular sheet'*. This student did not understand the demand of the

question as he/she failed to understand that both piece of wire and rectangular sheet were heated by *1ºC* and increased by 1 unit. In part (b) he/she listed the values given in the question such as *length = 50cm, centigrade =15ºC, length = 50.35cm* and *length =0.5mm.* This student failed to show clearly the difference of the two length as l_0, l_1 or l_2.Additionally, these students failed even to write the equation $\propto = \frac{L_2 - L_1}{L_1(\theta_2 - \theta_1)}$. This equation was appropriate for calculating the final temperature (θ_2) with which the iron tyre should be heated. For example, in part (a) one student wrote *1ºC/1+ 1ºC/1=1+1=2ºC.* In part (b), he/she added all the given values without considering their units such as *50cm+15ºC+50.35.*This suggest that most of these students lacked knowledge of linear and areal expansion of piece of metals when heated. Extract 8.1 depicts a sample of weak responses from a student's script.



Extract 8.1: A sample of the students' weak responses to Question 8

In Extract 8.1 part (a), the student wrote the difference between a piece of wire and that of a rectangular sheet based on their physical properties

instead of increment when heated by 1^{o}C. In part (b) he/she applied incorrect formula with wrong substitution of data values.

Some of the students who scored from 0.5 to 6.0 marks provided incorrect explanation in part (a) based on the difference between linear and areal expansion of heated piece of wire and a rectangular sheet respectively. In part (b), they wrote the correct formula but failed to apply in calculating the temperature required to heat the tire. For example, one student in part (a) wrote:*a piece of sheet will contact faster than that of wire*. In part (b) the student wrote the correct formula $\propto= \frac{L_2-L_1}{L_1(\theta_2-\theta_1\ )}$ but failed to substitute correctly the given data.

On the other hand, analysis shows that the highest score was 8.5 marks, of which only 3 (0.2%) students scored from 7.0to 8.5 marks. Most of these students had adequate knowledge about linear and superficial expansion of metals.They also had mathematical skills, as they were able to use the appropriate equation for solving the problem. Nonetheless, some had minor errors in performing calculations. For example, one student did not understand that the final length (L_2) was supposed to be the diameter of the wheel after being heated to the final temperature (θ_2) to create a radial gap of 0.5 mm. In Addition, other students did not understand that in order to get the final length (L_2),the radial gap of 0.5 mm had to be added in both ends of the diameter of the wheel. Thus, the final length (L_2) was supposed to be 50.35 cm + (0.5 cm x 2) = 50.45 cm. Extract 8.1 shows a sample of responses from a student's script who scored 8.5 marks.

The different Scenerios can be differentate by their linear expansivity. the type of materials used in heating. And also through their Linear expansivity

(b) You are given an iron tyre of diameter 50 cm at 15°C to shrink it on a wheel of diameter 50.35 cm. To what temperature will you heat the tyre so that it will slip over the wheel with a radial gap of 0.5 mm? (Linear expansively of iron = 0.000012/k).

Data given:

