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

CANDIDATES' ITEM RESPONSE ANALYSIS REPORT ON THE CERTIFICATE OF SECONDARY EDUCATION EXAMINATION (CSEE) 2021

ELECTRICAL ENGINEERING SCIENCE

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082 ELECTRICAL ENGINEERING SCIENCE

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LIST OF SYMBOLS AND ABBREVIATIONS

μ_o	Absolute permeability of air
η	Efficiency
μ_r	Relative permeability
A	Ampere
A.C	Alternating Current
μ	Absolute Permeability
AT/m	Ampere Turn per meter
B	Flux Density
CIRA	Candidates' Items Response Analysis
cm	Centimetre
CSEE	Certificate of Secondary Education Examinations
D.C	Direct Current
E.M.F	Electromotive Force
H	Henry
Hz	Hertz
I_L	Line Current
kVA	kilo volts Ampere
L	Inductance
mA	Milliampere
ms	Millisecond
mWb	milliweber
NECTA	National Examinations Council of Tanzania
^oC	Degree Centigrade
p.f	Power Factor
S	Reluctance
V	Volt
V_L	Line Voltage
V_P	Phase Voltage
W	Watt
Ω	Ohm

FOREWORD

The Certificate of Secondary Education Examination (CSEE) is administered by the National Examinations Council of Tanzania (NECTA). It intends to show the effectiveness of the education system in particular as it is a summative evaluation of four years of instructional period of ordinary level of secondary education. The National Examinations Council of Tanzania is pleased to issue the Candidates' Item Response Analysis (CIRA) report in order to give feedback to prospective candidates, teachers, examiners and other education stakeholders on the general performance, specific areas of the candidates' weakness and recommendations for improvement.

The report is based on the analysis of responses from candidates' scripts and statistical data. The candidates' responses on each question have been analysed and some of the factors which contributed to the observed candidates' performance have been identified. The factors which led to the candidates' poor performance include the candidates' inability to interpret the requirements of the questions, failure to apply correct formulae in solving problems, English language barrier, and lack of enough knowledge and skills on various topics. These factors have been illustrated by using some extracts selected from the candidates' scripts.

The National Examinations Council of Tanzania hopes that the feedback provided in this report will be useful to education stakeholders, and that the suggestions and recommendations offered will enable them to take appropriate measures to enhance learning and teaching strategies of the Electrical Engineering Science subject.

The National Examinations Council of Tanzania would like to thank various education stakeholders who devoted their energy and time to provide important inputs that have been useful in preparing this report.

Dr Charles E. Msonde
EXECUTIVE SECRETARY

1.0 INTRODUCTION

This report analyses the items response of the candidates who sat for the 2021 Certificate of Secondary Education Examination (CSEE) in Electrical Engineering Science subject.

The paper comprised of sections A, B and C. Section A had one (1) multiple choice question with **10** items, (i) to (x). The items were set from the following topics: *Cathode Ray Tube, Effects of Electric Current, A.C Generator, Rectifiers, A.C Voltages, Electromagnetism, Nature of Electricity, Magnetism* and *Measuring Instruments*. The candidates were required to answer all the items from this section. Each item carried 1 mark, to make a total of **10 marks**.

Section B consisted of **nine** (**9**) short answer questions set from the topics *Conductor, insulators and cables, Electric heating, A.C Voltages, Electromagnetism, Magnetism and Electromagnetism, Nature of electricity, DC Machines, D.C machines, Transformers* and *Illumination*. The candidates were required to answer all the questions in this section. Each question carried **5 marks**, making a total of **45 marks.**

Section C consisted of **four** (**4**) structured questions set from the topics *Transformer, Three Phase Circuits, Measuring Instruments,* and *Magnetism and Electromagnetism*. The candidates were required to answer three questions from this section. Each question carried **15 marks**, making a total of **45 marks**.

A total of 433 candidates sat for the CSEE in the Electrical Engineering Science subject in the year 2021. Among them, 349 (80.60%) candidates passed while 84 (19.40%) candidates failed. Generally, the candidates' performance in this paper is good. In the year 2020, a total of 275 (79.02%) candidates passed while 73 (20.98%) failed. Therefore, the candidates' performance in the year 2021 has increased by 1.58 per cent.

The analysis of the candidate's performance in each question is categorized into three grade ranges as shown in Table 1.

Table 1: Grade Ranges of the Candidates' Performance

Range in %	0 – 29	30 – 64	65 – 100
Remark on performance	Weak	Average	Good

T

he report provides a detailed analysis of the candidates' response indicating the specific areas of strengths and weaknesses for a particular question. Charts and samples of good and weak responses from the candidates' scripts have been included to justify such responses. Moreover, *red*, *yellow* and *green* colours are used to represent weak, average and good performances respectively. The following section presents analysis of the candidates' performance in each question.

2.0 THE ANALYSIS OF THE CANDIDATES' RESPONSE ON EACH QUESTION

This part presents strengths and weaknesses of the candidates as they responded to each question.

2.1 SECTION A: OBJECTIVE QUESTIONS

2.1.1 Question 1: Multiple Choice Items.

The analysis of the candidates' responses to Question 1 is based on the 10 multiple-choice items; (i) to (x). The candidates were required to choose the correct answer from the given alternatives A to E and write its letter in the answer booklet provided.

A total of 433 (100%) candidates attempted this question. Among them 25 (5.5%) scored from 0 to 2 marks. The candidates who scored from 3 to 6 marks were 235 (54.3%). The remaining 174 (40.2%) candidates scored from 7 to 10 marks. The performance was good since 416 (95%) candidates passed. Most of them proved to have sufficient knowledge on the areas tested. The candidates' performance on this question is summarizes in Figure 1.

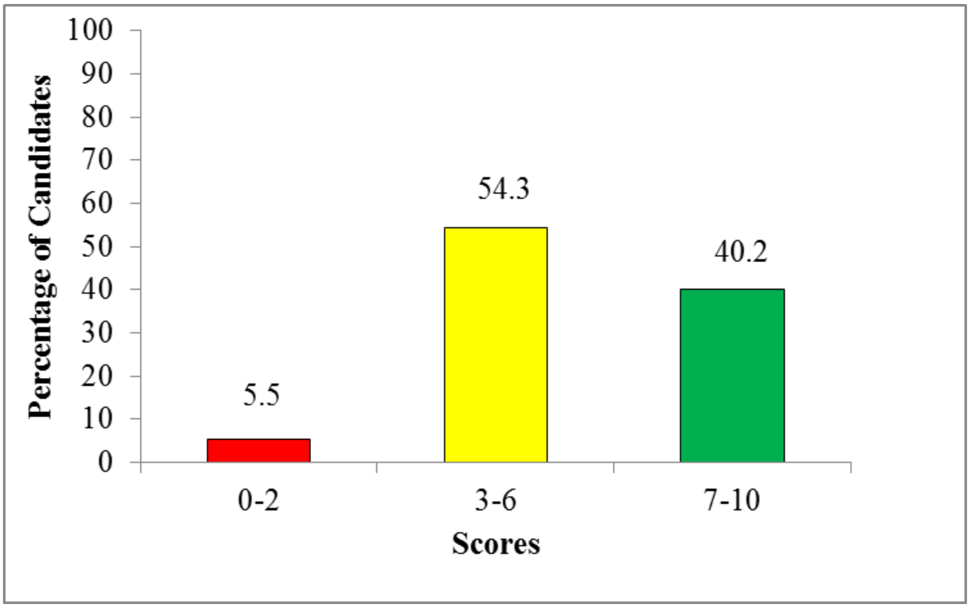


Figure 1: *The Candidates' Performance in Question 1*

The analysis of the candidates' response to this question shows that, most of the candidates chose the correct answer in items (ii), (iv) and (v) set from the topics *Effect of Electric Current*, *Rectifier,* and *Instruments and Measurements* respectively. This outcome suggests that the candidates acquired enough knowledge on the tested topics.

The analysis further shows that the average number of candidates responded correctly in items (vii), (viii), and (x) tested from the topics *Electromagnetisms*, *Nature of Electricity,* and *Instruments and Measurements* respectively. This performance shows that the candidates acquired partial knowledge on the tested concepts.

On the other hand, candidates had weak performance in items (i), *Cathode Ray Tube;* (iii), *A.C Generators*, and (ix) *Magnetism and Electromagnetism.* This suggested that the candidates lacked knowledge of the concepts tested from the prescribed topics.

The following is the analysis of the candidates' responses in each item for Question 1.

Item (i): *What is the name given to the two sets of deflection coils in the cathode ray tube?*

A *Scanning coils* *B* *Focussing coils* *C* *Electrostatic coils*
D *Brightness coils* *E* *Reflection coil*

The correct answer was **A**, *Scanning coils*. The candidates who identified the appropriate name were knowledgeable enough in the topic *Cathode Ray Tube*, especially the construction of cathode ray oscilloscope. Those who selected alternative B: *Focusing coils;* could not differentiate the role of scanning coils from focusing coils as both of them are found in the cathode ray tube. There were a few candidates who opted for alternative *C, Electrostatic coils.* These candidates had misconception with electrostatic deflection, which refers to as one of the methods of deflection commonly used in small cathode ray tubes. On the other hand, the candidates who selected option D, *Brightness coils,* lacked skills and knowledge on the construction of cathode ray oscilloscope because there is no such coils in the cathode ray tube. However, the candidates who opted for *E, Reflection coils,* had misconception between the concepts of reflection and deflection, thus incorrectly related deflection coils to reflection coils.

Item (ii): *Which of the following is the effect of electric current?*

A *Electrical effect* *B* *Mechanical effect* *C* *Heating effect*
D *Potential effect* *E* *Current effect*

Most of the candidates selected the correct alternative *C Heating effect*. A few candidates wrongly selected option A, *Electric effect* as they associated it with the term electric that appeared in the steam of the question. Other candidates chose alternatives D*, Potential effect* and *E, Current effect.* These candidates related the effects of electrical currents to the quantities of electric current which include potential and current. However, the minority who opted for alternative B*, Mechanical effect,* lacked knowledge of the tested concept.

Item (iii): *What is the term used to represent alternating current generators?*

A *Silent pole generators* *B* *Shielded pole generators*
C *Dynamometer* *D* *Alternators*
E *Dynamos*

This item was poorly performed, as a few candidates chose the correct response *D, Alternator*. The candidates who chose A, *Silent pole generator*, were tricked by the word *silent* which relates to word *salient* used to name one of the types of alternator (i.e. Salient pole alternator). For those who selected alternative B, *Shielded pole generator*, failed to understand that there is no such type of a generator; they transferred the knowledge of *a shaded-pole motor* which is also a type of a.c machines. The analysis also shows that candidates who opted for alternative C, *Dynamometer,* failed to realise that a dynamometer is not a generator rather a measuring device used to determine the torque, force, speed, and power required to operate the drive on electric machines. On the other hand, candidates who selected option E, *Dynamos*, had idea on generators, but they did forget that dynamo is an electrical generator that creates direct current using a commutator and not an A.C generator.

Item (iv): *What is the major function of a rectifier circuit in electrical devices?*

A To convert a.c to d.c
B To rectify d.c to a.c
C To change single phase to 3 phase
D To step up voltage and current
E To step up current

Most of the candidates correctly selected alternative A, *To convert a.c* to *d.c.* This shows that many candidates were knowledgeable on the area of *rectifiers*. A few candidates who selected alternative B, *To rectify d.c to a.c*, they reversed the correct function of rectifier which is to convert A.C to D.C. Others who selected alternative C, *To change single phase to 3 phase,* lacked knowledge of the function of rectifier. For those who selected the alternatives D, *To step up voltage and current* and E, *To step up current* also had little knowledge of rectifier because they selected options that relate to the functions of transformers instead of that of rectifiers.

Item (v): *How can the range of the voltmeter be extended?*

A By connecting a parallel resistor
B By connecting a shunt resistor
C By connecting a series resistor
D By connecting a low value resistor
E By connecting a load resistor

In this item, many candidates responded correctly by selecting alternative C, *By connecting a series resistor*. Some of them opted either A, *By connecting a parallel resistor*, B, *By connecting a shunt resistor*, D, *By connecting low value resistor* or E, *By connecting a load resistor*. These candidates lacked knowledge on the topic *Measurements and Instruments*. They easily misconceived among the alternatives because the extension of either an ammeter or a voltmeter is done by connecting resistance in parallel or in series to the meter respectively. It was possible for the candidates to retrieve the concept of converting an ammeter into voltmeter by connecting the high resistance in series with it. This uncertainty of the candidates led them to choose incorrect response.

Item (vi): *What will be the relationship between voltage and current when a.c voltage is applied across a pure resistor?*

A Voltage and current will be out of phase.

B Current will lead voltage by 90^o.

C Voltage will lead current by 90^o.

D Voltage and current will be in phase.

E Angle between voltage and current will be 90^o

The correct response was D, *Current and voltage will be in phase*. This item was performed poorly by most of the candidates, because they had insufficient knowledge on the topic *A.C circuit*, specifically the characteristics of the pure resistive circuits. For those who selected distractors A, *voltage and current will out of phase*, B, *Current will lead voltage* by 90^0, C, *Voltage will lead current by* 90^0 and E, *Angle between voltage and current will be* 90^0 failed to understand that in pure resistive circuit, the phase angle between voltage and current is zero which means voltage and current are in phase.

Item (vii): *Which laws are associated with electromagnetic induction?*

A Ohms' law and Faraday's law

B Faraday's law and Lenz's law

C Lenz's law and Newton's law

D Joule's law and Faraday's law

E Faraday's law and Kirchhoff's laws

The analysis shows that, candidates who selected the correct option B, *Faraday's law and Lenz's law* demonstrated their ability of integrating and relating the laws to their applications. Those who selected other alternatives A, *Ohm's law and Faraday's law*, C, *Lenz's law and Newton's law*, D, *Joule's law and Faraday's law* and E, *Faraday's law and Kirchhoff's law*, failed to categorize the fundamental laws of electricity and their applications.

Item (viii): *What is a characteristic of a material that is negatively charged?*

A Has more proton than electrons.

B Has more neutrons than electrons.

C Has more number of neutrons.

D Has more electrons than protons.

E Has equal number of protons and electrons.

Those who got the correct response D, *Has more electrons than protons*, had enough knowledge on the topic *Nature of Electricity*. The candidates who opted for distractor A, *Has more protons than electrons*, lacked knowledge of differentiating the positively charged materials and the negatively charged materials. For those who selected options B, *Has more neutrons than electrons* and C, *Has more number of electrons* did not understand that neutrons have no charge to be attracted by electrons. That means, it has a neutral (not positive or negative) charge. On the other hand, for those who selected option E, *Has equal number of electrons and protons* failed to understand that, if a material contains equal numbers of protons and electrons, it becomes electrically neutral.

Item (ix): *Which one is the basic requirement for an e.m.f to be induced in a coil?*

A The magnetic flux should link the coil.

B Current of the coil should be constant.

C The coil to be induced should form a loop.

D The flux density near the coil should be less

E The magnetic flux linking the coil should change.

The correct response was E, *the magnetic flux linking the coil should change*. Those who selected irrelevant responses A, *the magnetic flux should link the coil*, B, *Current of the coil should be constant*, C, *The coil to be induced should form a loop* and D, *The flux density near the coil* *should be less,* failed to recognise that, according to Faraday's law the necessary conditions for an electromagnetic induction is, the magnetic flux linking a coil or wire should change with respect to time. Thus, when a coil is kept in a changing magnetic flux, an electromotive force is induced in the coil and electric current is generated.

Item (x): *Why permanent magnet moving coil current ammeters have a uniform scale?*

A *It reduces eddy current damping.*

B *They have full deflection torque*

C *Its speed is constant.*

D *They are spring controlled*

E *Their deflection torque is equal to unit*

The item was averagely performed by most of the candidates. Many candidates could not select the correct response E, *Their deflection torque is equal to unit,* as they lacked knowledge and skills about measurements and instrumentation. Some of them selected option A, *It reduces eddy current damping.* These candidates had an idea that eddy current should be reduced in an ammeter, but failed to recognise that a uniform scale is just a set of levels or numbers used for measurement; therefore, it cannot be used to reduce the eddy current. Those who selected alternatives B, *They have full deflection torque* and C, *Its speed is constant,* just applied the terms related to measurements and instrumentation, particularly in permanent magnetic moving coil ammeter, which were actually incorrect. On the other hand, candidates who opted for incorrect alternative D, *They are spring controlled,* considered one of the advantages of using spring controlled method which is, “it has uniform scale”.

2.2 SECTION B: SHORT ANSWER QUESTIONS

2.2.1 Question 2: D.C Circuits

The question consisted of two parts namely (a) and (b), and was set as follows:

(a) Outline two necessary conditions to be considered when selecting a cable for a particular circuit.

(b) How is the resistance of the following materials affected by the increase in temperature?

(i) Conductor

(ii) Insulator

The question was attempted by 433 (100%) candidates, and their scores were as follows: 186 (43%) candidates scored from 0 to 1 mark; 145 (33.5%) scored from 1.5 to 3 marks and 102 (23.5%) candidates scored from 3.5 to 5 marks. The performance of the candidates on this question was average since 247 (57%) candidates passed. Figure 2 summarizes the candidates' performance.

