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

STUDENT'S ITEM RESPONSE ANALYSIS REPORT ON THE FORM TWO NATIONAL ASSESSMENT (FTNA) 2020

PHYSICS

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031 PHYSICS

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FOREWORD

The Form Two National Assessment (FTNA) is a formative evaluation after two years of study in secondary school. The assessment intends to diagnose students' progress towards mastering of various concepts as stipulated in the syllabus. Basically, the students' responses to the assessment questions is a strong indicator of what the education system was able or unable to offer to the students in their two years of secondary education.

This report highlights some of the factors which made the students fail to score high marks in the questions. The factors include the failure to understand the requirements of the questions, inadequate knowledge of the topics stipulated in the syllabus, lack of English proficiency, lack of computation skills and lack of drawing skills. The feedback provided will enable education administrators, school managers and teachers to identify proper measures to be taken in order to improve the students' performance in future.

The National Examinations Council of Tanzania will highly appreciate comments and suggestions from teachers, students and the public in general, which can help to improve future analysis reports.

Finally, the Council would like to thank the examiners and all those who participated in preparing and analysing the data used in this report.

Dr. Charles E. Msonde

EXECUTIVE SECRETARY

1.0 INTRODUCTION

This report is based on analysis of students' performance in the Physics subject for Form Two National Assessment (FTNA) paper in 2020. The paper was constructed based on the 2010 reviewed Physics syllabus for secondary education. The paper intended to measure the competences attained by the students after completing two years of study in ordinary level.

The paper had three sections, A, B and C. Section A comprised of three (3) objective questions. The first question had twenty (20) multiple choice items constructed from seventeen (17) topics of ordinary level physics syllabus. The second question contained five (5) homogeneous matching items. The third question consisted of five (5) items of filling in the blanks derived from five (5) topics. Section B had five (5) short answer questions constructed from five (5) topics. The last section C had two (2) questions composed from two (2) topics. The students were required to answer all questions to get a total of 100 marks.

A total of 598,386 students sat for this paper out of these 134,943 (22.57%) passed and 463,443 (77.43%) failed. This performance indicates that the general performance in this paper has decreased by 27.71 percent compared to last year (2019) when 50.28 percent of the students passed the assessment.

The report also provides an analysis of the students' performance in each question. The analysis categorizes the performance as weak, average and good if the percentage of students’ scores are within the ranges of 0 – 29, 30 - 64 and 65 -100, respectively. For emphasis, these ranges are represented by red, yellow and green colours, respectively.

Furthermore, the report highlights the requirements of the questions, the weaknesses observed and the possible reasons for good performance. Moreover, it provides some recommendations that may help to improve the performance of the students in future assessments. Comments on individual questions and extracts of students' answers have been exhaustively explained to illustrate the respective cases. Finally, the report presents appendices which indicate the performance in each question and the difference in performance as compared to that of last year.

2.0 ANALYSIS OF STUDENTS' PERFORMANCE IN EACH QUESTION

2.1 Section A: Objective Questions

This section comprised of three (3) questions (1, 2 and 3) which covered concepts from different topics. Question 1 had 20 multiple choice items which weighed 20 marks; Question 2 had 5 matching items which weighed 5 marks, and question 3 had 5 filling in the blanks items which weighed 5 marks, all together making a total of 30 marks.

2.1.1 Question 1: Multiple Choice Items

This question had twenty (20) multiple choice items (i) to (xx) which required students to choose the correct answer from among the four (4) alternatives (A-D) and write the letter in the box provided. The items were constructed from seventeen (17) topics which are *Introduction to Physics; Measurement; Force; Archimedes principle and the Law of Floatation; Structure and Properties of Matter; Pressure; Work, Energy and Power; Light; Static Electricity; Current Electricity; Magnetism; Forces in Equilibrium; Simple Machines; Motion in a Straight Line; Newton's Laws of Motion; Temperature* and *Sustainable Energy Sources.*

The question was attempted by 598,311 (100%) students. The results indicate that, 137,101 (22.9%) students scored from 0 to 5; marks, 384,593 (64.3%) students scored from 6 to 12 marks; and 76,617 (12.8%) students scored from 13 to 20 marks. Generally, the performance of this question was good as 461,210 (77.1%) students passed. Figure 1 is a graphic presentation of this analysis.

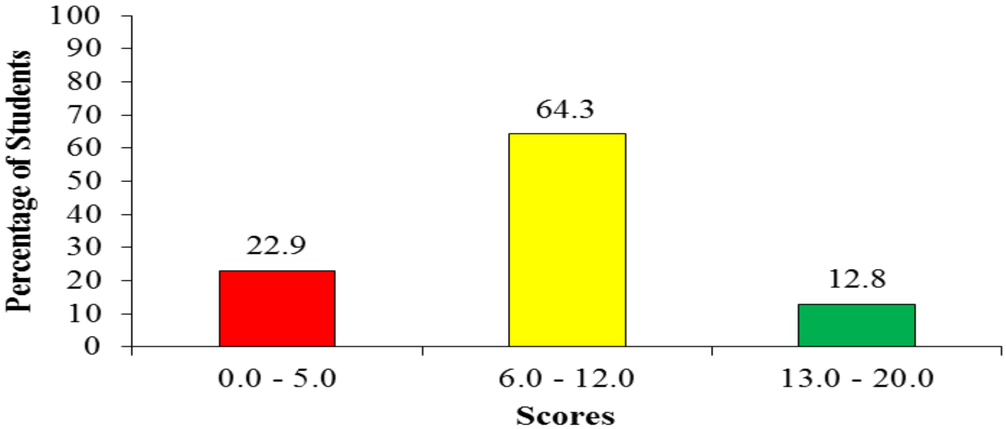


Figure 1: *Percentage of Students' Performance per Score in Question 1*

Item (i) asked, “Physics is the study which deals with matter. What does it relate to?” A. *Power;* B. *Energy;* C. *Force;* D. *Work*. The correct response was ‘B’ *Energy*. Most of the students managed to choose the correct answer by simply recalling the definition of Physics that, ‘it is the study of matter in relation to energy’.

Item (ii) asked, “what does someone pay for if he/she buys sugar from the shop?” A. *Mass;* B. *Density;* C. *volume;* D. *weight*. The correct answer was alternative ‘A’, *Mass*. Most of the students answered correctly because they had knowledge on the measurements in Physics especially units of physical quantities. However alternative ‘D’ (*weight*) distracted some students, due to the fact that weight is the quantity which depends on mass, but it is measured in Newton. The students who opted for incorrect responses B, *Density* and C, *Volume* did not know that, density is the ratio of mass (in kg) to volume (m^3), so it is a measure of the amount of matter contained in a given volume and it is measured in kilogram per cubic metre. Volume is a unit of three dimensional measure of space that comprises length, width and height, and it is measured in units of cubic centimetres or cubic metre.

Item (iii) asked, “what is 20,000 g mass equal to?” A. *20 tonnes;* B. *2 kg;* C. *200 kg;* D. *20 kg*. The correct alternative was ‘D’ *20 kg*. Some of the students did not get the right answer because of inadequate mathematical skills of converting units. They failed to recall the relationship between the units of mass, and to convert grams to kilograms.

Item (iv) asked “which one will need much force to pull or push than the other between 10 kg of stone and 10 kg of cotton?” The alternatives were A. *10 kg of stone will need much force than 10 kg of cotton;* B. *10 kg of cotton will need much force than 10 kg of stone;* C. *Same force will be needed in both;* D. *10 kg of stone is heavier than 10 kg of cotton*. The best answer was ‘C’ *same force will be needed in both*. Some students chose option ‘A’ *10 kg of stone will need much force than 10 kg of cotton* and option ‘D’ *‘10kg of stone is heavier than 10 kg of cotton.* These students failed to understand that both 10 kg of stone and 10 kg of cotton have the same magnitude and units since the acceleration due to gravity is a constant parameter; the same force will be needed for both types of materials.

In item (v), students were required to choose the alternative which gives the density of a substance whose relative density is 2.5. The alternatives were A. *Equal to density of water;* B. *Greater than the density of water;* C. *Equal to the volume of water displaced;* D. *Less than the density of water*. The correct response was ‘B’ *greater than the density of water*. Most students who failed to answer this question correctly did not know the differences between relative density and density of a substance. They failed to understand that density and relative density only differ in terms of units. Relative density has no units while density has the SI units of g/cm^3. Therefore, if the relative density of a substance is 2.5, its density is 2.5 g/cm^3, which is greater than the density of water ($1g/cm^3$). Therefore, the relative density of a substance is its density itself without its unit.

In item (vi), students were required to choose the statement which clearly gives the reason for a body to float in fluid. The alternatives were A. *because its density is greater than the density of the fluid displaced;* B. *because its density is less than the density of fluid;* C. *because the weight of the fluid displaced is equal to its weight;* D. *because the weight of the fluid displaced is less than its weight*. The right answer was alternative ‘B’ *because its density is less than the density of fluid*. Most of the students opted for distracter ‘C’ *because the weight of the fluid displaced is equal to its weight* because the statement is closely related to the law of flotation which says ‘*A floating body displaces its own weight of the fluid in which it floats*’. They failed to recall that for a body to float on a fluid its density should be less in comparison to that of the fluid in which it is immersed.

In item (vii) students were required to choose the correct alternative that best identifies the force which causes the mosquito larva to float on water. The alternatives were A. *surface tension;* B. *adhesive forces;* C. *friction forces;* and D. *cohesive forces*. The correct response was ‘A’ *surface tension*. Most of the students chose the correct response because flotation of mosquito larva in water is a common application of surface tension in properties and structure of matter but others opted for ‘C’ *friction force*, which is wrong. These students did not know that surface tension is a force that makes the surface of the liquid to behave like an elastic skin or membrane. The elastic skin enables mosquitoes to walk on it without sinking and even lay their eggs on the surface of water. Those who chose ‘C’ failed to understand that friction merely offers resistance to the motion of bodies, especially on rough or hard surfaces and not in fluid.

Item (viii) required students to choose the correct property of matter which explains the assertion that ‘the narrower the tube the further the water rise’. The alternatives were A. *Capillarity;* B. *Diffusion;* C. *Osmosis;* D. *Brownian movement*. The best alternative was A, *capillarity*. Most of the students got the answer correct because they were conversant with the concept of structure and properties of matter. However, some opted for distractor 'D' '*Brownian movement'* because they did not realize that Brownian movement refers to random motion of particles suspended in a medium. The students who opted for 'B', *Diffusion* and 'C', *Osmosis* did not understand that capillarity involves movement of fluid within a a narrow tube, caused by interaction between the molecules of the liquid and those of the surrounding material, while osmosis involves the movement of molecules of the liquid in which a substance (the solvent) is dissolved from one place to another through a semi-permeable membrane, they also failed to recall that diffusion refers to movement of a substance from an area of high concentration to an area of lower concentration.

In item (ix), students were required to identify a pair of parameters which affects pressure at any point in a liquid at rest. The given alternatives were A. *density and volume;* B. *depth and area;* C. *area and volume;* and D. *depth and density*. Some of the students chose the correct response 'D' *depth and density*. On the contrary, most of them chose wrong alternatives because they did not know the factors on which pressure in liquids at rest depends. They were supposed to recall that pressure exerted by a static liquid increases linearly with increasing depth and density of the liquid.

Item (x), asked "what is the SI unit of power? A. *Joule per metre*; B. *Meter per second;* C. *Meter per second*^{2}*;* D. *Joule per second*". The best alternative was 'D'. Students who failed this item did not recognize that *Watt* is the same as Joule per second and that both are units of power. This misconception resulted from lack of knowledge of the concept of power. Students were supposed to know that power is found from the ratio of work done (in joules) to time taken (in seconds). Therefore, the SI unit of power is Joule per second as shown in alternative D.