$d_1 = 50cm$

$T_1 = 15°C$

$d_2 = 50.35cm$

$T_2 = ?$

radial gap $= 0.5mm = 0.05cm$

$\alpha = 0.000012/K$

$L_1 = 50.35cm + 0.05cm + 0.05cm$

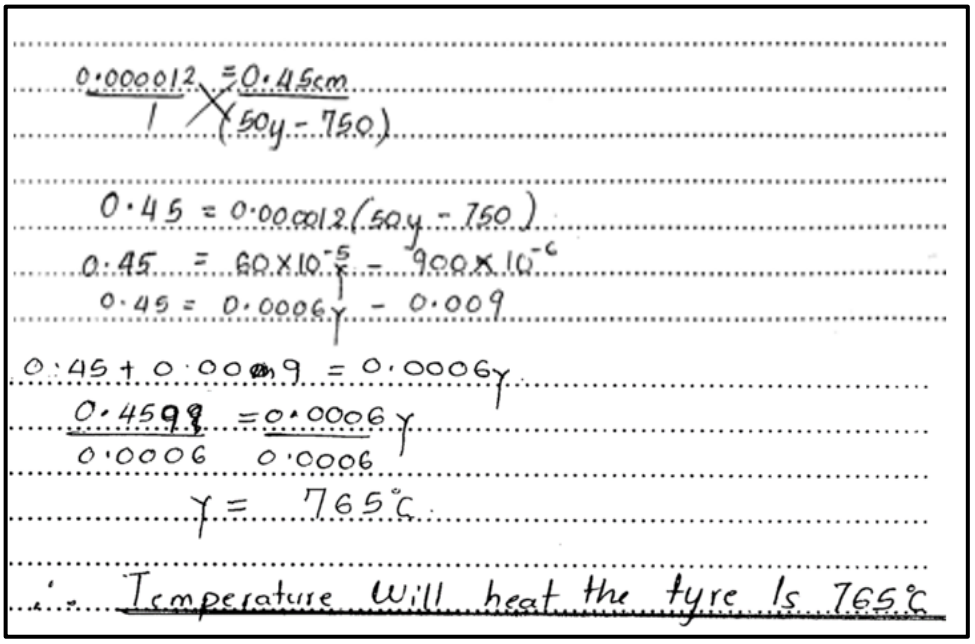
$L_i = 50.45cm$

$L_o = 50cm$

Let unknown temperature be "Y"

from, $\alpha = \frac{\Delta L}{L_o(\Delta\theta)}$

$0.000012 = \frac{50.35cm - 50cm}{50(y - 15)}$



Extract 8.1: A sample of the students' good responses to Question 8

In Extract 8.1 part (b), the student applied the mathematical skills to analyze the data when calculating the required temperature. In part (a), he/she missed the concept by explaining the difference between two pieces of metal instead of providing the factors, which lead to their difference when heated at 1^0C.

2.2.7 Question 9: Electricity

This question comprised of three parts (a), (b) and (c). It intended to measure students' competence in evaluating electric circuits. The question was as follows:

Two cells each having an e.m.f of 1.5V and internal resistance of 2Ω were connected in series and then in parallel.

(a) Find the current in each case when the cells are connected to a 1Ω resistor.

(b) If the 1Ω resistor is substituted by an 11Ω resistor, calculate the new current in both cases.

(c) Advise a better connection for 1Ω and11Ω resistors.

A total of 1818 (100%) students attempted this question and their scores were as follows: 1545 (85.0%) scored from 0 to 2.5 marks; 225 (12.4%) scored from 3.0 to 6.0 marks; and 48 (2.6%) scored from 6.5 to 10.0 marks.

The general performance in this question was weak as 85.5 per cent of the students scored below average. Figure 7 presents these scores.