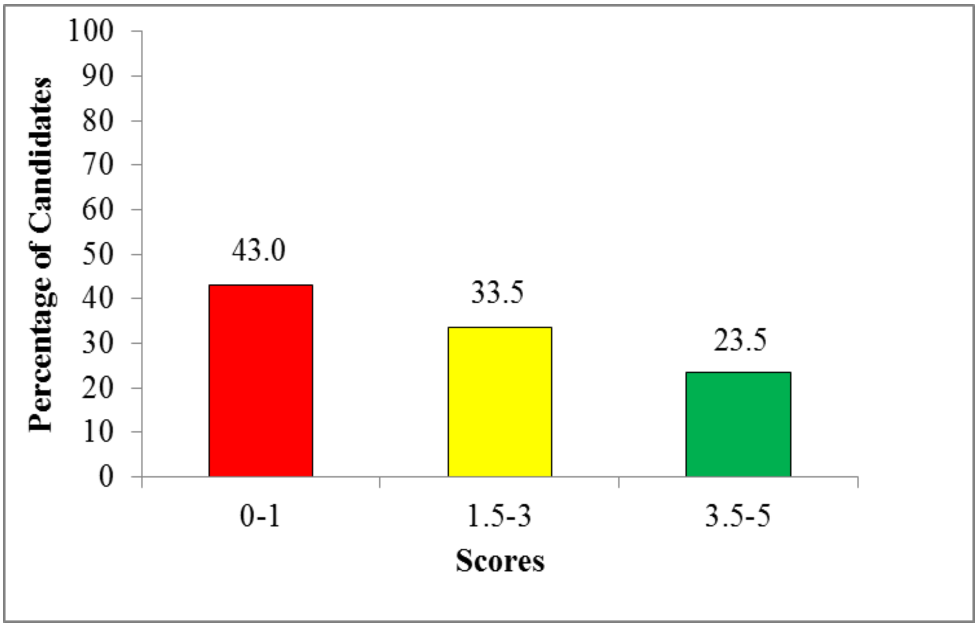
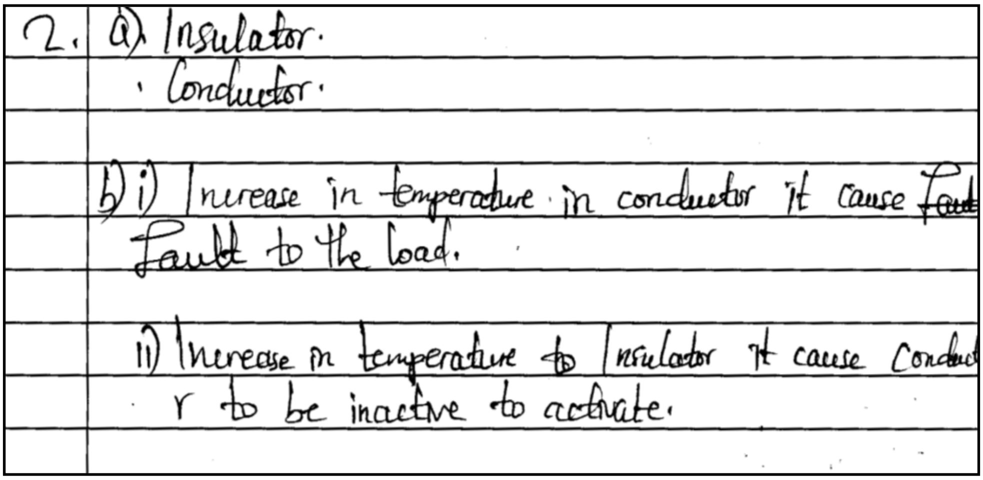


Figure 2*: The Candidates' Performance in Question 2*

The analysis of responses of the candidates shows that, 186 (43.0%) performed poorly, as they failed to give the correct response either in all parts of the question or managed to provide correct responses in less than two items. Most of them failed to adhere to the demands of the question and lacked knowledge of conductors, insulators, and cables. For example one of the candidates incorrectly responded part (a) by writing: (i) *Resistivity of a conductor/cable*, and (ii) *conductivity of a cable*. The candidate presented the factors to consider in determining electrical resistance of a conductor, which is contrary to the question requirements. In part (b) the candidate wrote the responses as: (i) *When the temperature is increased the resistance of the conductor it reduced or decreased*, and (ii) *The increase in temperature increases the conductivity while resistance became high.* This indicates that the candidate could not understand about the concept of temperature coefficient of resistance of the material. The analysis also shows that some of the candidates provided the physical properties of materials instead of necessary conditions to consider when selecting a cable as required in 2 (a). Another example of incorrect responses is illustrated in Extract 2.1.


2. a) Insulator.
· Conductor.

b) i) Increase in temperature in conductor it cause ~~Fault~~ Fault to the load.

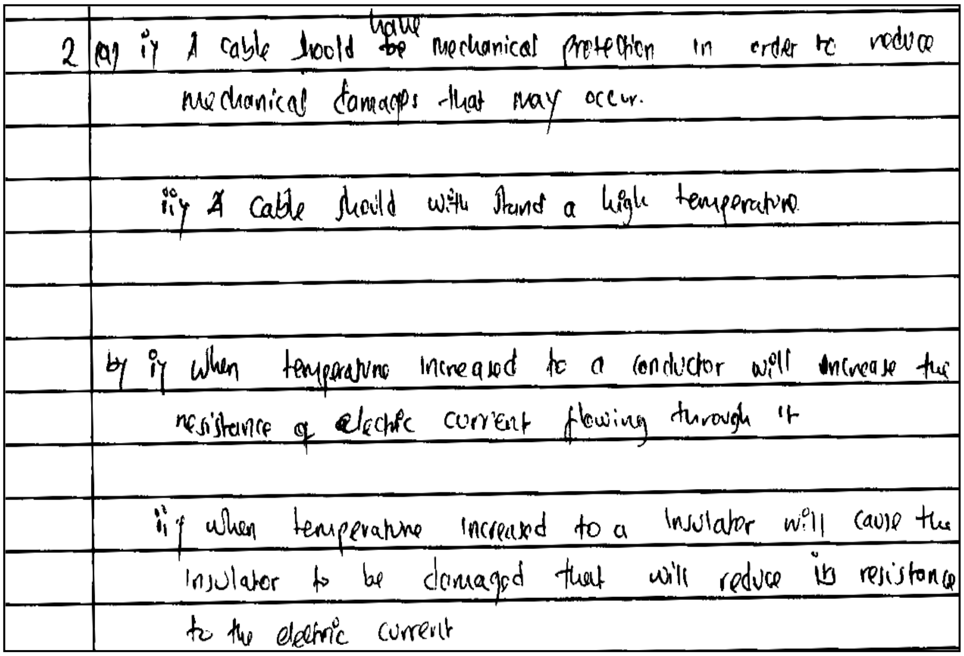
ii) Increase in temperature to Insulator it cause Conductor to be inactive to activate.

Extract 2.1: A sample of incorrect responses to Question 2

Extract 2.1 shows that the candidate copied the terms “insulator” and “conductor” from part 2 (b) (i) and (ii) of the question, and presented them as the responses to part 2 (a). The candidate also provided irrelevant answers in 2 (b).

Also there were 145 (33.5%) candidates who performed averagely. They provided correct responses to some parts of the question but failed the other parts. These candidates had partial knowledge of the concepts tested regarding D.C Circuits.

However, 247 (57.0%) candidates performed well because most of them managed to outline two necessary conditions to be considered when selecting a cable for a particular circuit. They also correctly described how the resistances of conductor and insulator materials are affected by the increase in temperature. Extract 2.2 shows a sample of correct responses from one of the candidates.



2 (a) i) A cable should have mechanical protection in order to reduce mechanical damages that may occur.

ii) A cable should with stand a high temperature

(b) i) when temperature increased to a conductor will increase the resistance of electric current flowing through it

ii) when temperature increased to a insulator will cause the insulator to be damaged that will reduce its resistance to the electric current

Extract 2.2*:* A sample of correct responses to Question 2

2.2.2 Question 3: Electric Heating

In this question, the candidates were asked to determine the value of resistance required to be connected in series with a 600 W kettle to cause voltage falling from 240 V to 220 V.

The question was attempted by 433 candidates. Among them, 138 (31.9%) candidates scored from 0 to 1 mark; 259 (59.8%) candidates scored from 1.5 to 3 marks and 36 (8.3%) candidates scored from 3.5 to 5 marks. Therefore, the candidates’ performance in this question was good because 295 (68.10%) candidates passed. Figure 3 summarizes the performance of the candidates in this question.

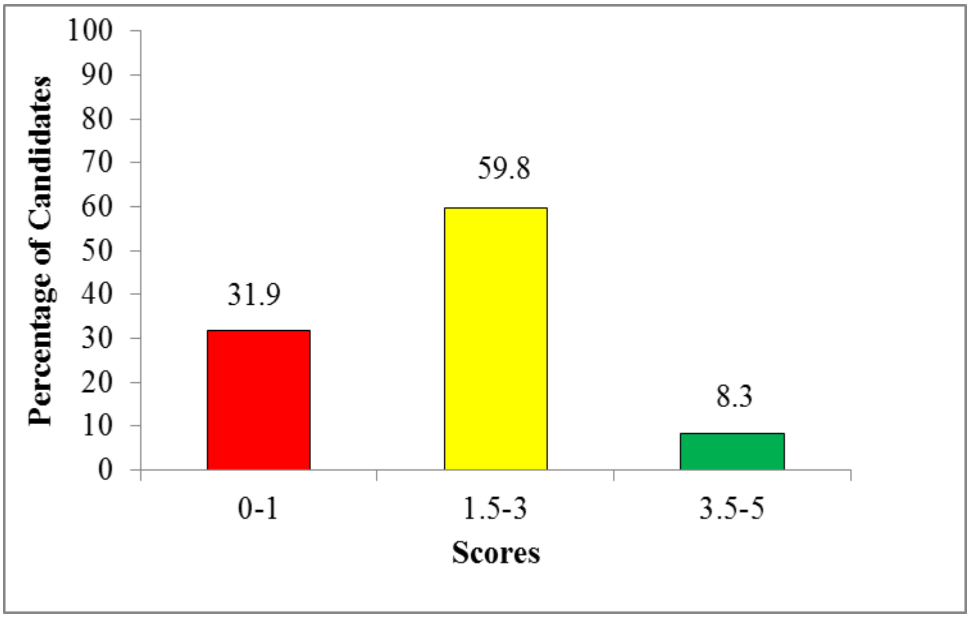
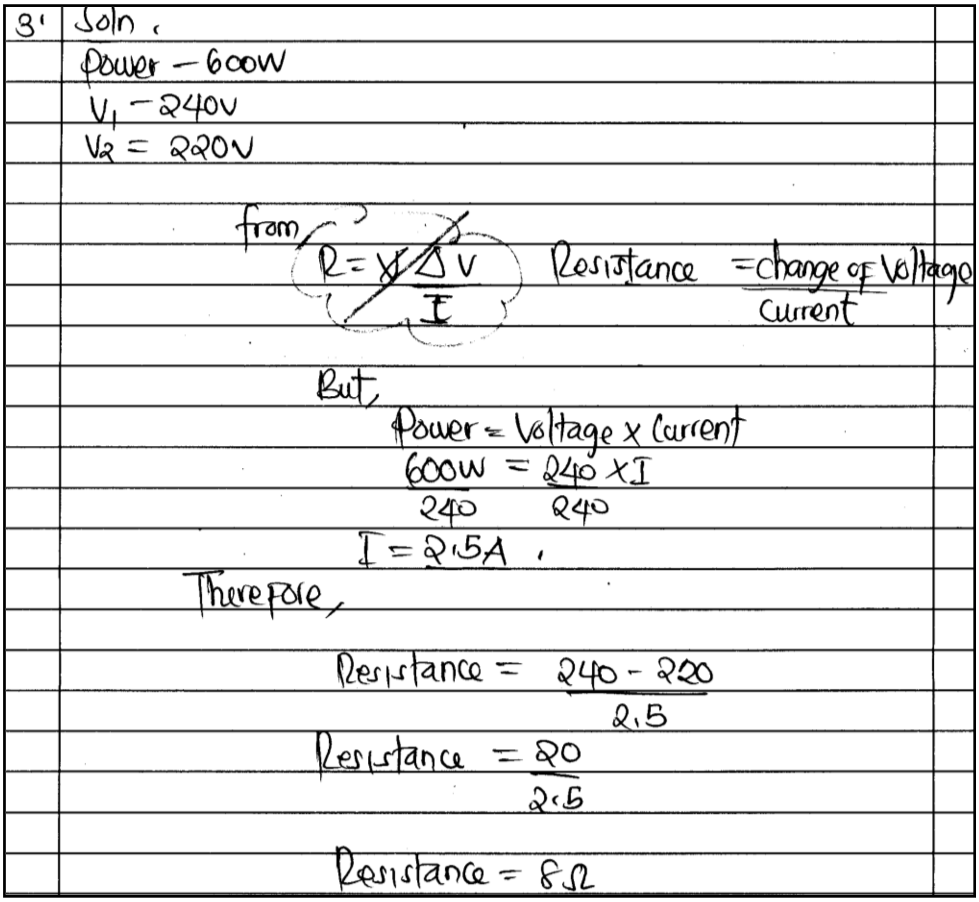


Figure 3: *The Candidates' Performance in Question 3*

The analysis of candidates' performance in this question indicates that most of the candidates demonstrated the ability to apply correct formula to determine the value of series resistance to be connected with an electric kettle element. They justified having sufficient knowledge on the tested concepts regarding Electric Heating. Extract 3.1 shows a sample of correct responses from one of the candidates.


3. Soln.

Power – 600W

V_1 – 240V

V_2 = 220V

from, ~~R = V/I~~ → $R = \frac{\Delta V}{I}$ Resistance = change of Voltage / Current

But,

Power = Voltage x Current

$\frac{600W}{240} = \frac{240 \times I}{240}$

I = 2.5A.

Therefore,

Resistance = $\frac{240 - 220}{2.5}$

Resistance = $\frac{20}{2.5}$

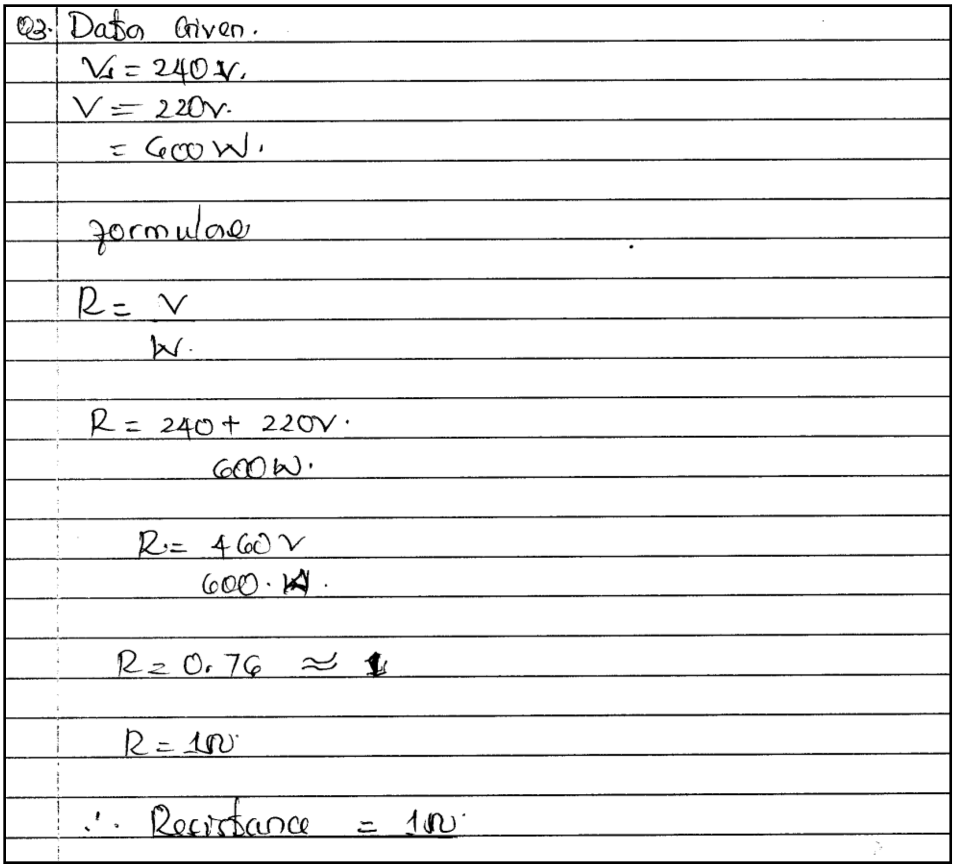
Resistance = 8Ω

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

Extract 3.1 shows that the candidate applied a correct formula to calculate the resistance to be connected in series with the electric kettle element when the voltage falls from 240 V to 220 V.

The statistical data shows that, there were 59.8 per cent of the candidates who performed averagely, since they responded to the question partially. Most of them managed to calculate the value of current, but failed to substitute it to the formula to obtain the required resistance.