In item (xi), students were required to specify the number of images formed when two plane mirrors are set perpendicular to each other. The alternatives were A. *4;* B. *3; C. 5;* and D. *2*. The correct response was 'B'. *3*. Some students failed to get the correct answer because they did not use the right formula and mathematical skills to calculate the answer, and thus ended up with an incorrect choice. These students were required to apply the formula, $n = \frac{360}{\theta} - 1$, where n = number of images and θ = angle subtended when the two plane mirrors are perpendicularly placed. They were also supposed to understand that when two plane mirrors are perpendicularly placed, the angle $\theta = 90^{o}$.

In item (xii), students were required to choose the correct alternatives which express the device used to detect small electric charges. The alternatives were A. *Proof plane;* B. *Capacitor;* C. *Electrophorus;* D. *Gold leaf electroscope*. The correct alternative was 'D' *Gold leaf electroscope*. Most students opted for distractor 'B' *capacitor*, which means they failed to differentiate between the device for storing electric charges and the one for detecting electric charges. Some students opted for alternative 'A' *Proof Plane*. These students did not recognize that proof plane is a small metal disk attached to an insulating handle which is used to safely transfer electrostatic charge from one body to another but not to detect small electric charges. A few students were attracted by distractor 'C' *Electrophorus*. They did not know that electrophorus refers to a device for producing electric charges consisting of a disk that is negatively electrified by friction and a metal plate that becomes charged by induction when placed on the disk.

Item (xiii) asked "what is the equivalent resistance of two resistors of 4 Ω and 6 Ω connected in parallel? A. *0.66* Ω*;* B. *10* Ω*;* C. *2.4* Ω*;* D. *1.5* Ω*"*. The correct response was 'C' *2.4* Ω. Most of the students got the correct answer. The students who failed to get the correct response opted for alternative 'B' 10 Ω. These students applied the formula for equivalent resistance of two resistors connected in series by taking the sum of the two resistances instead of using the relation 'the reciprocal of equivalent resistance equals to the sum of the reciprocals of individual resistances'. They could develop the formula for equivalent resistance of two resistors connected in parallel as 'Equivalent resistance = $\frac{\text{Product of resistances}}{\text{Sum of resistances}}$ to obtain the required value.

In item (xiv), students were required to identify the name of the region surrounding a magnet in which the magnetic force is exerted. The alternatives were A. *magnetic field;* B. *magnetic shielding;* C. *magnetic pole;* and D. *magnetic domain*. The correct answer was 'A' *Magnetic field*. Majority managed to get the right answer. However, some students opted for distractor 'B' magnetic shielding. These students did not understand that magnetic shielding is not related to the region surrounding a magnet. They were supposed to know that magnetic shielding is a process that limits the coupling of magnetic fields between two locations and thus prevent magnetic fields from interfering with electrical devices. Few students opted for incorrect response 'D' *magnetic domain*. This group of students failed to recall that magnetic domain only implies a region within a magnetic material in which the magnetization is a uniform direction. In general, they failed to describe the magnetic terms as applied in magnetism.

In item (xv) students were required to find the perpendicular distance between the point and the line of action of the force when the moment of a force about a point is 1120 Nm and the magnitude of the force 5600 N. The alternatives were A. *5 m;* B. *6720 m;* C. *0.2 m;* and D. *4480 m*. The answer was ‘C’ *0.2 m*. Most of the students chose alternatives ‘B’ and ‘D’ because their answers were obtained by adding 1120 m and 5600 m and subtracting 1120 m from 5600 m respectively. These students lacked content knowledge on the topic of Forces in Equilibrium. They had to use the relation for the moment of force = magnitude of force × perpendicular distance and deduce the Perpendicular distance = $\frac{\text{Moment of force (N m)}}{\text{Magnitude of force (N)}}$.

In item (xvi), students were required to identify the group of simple machines which represent the first class levers. The alternatives were A. *Wheel barrow and bottle openers*; B. *Fishing rod and sugar tongs*; C. *Crowbar and claw hammer;* and D. *Nutcracker and pair of scissors*. The correct alternative was ‘C’ *Crowbar and claw hammer*. Most students got the correct answer indicating that they had appropriate knowledge of the topic of simple machines, especially the subtopic of classes of levers. They were aware that for classes of levers, load, effort and fulcrum should exchange positions. Therefore, in the first class levers, fulcrum should be between load and effort. In alternative A, *wheel barrow and bottle openers* have the load placed between the fulcrum and the effort, so it belongs to second class levers. In alternative B, *fishing rod and sugar tongs* have effort placed between the load and fulcrum thus representing third class levers. Those who opted for alternative D, did not understand that a nutcracker belongs to a third class lever while pair of scissors belongs to the first class lever, thus cannot be expected to be in a group of machines that represent the first class lever.

In item (xvii), students were required to identify a suitable graph which represents the motion for a body moving in a straight line with a uniform acceleration. The alternatives were A. *Distance against time graph*; B. *Acceleration against time graph;* C. *Velocity against time graph;* and D. *Displacement against time graph*. The correct choice was ‘C’ *Velocity against time graph*. In order to provide the correct response one had to bear in mind that the slope of any given graph has its significant physical meaning. Students who chose alternative A, *Distance against time graph* had little knowledge of the uniform motion because, when a graph of distance is drawn versus time, the slope is the ratio of the distance moved by the body to the time taken to reach its destination. This slope refers to speed of the body. Similarly, when a graph of displacement is drawn against time, the slope obtained as the rate of change of displacement is called velocity. But when a graph of velocity is drawn against time, the slope developed gives the acceleration of the moving body. The students who chose distractors had insufficient knowledge on uniformly accelerated motion as applied in motion in a straight line.

Item (xviii) asked "what force is required to give a mass of 40 kg and acceleration of 0.2 m/s^2". The given alternatives were A. *200 N;* B. *0.005 N;* C. *8 N;* and D. *20 N*. The correct response was 'C', *8 N*. Most students managed to choose an appropriate response possibly because they had knowledge of the concept of Newton's second law of motion ($F = mass\ (kg) \times acceleration\ (m/s^2) = ma$). Those who provided incorrect responses were not conversant with Newton's laws of motion, particularly the calculations based on Newton's second law of motion.

In item (xix), students were required to choose a device used to measure the upper fixed point of a thermometer scale. The alternatives were A, *Hydrometer;* B, *Hypsometer;* C, Thermometer; and D, *Barometer*. The correct response was 'B' *Hypsometer*. Most of the students supplied incorrect alternatives because they did not understand the device necessary for determining the upper fixed point of a thermometer scale. They were supposed to know that, in order to determine the upper fixed point, a thermometer is pushed through a hole in a cork and is placed inside a double-walled copper vessel called a hypsometer. These students failed to recall that hydrometer is used for measuring the relative density of liquids based on the concept of buoyancy. They were also supposed to know that barometer refers to a scientific instrument that is used to measure air pressure in a certain environment, whereas a thermometer is a device that measures temperature or temperature gradient. From these definitions, it is obvious that the only device used to determine the upper fixed point of a thermometer scale is a hypsometer.

In item (xx) students were required to choose what is not sustainable energy among the given alternatives which were A. w*ater;* B. *wind;* C. *sun; and* D. *dry cell*. The correct response was 'D' *dry cell*. Most of the students responded correctly, indicating that they had enough knowledge about sustainable energy sources. Those who replied incorrectly did not understand the implication of sustainable energy sources and their possible areas of origin. These students were supposed to know that sustainable sources of energy are the natural sources that are used in the production of electricity without destroying the environment. They, were supposed to conclude that the natural occurring source of energy and which are readily available should encompass hydro-electric energy (water source), solar energy (sun), wind energy (wind), sea wave energy (sea water), geo-thermal energy (earth), and tidal energy (tides). This suggests that dry cell is not a natural source of energy because its energy or power diminishes as it is being used.

2.1.2 Question 2: Matching Items

This question consisted of five (5) items in list A and seven (7) phrases in list B constructed from the topic of *Sustainable energy sources*.

Students were required to match each item in list A with corresponding sources of energy in list B by writing the letter of the correct response below the corresponding item number in the table provided.

List A	List B
(i) The energy which is associated with the volcanic areas. (ii) The energy due to afforestation and deforestation. (iii) Natural resources that are used in the production of electricity without damaging the environment. (iv) The energy generated by means of large propeller on tall tower. (v) The energy produced by the sun.	A Wind energy. B Solar energy. C Hydroelectric energy. D Wood energy. E Tidal energy. F Geothermal energy. G Sustainable energy sources.

The question was attempted by 597,419 (99.8%) students, whose scores were as follows: 158,174 (26.5%) students scored from 0 to 1 mark, 292,583 (49.0%) students scored from 2 to 3 marks, and 146,662 (24.5%) scored from 4 to 5 marks. The performance of students in this question was good as 439,245 (73.5%) students scored from 2 to 5 out of 5 marks allotted to this question. Figure 2 provides the graphic presentation of these data.

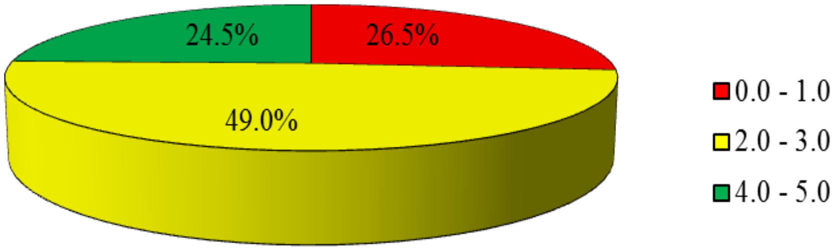


Figure 2: *Percentage of Students' Performance Per Score in Question 2*

The analysis of students' performance in each item is as follows:

In item (i), students were required to write the correct response that matched '*The energy which is associated with the volcanic areas'*. The correct response was F, *Geothermal energy*. Most of the students were able to match this item correctly. However, some students matched it with A, *Wind energy*. These students failed to recall that geothermal energy is generated by the flow of heat from the earths' surface which is associated with areas of frequent earthquakes and high volcanic activity. On the contrary, wind energy is converted into electricity by a tall tower with a large propeller on top called a wind mill. Students were also supposed to know that best areas for the construction of wind mills are coastal areas, at the top of rounded hills, in open plains and in gaps between mountains. Therefore, the wind energy is not associated with volcanic areas.

In item (ii), students were required to identify the energy source which matches to the statement, '*The energy due to the afforestation and deforestation'*. The appropriate response was D, *wood energy*. Most of the students were attracted by the correct response due to close relationship between wood energy and the terms afforestation and deforestation which obviously involve trees. Most of the students demonstrated a thorough understanding as they knew that wood energy is the energy generated from wood or wood-derived products usually through combustion processes, and that it is used for cooking, heating or generating electricity.

Item (iii) required the students to identify the response which matches correctly the statement, '*The natural resources that are used in the production of electricity without damaging the environment'*. The correct option was G, *sustainable energy sources*. Most of the students failed to choose the correct response because they confused it with the presence of *wind energy, solar energy* and *hydroelectric energy,* as common examples of sustainable energy sources. The students new that sustainable energy sources include natural resources that are used in the production of electricity without destroying the environment irrespective of the kind of the natural resource of energy used.

In item (iv), students were required to write the correct response that matches the statement '*The energy generated by means of large propeller on tall tower'*. The best response was A, *wind energy*. This item was attempted by most of the students, indicating that they had enough knowledge on the energy produced by means of large propeller on tall tower. However, a few students matched it with E, *tidal energy*. This small group of students failed to differentiate between tidal energy and wind energy. They were supposed to know that tidal energy is a renewable source of energy produced by the surge of ocean waters during the rise and fall of tides. On the contrary, wind energy is a renewable source of energy which is used to produce electricity using the kinetic energy created by air in motion which is transformed into electrical energy by using wind turbines.

In item (v), students were required to write a correct letter of the source of energy which matches correctly the statement, '*The energy produced by the sun'*. The correct response was B, *solar energy*. Performance in this item was good as most students responded correctly because they confidently knew that solar energy is the energy generated by the sun through the use of solar panels in their homes.