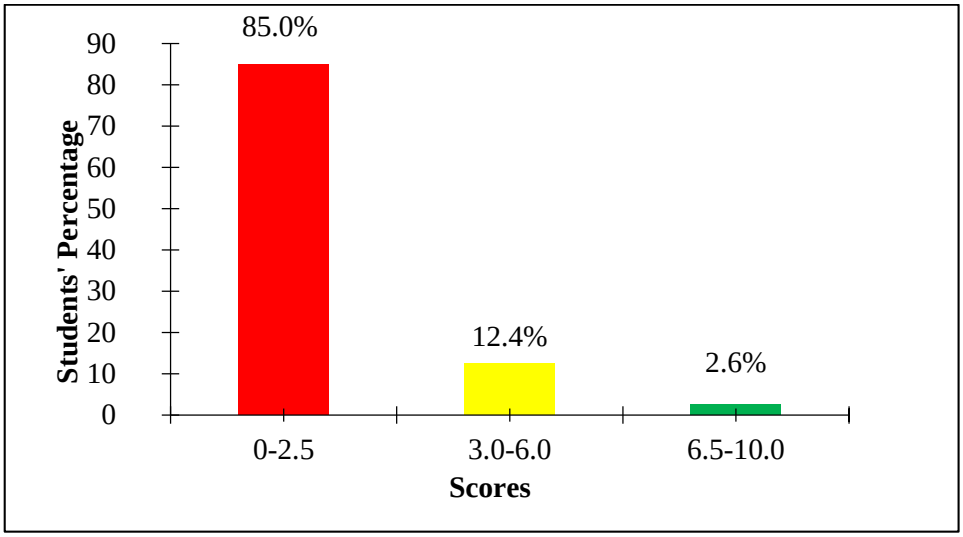
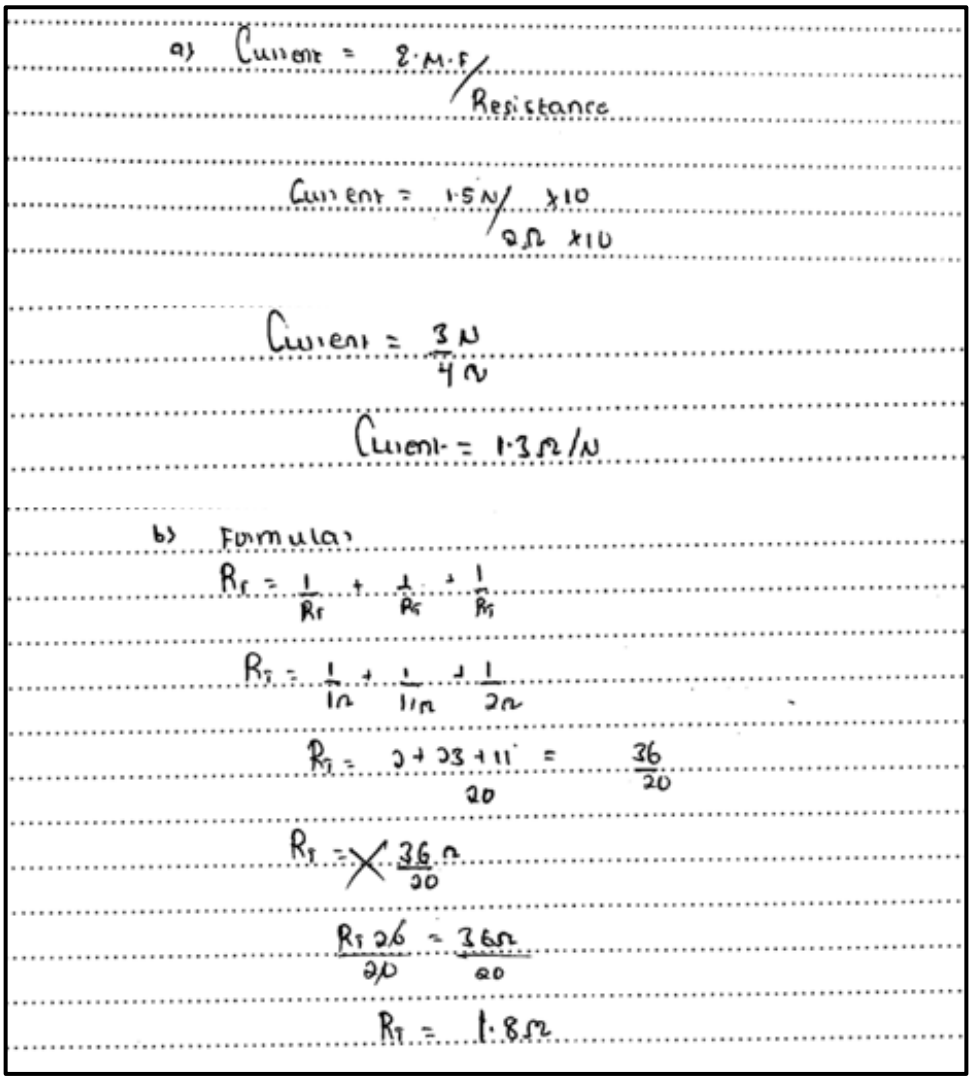


Figure 7: *The Students' Performance in Question 9*

There were 40.3% per cent out of 85.0% of students who scored low marks (0-2.5) lacked knowledge of *current electricity* as they failed to apply Ohm's Law (V=IR) or $E=IR+Ir$ to find the electromotive force and current. Analysis shows that they did not understand that when two cells are connected in series the emf (E) are added together such that $E=E_1+E_2$. Consequently, when two cells of *emfs* (E_1) and (E_2) are in parallel the effective *emf* (E) is given by $E=E_1=E_2$. For example, one student wrote: $(a) emf=\frac{r+R}{A}=1.5=\frac{4+1}{A}$, $\therefore A=3.3A$. This student lacked the knowledge of circuit formula. In addition, other students sketched the circuit but failed to put the values as stated by the question in each part. For example, in part (a), one student used 2Ω and 1Ω into the series and parallel circuit, then calculated the total resistances to obtain 3Ω and $6/5\Omega$ respectively then he/she substituted 3 Ω in the formula $emf=I/R$ to get $I=0.5A$. In part (b), the student wrote the incorrect response *current is the same in both cases=0.5A.*These students had insufficient knowledge on current electricity and some of them lacked mathematical skills to determine the currents when cells are connected in series and parallel. However, some of the students who scored from 0.5 to 2.5 marks some applied the formula but failed to insert the correct values to get answer in either one or all parts of the question. Extract 9.1 shows the sample of the weak responses from a students' script.