The analysis further shows that 138 (31.9%) candidates, who scored low marks, had inadequate knowledge on the subtopic *Electric Heating*. They mainly failed to apply the correct relationship of the given quantities (power, voltage and resistance) to obtain the formula to calculate the value of series resistance. Some of the candidates divided the product of power and supply when the voltage falls by the supply voltage. The approach was actually incorrect. Extract 3.2 illustrates a sample of incorrect responses from one of the candidates.


Q3. Data Given.
$V_1 = 240V$.
$V = 220V$.
$= 600W$.

formulae

$R = \frac{V}{W}$.

$R = \frac{240 + 220V}{600W}$.

$R = \frac{460V}{600 \cdot W}$.

$R = 0.76 \approx 1$

$R = 1\Omega$

∴ Resistance $= 1\Omega$

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

In Extract 3.2, the candidate applied incorrect formula to calculate the value of series resistance to be connected when the supply voltage falls. The candidate’s inability to provide correct answers suggests that he/she lacked sufficient knowledge of electrical heating.

2.2.3 Question 4: A.C Voltages

The question required the candidates to give five reasons for electrical engineers to concentrate much on improving power factor of A.C circuit.

This question was attempted by 433 (100%) candidates, out of which 255 (58.9%) scored from 0 to 1 mark, 133 (30.7 %) scored from 1.5 to 3 marks; and 45 (10.4%) scored from 3.5 to 5 marks. Figure 4 summarizes the performance of the candidates on this question.

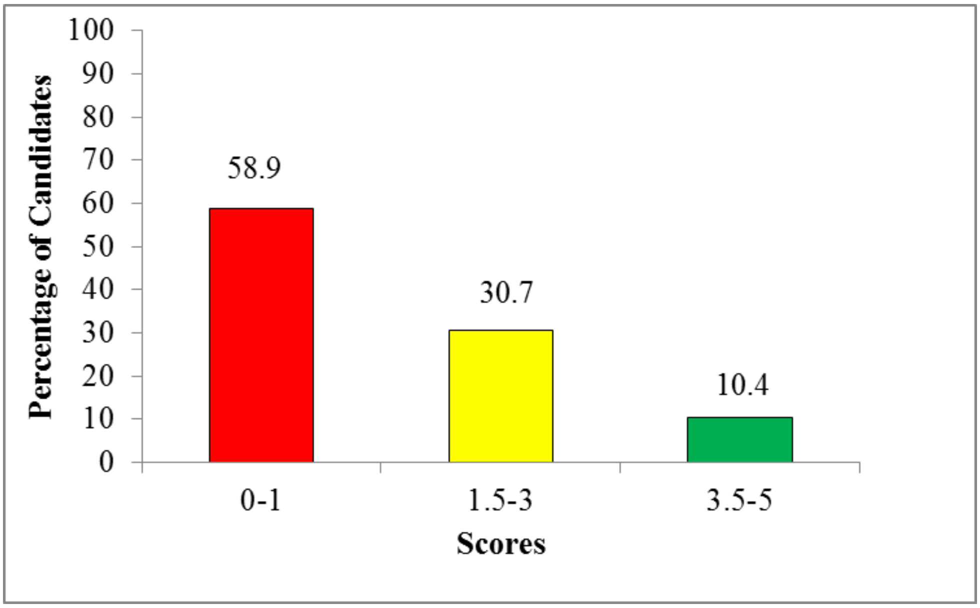


Figure 4: *The Candidates' Performance in Question 4*

The general performance of the candidate in this question was average, since 172 (41.1%) candidates passed by scoring from 1.5 to 5 marks. The candidates' average performance was due to the fact that most of them provided less than five reasons for engineers to concentrate much on improving power factor.

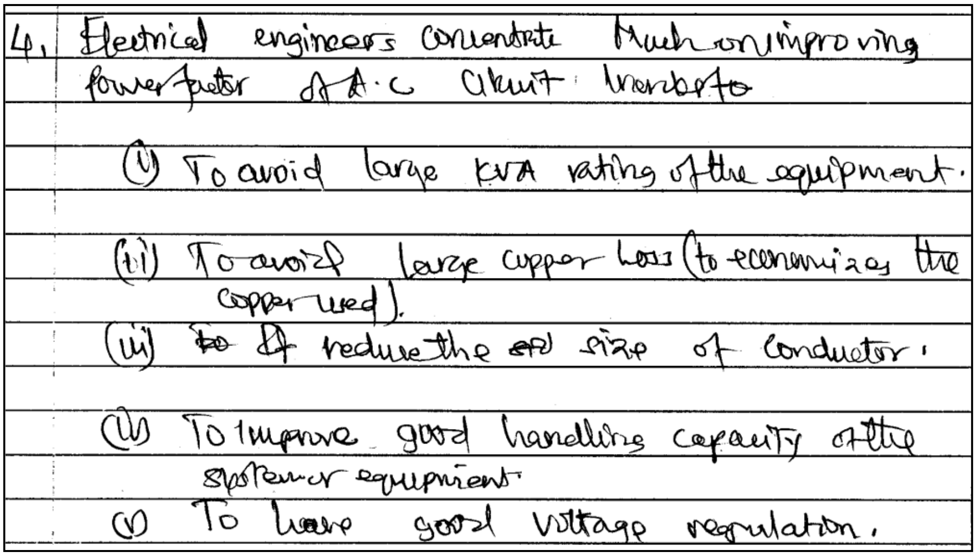
The analysis of candidates' responses shows that out of 58.9 per cent of the candidates who had weak performance, 39.7 per cent scored zero. Most of them failed to recognize the question demand and lacked knowledge of A.C voltage particularly the power factor correction. For example, one of the candidates provided irrelevant responses by writing; "(i) *in order to ensure the connections of the electrical wires", "(ii) in order to know the value of the electrical supply", "(iii) to ensure the supply of power in A.C circuit*" and *"(iv) to ensure the value of voltage produced*". Another example of an incorrect response is presented in Extract 4.1.

4.	i) Inorder to increase the efficiency of a circuit
	ii) Inorder to give greater output
	iii) low maintainir cost
	iv) to it Consumes low power
	v) Easy to ~~Req~~ Repair

Extract 4.1*:* A sample of incorrect responses to Question 4

Extract 4.1 shows that the candidate had misconception on the requirements of the question. Therefore, he/she provided the advantages of power factor instead of reasons for power factor correction.

On the other hand, the analysis shows that 178 (41.10%) candidates responded well to the question as they managed to provide five reasons of power factor improvement. This is an indication that the candidates under this group had a wide knowledge about A.C Voltages, particularly in the area of power factor correction. Extract 3.2 represents good responses from one of the candidates.


4. Electrical engineers concentrate much on improving power factor of A.C circuit inorder to

(i) To avoid large KVA rating of the equipment.

(ii) To avoid large copper loss (to economizes the copper used).

(iii) reduce the size of conductor.

(iv) To improve good handling capacity of the system or equipment

(v) To have good voltage regulation.

Extract 4.2: A sample of correct responses to Question 4

Extract 4.2 shows that the candidate gave five reasons for improving power factor correctly. The candidate manifested mastery of the concept of power factor correction.

2.2.4 Question 5: Electromagnetism

This question measured the candidates' ability to calculate some parameters related to electromagnetism. The question was as follows:

A flux of 25 mWb links with a 1500 turns coil when a current of 3A passes through the coil. Calculate:

(a) The inductance of the coil

(b) The energy stored in the magnetic field

(c) The average induced e.m.f if the current falls to zero in 150 ms

A total of 433 candidates attempted this question. Their scores were; 167 (38.6%) candidates scored from 0 to 1 mark; 102 (23.5%) candidates scored from 1.5 to 3 marks; and the rest 164 (37.9%) candidates scored from 3.5 to 5 marks. Figure 5 summarizes the candidates' performance in the question.

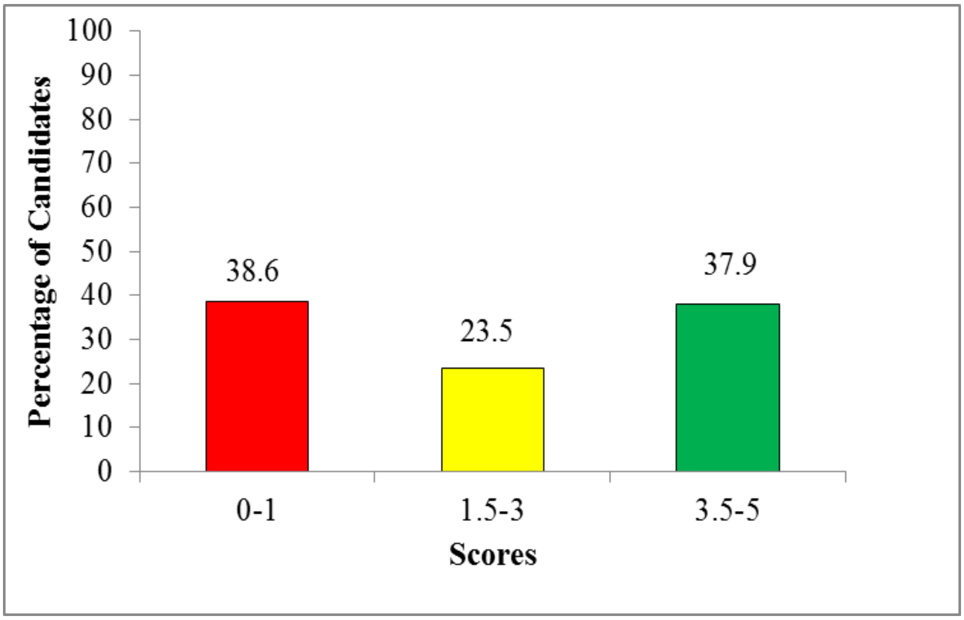


Figure 5: *The Candidates' Performance in Question 5*

Based on the analysis, the general performance in this question was average, since 266 (61.4%) candidates scored average marks and above. Most of the candidates provided correct responses in one or two parts of the question but failed on the other. The major challenge was the failure of the candidates to apply the correct formula to calculate the parameters as per question demand. However, 24.2 per cent of the candidates who scored full marks were able to provide correct responses in each part of the question. Extract 5.1 shows a sample of good responses from one of the candidates.

5 a. Data given.

b.

$L = \frac{N d\Phi}{dt}$

$L = \frac{1500 \times 25\times10^{-3}}{3}$

$L = 12.5$ H.

∴ Inductance of the coil is 12.5 Henry

Energy.

~~E =~~

$W = \frac{1}{2} L I^2$

$\frac{1}{2} \times 12.5 \times (3)^2$

$= 56.25$ J

∴ Energy stored is 56.25 J

$E = \frac{L dI}{dt}$

$\frac{12.5 \times 3}{150 \times 10^{-3}}$

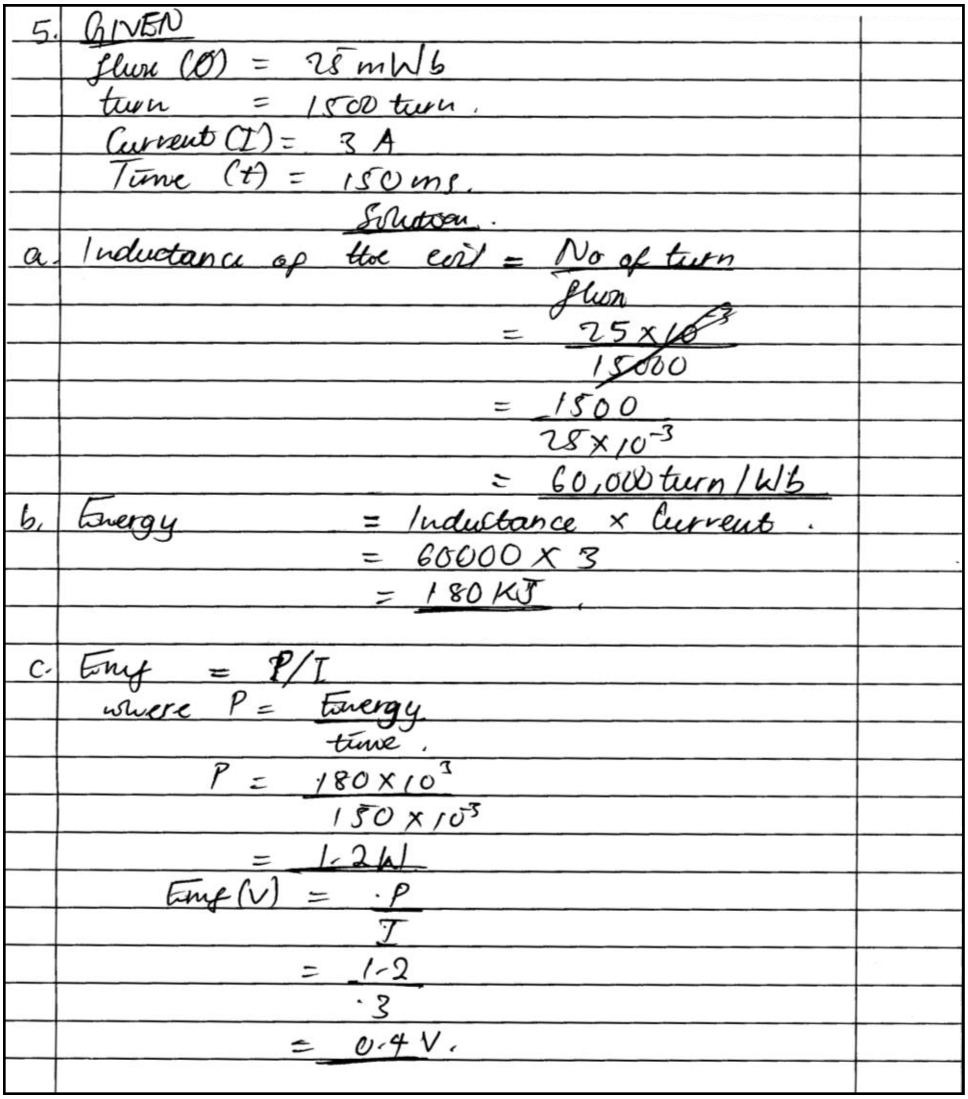
$= 250$ V

∴ Induced e.m.f is 250 V.

Extract 5.1: A sample of correct responses to Question 5

Extract 5.1 shows that the candidate applied the appropriate formulae to calculate inductance, energy stored in the magnetic field and average induced e.m.f as required in parts (a), (b), and (c).

Furthermore, the response analysis shows that there were 38.6 per cent of the candidates with weak performance. Most of them failed to apply the correct formula to calculate the parameters asked in each part of the question. For example, one candidate used incorrect formula in each part as follows: (a) Inductance (L) $=\left(\frac{\text{NI}}{\text{B}}\right)$, (b) Energy stored (E) $=\frac{1}{2}I^2N$ and, (c) Induced e.m.f average (e) $=\text{N}\left(\frac{\theta_2-\theta_1}{\text{t}}\right)$. This implies that the candidate lacked sufficient knowledge on the topic Electromagnetism. Extract 5.2 shows the poor response delivered by one of the candidates.


5. GIVEN
flux (Ø) = 25 mWb
turn = 1500 turn.
Current (I) = 3 A
Time (t) = 150 ms.
Solution.
a. Inductance of the coil = No of turn / flux
= $\frac{25\times10^{-3}}{1500}$
= $\frac{1500}{25\times10^{-3}}$
= 60,000 turn/Wb
b. Energy = Inductance × Current.
= 60000 × 3
= 180 KJ.
c. Emf = P/I
where P = Energy / time.
P = $\frac{180\times10^{3}}{150\times10^{-3}}$
= 1.2 W
Emf (V) = P / I
= $\frac{1.2}{3}$
= 0.4 V.

Extract 5.2: A sample of incorrect responses to Question 5

Based on Extract 5.2, the candidate used the formula which does not exist in electromagnetism as response to part (a). In part (b), the candidate used the formula for calculating magnetic flux instead of energy stored in the magnetic field. Likewise in (c) the candidate used the formula of calculating D.C electric power instead of average induced e.m.f. These responses led him/her to score zero.

2.2.5 Question 6: Magnetism and Electromagnetism

The question assessed the candidates' ability to determine the force on a current carrying conductor in a magnetic field and was set as follows:

A 70 cm long conductor carrying a current of 200 A lies perpendicular to the magnetic field strength of 3000 AT/m in air. If the conductor moves against this force, what will be the value of the following parameters?

Out of 433 candidates who sat for this paper, 326 (75.3%) candidates scored from 0 to 1 mark out of 5 marks allotted to this question. The analysis further shows that 29 (6.7%) candidates scored from 1.5 to 3 marks; and 78 (18.0%) candidates scored from 3.5 to 5 marks. The candidates' performance on this question was therefore weak because only 107 (24.7%) passed. Figure 6 shows the distribution of the candidates' scores in the question.