2.1.3 Question 3: Fill in the Blank Items

This question consisted of five (5) fill in the blanks items derived from five (5) topics, namely, *Measurement, Simple Machines, Newton's Laws of Motion, Light and Structure and properties of matter*. In this question, the students were required to complete the given statements by writing the correct answer in the given spaces. Each item weighed one (1) mark making a total of five (5) marks.

The question was attempted by 553,096 (92.4%) students of which 467,461 (84.5%) students scored from 0 to 1 mark, 72,526 (13.1%) students scored from 2 to 3 marks and 13,109 (2.4%) students scored from 4 to 5 marks. Generally, the question was weakly performed as only 85,635 (15.5%) students scored 2 marks out of 5 marks allotted to this question. Figure 3 summarizes the scores in this question.

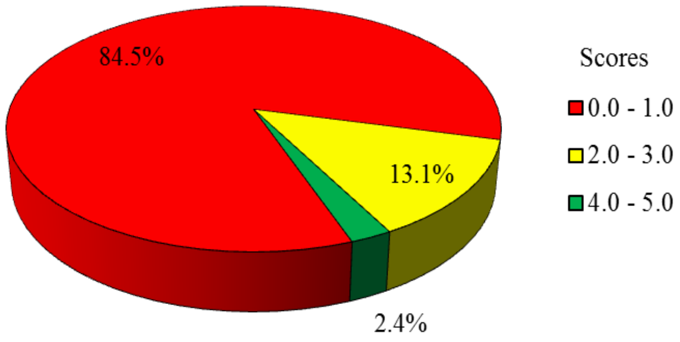


Figure3: *Percentage of Students' Performance per Score in Question 3*

The analysis of students' performance in each item is as follows:

In item (i) students were required to write the name of a complete measurement. The correct response was *Physical quantity.* Few students managed to write the correct response in this item while the rest provided either incorrect answers or skipped it, indicating that they lacked knowledge on the concept of measurement. For example, some of the students filled the blank by writing *hydroelectric energy; hydrometer, thermometer and SI units*. Others wrote *temperature*; *beam balance*; *instrument*; *acceleration*; *mass* and *gold–leaf*. All these responses are irrelevant to the asked question. They supplied mixed concepts which imply lack of knowledge on the topic being tested.

Item (ii) required the students to give the reason as to why efficiency of a machine is always less than 100%. Most of them wrote the correct answer, *Friction*. These students were aware that when a machine is operating, some machine parts are wearing and tearing due to friction which transforms some energy into other forms of energy such as heat and sound energy. However, some students filled the blank with incorrect responses. For example, some wrote: *human body*; *velocity*; *distance*; *gravity*; *mechanical advantage*; and *work in put*. This is an indication that the students in this category had insufficient knowledge on the concept of effect of friction on efficiency of a simple machine.

In item (iii), students were required to recall and apply the formula to find the linear momentum of a body of mass 5 kg moving with a velocity of 2 m/s. The appropriate answer was 10 kgm/s. Some students managed to provide the correct answer, but others filled the blank space with inappropriate answers. These students were supposed to realize that linear momentum of a body should be calculated by applying the relation: Linear momentum = Mass × velocity = 5 kg × 2 m/s = 10 kgm/s. By so doing they could have obtained the intended value for the linear momentum of a body. Most of the students demonstrated lack of incompetence in the topic of Newton's laws of motion, especially the concept of momentum.

Item (iv) required the students to write the name of a region of total shadow on a screen. The correct answer was *Umbra*. A few students wrote the correct answer while the rest either skipped it or provided incorrect responses. The students who failed to give correct answers lacked knowledge about formation of shadows. These students were supposed to understand that umbra and penumbra are two distinct parts of a shadow created by any light source after impinging on an opaque object. When one part of a shadow is totally dark as viewed on a screen, the shadow is called Umbra. On the other hand, when the other part of the shadow is partially dark, the shadow is penumbra. Many students failed this part because they did not know the distinctive features of umbra and penumbra as used in formation of shadows.

In item (v), students were required to give the name of the shape of the surface of water in a clean glass tube. The correct response was *Concave meniscus*. Performance in this part of the question was weak due to various challenges. Some of the students failed to understand the demand of the question item and lacked knowledge of the concept of cohesion and adhesion forces responsible for formation of meniscus. For example, some of the students wrote *'matter, depth, beaker, surface tension, earth, thermometer and boiled masses*. These students were supposed to recall that a concave meniscus, normally occurs when the molecules of the liquid (e.g. water) are attracted to those of the container. For the case of water, the situation occurs with water and a glass tube.

2.2 Section B: Short Answer Questions

This section had five (5) short answer questions constructed from five (5) topics which are *Motion in Straight Line, Work, Energy and Power, Pressure, Forces in Equilibrium* and *Newton's Laws of Motion.* Each question carried ten (10) marks, making a total of 50 marks.

2.2.1 Question 4: Motion in a Straight Line

The question had three parts, which are (a), (b) and (c). In part (a), the students were required to write down the second and third equations of motion in a straight line. In part (b), they were required to explain the terms (i) velocity and (ii) retardation as applied in motion in a straight line, and in part (c) (i), they were required to calculate the time taken by the stone to return back to the thrower and (ii) the maximum height reached when the stone is thrown vertically upwards with an initial velocity of 50 m/s.

This question was attempted by 549,213 (91.8%) students .The analysis of the data as shown in Figure 4 indicates that, 484,943 (88.3%) students scored from 0 to 2.5 marks, 54,002 (9.8%) students scored from 3 to 6 marks, and 10,268 (1.9%) students scored from 6.5 to 10 marks. Generally, the performance in this question was weak as only 64,270 (11.7%) students scored from 3 to 10 marks. Figure 4 shows the graphical presentation of the analysed data.

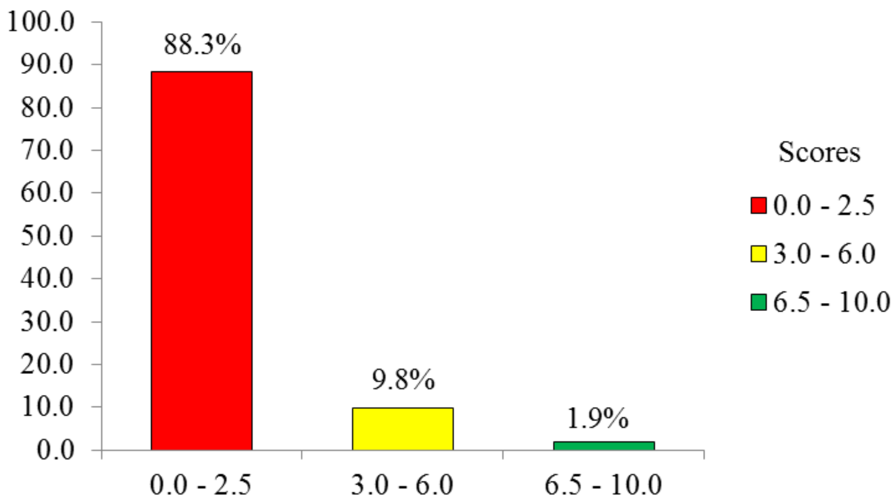


Figure 4: *Percentage of Students' Performance per Score in Question 4*

Students who scored low marks in this question faced a lot of challenges in attempting it. For example, most of them failed to write the second and third equations of motion in straight line in part (a). One student wrote: $m = w^2 + u^1$ and another one wrote $s = at_{1/2}u$. Another student, instead of writing the equations of motion, *"is the straight line of motion of an object"*. This is an indicatIO that most of them lacked content knowledge on the equations of uniformly accelerated motion. These students were supposed to write the second equation of motion as $S = u\,t + \frac{1}{2}\,a\,t^2$ and the third equation of motion as $v^2 = u^2 + 2\,a\,s$. Many students failed to explain the terms velocity and retardation as applied in motion in a straight line. For example, one student explained velocity as *"the rate of charges acceleration"*. Another one stated velocity as "*the equivalent resistance of electricity charges*". Others expressed velocity as *"the energy due to afforestation and deforestation"*. There was also one student who described velocity as "*the central gravity of mass"*.

In explaining retardation, one student wrote "*retardation is the energy which is associated with the volcanic areas"*, and, another one wrote retardation is *"the energy produced by sun"*. Based on these few samples of students' responses, it can be concluded that most of them had insufficient knowledge on the topic of motion in a straight line.

In attempting part (c) (i) and (ii) of the question, most students applied inappropriate formulae and poor computational approaches to find the time taken by the stone to return back to the thrower and the maximum height reached, when the stone is thrown vertically upwards with an initial velocity of 50 m/s. This signifies that they also lacked mathematical skills. Extract 4.1 is a sample of students' poor response.

4. (a) Write down the second and third equations of motion in a straight line.

Second and third equations of motion in a straight line there are ~~find~~ first motion in a straight line.

(b) Explain the following terms as they are applied in motion in a straight line:

(i) Velocity.

Velocity - is form of the motion in a straight line of the retardation on the motion will be there are three types of motion in straight line is used for the velocity is not be the formed.

(ii) Retardation.

Retardation - is the physical or chemical the reaction in the motion in a straight line is used for the vertically to be velocity is the Sustainable energy and sources has the used.

(c) A stone is thrown vertically upwards with an initial velocity of 50 m/s.

(i) Calculate the time that the stone will take to return back to the thrower.

Soln

Velocity 50m/s

Given g = 10m/s²

50 m/s x 10m/s²

= 50x10 = 500

= 500m/s²

Velocity is 500m/s²

(ii) What will be the maximum height reached?

Velocity = 50m/s

given 50m/s x 100m/s²

50m/s x 100m/s²

5000 m/s

= 5000m/s²

The maximum height is 0.500 m/s

500 ÷ 100

000

500

500

Extract 4.1: A student's weak responses to question 4.

In extract 4.1, a student failed to write down the second and third equations of motion in a straight line. He/she also failed to explain velocity and retardation as applied in motion in a straight line. In part (c) (i) and (ii), the student failed to write the necessary formula for calculations, thus demonstrating incompetence in mathematical skills.

On the other hand, students who scored high marks in this question wrote correctly the second and third equations of motion in a straight line and explained the terms velocity and retardation correctly as applied in motion in a straight line. They also managed to apply appropriate formula in calculating the time taken by the stone to return to the thrower and maximum height reached when the stone was thrown vertically upwards with an initial velocity of 50 m/s. Extract 4.2 is a sample of students' good response.

4. (a) Write down the second and third equations of motion in a straight line.

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

$V^2 = u^2 + 2as$

(b) Explain the following terms as they are applied in motion in a straight line:

(i) Velocity.

Is the rate of change of displacement whereby displacement is a distance from a fixed point to a specific direction. Velocity it is a vector quantity having both magnitude and direction. It's SI unit is m/s.

(ii) Retardation.

Is the rate of decrease in velocity of a moving body in a given time. Retardation is also known as Deceleration of a body.

(c) A stone is thrown vertically upwards with an initial velocity of 50 m/s.

(i) Calculate the time that the stone will take to return back to the thrower.

Soln

Data given

Initial velocity $(u) = 50m/s$

final velocity $(v) = 0$

time taken $= ?$

from first Newton's law of Motion $V = u - gt$

formulae $= V = u - gt$

$0 = u - gt$

$\frac{gt}{g} = \frac{u}{g}$ $t = 2(u/g)$

$t = \frac{50}{10} \times 2 = 10s$

∴ The time that stone will take to return back to thrower is 10s

(ii) What will be the maximum height reached?

Soln

Formulae $= h = ut - \frac{1}{2}gt^2$

Time taken to reach maximum height $= t = u/g$

$t = 50/10$ 5sec

$h = (50 \times 5) - \frac{1}{2} \times 10 \times 5^2$

$250 - \frac{1}{2} \times 10 \times 25$

$250 - 125 = 125m$

∴ The maximum height reached is 125M

Extract 4.2: The student's good responses to question 4.

Extract 4.2 shows that the student managed to provide a precise explanation of velocity and retardation, as well as clear and systematic calculations for time and maximum height of the velocity thrown upwards.