Extract 9.1: A sample of the students' weak responses to Question 9

In Extract 9.1, the student applied incorrect formula and procedure in performing calculations, so he/she ended up coming up with incorrect answers.

On the other hand, the students who scored good marks (6.5-10.0) were competent in *current electricity* as they were able to apply all the equations necessary for performing calculation. Most of them drew relevant circuit diagrams to show how cells are connected in both parallel and series arrangements. Extract 9.2 shows a sample of good responses as extracted from the students' script.

Given data:

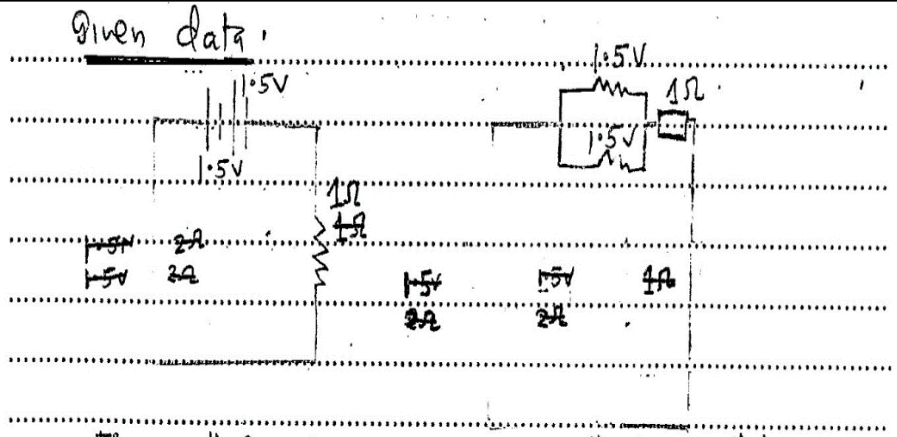


Fig (a) cells in series Fig(b) cells in parallel.

case (a)

(a) From ~~Fig (a)~~ connected in series.