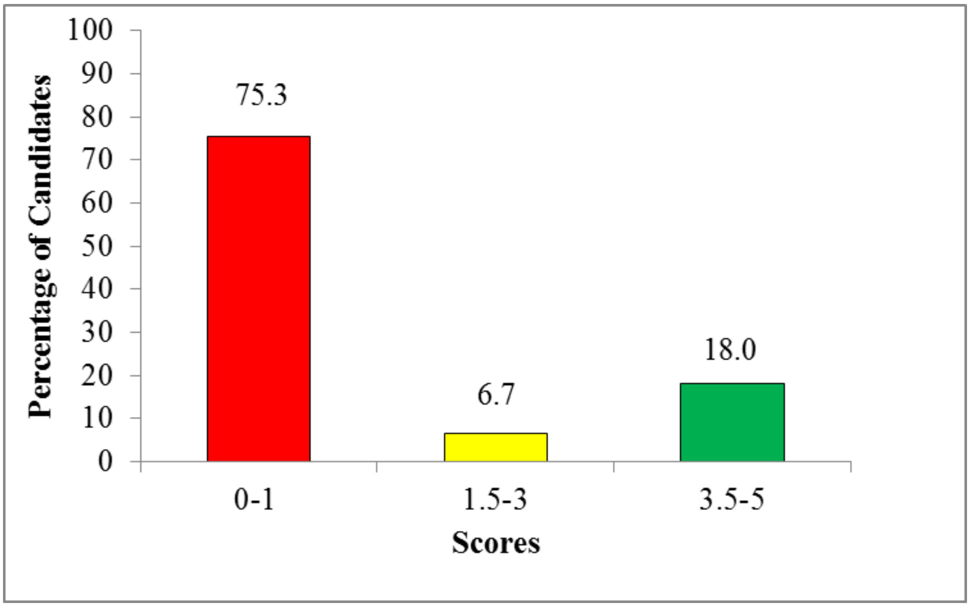
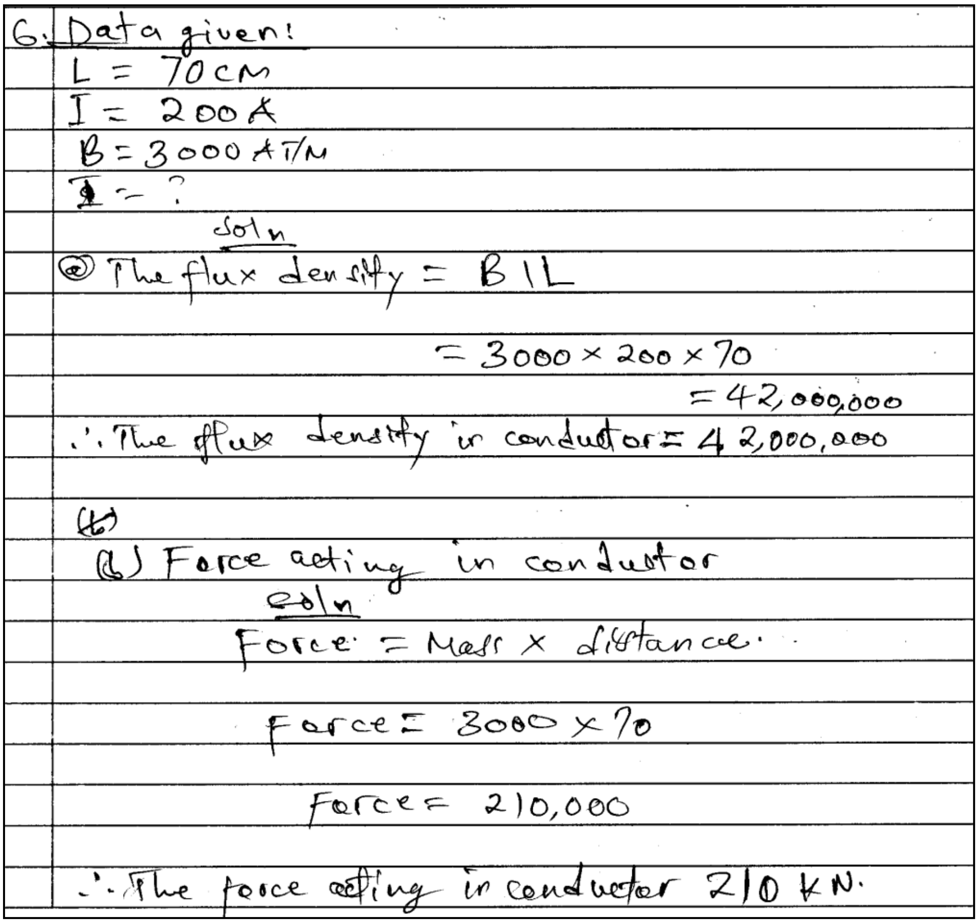


Figure 6: *The Candidates' Performance in Question 6*

The analysis of the candidate's responses shows that some of the candidates were unable to use the expression of magnitude of the force on current carrying conductor which is F=BIL to calculate the force on a current carrying conductor in a magnetic field (where, F= force; B = magnetic flux density; I = current and L = length). Another challenge observed was incorrectness of response in the first item that leads to wrong responses in the subsequent items. The wrong responses indicate that the candidates had inadequate knowledge of the concepts tested on the topic Magnetism and Electromagnetism. Extract 6.1 presents a sample of poor responses from one of the candidates.


6. Data given:
L = 70 CM
I = 200 A
B = 3000 AT/M
I = ?
Soln
(a) The flux density = BIL
= 3000 × 200 × 70
= 42,000,000
∴ The flux density in conductor = 42,000,000
(b)
(b) Force acting in conductor
soln
Force = Mass × distance.
Force = 3000 × 70
Force = 210,000
∴ The force acting in conductor 210 KN.

Extract 6.1*:* A sample of incorrect responses to Question 6

Based on Extract 6.1, the candidate wrongly applied the formula of force acting on the conductor (F=BIL) to calculate the flux density in part (a). In part (b), the candidate used irrelevant formula to calculate the force acting in the conductor. The responses show that the candidate lacked enough knowledge in the topic Magnetism and Electromagnetism, particularly in application of various formulae associated with the tested concepts.

However, out of 107 (24.7%) candidates who attempted the question well, 14.10 per cent responded correctly to all parts, whereas the rest were able to provide correct responses in either part (a) or (b). These candidates acquired sufficient knowledge of the concepts tested on Magnetism and Electromagnetisms especially in the subtopic e.m.f induced by a conductor. Extract 6.2 shows a sample of correct responses to the question.

6 DATA GIVEN

$l = 70cm$

$I = 200A$

$H = 3000\ AT/m$

(a) From,

$B = \mu_o \mu_r H$

$B = 4\pi \times 10^{-7} \times 1 \times 3000$

$B = 0.00376\ wb/m^2$

$\therefore$ Flux density $= 0.00376\ wb/m^2$

(b) $F = BIL$

$F = 0.00376 \times 200 \times 70 \times 10^{-2}$

$F = 0.52N$

$\therefore$ Force acting on conductor is $0.52N$

Extract 6.2*:* A sample of correct responses to Question 6

In Extract 6.2, the candidate correctly applied the formula of calculating flux density in a conductor and the force acting in the conductor as asked in parts (a) and (b).

2.2.6 Question 7: Nature of Electricity

The question had two parts (a) and (b) and was set as follows:

(a) What does it imply when a material is said to have positive temperature coefficient?

(b) A coil has a resistance of 10 Ω when its mean temperature is 20ºC and it is 20 Ω when its mean temperature is 50 ºC. Find the temperature coefficient of the coil at 0ºC.

This question was attempted by 433 candidates. Out of them 223 (51.5 %) candidates scored from 0 to 1 mark, 149 (34.4%) scored 1.5 to 3 marks and 61 (14.1%) scored from 3.5 to 5 marks. This trend of performance verifies that the average number (48.5%) of the candidates had good performance. Figure 7 illustrates the candidates' performance.

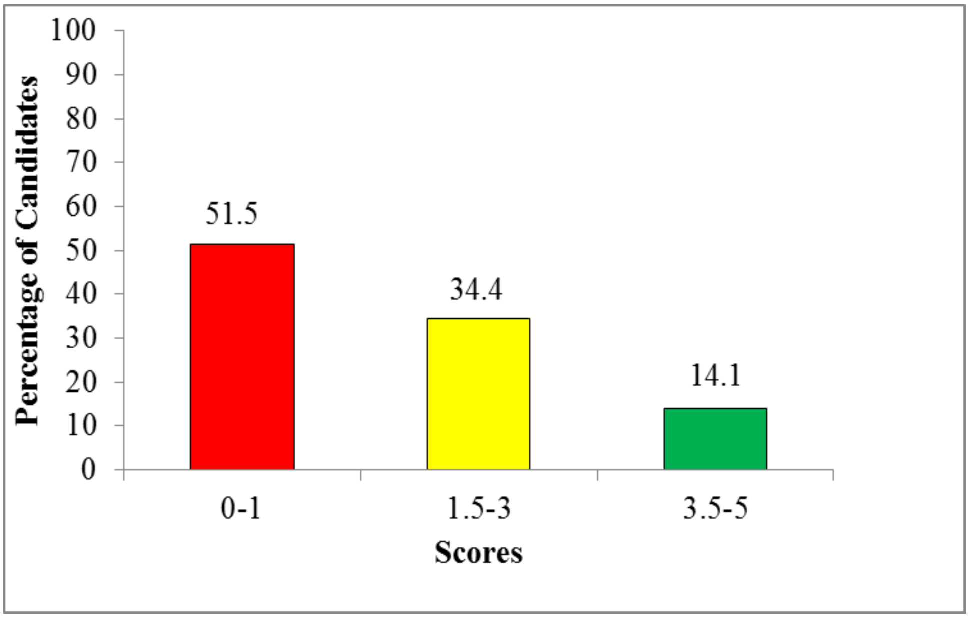


Figure 7: *The Candidates' Performance in Question 7*

Despite of the average performance of this question, there were 51.5 per cent of the candidates who had weak performance. Some of them failed to provide the meaning of a positive temperature coefficient and wrongly calculated the temperature coefficient of the coil. The following are the irrelevant responses provided by one of the candidates:

(a) When material have positive temperature coefficient this implies that material have high capability of a resistance in a circuit

(b) $\alpha_{\circ} = \frac{R_2 - R_1}{R_1} \times \frac{1}{\theta_2 - \theta_0}$

$\alpha_{\circ} = \frac{20\text{-}15}{18} \times \frac{1}{50 - 0°}$

$\alpha_{\circ} = \frac{2}{18 \times 50} = \frac{2}{900}$

$\alpha_{\circ} = 0.0022\ C^{-1}$

∴ *The temperature coefficient at 0°C is 0.0022C^{-1}*

The candidate's response shows that he/she lacked knowledge on concepts of temperature coefficient of the material which includes calculations. Another example of incorrect response to the question is shown in Extract 7.1.

7a. The material said to be positive temprature coefficient the material must have positive charge and low resistivity.

b. Given
R1 = 18Ω
T1 = 20°C
R2 = 20Ω
T2 = 50°C
R.T.C = ∝o

Solution

R1 = 1+∝ (t2 − t1)
R2 = 1+∝ (t2 − t1)

R1 (1+∝(t2 − t1)) / R2(1 (t2 − t1)) = R2 (1+∝(t2 − t1)) / R2 (1 (t2 − t1))

∝ = R1 (1(t2 − t1)) / R2 (1 (t2 − t1))

= 18 (1 (50 − 20)) / 20 (1 (50 − 20))

= 18 (1 (30)) / 20 (1 (30))

Extract 7.1*:* A sample of incorrect responses to Question 7

Extract 7.1 shows that the candidate gave the nature of the material instead of behavior of the material when it is subjected to temperature. Also the candidate reversed the formula for calculating the temperature coefficient of the coil at 0ºC.

However, 210 (48.5%) candidates performed well, because they scored average and above marks. Most of them provided correct responses in both parts of the question. This indicates that the candidates had acquired sufficient knowledge on the concept of temperature coefficient of the material. Extract 7.2 shows a sample of good responses from one of the candidates.

07 (a) A material is said to have positive temperature coefficient, This implies that, A material increases it's resistance when temperature rise and its viceversa. ie. resistance of material varies proportional with temperature.

(b) solution

Data given

Resistance $(R_1) = 18\Omega$

Temperature $(\theta_1) = 20^\circ C$

Resistance $(R_2) = 20\Omega$

Temperature $(\theta_2) = 50^\circ C$:

Required,

Temperature coefficient (α)

From,

$$\frac{R_1}{R_2} = \frac{\alpha\theta_1 + 1}{\alpha\theta_2 + 1}$$

$$\frac{18}{20} = \frac{\alpha \times 20 + 1}{\alpha \times 50 + 1}$$

$$\frac{18}{20} = \frac{20\alpha + 1}{50\alpha + 1}$$

$$18(50\alpha + 1) = 20(20\alpha + 1)$$

$$900\alpha + 18 = 400\alpha + 20$$

$$900\alpha - 400\alpha = 20 - 18$$

$$500\alpha = 2$$

$$\alpha = \frac{2}{500}$$

$$\alpha = 4 \times 10^{-3} /\Omega.$$

∴ The temperature coefficient at 0°C of the coil is $4 \times 10^{-3} /\Omega$.

Extract 7.2*:* A sample of correct responses to Question 7

Extract 7.2 shows that the candidate managed to explain the meaning of a positive temperature coefficient and correctly applied the appropriate formula to find the temperature coefficient of the coil.

2.2.7 Question 8: D.C Machines

The question had three parts namely (a), (b) and (c). It was asked as follows:

(a) Give the meaning of the term "armature reaction" as applied in D.C machines.

(b) Why ammeter reaction is not suitable on d.c machine? Give two reasons.

(c) Why is it not recommended for the d.c series motor to be switched ON at no load?

There were 433 candidates attempted this question, out of whom 298 (68.8%) candidates scored from 0 to 1 mark; 81 (18.7%) scored from 1.5 to 3 marks. Furthermore, the analysis shows that 54 (12.5%) candidates scored from 3.5 to 5 marks. Figure 8 summarises the performance of the candidates in Question 8.

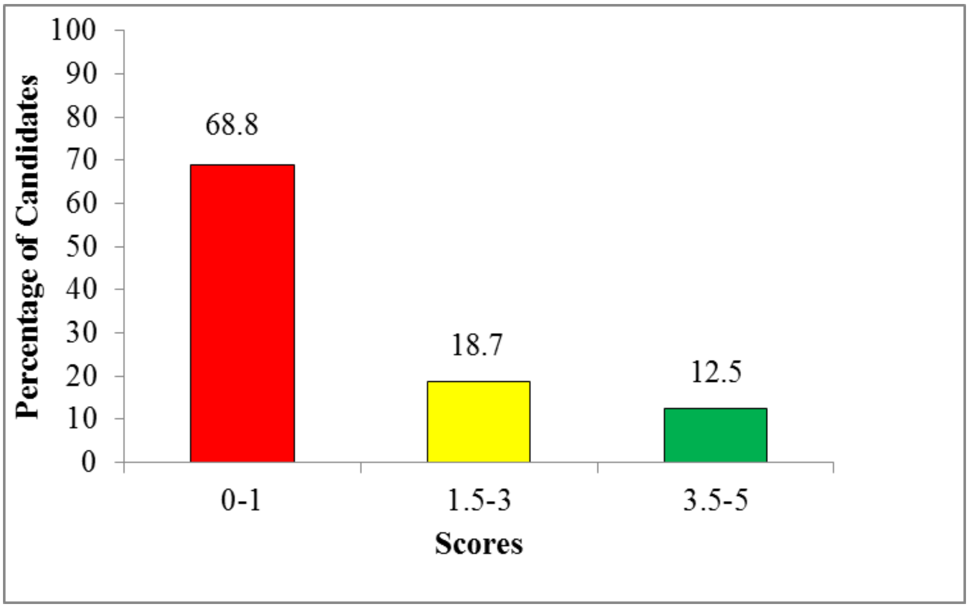
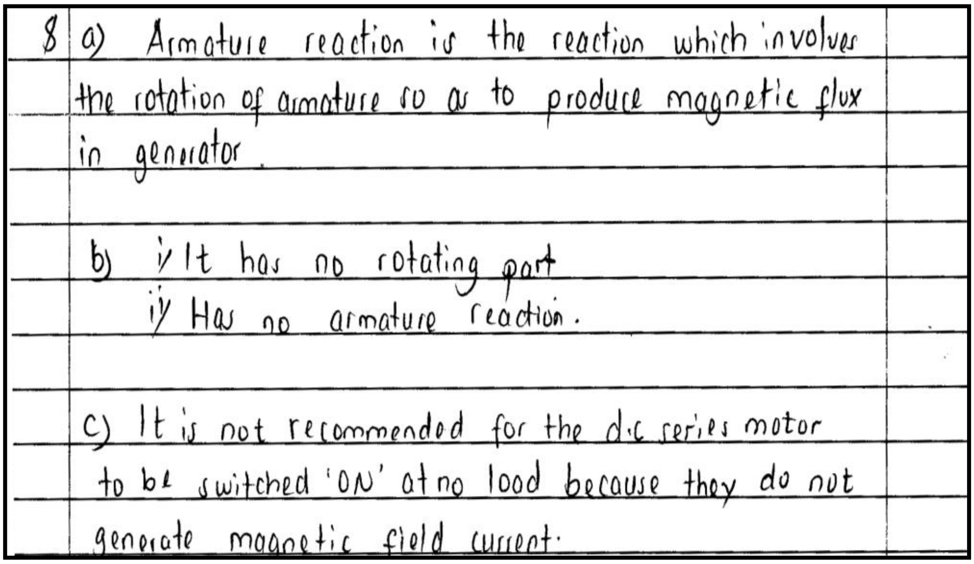


Figure 8: *The Candidates' Performance in Question 8*

Figure 8 shows that although the average number of the candidates performed well, there were 68.8 per cent who had weak performance. Most of them could not provide correct responses in more than two parts of the question while others provided irrelevant responses in all parts. For example, one of the candidates attempted only part (a) and (b) and still provided incorrect responses as follows. (a) *Armature reaction is the type of motion which takes place of the armature and causes drop in the armature, part (b) (i) leads to potential different or voltage drop in the circuit (b) (ii) reduces efficiency of the current.* The candidates under this category lacked knowledge on D.C Machine. Extract 8.1 presents a sample of poor candidate's responses.