2.2.2 Question 5: Work, Energy and Power

This question comprised three parts, namely (a), (b) and (c). In part (a) students were required to identify the kind of energy stored in objects like springs as a result of reversible deformation. Part (b) required the students to explain why there is no work done on the books when carried horizontally, and in part (c) they were required to calculate the height reached by the ball on the rebound when a ball of 0.2 kg was dropped from a height of 20 m when 30 J of energy was lost on impact with the ground.

The question was attempted by 541,752 (90.5%) students. The analysis of the data shown in Figure 5 indicates that 483,029 (89.2%) students scored from 0 to 2.5 marks, 51,815 (9.5%) students scored from 3.0 to 6.0 marks, and 6,908 (1.3%) students scored from 6.5 to 10 marks. These data indicate that the general performance was weak since only 58,723 (10.8%) students scored from 3.0 to 10 marks.

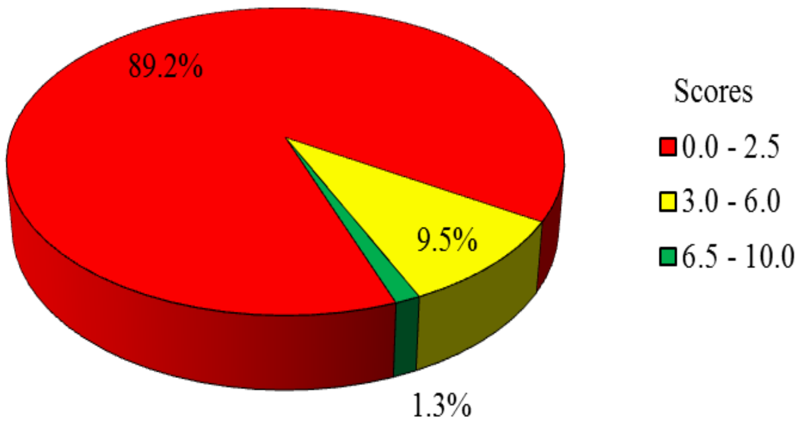


Figure 5: *Percentage of Students' Performance per Score in Question 5*

The students who scored low marks in this question failed to identify the kind of energy stored in objects like springs as a result of reversible deformation. Some ended up writing a wrong type of energy instead of elastic potential energy. For example, one student wrote *kinetic energy*, another wrote *geothermal energy* and the other one, *nuclear energy*. One of the students defined energy as *the ability of doing work* instead of giving a kind of energy stored in objects like springs. In part (b), some students did not know that work is done only when a body moves in the direction of applied force. Moreover some lacked mathematical skills and thus failed to use appropriate formula to calculate the rebound height of the ball. In order to calculate the height of the ball in part (c), students were supposed to analyse the data: $m = 0.2$ kg, $g = 10\ m/s^2$, $h_1 = 20$ m, $E = 30$ J, $h_2 =?$

Initial P.E of the ball = $mgh_1 = 0.2\text{ kg} \times 10\text{ m/s}^2 \times 20\text{ m} = 40\text{ J}$
Energy remaining after impact is: $40\text{ J} - 30\text{ J} = 10\text{ J}$
At the highest point after impact, total PE is equal to the energy remaining in the ball: which means $mgh_2 = 10\text{ J}$

$$h_2 = \frac{10}{0.2 \times 10} = 5\text{ m}.$$

The highest height reached after rebound is 5 m. Extract 5.1 is a sample of a student who attained low marks in this question.

5. (a) Which kind of energy is stored in objects like springs as a result of reversible deformation?
The kind of energy stored in object is kinetic energy.

(b) Why there is no work done on the books when carried horizontally?
Because its stable than when carried vertically.

(c) A ball of 0.2 kg is dropped from a height of 20 m. On impact with the ground, it loses 30 J of energy. Calculate the height it reaches on the rebound.

Data given

Mass = 0.2kg
Height = 20m
Energy = 30J
From

$$\text{Potential energy} = \frac{\text{Mass} \times \text{Energy}}{\text{Hergh}}$$
$$= \frac{0.2\text{kg} \times 30\text{J}}{20\text{m}}$$
$$= \frac{1}{10}\text{kgJ/m}$$

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

In extract 5.1, a student failed to write the name of energy stored in objects such as springs. He/she failed to give reason why there is no work done on the books carried horizontally. The student also demonstrated incompetence in the use of mathematics knowledge to perform part (c) that requires the manipulation of the concept of potential energy.

The students who performed well in this question, managed clearly to give the name of the energy stored in springs as a result of reversible deformation. Furthermore, these students were able to explain correctly why there is no work done on the books when carried horizontally and they used correct formula to calculate the height reached by the ball after rebound. Extract 5.2 is a sample of responses of a student who performed well in this question.

5. (a) Which kind of energy is stored in objects like springs as a result of reversible deformation?

Elastic Potential energy

(b) Why there is no work done on the books when carried horizontally?

- There is no work done because the books aren't moving in the direction of the force applied (displacement)

(c) A ball of 0.2 kg is dropped from a height of 20 m. On impact with the ground, it loses 30 J of energy. Calculate the height it reaches on the rebound.

Data given;
Mass (m) = 0.2kg
Height (h) = 20m
gravitational force (g) = 10N/kg
Lost energy (e) = 30J
Required: Height at rebound (H)
From: P.E = m × h × g
= 0.2 × 20 × 10
= 40J

40J - 30J
= 10Joules
P.E = m×h×g
10 = 0.2 × H × 10
$\frac{10}{2} = \frac{2H}{2}$
H = 5m
∴ The height at rebound is 5m

Extract 5.2: A sample of students' good responses to question 5.

Extract 5.2 shows responses from one a student who had sufficient knowledge of the topic of work, energy and power. The student provided correct answers to each item of the question especially part (c) where he/she seemed to have adequate knowledge and computational skills on the concept of potential energy.

2.2.3 Question 6: Pressure

In this question students were required to: (a) explain why it is easier to cut a bar of soap using a thin piece of wire than a thick one, (b) state four applications of atmospheric pressure and (c) calculate the pressure exerted on the ground by the car of mass 8000 kg with one of its tyres having an area of 50 cm^2 in contact with the ground for a four wheel drive vehicle.

The question was attempted by 561,436 (93.8%) students. The results show that 483,580 (86.1%) students scored from 0 to 2.5 marks, 64,795 (11.6%) students scored from 3 to 6 marks, and 13,061 (2.3%) students scored from 6.5 to 10 marks. This performance suggests that the question was weakly performed as 77,856 (13.9%) students scored 3.0 marks and above. Figure 6 shows the performance of students in this question.

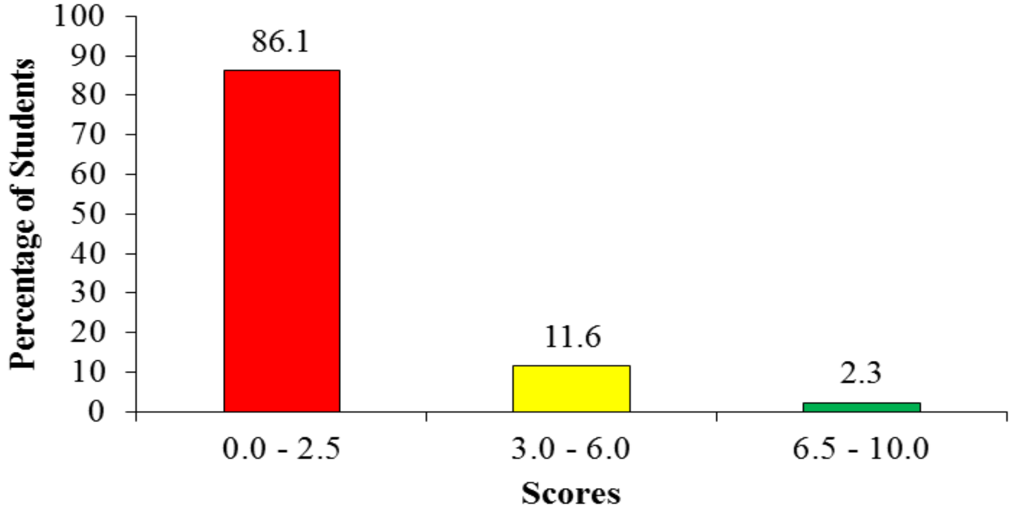


Figure 6: *Distribution of students' scores in question 6*

The analysis shows that students who scored low marks in this question did not understand the demand of the question and had inadequate knowledge of the concepts of pressure, especially part (a) which required detailed explanations, and part (c) that involved the applications of mathematical skills. In attempting part (a) of the question, one student wrote *"it is easier to cut a bar of soap using a thin piece of wire than a thick piece of wire because of frictional force"*. This student lacked knowledge on the concept of pressure in solids. Such students were supposed to understand that objects with sharp points or edges have a minimal area over which an applied force exerts large pressure, which facilitates the cutting a bar of soap.

On the other hand, some students failed to state correctly the applications of atmospheric pressure. These students failed to recall a variety of simple devices whose uses depend on the atmospheric pressure in our day to day life experience, such as siphon, a bicycle pump, lift pump, force pump, a syringe and others. For example, one student stated the applications of atmospheric pressure as *"length, mass, time and temperature"* which are the basic quantities in the topic of measurement. This is an indication that those students lacked knowledge on various topics tested.

In part (c), most of the students applied inappropriate formula to calculate the pressure exerted on the ground by the car. Extract 6.1 shows a sample of incorrect responses from one student.

6. (a) Why is it easier to cut a bar of soap using a thin piece of wire than a thick one?

It is Soap of thim wire of powen of energy ground using thew ane currect.

(b) State four applications of atmospheric pressure.

(i) It low pressure

(ii) It water pressure

(iii) It per pressure

(iv) It unit pressure

(c) A car of mass 8000 kg has one of its tyres having an area of 50 cm^2 in contact with the ground. If this is four wheel drive vehicle, calculate the pressure exerted on the ground by the car.

Soln

Datagwe

mass 800 kg

having 50cm²

pressure?

from

$8000 \times 50cm^2$

$8000 \times 50 = 4000$

$\frac{4000}{2}$

~~8000~~

= 8000cm

Extract 6.1: A sample of students' poor responses to question 6.

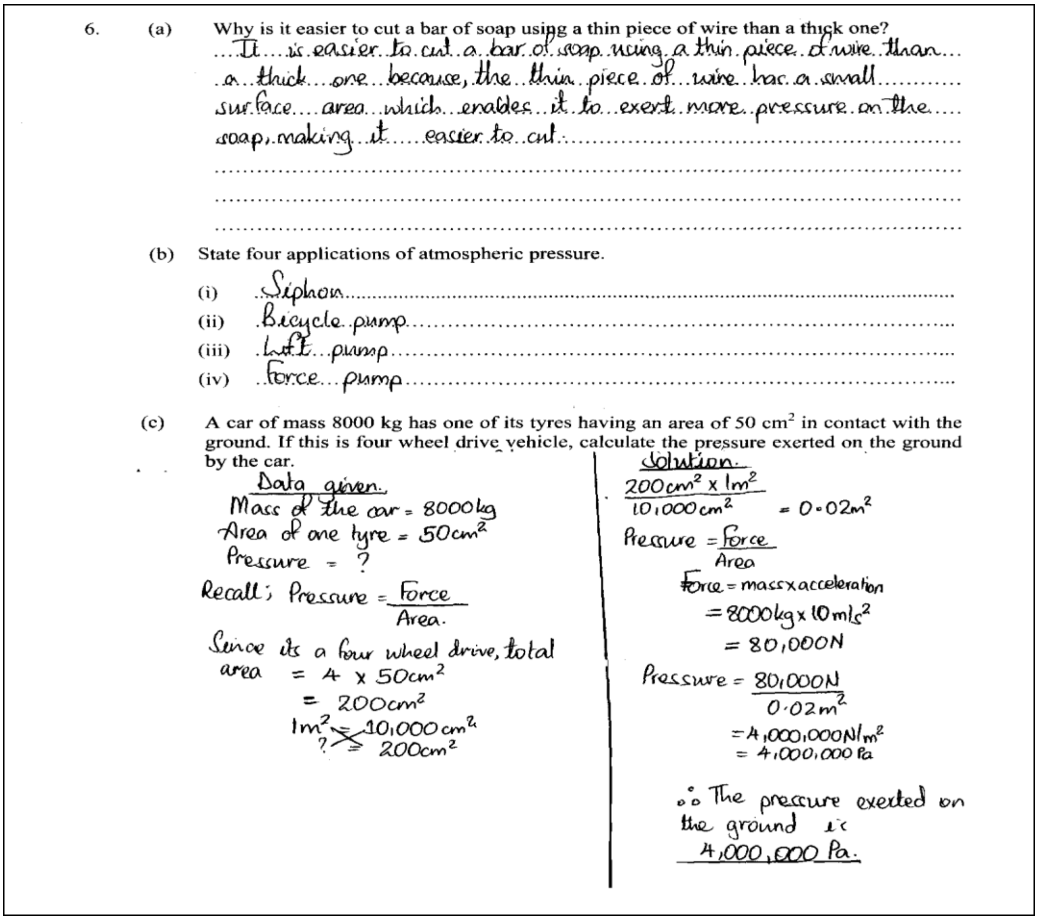
In extract 6.1, the student lacked both content knowledge and arithmetic skills of the concepts tested, and thus provided incorrect responses to all parts of the question.