Given; $R_T = 2r + R_1$,

$= (2 \times 2)\Omega + 1\Omega$

$= 4\Omega + 1\Omega$

$= 5\Omega$

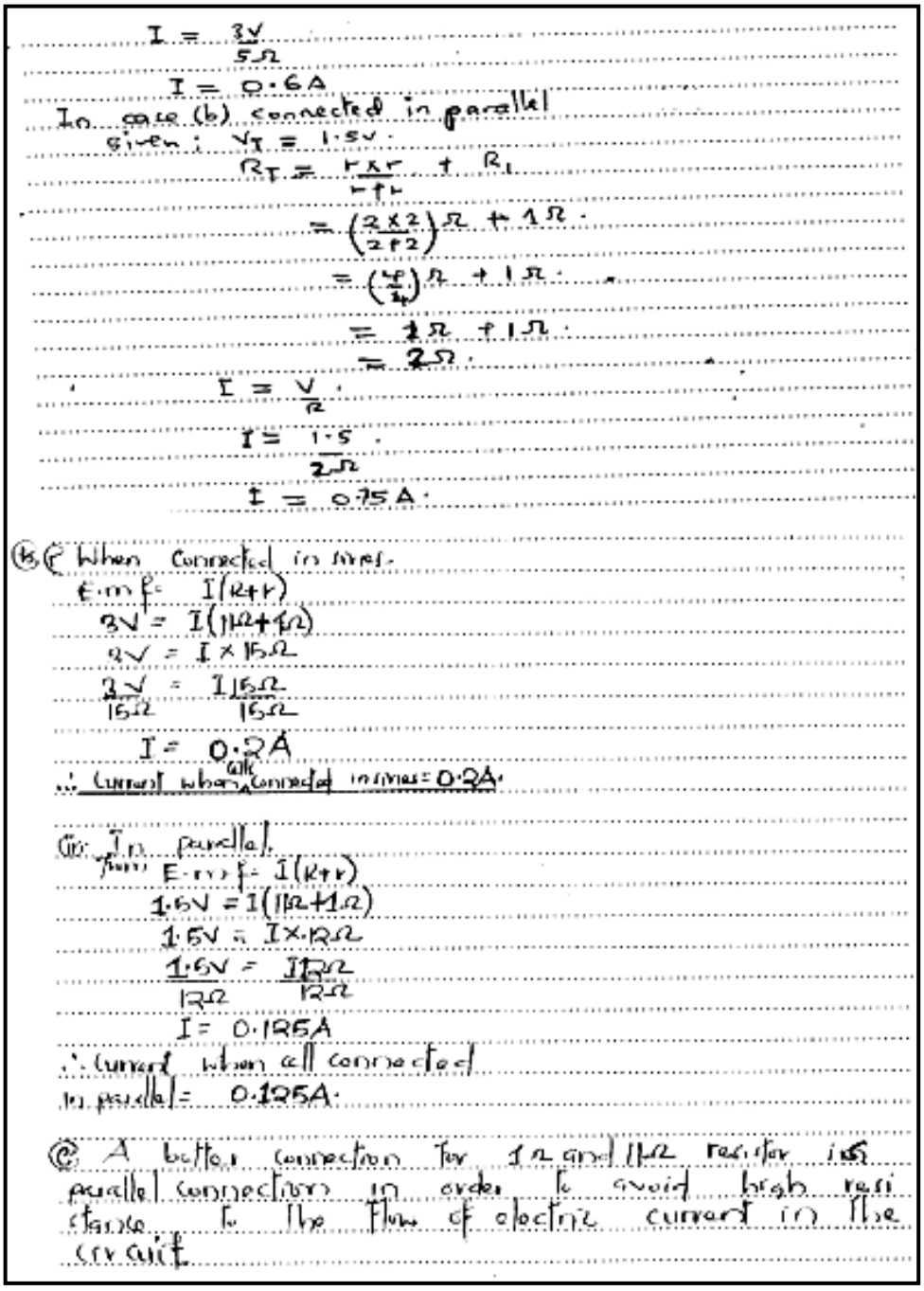
$V_T = V + V$,

$= 1{\cdot}5V + 1{\cdot}5V$,

$= 3V$.

rnb2022

From $I = \frac{V}{R}$



Extract 9.2: A sample of the students' good responses to Question 9

In Extract 9.2, the student correctly applied the required formulas and procedures in both parallel and series cells connections to obtain the correct answers.

2.3 SECTION C: Structured Question

Section C had one (1) structured question, which was set from the topic of *Work, Energy and Power*. This question was compulsory to be attempted by all students. The total mark allotted to this question was 15.

2.3.1 Question10: Work, Energy and Power

This question intended to measure students' competence in solving real life problem involving Work, Energy and Power. The question was as follows:

Afarmer threw an arrow of mass 15g at a speed of 50m/s after a monkey which was in a farm of maize. Unfortunately, the arrow penetrated a depth of 5cm in a soft body of the tree. Calculate the power on the arrow.

A total of 1818 (100%) students attempted this question, out of which 1498 (82.4%) scored from 0 to 4.0 marks; 312 (17.2%) scored from 4.5 and 9.0 marks; and 8 (0.4%) scored from 11.0 and 15.0 marks. the performance is shown in Table 3 below.

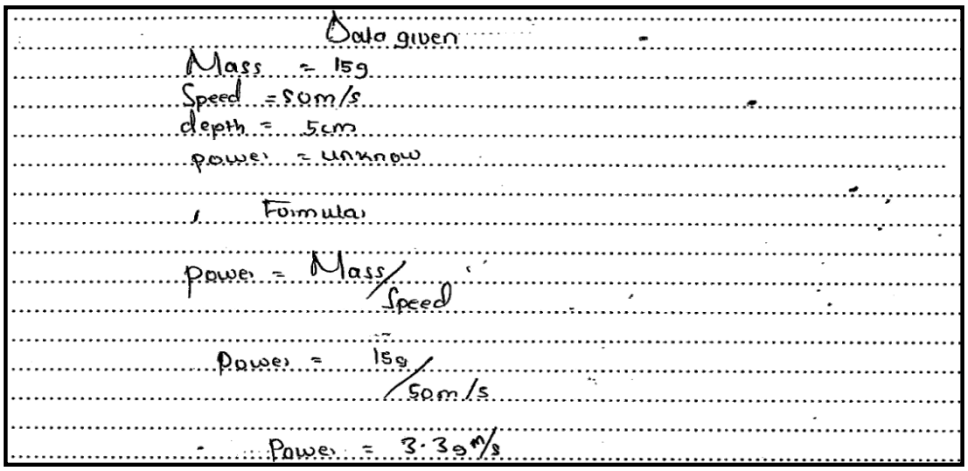
Table 3: The *Students' Performance in Question 10*

Grade General	Percentage Range	Description	Number of Students	Percentage
0-4.0	0 – 29	Unsatisfactory	1498	82.4
4.5-9.0	30 – 64	Average	312	17.2
11.0-15.0	65 – 100	Good	8	0.4
Total			**1818**	**100**

Table 3 indicates that the students' general performance in this question was weak, because 82.4 per cent of the students scored below average.