8 a) Armature reaction is the reaction which involves the rotation of armature so as to produce magnetic flux in generator.

b) i) It has no rotating part
ii) Has no armature reaction.

c) It is not recommended for the d.c series motor to be switched 'ON' at no lood because they do not generate magnetic field current.

Extract 8.1*:* A sample of incorrect responses to Question 8

In Extract 8.1, the candidate provided irrelevant responses in parts (a) and (c). In part (b), the candidate outlined some advantages of transformer instead of the reasons for armature reaction to be used in D.C machines.

Another sample of an incorrect response is illustrated in Extract 8.2.

8. (a)

Armature

Is the connected of a motor supply which the impedance

which the supported to which connected

b) ammeter machine is not suitable on d.c machine

is the supported of controlling power of voltage which

the connected to control electrical shock.

- can be represented to control machine is the collect

of electric shock or collect of electric accessories.

C) why is it not recommended for

d.c series motor to be switched on at no load.

d.c. series - is the support can also the cont consum to no

in part of solve connected to home of which the

electrical of motor, or of transformer.

on ON no Load

that ON is contro power of voltage is no depend

to that because to supply of power to the

sommol super of switch of the sockets.

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

Extract 8.2 indicate that the candidate lacked knowledge of the concepts under D.C machines. This candidate could not understand what the question required due to his/her poor understanding of the English language. He/she therefore ended up providing irrelevant responses.

On the other hand, the analysis shows that 135 (31.2%) of the candidates performed well as they provided the reasonable responses to each part of the question. This shows that the candidates assimilated sufficient knowledge of D.C Machines, particularly in D.C generator. Extract 8.3 presents a sample of good responses from one of the candidates.

8. a) Armature reaction is the distortion of the main field by the field due to the Current flowing through the armature conductors.

b) ~~Ammeter~~ Armature reaction is not suitable on d.C machine because:-
i. It demagnetises / weakens the main flux.
ii. It distort the main field.

c) It is not recommended for the d.C series motor to be switched ON at no load, because has high poor starting torque hence it is speed dangerously high on starting.

Extract 8.3*:* A sample of good responses to Question 8

2.2.8 Question 9: Transformer

The question was as follows: *A load of 30 KVA at unity power factor is used to supply primary voltage of 3300 V. if the step down transformer ratio is 15:1; Calculate:*
(a) Secondary voltage.
(b) Primary current.
(c) Secondary current.

A total of 433 (100%) candidates attempted this question. The performance analysis of this question indicates that 49 (11.3%) candidates scored from 0 to 1 mark; 57 (13.2%) scored from 1.5 to 3 marks; and 327 (75.5%) candidates scored from 3.5 to 5 marks. The candidates' performance in this question was good. Figure 9 summarizes the candidates' performance in this question.

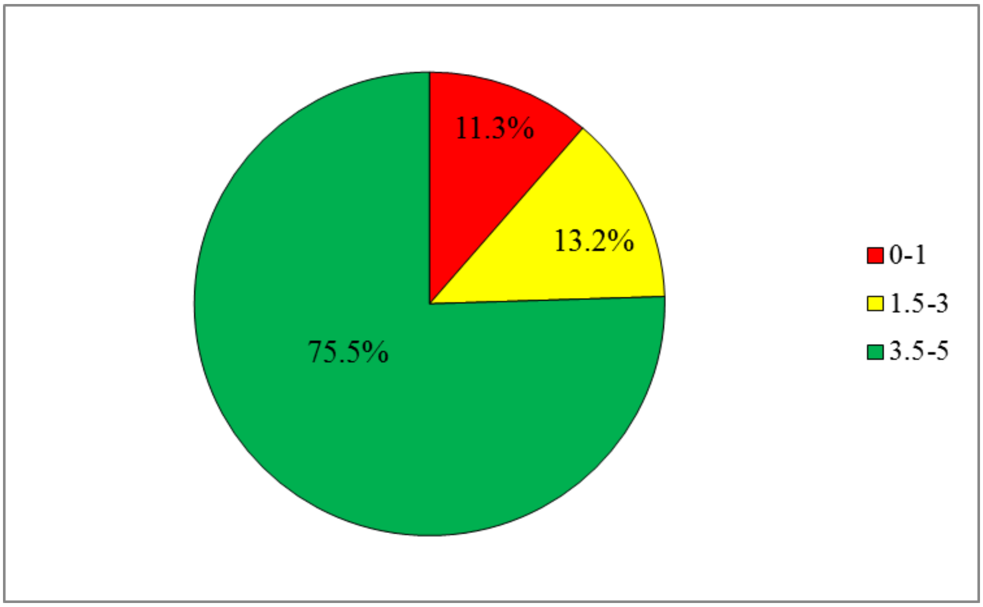


Figure 9*: The Candidates' Performance in Question 9*

The analysis of the candidates' response in Figure 9 reveals that most of the candidates had sufficient knowledge on the topic *Transformer*. They applied the correct formula to calculate secondary voltage, primary current, and secondary current. Extract 9.1 is a sample of correct responses by one of the candidates.

09. Data provided

$P = 30KVA$

$P.f = 1$

$V_p = 3300V$

$K = 15:1$

From

$$K = \frac{V_p}{V_s}$$

(a) secondary voltage

$$\frac{15}{1} = \frac{3300V}{V_s}$$

$$\frac{15V_s}{15} = \frac{3300V}{15}$$

$$V_s = 220V$$

∴ The secondary voltage is 220V

(b) Primary current

From

$$P = VI$$

$$\frac{30KVA}{3300V} = \frac{3300V \times I}{3300V}$$

$$I = 9.09A$$

∴ The primary current is 9.09 A

(c) Secondary current

From

$$\frac{V_p}{V_s} = \frac{I_s}{I_p}$$

$$\frac{3300V}{220V} = \frac{I_s}{9.09}$$

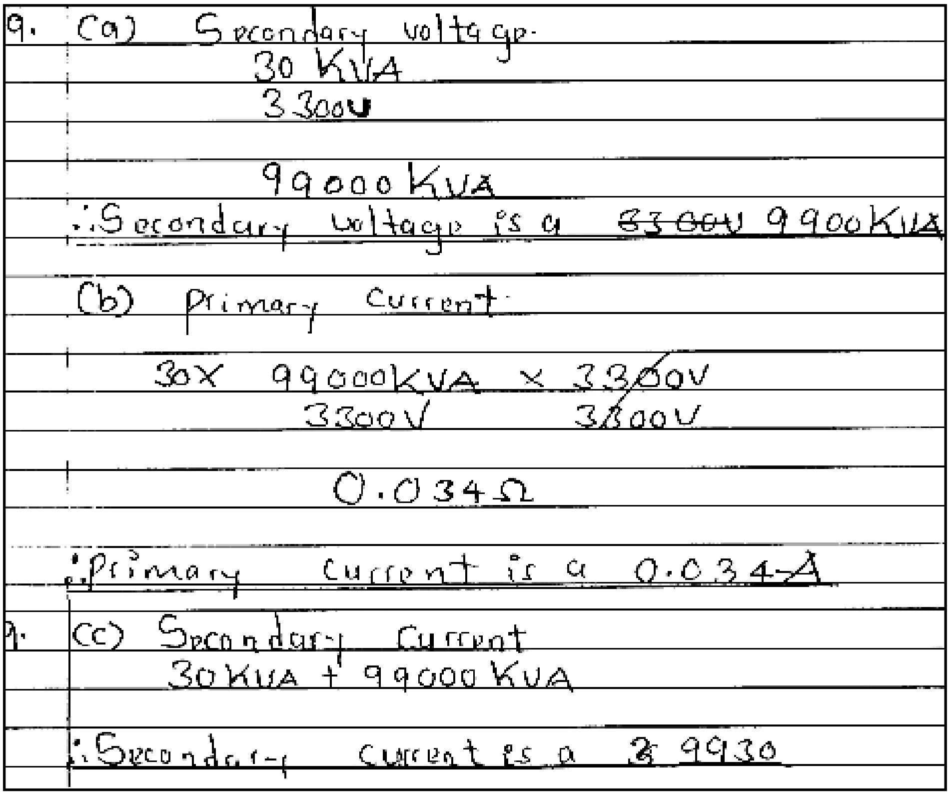
$$I_s = 136.36$$

∴ The secondary current is 136.36 A

Extract 9.1: A sample of good responses to Question 9

In Extract 9.1, the candidate correctly used appropriate formulae and made proper substitution to calculate the required parameters. This candidate had sufficient knowledge in the topic *Transformer*.

Despite the good performance of the candidates in this question, there were 11.3 per cent of them who scored low marks, because they applied incorrect formula to calculate the values of the required parameters. For example, one of the candidates divided voltage by load in order to calculate the secondary voltage as required in part (a). In part (b), the candidate divided load by transformer ratio to calculate the primary current. Likewise in (c), the candidate calculated the secondary current by multiplying load and voltage. Extract 9.2 is another sample of incorrect response from one of the candidates.



9. (a) Secondary voltage.
30 KVA
3300V

99000 KVA
∴ Secondary voltage is a ~~3300V~~ 9900KVA

(b) Primary current.
30 × 99000KVA × 3300V / 3300V / 3300V

0.034Ω

∴ Primary current is a 0.034A

9. (c) Secondary current
30KVA + 99000 KVA

∴ Secondary current is a 99030

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

In Extract 9.2, the candidate just multiplied apparent power by primary voltage $(30\ \text{kVA} \times 3300\ \text{V})$ as the response in part (a). He/she also used the wrong formula in (b) to calculate primary current. Finally the candidate added the apparent power to the wrong value of secondary voltage he/she obtained in (a). The entire candidate's procedure was incorrect that led him/her to wrong answer. The candidate was incompetent in performing calculation related to transformer.

2.2.9 Question 10: Illumination

The question had two parts namely part (a) and (b). It was set as follows:

(a) A lamp rated 230 V gives an illumination of 6000 lux and takes 1.5 A from the mains. Calculate the efficiency of the lamp.

(b) A school electrical technician wants to fix fluorescent lamps in a new classroom. He decided to use startles method in starting the lamps. Why does the technician decided to use startles method? Give two reasons.

A total of 433 (100%) candidates attempted this question, whereby 179 (41.4%) candidates scored from 0 to 1 mark; 250 (57.7%) scored from 1.5 to 3.0 marks and 4 (0.9%) scored 3.5 marks. The candidates' performance in this question was average since 254 (58.6%) of them passed by scoring from 1.5 to 3.5 marks. Table 2 presents the performance of the candidates in this question.

Table 2: The Candidates' Performance in Question 10

Scores	Number of Candidates	Percentage (%)	Remarks
0-1	179	41.4	Weak
1.5-3	250	57.7	Average
3.5	4	0.9	Good
Total	**433**	**100**	

The average performance of the candidates in this question was due to the fact that, most of them (57.7%) managed to provide correct responses to one part of the question but failed the other part. These candidates had partial knowledge of the concepts tested on the topic *Illumination*.

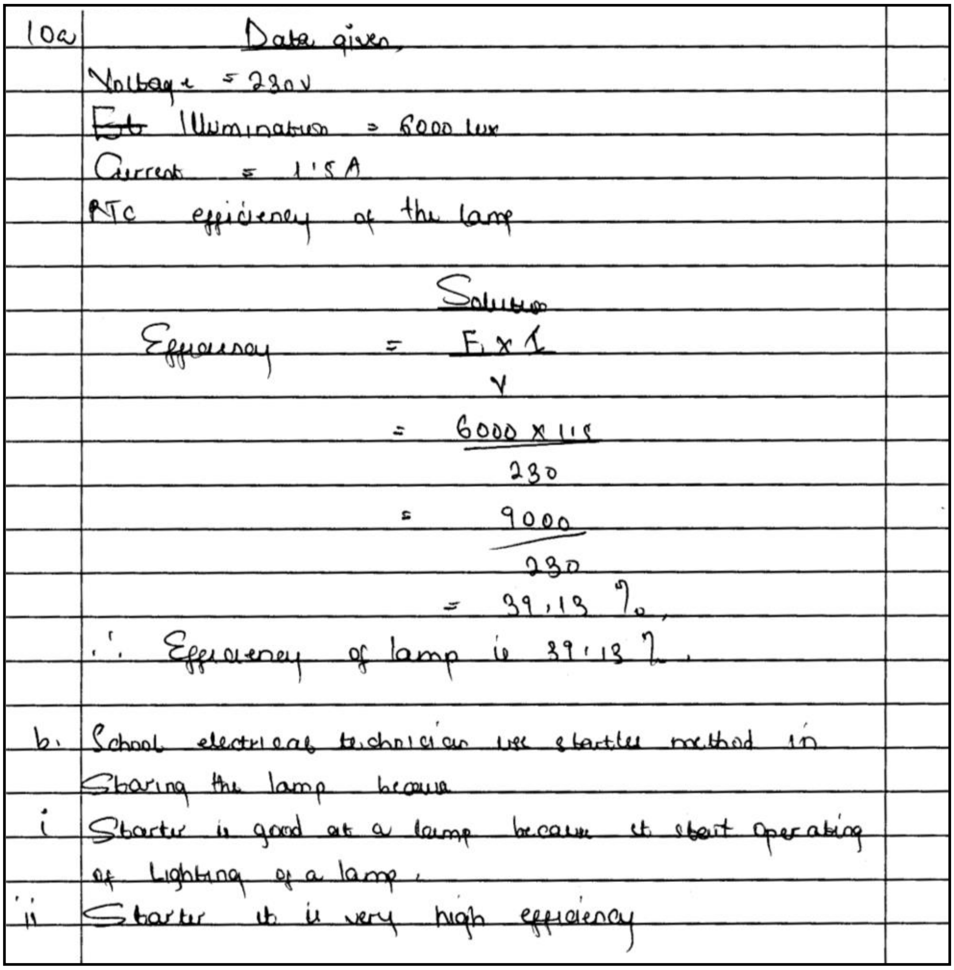
Despite the average performance of the candidates, there were 41.4 per cent of the candidates who had low scores. They failed to use appropriate formula to calculate the efficiency of the lamp. Also most of the candidates either could not provide the reasons for using startles method or provided only one reason instead of two reasons of using startles method. For example, one candidate provided incorrect response as:

(a) Efficiency= $\frac{\text{Lamp Voltage} \times \text{Illumination}}{\text{Ilumination}}$.

(b) *(i)* *The startles method is a simplest method that in starting fluorescent lamp in classroom.*

(ii) *The startles method does not have many effect then other methods.*

This candidate lacked knowledge and skills on the area of Illumination. Extract 10.1 shows a sample of incorrect responses from one of the candidates.


10a Data given
Voltage = 230V
~~Et~~ Illumination = 6000 lux
Current = 1.5A
RTC efficiency of the lamp

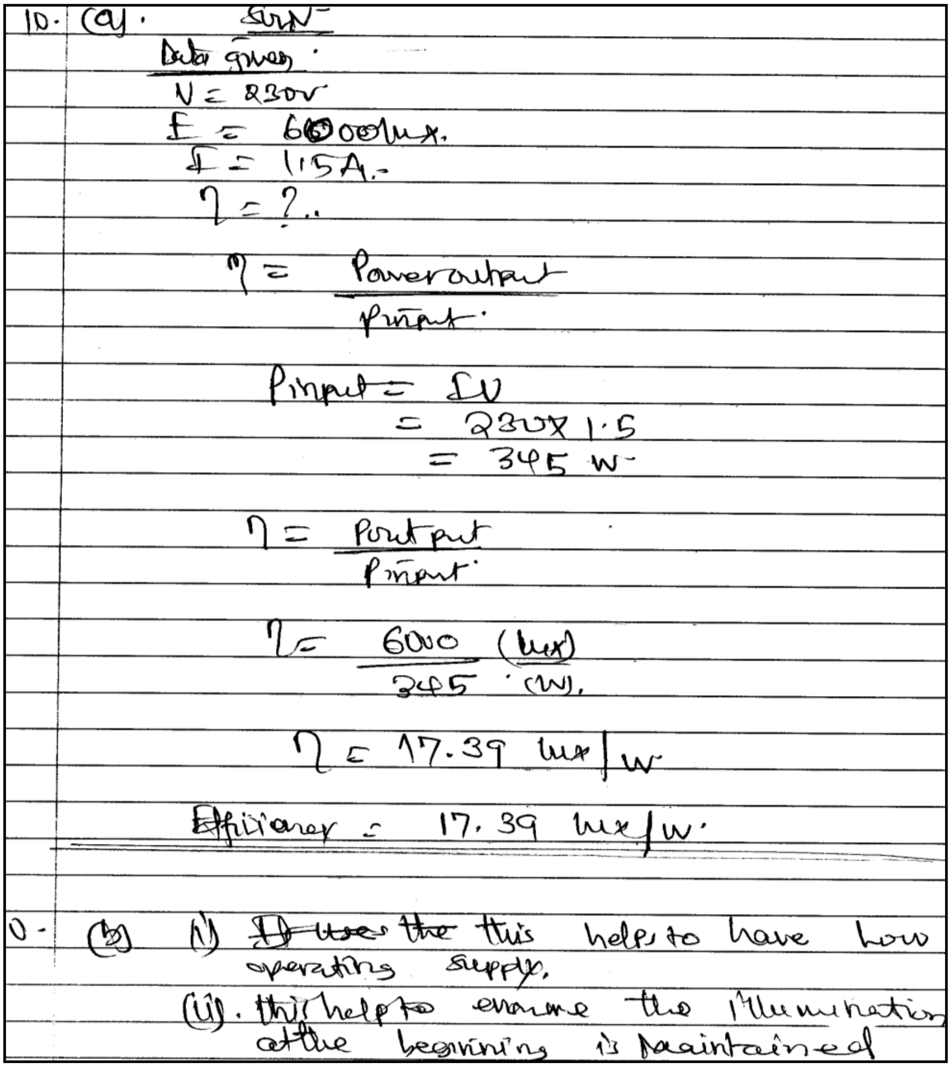
Solution
Efficiency = E × I / V
= 6000 × 1.5 / 230
= 9000 / 230
= 39.13 %
∴ Efficiency of lamp is 39.13 %.

b. School electrical technician use startles method in Staring the lamp because
i Starter is good at a lamp because it start operating of Lighting of a lamp.
ii Starter it is very high efficiency

Extract 10.1*:* A sample of incorrect responses to Question 10

Extract 10.1 shows that in part (a), the candidate applied the formula which was irrelevant in illumination and in (b) he/she provided incorrect reasons of using startles method.