Although more students performed poorly in this question, some of them had good performance, because they had adequate knowledge on the concepts of pressure. For example, one student explained precisely why it is easier to cut a bar of soap using a thin wire than a thick one as follows:

> *"Because thin piece of wire has a small surface area which makes it produce greater pressure hence it is simple to cut a bar of soap but a*

thick piece of wire has large surface area which makes it produce small pressure and hence become difficult to cut a bar of soap. The greater the surface area, the smaller is the pressure and vice versa.

Moreover, they accurately applied the formula of calculating pressure exerted on the ground by the car. Extract 6.2 is a sample of a response from a student who responded well.



6. (a) Why is it easier to cut a bar of soap using a thin piece of wire than a thick one?

It is easier to cut a bar of soap using a thin piece of wire than a thick one because, the thin piece of wire has a small surface area which enables it to exert more pressure on the soap, making it easier to cut.

(b) State four applications of atmospheric pressure.

(i) Siphon

(ii) Bicycle pump

(iii) Lift pump

(iv) Force pump

(c) A car of mass 8000 kg has one of its tyres having an area of 50 cm^2 in contact with the ground. If this is four wheel drive vehicle, calculate the pressure exerted on the ground by the car.

Data given.

Mass of the car = 8000kg

Area of one tyre = 50cm^2

Pressure = ?

Recall; $\text{Pressure} = \frac{\text{Force}}{\text{Area}}$

Since its a four wheel drive, total area $= 4 \times 50\text{cm}^2$

$= 200\text{cm}^2$

$1\text{m}^2 = 10{,}000\text{cm}^2$

$? = 200\text{cm}^2$

Solution.

$\frac{200\text{cm}^2 \times 1\text{m}^2}{10{,}000\text{cm}^2} = 0.02\text{m}^2$

$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$

Force = mass x acceleration

$= 8000\text{kg} \times 10\text{m/s}^2$

$= 80{,}000\text{N}$

$\text{Pressure} = \frac{80{,}000\text{N}}{0.02\text{m}^2}$

$= 4{,}000{,}000\text{N/m}^2$

$= 4{,}000{,}000\text{ Pa}$

∴ The pressure exerted on the ground is 4,000,000 Pa.

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

In extract 6.2, the student managed to give a reason for a thin piece of wire to be able to cut a bar of soap so easily than a thick one. Similarly, he/she stated correctly the applications of atmospheric pressure and utilized correct formula to calculate the pressure exerted on the ground by the car.

2.2.4 Question 7: Forces in Equilibrium

In this question, the students were required to (a) differentiate the centre of gravity of an extended body from the centre of mass of an object, (b) explain why a person climbing up a mountain is observed to bend forward and (c) find the length of the spanner when a force of 120 N is applied at right angle to the end of a spanner while a moment of a force of 320 Nm is formed.

The question was attempted by 506,283 (84.6%) students whose scores were as follows: 424,157 (83.8%) students scored from 0 to 2.5 marks, 73,279 (14.5%) students scored from 3.0 to 6.0 marks, and 8,847 (1.7%) students scored from 6.5 to10 marks. These scores indicate that the question was weakly performed as only 82,126 (16.2%) students scored 3 marks and above. Figure 7 presents the performance of students in this question.

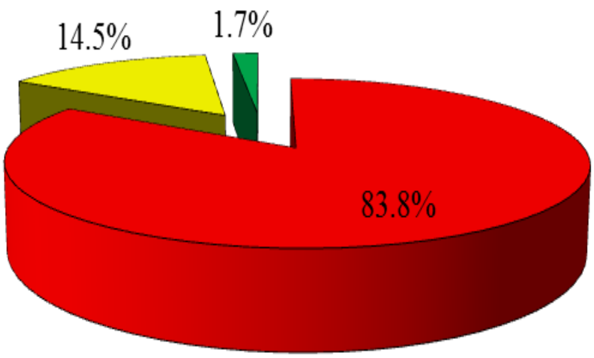


Figure 7: *Percentage of Students' Performance per Score in Question 7*

The students who achieved low marks in this question had insufficient knowledge on the concepts of *Forces in equilibrium* particularly on the centre of gravity and centre of mass in conjunction with applications of equilibrium and stability. Many students failed to distinguish the centre of gravity from centre of mass of the body. For example, one student wrote as *"the centre of gravity of an extended body differs from the centre of mass when the body is in anti-clockwise"*. Another one wrote as *"because the centre of gravity is extended to the upper of an object so as different from the centre of mass"*. These students did not even understand the meaning of the two quantities. They were supposed to know that centre of mass is the point at which the distribution of mass is equal in all directions, and it does not depend on gravitational field, while the centre of gravity is the point at which the distribution of weight is equal in all directions, and it depends on gravitational field. In other words, the centre of mass of an extended object is the point where all its mass are concentrated while the centre of gravity of an object is the point where the centre of gravity acts.

Most of the students failed to explain why a person bends forward when climbing up the mountain. As explained earlier, these students did not understand the concept of applications of equilibrium and stability. For example, one student wrote *"a person climbing a mountain is observed to bend forward because at a mountain there is high altitude".* To elaborate this concept, the students were supposed to know that a person leans/ bends forward in order to keep himself in stable equilibrium. By leaning forward, a person increases the base of the support, so that the vertical line passing through his centre of gravity may fall within the base. Furthermore, some students faced challenges in computing the length of the spanner by using inappropriate formula; as a result they ended with incorrect answers. For example, one student employed a wrong formula to calculate the length of the spanner by subtracting the value of the given force from the moment of force $(320 \text{ Nm} - 120 \text{ N} = 200 \text{ m})$ and eventually obtained incorrect length of the spanner as 200 m. This student was not able to recall the formula that relates the moment of force, the force applied and the perpendicular distance or length of the material used. Apart from that, he/she seemed to lack knowledge on quantities of measurement and their SI units. The student was supposed to recognize that quantities of different units cannot be added or subtracted from each other. The student subtracted force applied from the moment of force. The students were supposed to use the following procedures:

$$\text{Moment of force} = \text{Force applied} \times \text{perpendicular distance (Length)}.$$

$$\text{Length of spanner} = \frac{\text{Moment of force}}{\text{Force apllied}} = \frac{320 \text{ (Nm)}}{120 \text{ (N)}} = 2.67 \text{ m}.$$

Extract 7.1 is a sample of student's poor responses to this question.

7. (a) How does the centre of gravity of an extended body differ from the centre of mass of an object?

The centre of gravity differe from the centre of mass because the gravity is the point where by the application of the reaction force is due to the earth extraction of the body.

(b) Why a person climbing up a mountain is observed to bend forward?

Because this is due to the force applied on a mountain is equal to the lower force applied to bend.

(c) A moment of force of 320 Nm is formed when a force of 120 N is applied at right angle on the end of a spanner. How long is the spanner?

Soln

Moment of force = 320Nm

Force = 120N

Angle of spanner = ?

$P = \frac{\text{Force}}{\text{Area}}$

$P = \frac{\cancel{120N}\ \cancel{6}\ 3}{\cancel{320Nm}\ \cancel{16}\ 8}$

$P = 0.375m$

0.375
$8\overline{)3.0}$
-24
60
-56
40
-40

∴ The ~~span~~ long of the spanner is 0.375m

Extract 7.1 A sample of student's incorrect responses to question 7.

In extract 7.1, the student failed to differentiate the centre of gravity of an extended body from the centre of mass of an object. He/she also failed to explain why a person climbing up a mountain is observed to bend forward. In attempting part (c), the student used the formula $P = \frac{\text{Force}}{\text{Area}}$ instead of moment of force = Force applied × perpendicular distance (Length).

Those who attained high marks (6.5 – 10) in this question were conversant with the concept of forces in equilibrium, especially the concept of centre of gravity, centre of mass and moment of a force. These students correctly applied the formula in finding the length of the spanner. Extract 7.2 is a sample of good response.

7. (a) How does the centre of gravity of an extended body differ from the centre of mass of an object?

Centre of gravity is a point where all the weight of a certain body are concetrated while centre of mass is a point where all the mass of a certain body is concetrated.

(b) Why a person climbing up a mountain is observed to bend forward?

Inorder to keep the body's centre of gravity to be low so as the person can be stable while climbing the mountain.

(c) A moment of force of 320 Nm is formed when a force of 120 N is applied at right angle on the end of a spanner. How long is the spanner?

Soln.

Data given

Moment of force 320Nm

Force 120N

Distance x

Moment of force = Force X Distance

$320Nm = 120N \times x$

$$\frac{320Nm}{120N} = \frac{120Nx}{120N}$$

$$x = \frac{320m}{120}$$

$$x = \frac{8}{3}$$

$= 2.67m$

$\therefore$ The length of the sponner is 2.67m

Extract 7.2: A sample of students' good responses to question 7.

In extract 7.2, a student answered correctly almost all parts of the question.

2.2.5 'Question 8: Newton's Laws of Motion

The question required the students to (a) state Newton's second law of motion, (b) give two examples of the application of Newton's third law of motion and (c) (i) calculate the common velocity 'V' and (ii) identify the type of collision when a ball A of mass 100 g moving with a velocity of 5 m/s makes a "head-on" collisions with a ball 'B' of mass 500 g moving with a velocity of 1 m/s in the opposite direction and stick together after collision.

The question was attempted by 534,826 (89.4%) students. According to the results, 490,539 (91.7%) students scored from 0 to 2.5 marks, 41,007 (7.7%) students scored from 3.0 to 6.0 marks, and 3,280 (0.6%) students scored from 6.5 to10 marks. The question was most poorly performed as 44,287 (8.3%)

students scored from 3.0 to 10.0 marks. Figure 8 summarizes the students' performance in this question.