The studentswho scored 0 marks (40.5%) had inadequate knowledge about Work, Energy and Power. Most of them did not understand the relationship between force, work and energy as they failed to write the basic equations for calculating the power. Consequently, they failed to write and use the equation of linear motion such as $v^2=u^2+2as$ which could have helped them to calculate the acceleration of the arrow. In addition, most of them failed to realize that the equation $v=u+at$ could be used to find the time taken for the arrow to travel the *distance 's'*.For example, one student provided incorrect formula such as $\frac{m}{s}=\frac{15gx50m/s}{5}=113.50$, with conclusion *a*

farmer an arrow of mass in the 113.5 and or 4/1 and g x m/s. Another student provided incorrect formula such as *power* = $\frac{P^2xS}{MA} = \frac{5^2x50}{15x10} = \frac{25x50}{150} = 8.3w.$ All these irrelevant and incorrect responses suggest they had inadequate knowledge on the subject matter. However, the students who scored from 0.5 to 4.0 marks had inadequate knowledge about work, energy, and power as most of them provided the correct formula of power and third equation of motion but failed to substitute the correct data in calculating the time, work-done and force. Extract 10.1 shows weak responses from a student's script.

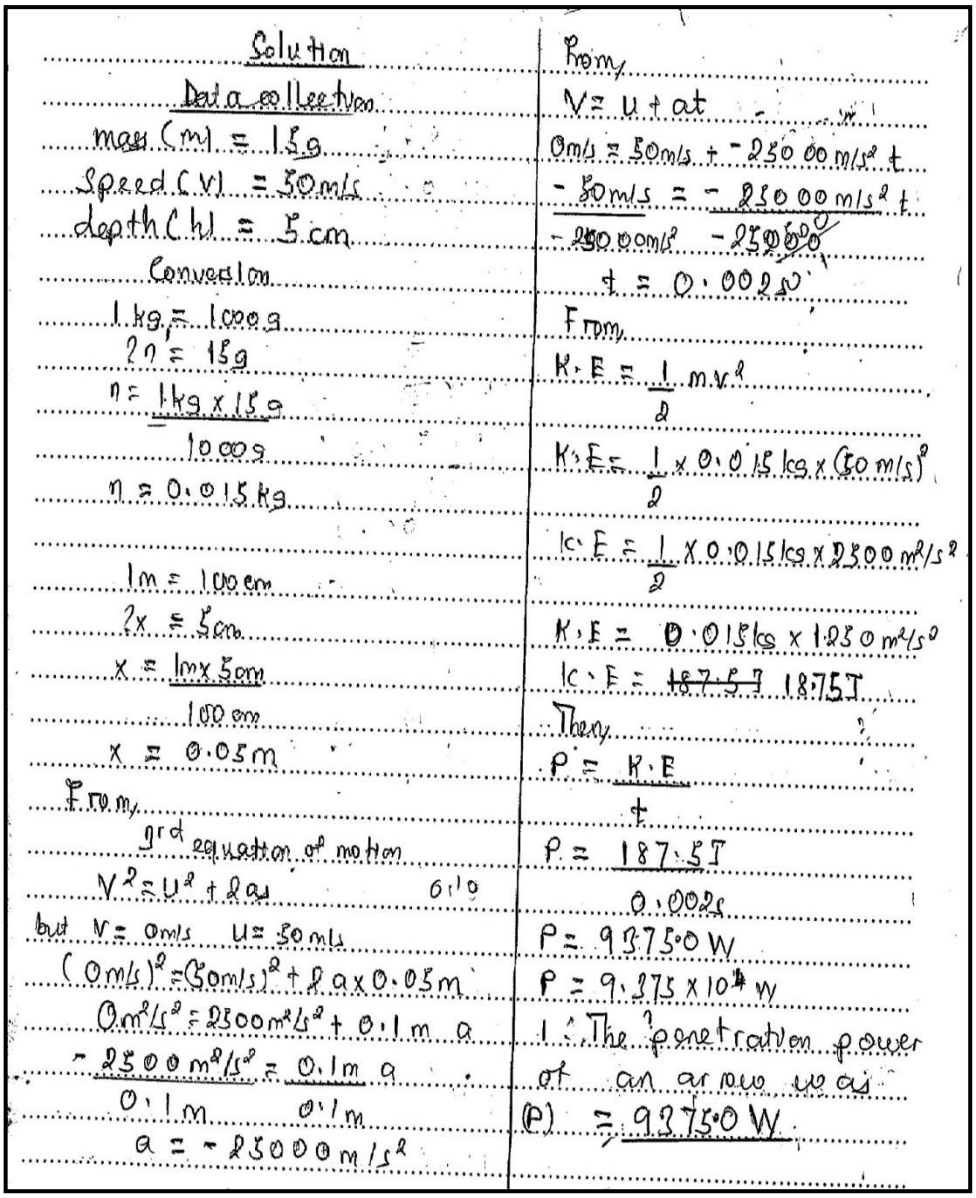


Extract 10.1: A sample of the students' weak responses to Question 10

In Extract 10.1, the student wrote incorrect formula and procedure to find power. It seems he/she did not understand the relationship between power, mass and speed with their SI units.

However, those who scored average marks (4.5-9.0) had partial knowledge about work, energy, and power. Most of them wrote the correct formulas in calculating the values of energy and time. Some of them however had minor errors in the substitution when performing calculation. For example, one student calculated the energy by using the correct formula of kinetic energy but substituted incorrect data of distance to obtain wrong answer such as: $K.E = \frac{1}{2}mv^2.