Contrarily, 4 (0.9%) candidates who performed well by scoring 3.5 marks managed to provide correct responses in some parts, but failed in the other parts. Extract 10.2 illustrates the performance.



10. (a). Soln

Data given.

V = 230V

F = 6000lux.

I = 1.5A.

η = ?..

η = Power output / Pinput.

Pinput = IV
= 230 × 1.5
= 345 W.

η = Poutput / Pinput.

η = 6000 (lux) / 345 (W).

η = 17.39 lux/w

Efficiency = 17.39 lux/w.

10. (b) (i) ~~It uses the~~ this helps to have low operating supply.

(ii). this helps to ensure the illumination at the beginning is maintained

Extract 10.2*:* A sample of good responses to Question 10

Extract 10.2 shows that the candidate managed to provide correct response in part (a) but failed in part (b). The candidate lacked competence in methods used to start lamps.

2.3 SECTION C: STRUCTURED QUESTIONS

2.3.1 Question 11: Transformer

The question had two parts, (a) and (b) which was set as follows:

(a) Identify two types of tests which must be carried out in transformer and for each type give reason for carrying such a test.

(b) When tested, a 20 kVA transformer was found to have 600 watts iron losses, and 700 watts copper losses when supplying full load at unity power factor. Calculate;

(i) The efficiency of a transformer at unity p.f on full load.

(ii) Output power on half load.

(iii) Copper loss at half load.

This question was attempted by 416 (96.1%) candidates of which, 142 (34.2%) candidates scored from 0 to 4 marks; 149 (35.8%) candidates scored from 4.5 to 9.5 marks and 125 (30.0%) scored from 10 to 15 marks. The performance of the candidates was good, since 274 (65.8%) of the candidates responded well. Figure 10 shows the candidates' performance in Question 11.

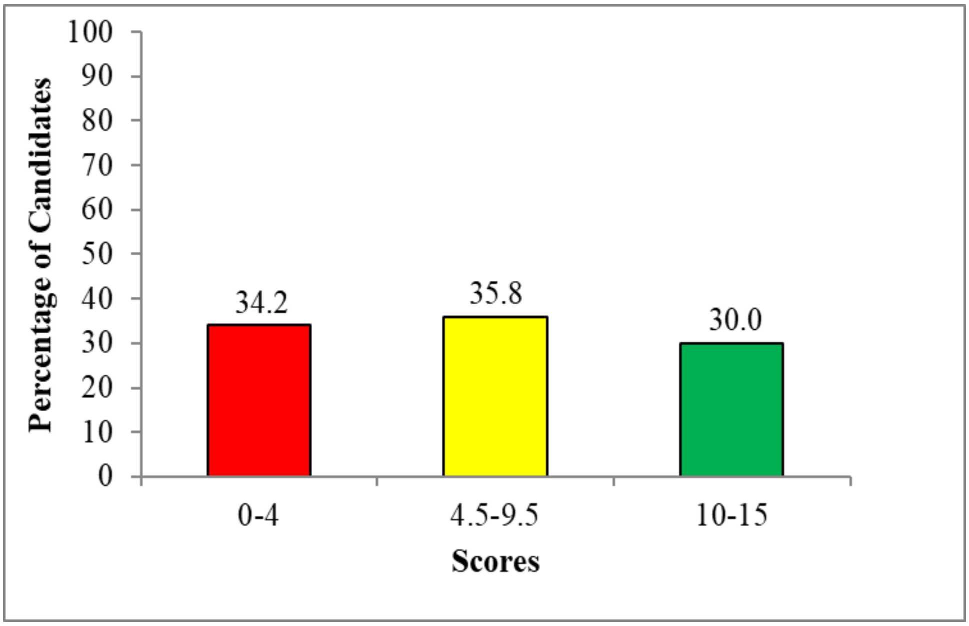


Figure 10: *The Candidates' Performance in Question 11*

Based on Figure 10, the analysis of the candidates' response indicates that 34.2 per cent of the candidates who had weak performance either provided unsatisfactory responses in all parts of the question or gave correct answers in less than two items. For example, in part (a) one of the candidates identified eddy current test and earth resistance test instead of open circuit test and short circuit test. In part (b) the candidate reversed the formula of calculating efficiency by writing $\eta = \frac{Pin}{Pout} \times 100\%$ instead of $\eta = \frac{Pout}{Pin} \times 100\%$. The candidates who performed poorly demonstrated inadequate knowledge and skills in the topic of Transformer. Extract 11.1 is a sample of incorrect responses from one of the candidates.

11 a)

- Single transformer : Is the type of transformer which contain one winding in their manufacture.
- Double transformer : Is the type of transformer which contain two or more winding in their manufacture.

b. GIVEN.

Power = 20 KVA

Iron lossed = 600 W.

Copper losses = 700 W

Solution

In ~~Iron~~ losses

~~I = P~~

(i) Efficiency of the transformer

Total losses = 600 + 700

= 1300 W.

Total iron loses = P + total losses

= 1300 + 600

= 1900 W.

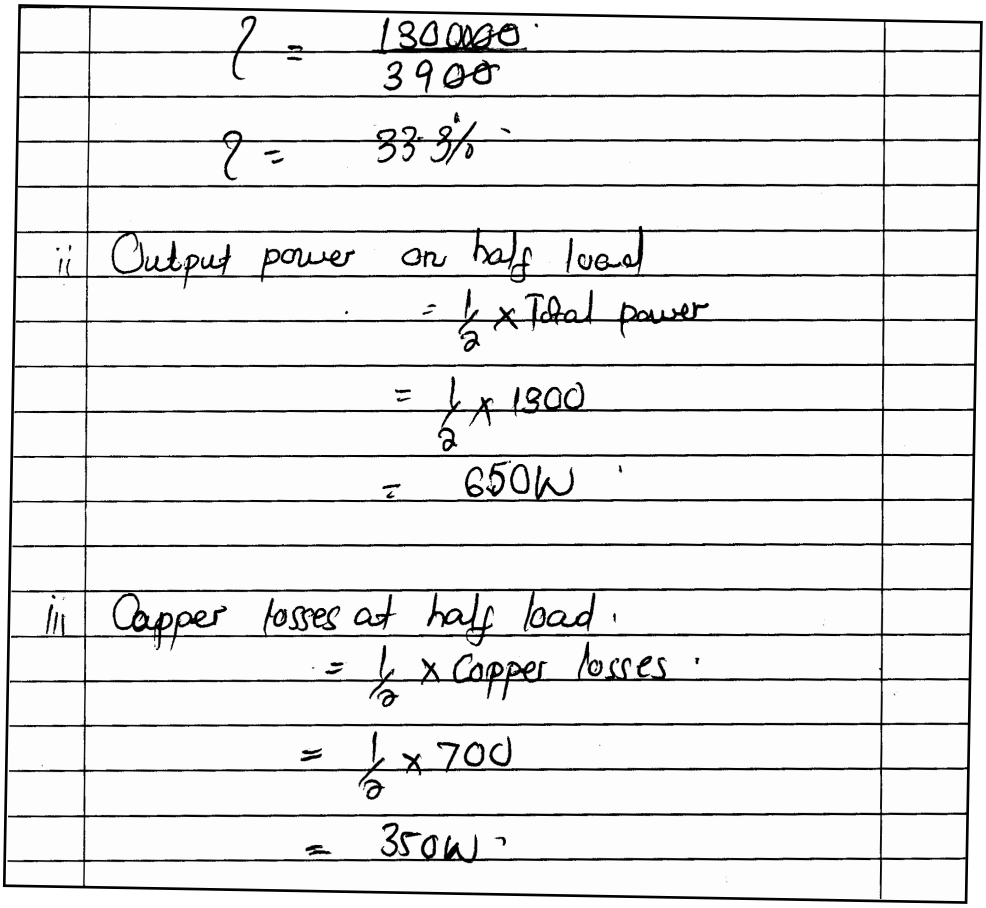
Total cu losse = P + total loses.

= 700 + 1300

2000 W

$\% = \frac{\text{Total losesc}}{\text{Total cu loss} + \text{Total iron loss}} \times 100\%$

$\frac{1300}{\quad} \times 100\%$



η = 1300000 / 3900

η = 33.3%

ii Output power on half load

= 1/2 × Total power

= 1/2 × 1300

= 650W

iii Copper losses at half load

= 1/2 × Copper losses

= 1/2 × 700

= 350W

Extract 11.1: A sample of incorrect responses to Question 11

In Extract 11.1, the candidate described the types of transformer instead of two types of tests to be carried out in transformer. Also she/he provided irrelevant formula and applied them to calculate the efficiency of transformer at unit power factor on full load and copper loss at half load. The candidate therefore ended up providing wrong answers in both cases.

Conversely, there were 149 (35.8%) candidates with average performance. Most of them provided correct response in part (a), but failed to calculate the values of the parameters asked in part (b) or vice versa. The average performance of the candidates implies that they acquired partial knowledge on the concepts tested in the topic of Transformer.

Furthermore, the candidates who performed well proved to have sufficient knowledge on transformer as they managed to provide correct responses in both parts of the question. Most of them were able to identify the types of test to be carried out in transformer and gave the reasons for carrying out the test. They correctly calculated the parameter asked in 11(b). Extract 11.2 is a sample of good responses provided by one of the candidates.

11 a) (i) OPEAN CIRCUIT TEST

- This type of Test is carried out in transformer inorder to identify Iron losses in kilowatts. Iron losses = I^2R = Watts

(ii) SHORT CIRCUIT TEST

- This test is carried out in a transformer inorder to identify copper losses other than Resistance of induced emf (Lenz Low). Copper losses = I^2R = watts

b) DATA GIVEN.

S = 20kVA

Iron losses = 600watts

Copper losses = 700 watts.

Cosθ = 1

(i) E at full load = ?

(ii) output power in half load = ?

(iii) copper losses at half load = ?

(ii) Output power = S x Cosθ

derived from,

$$\cos\theta = \frac{kW}{kVA}$$

$P_o = 20 \times 10^3 \times 1$

$P_o = 20,000W$

$\therefore$ Power output = 20,000W

but, input power = P_o + Cu losses + Fe losses

$P_{in} = 20,000 + 700 + 600$

$P_{in} = 21,300\,W$

∴ power input in full Load is 21,300W

$$\text{Efficency} = \frac{\text{output power}}{\text{Input power}} ~~\times 100\%~~$$

$$\text{Efficency} = \frac{20,000W}{21,300W} ~~\times 100\%~~$$

Efficency = 93.89%

∴ Efficency of Transformer on full Load is 93.89%

(ii) Output power on half load $= \frac{\text{Total output power}}{2}$

$$= \frac{20,000}{2}$$

$$= 10,000W$$

∴ Total output power on half load = 10,000W

(iii) copper losses on half load $= \left(\frac{1}{2}\right)^2 \times$ Total copper losses

$$= \frac{1}{4} \times 700$$

$$= 175W$$

∴ Copper losses on half load is 175W

Extract 11.2: A sample of correct responses to Question 11

Extract 11.2 shows that in part (a) the candidate correctly identified the two types of transformer test and provided the reasons for carrying out such a test. In part (b), the candidate applied the correct formula to calculate the efficiency of transformer at unity power factor on full load, output power on half load and copper loss at half load.

2.3.2 Question 12: Three Phase Circuits

The question had two parts namely, (a) and (b) and was set as follows:

Three coils, each having a resistance of 15 **Ω** *and an inductance of 10* **Ω***, connected in star at a 400V, 3 phase 50Hz supply.*

(a) Sketch a circuit for 3 phase star connected coils showing the position of phase and line voltages.

(b) Calculate

(i) The line current.

(ii) Power factor.

(iii) Power supplied.

A total of 425 candidates corresponding to 98.2% per cent attempted this question. The candidates' scores were; 143 (33.6%) scored from 0 to 4 marks and 163 (38.4%) candidates scored from 5 to 9 marks. The rest 119 (28.8%) scored from 10 to 15 marks. The analysis shows that 282 (66.4%) of the candidates performed well because they had average and above marks. The performance of the candidates on this question is summarized in Figure 11.

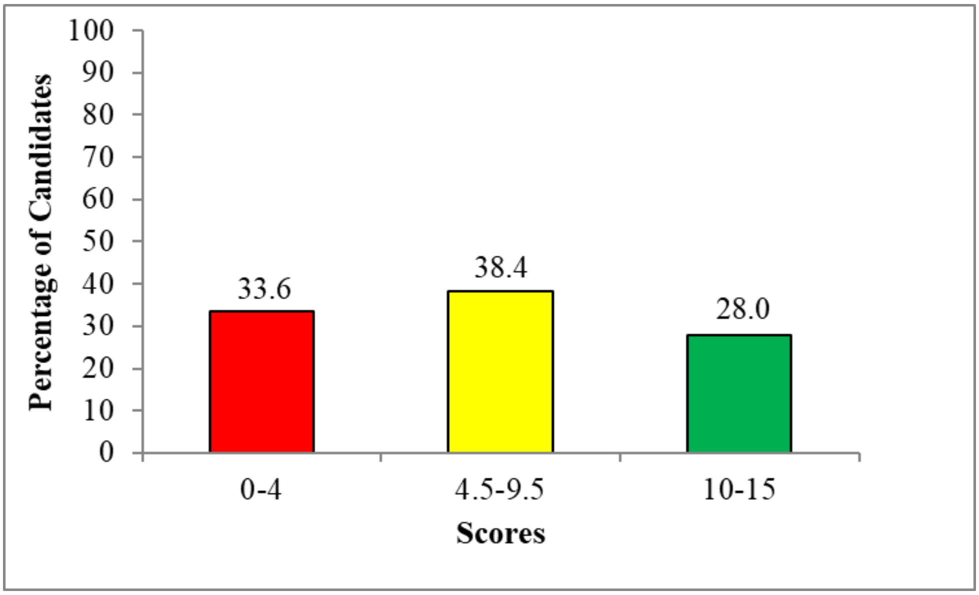
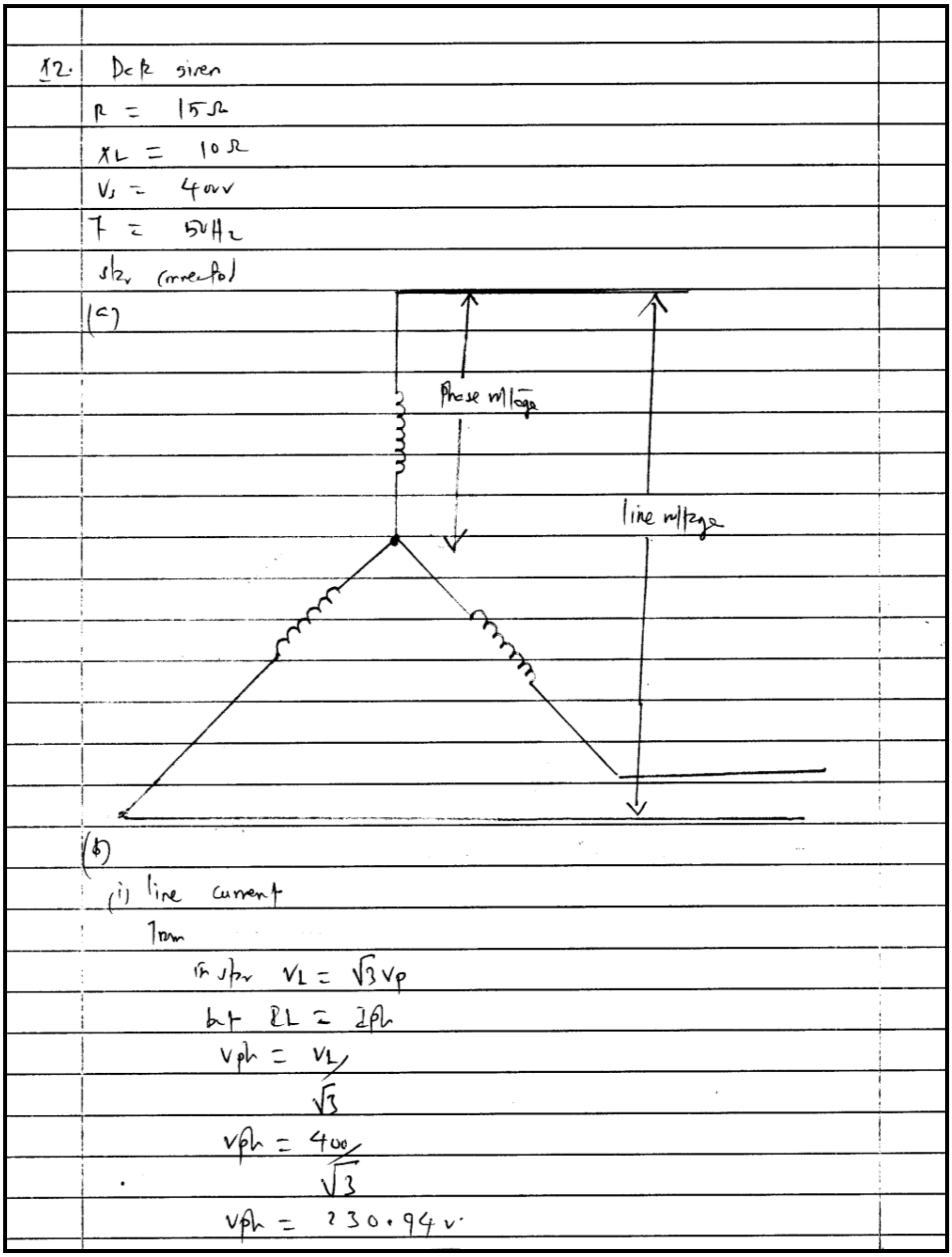