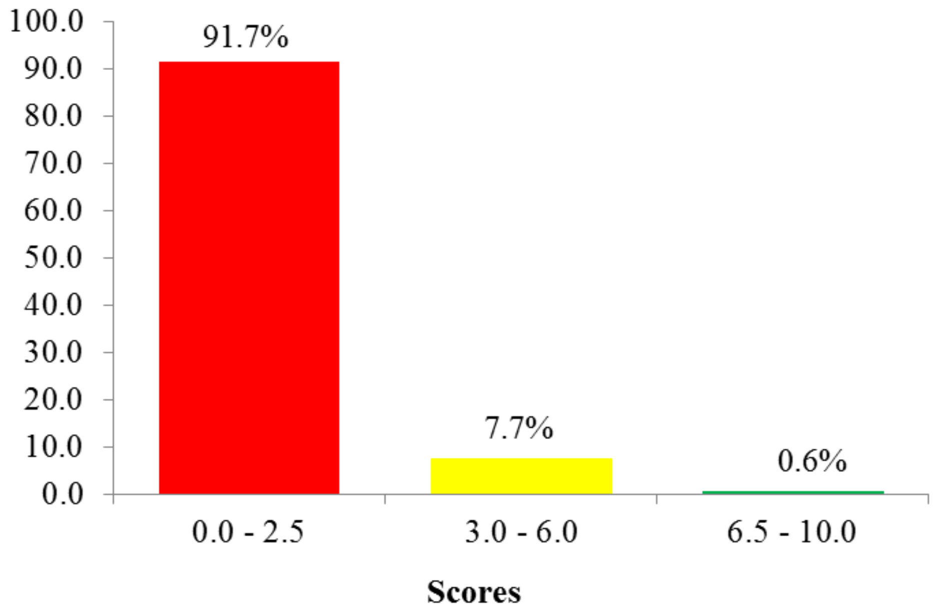


Figure 8: *The Percentage of Students' Performance per Score in Question 8*

Further analysis shows that most of the students scored below 3.0 marks. Some of them demonstrated incompetence in the topic of Newton's laws of motion, particularly, second and third law of motion, including the use of the principle of conservation of linear momentum and collisions of different objects in motion to perform the calculations in part (c) of the question.

In part (a), the students failed to state Newton's second law of motion due to lack of knowledge of the topic tested. For instance, one of the students incorrectly stated as *"it states that all matter are made up of smallest particles called atoms"*. The student's statement does not answer the question but rather articulates the kinetic molecular theory of matter which offers a description of the microscopic properties of atoms (or molecules) and their interactions. Another student stated Newton's second law of motion as *"when an object is partially or totally immersed in a fluid it experiences an upthrust equal to the weight of the fluid displaced"*. This is actually not Newton's second law of motion but the Archimedes principle, which is referred to as the law of buoyancy. These students were supposed to know that Newton's second law of motion is based on the fact that the acceleration of an object is directly proportional to and in the same direction as the net force acting on it. So, they should have stated Newton's second law of motion as *"the rate of change of* *momentum of a body is directly proportional to the applied force and takes place in the direction in which the force acts"*.

In part (b), most of students failed to give examples of the application of the Newton's third law of motion. The analysis done through the scripts of students revealed that a large number of them skipped this part. However, those who tried provided undesirable responses. For instance, one student gave two examples of the application of the Newton's third law of motion as (i) *"the joule Newton's third law of motion* and (ii) *"the coulomb Newton's third law of motion"*. Students were supposed to bear in mind that in Newton's third law of motion, forces always come in pairs which are equal in magnitude and opposite in direction. Some of the essential practical situations involving Newton's third law of motion that students had to know include *"When a person throws a package out of a boat, the boat moves in the opposite direction from the package. The package exerts an equal but opposite force on the person". "When a person walks on the ground, he or she exerts a force on the ground and the ground exerts an equal force on the person". "A car accelerates forward because its tyres are pushing backward on the road while the road is pushing forward on the tyres"*.

In part (c), most of the students not only failed to calculate common velocity as per data provided, but also failed to identify the type of collision resulting from the interaction of the two balls. These students lacked both content knowledge and computational skills about the concept of the principle of conservation of linear momentum. They were supposed to understand that when two bodies collide and stick together and move with a common velocity, the type of collision produced is inelastic collision. Extract 8.1 is a sample of the student's poor response.

8. (a) State Newton's second law of motion.

Any achan in abody are equal and oppo site reachun in the body

(b) Give two examples of the application of the Newton's third law of motion.

(i) Human being and their legs

(ii) The building of pople are tot chang position

(c) A ball A of mass 100 g moving with a velocity of 5 m/s makes a "head-on" collision with a ball B of mass 500 g moving with a velocity of 1 m/s in the opposite direction. If A and B stick together after the collision;

(i) Calculate their common velocity V.

Data given
Mass = 100g
Velocity 5m/s
Ball B = mas 500g
Velocity = 1

$\frac{U-V}{time}$

$\frac{500g - 100g}{5m/s}$

$\frac{400g}{5m/s} = 80m/s^2$

∴ Velocity $80m/s^2$

(ii) Identify the type of collision Elastic collision

Extract 8.1: A Sample of Students' Poor Responses to Question 8.

Extract 8.1 shows that the student lacked content knowledge and mathematics skills on the concept of Newton's laws of motion and thus failed to give correct answers to all parts of the question.

However, few students managed to score high (6.5 – 10.0) marks in this question. The students who did the question perfectly managed to state clearly Newton's second law of motion and to list two examples of the applications of Newton's third law of motion. These students were conversant with the following facts about Newton's third law of motion: *The action and reaction forces are equal in magnitude but opposite direction*; *the action and reaction forces act on different bodies hence cannot cancel each other*; *only the third law involves two separate bodies*; and that *forces occur in pairs only*. In these cases, some students managed to give examples of applications of the Newton's third law of motion. For example, one student wrote:

> *"Newton's third law of motion is applied in the rocket whereby the burnt fuel goes backwards to push the rocket forward"* and

"Newton's third law of motion is also applied on the moving vehicles such as cars whereby the tyres push the ground backwards and the ground pushes the cars forwards".

This suggests that, though most of the students (91.7%) scored below 3 marks, few of them had adequate knowledge on that particular subject matter.

In part (c) of the question, they were able to calculate the common velocity of two balls which stick together after collision using data provided, and they identified correctly the type of collision produced. Extract 8.2 is a sample of responses from a student who scored high marks in this question.

8. (a) State Newton's second law of motion.

Newton's second law of motion states that," The rate of change of momentum of an object is directly proportional to the applied force and takes place in the direction of force.

(b) Give two examples of the application of the Newton's third law of motion.

(i) Rocket propulsion: Rockets remove some gas to the ground, which exerts a force on the ground, the ground then exerts a force equal to the one from the rocket and thus enables it to be launched:

(ii) Jumping castles; In jumping/bouncing castles, one exerts a force on the bouncing castle on jumping, the bouncing castle then exerts a force equal to the persons force, onto the person which enables the person to bounce back.

(c) A ball A of mass 100 g moving with a velocity of 5 m/s makes a "head-on" collision with a ball B of mass 500 g moving with a velocity of 1 m/s in the opposite direction. If A and B stick together after the collision;,

(i) Calculate their common velocity V.

Solution.

Data given.

Mass of ball A, ⟨m_A⟩ = 100g = 0.1kg

Velocity of A, ⟨u_A⟩ = 5m/s

Mass of ball B, ⟨m_B⟩ = 500g = 0.5kg

Velocity of B, ⟨u_B⟩ = −1m/s

Recall; Total momentum before collision = Total momentum after the collision

Momentum = m × v

So; $(M_A \times U_A) + (M_B \times U_B) = V(M_A + M_B)$

Mass B = 0.5kg

Mass A = 0.1kg

So; $(0.1kg \times 5m/s) + (0.5kg \times -1m/s) = v(0.5kg + 0.1kg)$

$0.5kg\,m/s + -0.5kg\,m/s = v \times 0.6kg$

$\frac{0}{0.6kg} = \frac{0.6kg \times v}{0.6kg}$

Velocity = 0 m/s

∴ Their common velocity ⟨V⟩ is 0m/s.

(ii) Identify the type of collision... Inelastic collision.

Extract 8.2: A sample of Students' Good Responses to Question 8.

In extract 8.2, a student stated the Newton's second law of motion and gave two practical applications of the law correctly. He/she correctly applied the principle of conservation of linear momentum to calculate the common velocity of the two balls, and managed to identify the type of collision produced.

2.3 Section C: Short Answer Questions

This section had two (2) questions set from the topics of *Simple Machines* and *Current Electricity*. Each question carried ten (10) marks, making a total of 20 marks.

2.3.1 Question 9: Simple Machines

This question comprised three parts (a), (b) and (c). In part (a), the students were required to explain how the inclined plane makes easier to move a load from a lower to a higher position. In part (b), they were asked to draw a diagram of combined pulley system with velocity ratio of 4 while in part (c), they were required to find the (i) mechanical advantage of a pulley and (ii) maximum load that can be raised by an effort of 200 N, when a pulley system of efficiency of 80% is made up of 8 pulleys.

The question was attempted by 549,171 (91.8%) students whose scores were as follows: 500,963 (91.2%) students scored from 0 to 2.5 marks, 46,104 (8.4%) students scored from 3.0 to 6.0 marks, and 2,104 (0.4%) students scored from 6.5 to10 marks. In general, this question was poorly performed since only 48,208 (8.8%) students scored from 3 to 10 marks. Figure 9 is a graphic presentation of the scores in question 9.

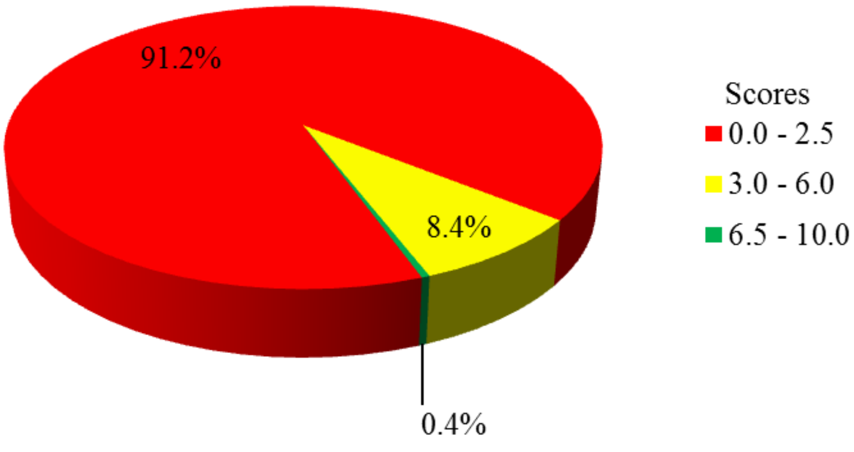


Figure 9: *The Percentage of Students' Performance per Score in Question 9*

The analysis of data in this question shows that, 91.2 percent scored below 3 marks. This low performance was attributed to lack of knowledge on the basic concepts of simple machines particularly inclined plane and pulleys. In part (a) of the question, most of the students failed to explain how the inclined plane makes it easier to move a load from a lower to a higher position. In attempting this part of the question, one student wrote *"because in an inclined plane effort is smaller than load"*. Another one wrote *"because moment of force is the turning effect of a force about a point"*. These two responses given by students suggest they lacked knowledge on the subtopic tested and failed to identify the demand of the question. The question required the students to explain 'how' but the students tried to explain 'why'. They were supposed to know that an inclined plane is a smooth flat rigid surface slanted at a certain angle to the horizontal and that makes it easier to move a load from a lower to a higher position by reducing the effort and increasing the distance through which the effort is applied. The smaller the angle of incline, the easier it is to move the load.

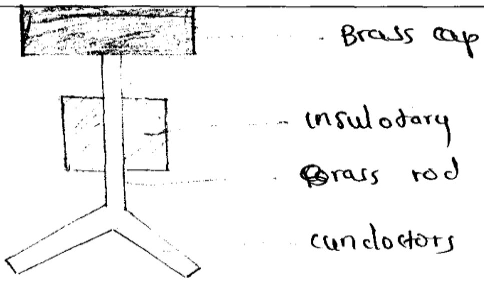
Most of the students skipped part (b) while others drew irrelevant diagrams to represent combined pulley system with a velocity ratio of 4.

Moreover, some students failed to recall correctly the formula for finding the mechanical advantage of a pulley and the maximum load that can be raised by the effort in part (c). For example, one student tried to find the mechanical advantage by using the formula: $\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}} \times 100\%$. This student had an idea of the concept of mechanical advantage of a pulley but wrongly expressed it in percentage. The mechanical advantage is expressed as: $\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}}$ with no SI units. Extract 9.1 is the sample of poor responses to this question.

9. (a) Explain how the inclined plane makes it easier to move a load from a lower to a higher position.

because when plane makes it easier to move load you should be the lower to highter positi on the body

(b) Draw a diagram of combined pulley system with velocity ratio of 4.