$, but $time = \frac{dis\tan ce}{speed} = 0.005m \therefore power =$ $\frac{energy}{time} = \frac{0.0075J}{0.001\sec} = 7.5W.$ This shows that this student lacked mathematical skills.

In contrast, most of the students who scored marks (11.0-15.0) demonstrated their competence in applying different formula in finding work, energy and power. Most of them demonstrated their ability to analyse data by substituting the values of acceleration '*a*', energy and the time '*t*' to get the required power of the arrow. Extract 10.2 shows the good answers from a student's script.


Solution

Data collection

mass (m) = 15g

Speed (v) = 50m/s

depth (h) = 5cm

Conversion

1kg = 1000g

2n = 15g

n = 1kg x 15g / 1000g

n = 0.015kg

1m = 100cm

2x = 5cm

x = 1m x 5cm / 100cm

x = 0.05m

From,

3rd equation of motion

$V^2 = u^2 + 2as$ 6:10

but V = 0m/s u = 50m/s

$(0m/s)^2 = (50m/s)^2 + 2 \times a \times 0.05m$

$0m^2/s^2 = 2500m^2/s^2 + 0.1m\ a$

$-2500m^2/s^2 = 0.1m\ a$

$0.1m \quad 0.1m$

$a = -25000m/s^2$

From,

$V = u + at$

$0m/s = 50m/s + -250000m/s^2\ t$

$-50m/s = -250000m/s^2\ t$

$-250000m/s^2 \quad -250000$

$t = 0.002s$

From,

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

$K.E = \frac{1}{2} \times 0.015kg \times (50m/s)^2$

$K.E = \frac{1}{2} \times 0.015kg \times 2500m^2/s^2$

$K.E = 0.015kg \times 1250m^2/s^2$

K.E = ~~187.5J~~ 18.75J

Then,

$P = \frac{K.E}{t}$

$P = \frac{18.75J}{0.002s}$

P = 9375.0W

$P = 9.375 \times 10^4 W$

∴ The penetration power of an arrow we ais

(P) = 9375.0W

Extract 10.2: A sample of the students' good responses to Question 10

In Extract 10.2, the student demonstrated his/her ability in applying the formula of work, energy, power, and linear motion in calculating the power used to throw an arrow.