Figure 11: *The Candidates' Performance in Question 12*

The response analysis shows that, most of the candidates who passed were capable of providing the correct response in all parts of the questions. They managed to sketch a circuit for 3-phase star connected coils showing the position of the phase and line voltages. They correctly calculated the line current, power factor and supplied power. These candidates had sufficient knowledge of three phase circuits. Extract 12.1 presents good responses from one of the candidates.



but

$I_{ph} = \frac{V_{ph}}{Z}$.

but $Z = \sqrt{R^2 + X_L^2}$

$Z = \sqrt{15^2 + 10^2}$

$Z = \sqrt{225 + 100}$

$Z = \sqrt{325}$

$Z = 18.028\,\Omega$

from

$I_{ph} = \frac{V_{ph}}{Z}$

$I_{ph} = \frac{230.94}{18.028}$

$I_{ph} = 12.81\,A$

But

$I_{ph} = I_L$.

$I_L = 12.81\,A$

The line current $= 12.81\,A$

(iii) power supplied

$P = \sqrt{3} V_L I_L \cos\theta$

$P = \sqrt{3} \times 400 \times 12.81 \times \cos\theta$

But

$\cos\theta = R/Z$

$\cos\theta = \frac{15}{18.028} = 0.83$ lag

Extract 12.1: A sample of correct responses to Question 12.

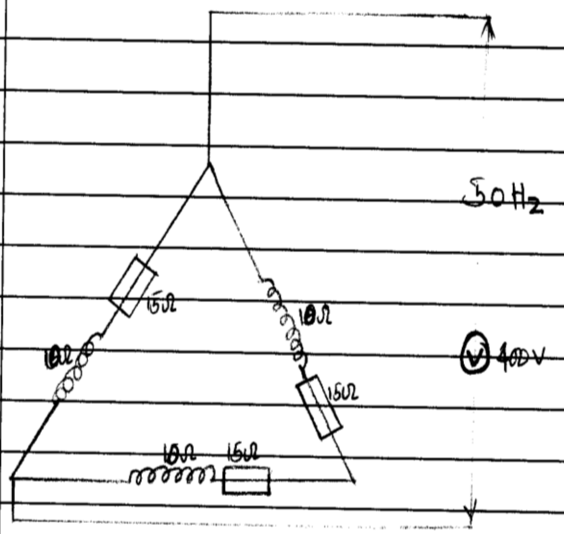
Extract 12.1 shows that, the candidate managed to sketch a circuit for 3-phase star connected coils showing the position of phase and line voltages in part (a). He/she also correctly calculated the line current, power factor, and supplied power as required in part (b).

The analysis also shows that 3.7 per cent of the candidates performed average, as they managed to provide correct answers in one part of the question, but failed on another. Some of them failed to understand that for star connected load, Line current (I_L) = Phase current (I_P). This is the necessary condition when calculating the asked parameters in part (b) of the question. The candidates' responses indicate that they had partial knowledge about three phase circuit.

Furthermore, the analysis indicates that 28 per cent of the candidates had weak performance. Some of the candidates failed to fulfil the requirements of the question. Other candidates had misconception regarding star and delta connected load, that's why they could not recognized the appropriate formula to calculate the asked parameters in part (b) of the question. Extract 12.2 and 12.3 illustrate samples of poor responses to the question.

12. ~~Data~~

(a)



(b) Calculate

(i) The line Current

(ii) Power factor

(iii) Power supplied.

Data given.

frequency → 50 Hz

I_L, Current line = ?

(i) Line Current

from $I_L = R_L V_T$

∴ $I_L = R_L V_T \sqrt{3}$

where $V_T = 400V$

$R_L = ?$

from $R_L = \frac{\sqrt{3}}{R_T}$

$R_L = \frac{\sqrt{3}}{15 + 15 + 15}$

$$R_L = \frac{\sqrt{3}}{45}$$

$R_L = 0.038\Omega$

$\therefore I_L = R_L V_T \sqrt{3}$

$I_L = 0.038 \times 400 \times \sqrt{3}$

$I_L = 15.2 \times \sqrt{3}$

$I_L = 26.327$

$\simeq 26.33A$

$\therefore$ The Current line is 26.33A.

(ii) Power factor.

~~from $P_f = I_L I_R$~~

from $P_f = \frac{I_L R_L \cos\theta}{\sqrt{3} \times F}$

where $I_L = 26.33A$

$R_L = 0.038\Omega$

$F = 50Hz$

$\cos\theta = 10$

$$\therefore P_f = \frac{I_L R_L \cos\theta}{\sqrt{3} \times F}$$

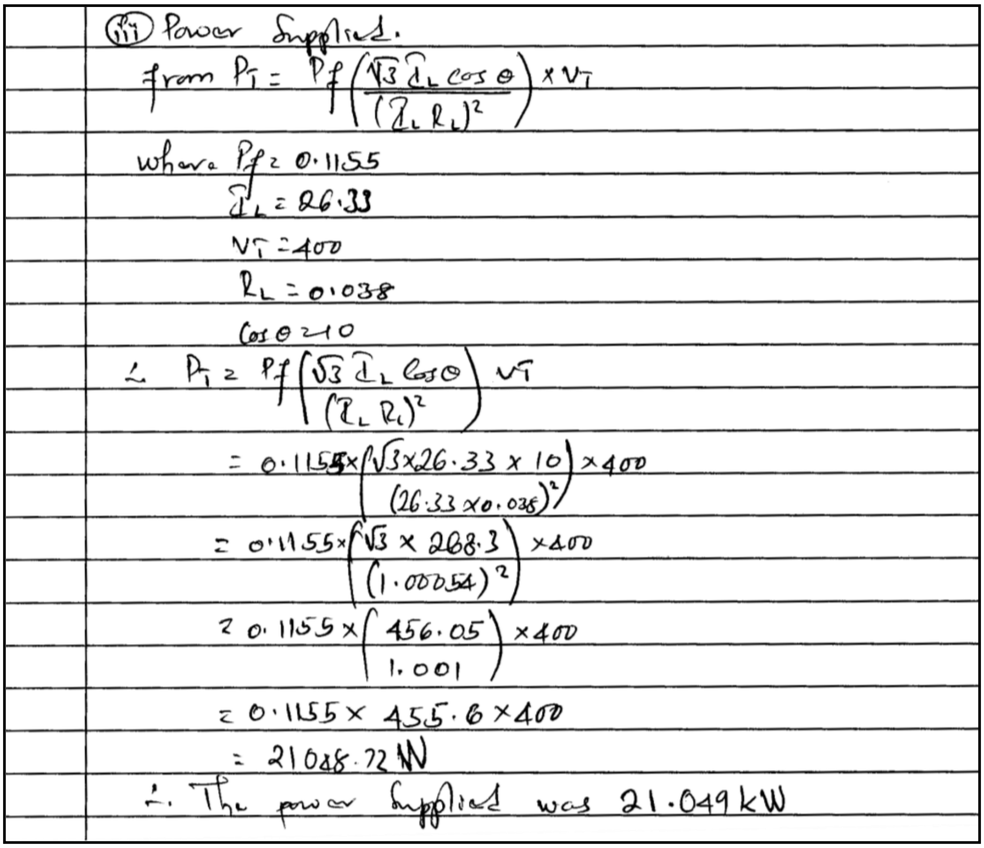
$$= \frac{26.33A \times 0.038\Omega \times 10}{\sqrt{3} \times 50}$$

$$= \frac{263.3 \times 0.038}{86.6}$$

$$= \frac{10.0054}{86.6}$$

$= 0.1155$

$\therefore$ The power factor is 0.1155.



(iii) Power Supplied.

from $P_T = Pf\left(\frac{\sqrt{3}\, I_L \cos\theta}{(I_L R_L)^2}\right) \times V_T$

where $Pf = 0.1155$

$I_L = 26.33$

$V_T = 400$

$R_L = 0.038$

$\cos\theta = 10$

$\therefore P_T = Pf\left(\frac{\sqrt{3}\, I_L \cos\theta}{(I_L R_L)^2}\right) V_T$

$= 0.1155 \times \left(\frac{\sqrt{3} \times 26.33 \times 10}{(26.33 \times 0.038)^2}\right) \times 400$

$= 0.1155 \times \left(\frac{\sqrt{3} \times 263.3}{(1.00054)^2}\right) \times 400$

$= 0.1155 \times \left(\frac{456.05}{1.001}\right) \times 400$

$= 0.1155 \times 455.6 \times 400$

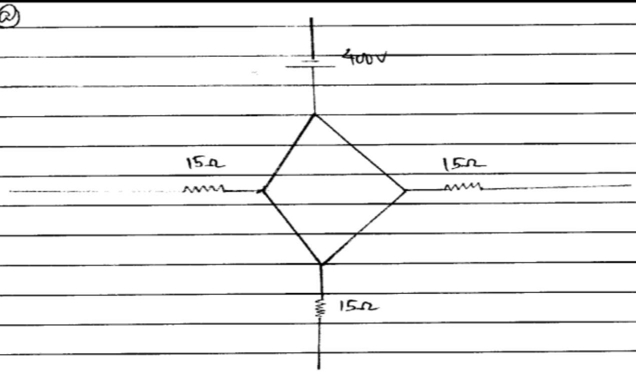
$= 21048.72\ W$

$\therefore$ The power supplied was 21.049 kW

Extract 12.2: A sample of incorrect responses to Question 12

Extract 12.2 shows that in a part (a), the candidate drew delta connection instead of star connection. Also the candidate formulated irrelevant expressions and applied them to determine the line current, power factor and power supplied required in part (b). This candidate seems to have acquired insufficient knowledge and skills about three phase circuits. Another example of incorrect responses is shown in Extract 12.3.

12 (a)



b) i) line current

$I = V/R$

$= 400/15$

$= 66.6 \simeq 67$

∴ The line current is 67 A

ii) Power factor

Power = Current / Frequency

$= 67/50$

$= 1.34$ W

∴ Power factor is 1.34 W

iii) Power supplied

= Power factor / 2

$= 1.34/2$

$= 0.67 \simeq 0.7$

∴ The power supplied is 0.7 W

$= 1.34/2$

$= 0.67 \simeq 0.7$

∴ The power supplied is 0.7 W

Extract 12.3: A sample of incorrect responses to Question 12

Extract 12.3 shows that the candidate drew a rhombus like shape instead of star connection circuit. Also, the candidate applied the formula of d.c current to calculate the line current in three phase circuit. In part (b) (i) and (ii), the candidate applied inappropriate formula to calculate power factor and power supplied. For these approaches, the candidate demonstrated insufficient knowledge about three phase circuits.

2.3.3 Question 13: Measuring Instrument

The question had two parts (a) and (b) and was set as follows:

(a) *Briefly describe three types of torques required for operation of indicating measuring instruments.*

(b) *A voltage coil of a dynamometer type wattmeter is connected across the load side and reads 200 W. If the load voltage is 245 V and the resistance of the voltage being 3612 Ω. Calculate the following:*

(i) True power across the load.

(ii) Percentage error due to wattmeter connection.

The question was attempted by 217 candidates which is equivalent to 50.1 per cent. The candidates' scores were categorised as follows: 167 (77%) candidates scored from 0 to 4 marks; 40 (18.4%) scored from 4. 5 to 9.5 marks; and the remaining 10 (4.6%) scored from 10 to 15 marks. Table 3 illustrates the candidates' performance on this question.

1.

Table 3: The Candidates' Performance in Question 13

Scores	Number of Candidates	Percentage (%)	Remarks
0-4	167	77	Weak
5-9	40	18.4	Average
10-14	10	4.6	Good
Total	**217**	**100**	

The general performance of the candidates in this question was weak, because the statistical analysis reveals that 50 (23%) candidates passed while 77 per cent failed. Analysis shows that most of the candidates failed to describe three types of torque required for the operation of indicating measuring instruments. Some of the candidates described *Operating torques*: as torque required when the machine is operating: *Component torques:* these are torques which are used for operation of indicating measuring instruments; *Coupling torques*: these are torques which are used for operation of indicating measuring instruments and *Separated torques*: these are torques which are used for operation of indicating measuring instruments. Other candidates just mentioned *reflection torque* and *centripetal torque*. These responses reveal that the candidates lacked enough knowledge about measuring instruments. Some candidates expressed inability to apply formula to find the asked parameters in part (b), because the answers obtained were not correct. For example, in part (b) (i) some candidates used wrong formula to calculate D.C power; $\left(P = \frac{VR}{f}\right)$ which is irrelevant to the question demand and others used $\left(Power = V_L I_L\right)$ which is the formula of calculating three phase power instead of $\left(P_r = P - P_L\right)$ which is the correct formula required for calculating true power across the load. Furthermore, in calculating a percentage error due to wattmeter connection, some candidates used the wrong formula; $\%error = \left(\frac{P_1 - P_2}{Voltage}\right)$ instead of $\%error = \left(\frac{P - P_T}{P_T}\right)$ as required in part (b) (ii). Extract 13.1 is a sample of the candidates' incorrect responses.

13.

a:- Accumulator : Is the type of the torque that a ccumulate ~~the~~ the field.

- Core : Is the type of torque that give the ~~bases~~ of the ~~to~~rque.

- Iron : Is the type of torque that made up of the iron only.

b. GIVEN

Power (P) = 200W.

Voltage (V) = 245 V.

Resistance = 3612 Ω.

Solution.

i The true power accross the load.(P).