(c) A pulley system is made up of 8 pulleys. An effort of 200 N is applied on the pulley system. If the pulley has an efficiency of 80%, find the:

(i) Mechanical advantage of pulley?

$M \cdot A = \frac{Fd}{Fe}$

$M \cdot A = \frac{\cancel{8}\,4 \times 1\cancel{00}\%}{\cancel{200}\,1}$

$M \cdot A = 4N$

∴ the mechanical advantage of pulley 4N

(ii) Maximum load that can be raised by the effort?

Effort $\frac{d}{L} \times 100\%$

$\frac{4}{8\cancel{0}\%} \times 10\cancel{0}\%$

$\frac{\cancel{40}\,5}{\cancel{8}\,1} = 5$

∴ the maxium load that can be raised by the effort is 5N

Extract 9.1: A Sample of Students' Poor Responses in Question 9.

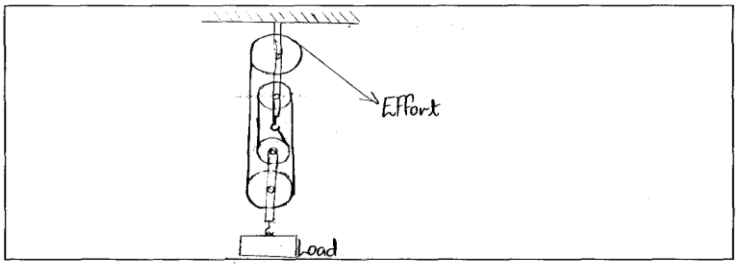
Extract 9.1 shows how the student failed to explain the mode of action of inclined plane in moving the load from a lower to a higher position. He/she drew a diagram that relates to gold - leaf electroscope instead of a diagram of combined pulley system with velocity ratio of 4. He/she lacked mathematical skills in calculating mechanical advantage and maximum load raised by the effort.

On the other hand, the students who performed well in this question demonstrated enough knowledge on the concept of simple machines. They managed to explain correctly how the inclined plane makes it easier to move a load from a low to a higher position. They also, managed to draw a clear diagram of a combined pulley system with a velocity ratio of 4. Furthermore, these students employed correct formula for finding the mechanical advantage of a pulley and they determined the maximum load that can be raised by the effort. Extract 9.2 is a sample of good responses.

9. (a) Explain how the inclined plane makes it easier to move a load from a lower to a higher position.

...The...inclined..plane..has.a...slanted..length...which...makes...a....... higher...effort.....distance, the longer the effort distance in a plane(inclined plane) the easier it is to move a load from one point to another.

(b) Draw a diagram of combined pulley system with velocity ratio of 4.



(c) A pulley system is made up of 8 pulleys. An effort of 200 N is applied on the pulley system. If the pulley has an efficiency of 80%, find the:

(i) Mechanical advantage of pulley?

Data given   Solution:

(VR), Velocity ratio = Number of pulleys = 8

Effort, (E) = 200N

Efficiency (Eff) = 80%

(M.A) Mechanical advantage = ?

Recall; $\frac{\text{Mechanical Advantage}}{\text{Velocity ratio}} \times 100\% = \text{Efficiency}$

So; $80\% = \frac{M.A}{8} \times 100\%$

$M.A = \frac{80\%}{100\%} \times 8$

Mechanical Advantage $= 6.4$

∴ The mechanical advantage of the pulley system is 6.4

(ii) Maximum load that can be raised by the effort?

Solution

From the data given in (i)

Effort = 200N

Load, (L) = ?

Recall; $\text{Mechanical Advantage} = \frac{\text{Load}}{\text{Effort}}$.

But; $\text{Mechanical advantage (MA)} = \frac{\text{Load}}{200N}$

$6.4 \times \frac{\text{Load}}{200N}$

Load $= 200N \times 6.4$

$= 1280N$

∴ The maximum load that can be raised by the effort is 1280N.

Extract 9.2: A Sample of Students' Good Responses to Question 9.

Extract 9.2 shows a sample response of a student who answered all parts of the question correctly.

2.3.2 Question 10: Current Electricity

The question had three parts, (a), (b) and (c). Part (a) required students to draw a circuit diagram that include three resistors of 2Ω, 4Ω and 6Ω connected in series to a battery of e.m.f 24V of negligible internal resistance, ammeter and switch. Part (b) required the students to find the current flowing in a circuit drawn in 10 (a), and in part (c), the students were required to find the potential difference at the end of each resistor in 10 (a).

The question was attempted by 548,263 (91.6%) students whose scores were as follows: 471,444 (86.0%) students scored from 0 to 2.5 marks; 46,183 (8.4%) students scored from 3.0 to 6.0 marks; and 30,636 (5.6%) students scored from 6.5 to10 marks. Generally, the performance was weak as only 76,819 (14.0%) students scored from 3.0 to 10.0 marks. Figure 10 is a graphic presentation of students' performance in this question.

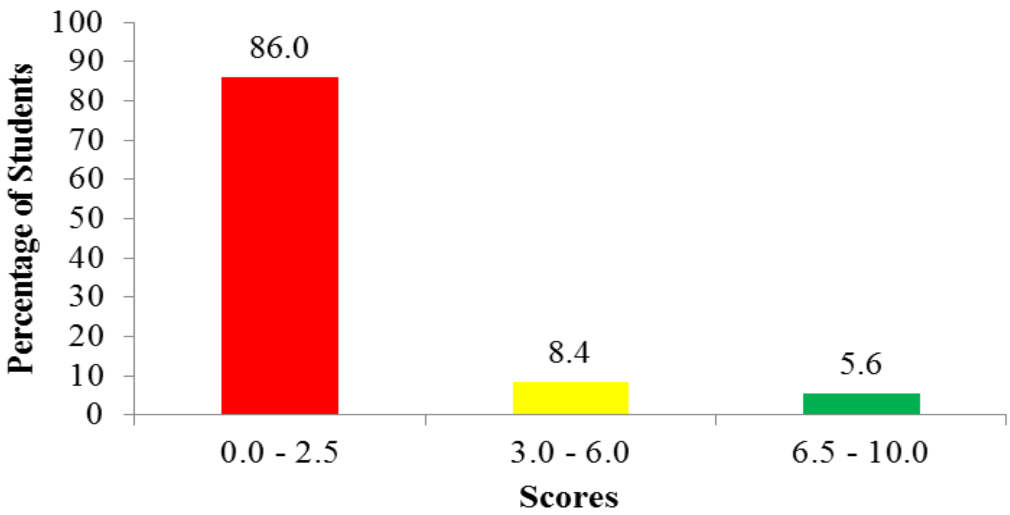
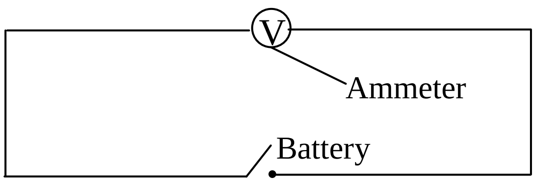


Figure 10: *The Percentage of Students' Performance per Score in Question 10*

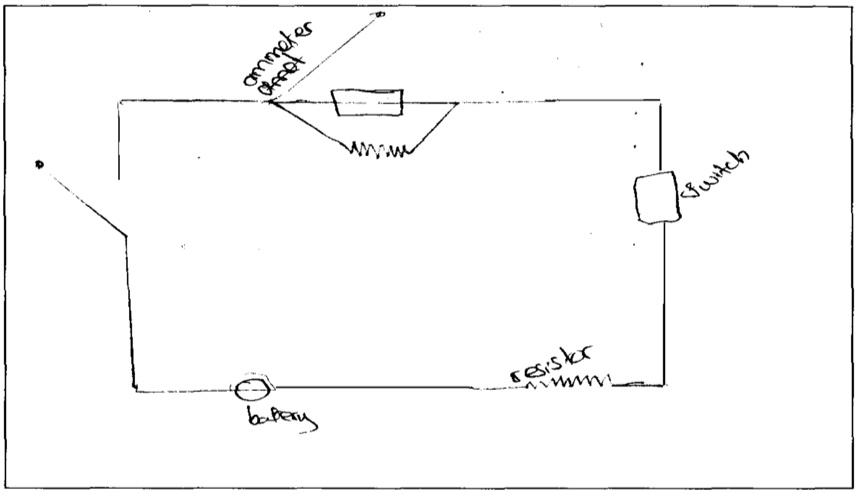
The students who performed poorly in this question had little knowledge of the concept of current electricity. They confused the concept of series with parallel connection of resistors and ended up drawing wrong circuit diagram. In one case, a student drew a circuit with a voltmeter and switch connected in series but labelled them as ammeter and battery respectively, as shown below.



This is an indication that some students lacked knowledge of the concept of common circuit components, labelling of their symbols and how they are connected in a circuit. Other students drew circuit symbols of individual electric devices like *battery*, *ammeter*, *switch* and *resistors* instead of the required complete circuit diagram. Some students applied inappropriate formula to compute the current flowing in the circuit and the potential difference at the ends of each resistor. In order to obtain the current flowing in the circuit, in part (b), students were supposed to find the total resistance R_T for three resistors connected in series by using the formula: $R_T = R_1+R_2+R_3 = (2+4+6)\ \Omega = 12\ \Omega$. then apply Ohm's law $V = IR_T$, such that $I = \frac{V}{R_T} = \frac{24}{12} = 2\ A$. The same law had to be used to find the potential difference at the ends of each resistance as follows: p.d across $R_1 = IR_1 = 2 \times 2 = 4$ V; p.d across $R_2 = IR_2 = 2 \times 4 = 8$ V; and the p.d across $R_3 = IR_3 = 2 \times 6 = 12$ V. Generally, in part (b) and (c), most of the students seemed to lack content knowledge on how to apply the Ohm's law. They also demonstrated poor mathematical skills. Extract 10.1 is a sample of responses from a student who scored low marks in this question.

10. Three resistors of 2 Ω, 4 Ω and 6 Ω are connected in series to a battery of e.m.f 24 V and have negligible internal resistance.

(a) Draw the circuit diagram including the battery, ammeter, switch and the three resistors.



(b) Find the current flowing in the circuit drawn in 10 (a) above.

Data
resistors₁ = 2Ω
resistors₂ = 4Ω
battery = 6Ω

from,
r₁ + r₂
2Ω + 4Ω

∴ resistor = 6Ω

(c) Find the potential difference at the ends of each resistor in 10 (a).

The potential difference at the ends of each resistor

Data given
resistor = 12
vortage = 24
current = 24
resistance = ?

$R = \frac{I}{V} = R = \frac{24}{2}$

∴ The potential difference is 12

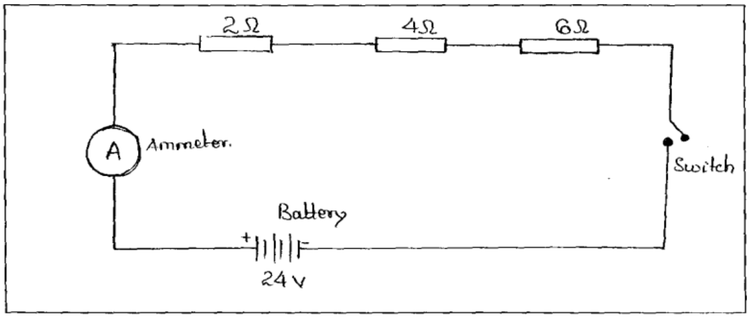
Extract 10.1: A Sample of Students' Poor Responses to Question 10.

Extract 10.1 shows how a student was incompetent in the concept of current electricity as applied in simple electric circuits. The student lacked both drawing and computation skills.

Despite the general weak performance observed in this question, few (14.0%) students managed to score from 3.0 to 10.0 marks. Some of these students provided correct answers in most or all parts of the question. They managed to draw a proper circuit diagram which included three resistors connected in series to the battery, ammeter and switch. Moreover, some of them had good understanding of the use of Ohm's law to find the current flowing through the circuit and the potential difference across each resistor. This shows that they had enough knowledge of the concept of current electricity, simple electric circuits and use of Ohm's law. Extract 10.2 is a sample of responses from a student who scored higher marks in this question.