3.0 ANALYSIS OF STUDENTS' PERFOMANCE IN EACH TOPIC

Ten (10) questions set from various topics were included in the 2022 FTNA Engineering Science assessment. The analysis of the performance indicates that questions 1 and 2 had good performance since the percentages of the students who passed were 90.87% and 77.06% respectively. Question 1 had ten multiple-choice items set from the topics of: *Linea*r *Motion*, *Measurements*, *Properties of Matter*, *Work, Energy and Power*, *Sound Waves*, *Light*, *Turning Forces* and *Simple Machines*. Question 2 had five matching items set from the topic of '*Fluid Mechanics'*. The students who scored good marks understood the demand of the question. They were also able to apply different formula in computing the mathematical oriented topics tested, they had ability to apply the drawing skills, as they were able to produce sketches and interpret the graphs. On these grounds, they had enough knowledge on thetested topics as they provided proper explanations and reasons on different tasks.

The data analysis reveals that Question 3, 4, 5 and 7 from the topics of *Measurements* (53.91%), *Friction* (44.55%), *Linear Motion* (41.4%) and *Simple Machines* (45.43%) respectively were average performed. Students with average scores demonstrated their competence in the subject matter as they correctly analysed the tested concepts. However, some of them had insufficient knowledge and lacked skills for applying the correct formula to perform calculations.

On the other hand, student's weak performance was observed in Questions 6, 8, 9, and 10. These questions were set from the following topics: *Turning forces* (8.14%), *Heat* (9.02%), *Electricity* (15.02%), and *Work, Energy and Power* (17.60%) respectively. The students' weak performance in these questions was associated with failure to understand the demands of the question, lack of mathematical and drawing skills and failure to make the correct substitution in analyzing the data.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The students'general performance in the FTNA 2022 Engineering Science was average because 47.03 per cent of the students had average and above scores.

However, some students had weak performance, which was attributed by different factors as explained in the analysis of each question. These include; insufficient knowledge on the tested subject matters, lack of mathematical and drawing skills and failure to determine the demands of the questions.

Further analysis shows that students with average and good scores were competent in the assessed topics as they provided correct responses, which met the requirements of the questions. In addition, they adhered to the requirements of the questions.

4.2 Recommendations

In order to improve future performance in the Engineering Science subject, the following are recommended:

(a) Students should organize themselves in groups to preform sufficient exercises, involving the application of various principles and formula in performing calculations.

(b) Students should engage in small discussion groups and create various electrical circuits, using devices such as batteries, cells, resistors, switches, ammeters and connecting wires in the topic of *Current Electricity*.

(c) Teachers should prepare tests concerning stable, unstable, and neutral equilibrium in using materials in our daily life like 'meter rule, wooden rods, metal rods, knife edges for the topic *Turning Force*.

(d) Teachers should guide the students in preparing various experiments in burning various materials using heat sources around us such as Bunsen burner and kerosene, in order to study the various temperature levels in each material for the topic of *Heat*.

(e) Students should use a mnemonic for remembering different principles and formula. For example, the three classes of levers as **"FRE 123"**. In

a 1^{st} class lever, the Fulcrum is in the middle, 2^{nd} class the Resistance is in the middle and 3^{rd} class the Effort is in the middle.

(f) Students should always read the assessed questions carefully so they understand the demand of the questions.

(g) Students should spare enough time to practice drawing different sketches and graphs based on engineering science.

Appendix I:

A summary of Students' Performance Question-Wise in 2022

S/N	Topic	Performance For Each Topic		Remarks
		Question Number	Percentage of Students Who Scored 30% or More	
1.	Linear motion, Measurement, Properties of Matter, Sound Waves, Light, Turning Forces, Simple Machines, and Work, Energy and Power.	1	90.9%	Good
2.	Fluid Mechanics	2	76.8%	Good
3.	Measurements	3	54.7%	Average
4.	Friction	4	44.8%	Average
5.	Linear Motion	5	41.4%	Average
6.	Simple Machine	7	33.3%	Average
7.	Work, Energy and Power	10	19.3%	Weak
8.	Electricity	9	14.6%	Weak
9.	Heat	8	10.8%	Weak
10.	Turning Forces	6	8.6%	Weak

Appendix II: Comparison of Candidates' Performance in 2021 and 2022

Year	A	B	C	D	F	Total
2021	28	86	403	380	776	**1673**
2022	09	36	337	473	963	**1818**

Table 5: The General Students' Performance in Grade Wise

Grade	Percentage Range	Description	Number of Students	Percentage
F	0 – 29	Weak	963	53.0
D & C	30 – 64	Average	810	44.5
B & A	65 – 100	Good	45	2.5
Total			**1818**	**100**