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

$$= \frac{200}{245}$$

$$= 0.8A.$$

$$P = VI \cos\theta$$

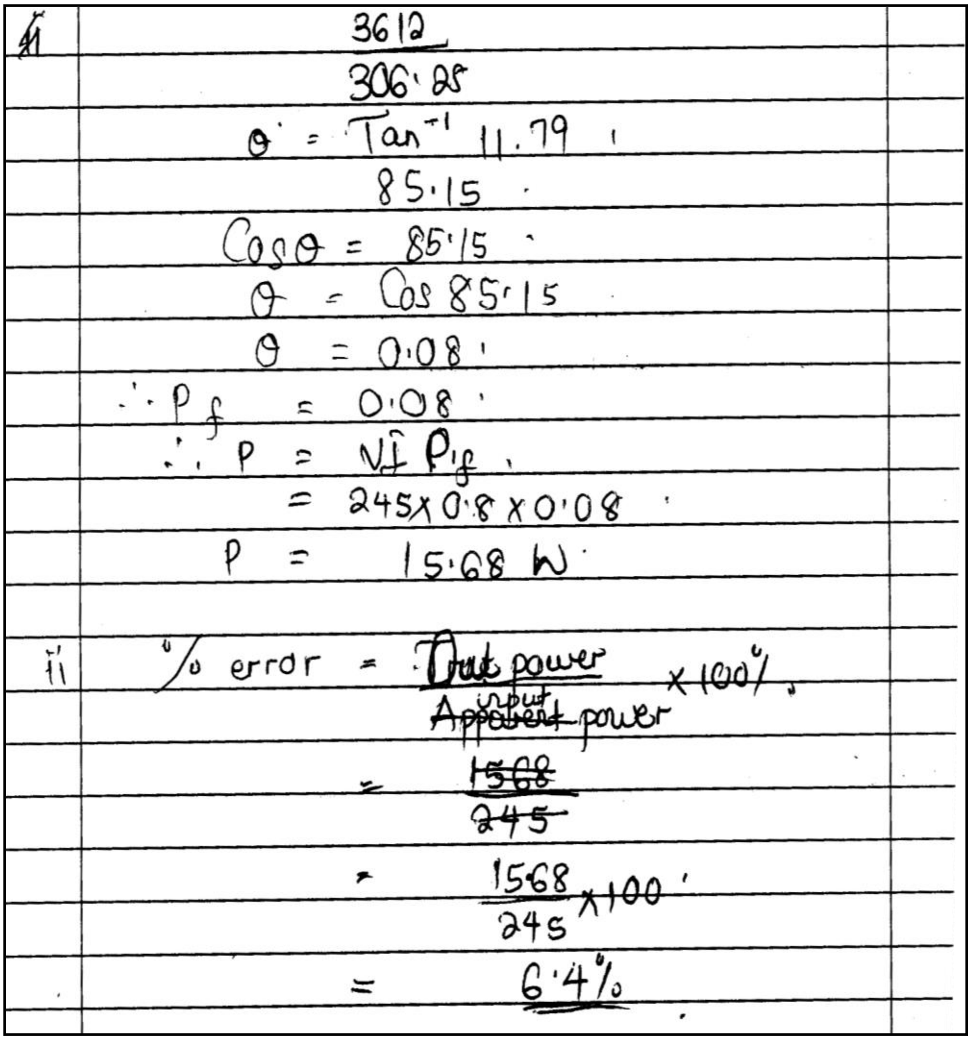
where $\cos\theta = \frac{R}{Z}$.

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

$$= \frac{245}{0.8}$$

306.25 Ω

Tan θ ~~Cos θ~~ = $\frac{R}{Z}$


$\frac{3612}{306.25}$

$\theta = Tan^{-1}\ 11.79$

85.15

$Cos\theta = 85.15$

$\theta = Cos\ 85.15$

$\theta = 0.08$

$\therefore P_f = 0.08$

$\therefore P = VI\,P_f$

$= 245 \times 0.8 \times 0.08$

$P = 15.68\ W$

ii % error = ~~True~~ power (input) / ~~Apparent~~ power × 100%

= ~~1568 / 245~~

$= \frac{1568}{245} \times 100$

$= 6.4\%$

Extract 13.1: A sample of incorrect responses to Question 13

In Extract 13.1, the candidate described the parts of the machines (*accumulator, core and iron*) instead of deflection torque, controlling torque, and damping torque as required in part (a). In part (b), he/she used irrelevant formulae to calculate true power across the load and percentage error due to wattmeter connection.

The analysis also shows that 18.4 per cent of the candidates performed averagely. These candidates could not provide correct responses in one part of the question and failed in the other part. Candidates under this category seem to have acquired inadequate knowledge about Measurements and Instruments. On the other hand, there were 4.6 per cent of the candidates who performed excellently. These candidates demonstrated the ability to apply the knowledge acquired on Measurements and Instruments to describe types of torques in (a) and calculate the asked parameters in (b). Extract 13.2 is a sample of correct responses from one of the candidates.

13. a) i) Deflecting/operating torque : This produce the mechanical force which cause the part or deflection to the quantity being measured and is caused by electromagnetic induction after electric current to pass through it.

ii) Controlling torque : This ensure that the pointer deflection is directly proportional to the quantity to be measured

iii) Damping torque : this part ensure that the pointer deflection is directly proportional to the steady quantity measured without any oscillation.

13. Data given

Reading power = 200W.

Voltage = 240V

R = 8612 Ω.

13. (b) i)

from.

$$\text{power} = \frac{V^2}{R}$$

$$= \frac{245^2}{3612}$$

$$= \frac{60,025}{3612}$$

∴ power = 16.618 watt.

Then

True power = Reading power − recording

= 200 − 16.618

∴ True power = 183.38 watt

∴ True power of an Instrument is 183.38 watt

ii) percentage error (%error).

$$\%\ \text{error} = \frac{\text{Reading power} - \text{True power}}{\text{True power}}$$

$$= \frac{200 - 183.38}{183.38}$$

% error = 9.06%

∴ The percentage error is 9.06%

Extract 13.2: A sample of correct responses to Question 13

Extract 13.2 shows that the candidate managed to describe three types of torque required for operation of indicating measuring instruments in part (a) and used the correct formula to calculate true power across the load and the percentage error due to wattmeter connection. This implies that the candidate had adequate and skills about measurement and instruments.

2.3.4 Question 14: Magnetism and Electromagnetism

In this question the candidates were required to calculate the flux density in the iron, absolute permeability of iron, relative permeability of iron and resistance of the magnetic circuit consisting of an iron ring of mean circumference of 80 cm with a cross sectional area of 12 cm^2 throughout, if a current of 1 ampere in the magnetizing coil of 200 turns produced a total flux of 1.2 mWb in the core.

A total of 241 (55.7%) candidates attempted this question. The analysis shows that 118 (49%) candidates scored from 0 to 4 marks; 45 (18.6%) scored from 4.5 to 9.5 marks; and 78 (32.4%) candidates scored from 10 to 15 marks. Therefore, the general performance of candidates for this question was average, because 123 (51%) of the candidates scored 4.5 to 15 marks. The candidates' performance for this question is summarized in Figure 12.

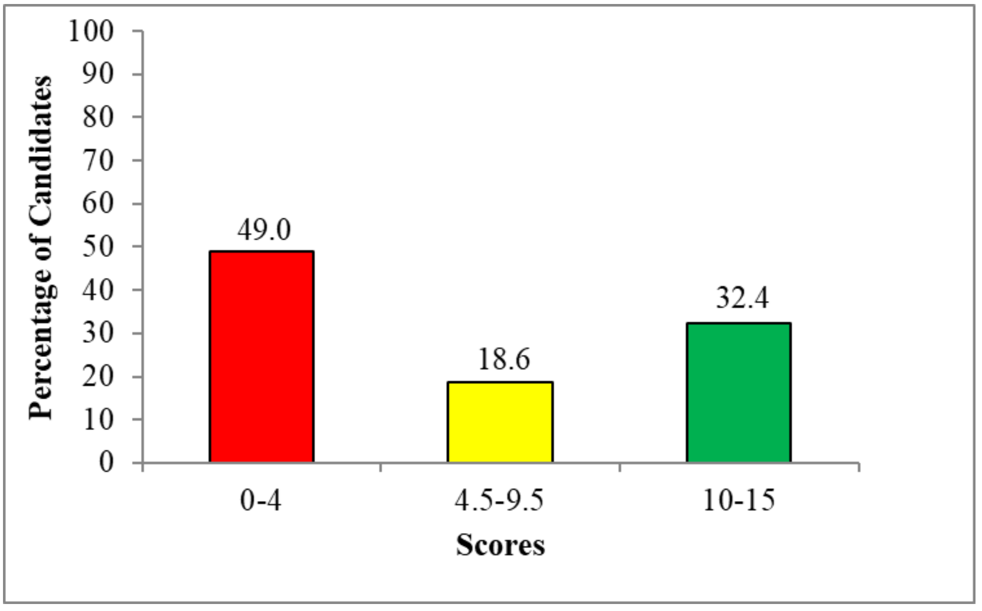


Figure 12: *The Candidates' Performance in Question 14*

The candidates who performed well were able to calculate (a) the flux density in the iron, (b) absolute permeability of iron (c) relative permeability of iron and (d) resistance of the circuit. This suggests that the topic Magnetism and Electromagnetism was knowledgeable to the candidates. Extract 14.1 represents candidates' work which was correctly performed.

14, (b) $H = \frac{200}{0.8}$

$H = 250$ AT/m

so, $B = \mu H$.

$\mu = \frac{B}{H}$.

$\mu = \frac{1}{250}$.

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

the Absolute permeability is 4×10^{-3} wb/mA.

14. (c) Relative permeability, (μr)

$\mu r = \frac{\text{Absolute permeability}}{\text{permeability of freespace}}$.

$\mu r = \frac{4 \times 10^{-3}}{4\pi \times 10^{-7}}$.

$\mu r = 3184.7$,

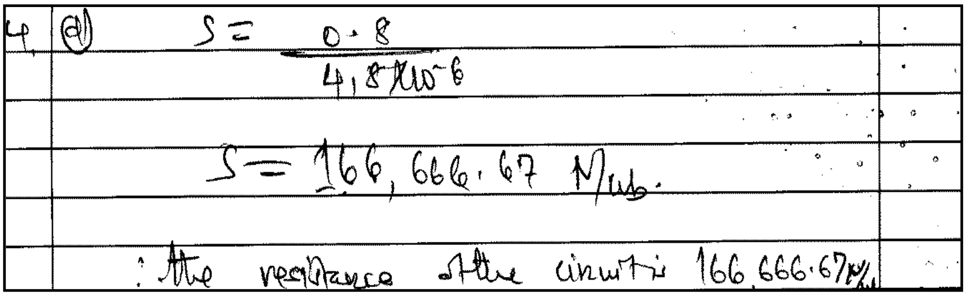
∴ the relative permeability is 3184.7.

14 (d). Resistance of the circuit.

= Magnetic resistance of circuit = Reluctance

from Reluctance, $S = \frac{L}{\mu_0 \mu r A}$.

$S = \frac{80 \times 10^{-2}}{4 \times 10^{-3} \times 12 \times 10^{-4}}$,



4. (d) $S = \frac{0.8}{4.8 \times 10^{-6}}$

$S = 166,666.67$ N/wb.

∴ The reactance of the circuit is 166,666.67 N/wb

Extract 14.1: A sample of good responses to Question 14

In Extract 14.1, the candidate applied the correct formulae to calculate the elements of magnetic circuit as required in part (a) to (d) as per question's requirement.

Moreover, the analysis shows that 49 per cent of the candidates who performed poorly lacked knowledge on Magnetism and Electromagnetism. Most of them applied wrong formula to calculate the required parameters. Some of the candidates calculated flux density by using wrong torque formula $\Phi = NBA$ instead of flux density $B = \frac{\Phi}{A}$ which led them to wrong answer. Likewise, they calculated the absolute permeability of iron by using the formula related to the one used to calculate mutual inductance $\Phi = \frac{N\mu_o\mu_r A}{L}$ instead of $\mu = \frac{B}{H}$. Moreover, candidates used the formula for resistance of a D.C circuits $\left(R = \frac{V}{I}\right)$ instead of the formula for calculating reluctance of a magnetic circuit which is referred to reluctance (S) and it is given by $\left(S = \frac{l}{\mu_o\mu_r A}\right)$. Extract 14.2 is a sample of incorrect responses from one of the candidates.

Φ E = 1.2 mWb

To calculate

i, Flux density in The iron

from,

$\frac{E}{\Phi} = \frac{4.44 \Phi N_i}{\Phi}$

$E/\Phi = 4.44 N$

$1.2/\Phi = 4.44 \times 200$

$1.2/\Phi = 888$

$\frac{1.2}{888} = \frac{888\Phi}{888}$

$\Phi = 1.35L$

∴ The flux density of the iron is 1.35lumen

ii, Absolute permibility of iron

solution:

$\frac{\text{Cross sectional area}}{\text{Distance}}$

$80 cm^2 / 12 cm^2$

= 6.667

∴ The Absolute permibility of iron is 6.667

iii, Relative permeability of iron

Distance − Absolute permibility

80 − 6.667

= 73.33

∴ Relative permibility of iron is 73.33

d) Resistance of the circuit

from

$R = A_1 / N_1$

$R = 1 / 200$

$R = 5 \times 10^{-3}\ \Omega$

∴ The Resistance of the circuit is $5 \times 10^{-3}\ \Omega$

Extract 14.2: A sample of incorrect responses to Question 14

Extract 14.2 shows that in part (a), the candidate used the e.m.f equation to calculate flux density in the iron. Also in part (b), the candidate used irrelevant formula to calculate absolute permeability of iron as he/she divided cross sectional area by distance. In part (c) and (d), the candidate used incorrect formula and wrong substitution to calculate relative permeability of the iron and resistance of the circuit respectively. The candidate's response suggests that he/she lacked knowledge and skills about the topic Magnetism and Electromagnetisms.

3.0 THE CANDIDATES' PERFORMANCE ON EACH TOPIC

The analysis of candidates' performance on the topics which were assessed in Electrical Engineering Science subject for the year 2021 indicates that, the performance was good in four topics, average in seven topics and weak in one topic.

The topics that were performed well include: *Cathode Ray Tube, Effect of Electric Current, A.C Machines, Rectifier, Instrument and Measurements, A.C Voltages, Electromagnetism*, *Nature of Electricity* and *Magnetism and Electromagnetism* (94.5%) (from which the multiple choice items were developed); *Transformer* (77.2%); *Electric Heating* (68.0%) and *Three Phase Circuits* (66.4%). The good performance in these topics denotes that, the candidates had enough knowledge, skills, and competence on the concepts tested.

The topics in which the candidates performed averagely were; *Electromagnetisms* (61.4%); *Illumination* (58.6%); *D.C Circuits* (57.0%); *Magnetism and Electromagnetism* (51.1%); *Nature of Electricity* (48.5%); *A.C Voltages* (41.1%) and *D.C Machines* (31.2%). The average performance shows that, the candidates had partial knowledge, skills, and competence in the prescribed topics.

The candidates performed poorly on the topic *Measurements and Instruments* (23.0%). The analysis shows that the candidates lacked sufficient knowledge on this topic.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The general performance of the candidates in Electrical Engineering Science for Form Four National Examinations (CSEE) in the year 2021 was good. Out of 433 candidates who sat for the paper, 349 (80.6%) passed, while 84 (19.4%) failed and their grade scores are presented in Table 4.

Table 4: The Candidates' Grade Scores in the year 2020 and 2021

Year	Clean Data	Passed		Percentage of Candidates and their Grade of Scores				
		No.	%	A	B	C	D	F
2020	348	275	79.02	7.47	17.82	35.06	18.68	20.98
2021	433	349	80.60	6.70	11.55	37.41	24.94	19.40

The analysis of the candidates' responses reveals some few shortcomings. These include the candidates' insufficient knowledge in responding to some of the questions and lack of knowledge, skills, and competence particularly in the topic *Measurements and Instruments* which was poorly performed.

Another weakness observed was inability of some of the candidates to apply appropriate mathematical formula in computations as it was observed in many topics especially *Measurements and Instruments* and *Magnetism and Electromagnetisms*. This goes together with the failure of the candidates to understand the requirements of the questions. Also, it was observed that lack of practical skills, misconception and English language barrier were the other challenges that candidates faced when responding to some of the questions.

It is therefore suggested that the weaknesses noted in this report will be taken as a reflection to teachers, future candidates, and other education stakeholders for the purpose of enhancing teaching and learning processes for future improvement of candidates' performance in the Electrical Engineering Science subject.

4.2 Recommendations

Based on the challenges identified in the analysis of the candidates' item responses, it is therefore recommended that:

(i) The teaching and learning process for the Electrical Engineering Science subject should focus on learner-centered pedagogies to give room for the learners to build their skills and competencies in the subject.

(ii) Students are advised to be very keen in studying in order to acquire sufficient knowledge of the concepts in the syllabus.

(iii) Students should be oriented to various terms and concepts used in composing questions for easy understanding of the requirements of the questions.

(iv) Students should undertake different computation exercises to strengthen their ability to tackle questions which require applications of formulae and calculations. This was observed in many tested topics especially *Measurements and Instruments* and *Magnetism and Electromagnetisms.*

(v) Since English language is the medium of instruction for the Electrical Engineering Science subject, both teachers and the prospective candidates should put more emphasis on the use of English language by exercising it through writing, reading, listening and speaking. This strategy will improve the candidates' English proficiency.

(vi) Competence-based mode of material delivery should be put into practiced in various topics. This will ensure sufficient knowledge, skills, and competences are acquired and mastered by the prospective candidates.

(vii) Whenever possible, the use of models should be emphasized as they provide representations of scientific concepts that can make the ideas more understandable to learners especially in teaching *magnetism and electromagnetism*.

Appendix

A Summary of the Candidates' Performance in Each Topic in the Electrical Engineering Science Subject for the Year 2021

S/n	Topic	Question Number	Percentage of Candidates who Scored 30 Per cent and Above	Remarks
1	Cathode Ray Tube, Effect of Electric Current, AC Machines, Rectifier, Instrument and Measurements, A.C Voltages, Electromagnetism, Nature of Electricity and Magnetism and Electromagnetism.	1	94.5	Good
2	Transformer	9 &11	77.2	Good
3	Electric Heating	3	68.0	Good
4	Three Phase Circuits	12	66.4	Good
5	Electromagnetism	5	61.4	Average
6	Illumination	10	58.6	Average
7	D.C Circuit	2	57.0	Average
8	Magnetism and Electromagnetism	6 & 14	51.1	Average
9	Nature of Electricity	7	48.5	Average
10	A.C Voltages	4	41.1	Average
11	D.C Machines	78	31.2	Average
12	Measurements and Instruments	13	23.0	Weak