10 Three resistors of 2 Ω, 4 Ω and 6 Ω are connected in series to a battery of e.m.f 24 V and have negligible internal resistance.

(a) Draw the circuit diagram including the battery, ammeter, switch and the three resistors.



(b) Find the current flowing in the circuit drawn in 10 (a) above.

Total resistance = $2\Omega + 4\Omega + 6\Omega$

$= 12\Omega$

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

$I = \frac{24V}{12\Omega}$

$I = 2A$

∴ Current flowing in the circuit is 2A

(c) Find the potential difference at the ends of each resistor in 10 (a).

Data:

$I = 2A$ $R_1 = 2\Omega$ $R_2 = 4\Omega$ $R_3 = 6\Omega$

$V = ?$

(i) Potential difference on the first resistor.

$V = IR = 2A \times 2\Omega = 4V$

∴ Potential difference on the first resistor = 4V

(ii) R_2

$V = IR = 2A \times 4\Omega = 8V$

∴ Potential difference on the second resistor = 8V

(iii) R_3

$V = IR = 2A \times 6\Omega = 12V$

∴ Potential difference on the third resistor = 12V

Extract 10.2: A Sample of student's' Good Responses to Question 10.

In extract 10.2, a student drew a correct circuit diagram with the stated electric components and connections. Consequently, he/she performed part (b) and (c) step by step to obtain the values of current flowing in the circuit and the difference across each resistor.

3.0 ANALYSIS OF STUDENTS' PERFORMANCE

3.1 Students' Performance in Each Topic

The Physics paper had ten (10) questions prepared from various topics of form I and Form II based on the Form Two National Assessment Format issued in 2017. The analysis of performance reveals that the students' performance for questions 1 and 2 was good as the percentage of students who passed were 77.1 and 73.5 respectively. Question 1 was set from various topics, including: *Introduction to Physics; Measurement; Force; Archimedes principle and the Law of Floatation; Structure and Properties of Matter; Pressure; Work, Energy and Power; Light; Static Electricity; Current Electricity; Magnetism; Forces in Equilibrium; Simple Machines; Motion in a Straight Line; Newton's Laws of Motion; Temperature* and *Sustainable Energy Sources.* Question 2 was a homogeneous matching item questions tested from the topic of *Sustainable Energy Sources*. There was no topic with an average performance (30-64%) in Physics paper.

Further analysis shows that most students, 463,443 (77.43%) scored marks ranging from 0 to 29 percent. A total of eight (8) topics had weak performance, which include *Measurement, Simple Machines, Newton's Laws of Motion, Light and Structure and properties of matter* from question 3 which required the students to fill in blank spaces whose general performance was 15.5 percent. The topic of *Motion in a Straight Line* which was tested in question 4 had also weak performance of 11.7 percent. Other topics with weak performance were *Work, Energy and Power* (10.8%) tested in question 5, *Pressure* (13.9%) tested in question 6, *Forces in Equilibrium* (16.2%) tested in question 7, *Newton's Laws of Motion* (8.3%) tested in question 8, *Simple Machines* (8.8%) tested in question 9 and *Current Electricity* (14.0%) tested in question 10. A summary of students' performance in each topic is presented in Appendix 1 (a) and (b).

3.2 Comparison of Students' Performance between 2019 and 2020 in Terms of Topics

The comparison of students' performance in terms of topics tested between 2019 and 2020 reveals a tremendous drop or rise in some topics when compared to the two successive years. The multiple choice items constructed from various topics in question 1 shows a significant increase in performance from 75.2 percent in 2019 to 77.1 percent in 2020. The matching item question showed a significant decrease in performance; in 2019, the performance was 75.6 while in 2020 it was 73.5 percent. Further analysis reveals that many topics were weakly performed in both 2019 and 2020. These topics include *Forces in Equilibrium* whose performance slightly increased from 14.3 in 2019 to 16.2 in 2020. Various topics which were tested in fill in the blanks items indicated a substantial increase in performance from 9.8 percent in 2019 to 15.5 percent in

2020; the topic of *Current Electricity* dropped from 15.9 percent in 2019 to 14.0 percent in 2020; *Pressure* whose performance in 2019 was 18.6 percent dropped up to 13.9 in 2020; *Motion in a Straight Line* whose performance was 12.5 percent in 2019 decreased in performance to 11.7 percent in 2020. Another significant drop in performance was observed in the topic of *Work*, *Energy and Power* whose performance in 2019 was 49.0 percent but decreased to 10.8 percent in 2020. The topics of *Simple Machines* and *Newton's Laws of Motion* which were not separately tested in 2019 were also poorly performed in 2020 (8.3%). From this comparison, teachers have to look for better ways of teaching in order to alleviate this problem of poor performance in the same topics each year.

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

The analysis of students' performance reveals that the general performance was extremely weak since most students, 463,443 (77.43%) scored below the passing marks (30). This poor performance is an indication that, students faced a lot of challenges in attempting various questions from certain topics.

The responses given by students have shown that a number of challenges had affected their performance in this paper. One of the challenges was inadequate knowledge on the concepts of different topics, which made them fail to attempt some items or provide inappropriate responses. Another impediment was lack of English language skills in understanding the demands of the questions and answering questions which really required detailed explanations. This challenge was observed in questions 5, 6, 7 and 9. Another remarkable challenge that students encountered was lack of numerical skills; most of the students failed to apply the relevant formula in items which required some essential procedures before obtaining the anticipated answers. This challenge was observed in question 5, 6, 7, 8, 9 and 10. In addition to this, some students' answers lacked logical flow and consistency of ideas, or steps particularly those involving calculations.

Another challenge is that, most of the students lacked drawing skills. Most of them drew diagrams which were not related to the intended tasks. For example, in questions 9 and 10 students failed to draw a diagram of combined pulley system with velocity ratio of 4 and a circuit diagram in the topics of *Simple Machines* and *Current Electricity* respectively.

This report has provided feedback and recommendations that will help to overcome the encountered challenges. It is expected that, teachers, students and other stakeholders will take necessary measures to improve the students' performance in future Physics Form Two National Assessments (FTNA).

4.2 Recommendations

In order to improve the students' performance in the poorly performed topics, such as *Motion in a Straight Line*; *Work Energy and Power*; *Pressure*; *Forces in Equilibrium*; *Newton's Laws of Motion*; *Simple Machines* and *Current Electricity*, Teachers should:

(a) Guide students to apply deductive thinking to derive equations of uniformly accelerated motion. They should also lead students through question and answer technique to describe the concept of retardation by using trolleys, ticker-tape-timer and velocity-time graph.

(b) Guide students to brainstorm different forms of energy by using helical spring, stone, thread and the concept of work as applied in Physics using a block of wood, thread, pulley, spring balance, metre rule and stop watch.

(c) Guide students to form small groups and use thick and thin wire loops to cut bars of soap into pieces and then explain the dependence of pressure on surface area of contact. They should also use Think-Pair-Share technique to guide students to identify the applications of atmospheric pressure by using bicycle pump, siphon, syringes, water and flushing tanks.

(d) Organize students' gallery walk presentation to distinguish centre of gravity from the centre of mass of an object by using a piece of uniform triangular cardboard, a plumb line and bob, supporting nail and ruler. They should also discuss how to apply conditions of stable, unstable and neutral equilibrium in daily life by using solid objects of various shapes and a model of a bus or lorry.

(e) Prepare an experiment for students to investigate the rate of change of momentum when the applied force is varied by using trolleys, various masses, and string and trick-tape timer. They should also discuss the applications of Newton's third law of motion in daily life by using stand-on weighing scale.

(f) Guide students to discuss the applications of inclined plane in daily life by using a ladder and building stops. They should also guide students' gallery walk presentation on different pulley systems and how the mechanical advantage, velocity ratio and efficiency of the pulley system are determined through the use of single fixed pulley, single movable pulley, block-and-tackle pulleys, two masses, metre rule and ropes.

(g) Guide students to discuss different circuit components by using a battery, cell, resistor, switch and connecting wires. They should also; guide them through inquiry deductive technique to deduce the equivalent resistance for parallel and series connections, the amount of current flowing in a circuit and the potential drop by using circuit diagrams.

(h) Put emphasis on mastering English in writing and speaking skills, through various techniques including checking and correcting grammatical errors in their day to day learning progress.

(i) Develop the art and talent of drawing skills related to different topics.

(j) Ensure that students work hard on attaining computational skills in order to solve problems which require application of mathematical skills.

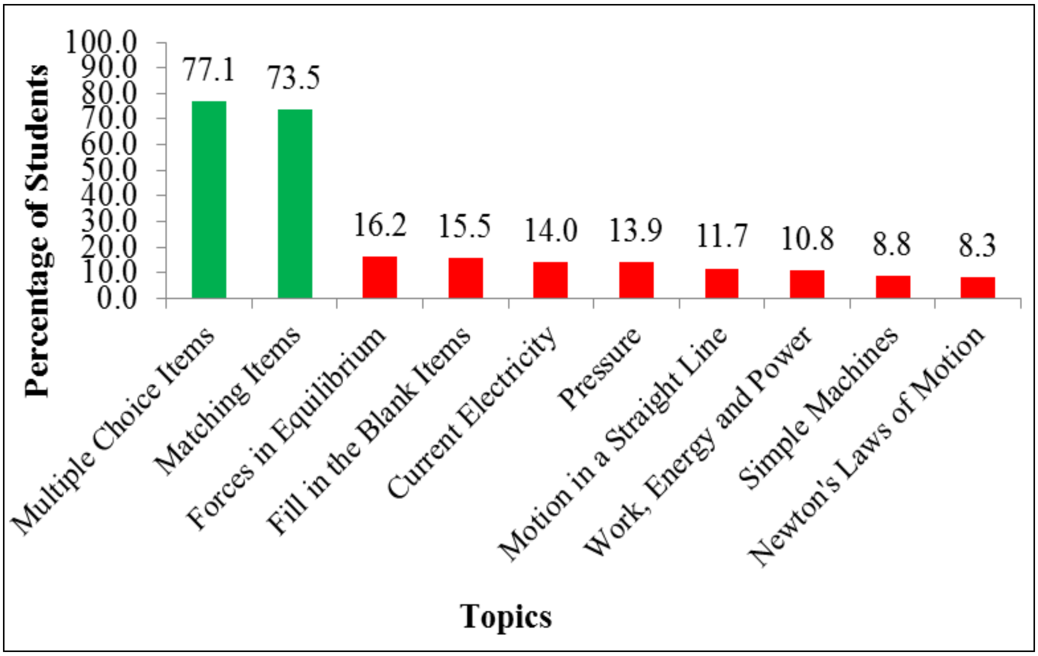
Appendix 1

Summary of the Performance of Students in Each Topic

S/N	Topic	Total Number of Questions	The % of Candidates Who Scored an Average of 35 % or Above	Remarks
1.	*Introduction to Physics, Measurement, Work, Energy and Power, Light, Static Electricity, Current Electricity, Magnetism, Forces in Equilibrium, Simple Machines, Motion in a Straight Line, Newton's Laws of Motion, Temperature and Sustainable Energy Sources*	1	77.1	Good
2.	Sustainable Energy Sources	1	73.5	Good
3.	Forces in Equilibrium	1	16.2	Weak
4.	*Measurement, Simple Machines, Newton's Laws of Motion, Light* na *Structure and Properties of Matter*	1	15.5	Weak
5.	*Current Electricity*	1	14.0	Weak
6.	*Pressure*	1	13.9	Weak
7.	*Motion in a Straight Line*	1	11.7	Weak
8.	*Work*, *Energy* and *Power*	1	10.8	Weak
9.	*Simple Machines*	1	8.8	Weak
10.	*Newton's Laws of Motion*	1	8.3	Weak

(a)

Summary of the Performance of Students in Each Topic



(b)

Appendix 2

Comparison of Students' Performance between 2019 and 2020 in Terms of Topics