C A R I B B E A N E X A M I N A T I O N S C O U N C I L

REPORT ON CANDIDATES' WORK IN THE CARIBBEAN SECONDARY EDUCATION CERTIFICATE EXAMINATION

MAY/JUNE 2014

ELECTRICAL AND ELECTRONIC TECHNOLOGY TECHNICAL PROFICIENCY EXAMINATION

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GENERAL COMMENTS

The number of candidates who wrote the examination was 3459. This was an increase from last year by about 1 per cent. The overall performance of candidates resulted in 58 per cent earning Grades I-III. Candidates did well on the practical project of the internal assessment but displayed the need for improvement on the written project. Competencies tested in Paper 01 (Multiple Choice) and Paper 2 (Essay and Problem Questions) were Knowledge and Application. Paper 02 also consisted of compulsory short-answer questions.

DETAILED COMMENTS

Paper 01 — (Multiple Choice)

This paper consisted of 60 multiple-choice questions, testing the profile dimensions of Knowledge and Application. Candidate performance on this paper was comparable to performance in 2013. The mean score achieved was 30.3 against 32.1 for 2013. The highest score achieved in 2014 was 57 compared with 56 for 2013. However, the analysis shows that there is still the need for more comprehensive and complete coverage of Modules 1–4 and 6–7 of the Syllabus. The results also show that candidates need practice in responding to the multiple-choice test format used in the paper.

Paper 02 — Essay/Problem

The paper comprised THREE sections: – Sections A, B and C. Section A contained five short-answer questions. Candidates were required to attempt all five questions. Each question was worth eight marks.

Section B comprised FOUR questions. Candidates were required to answer THREE questions. Each question was worth 20 marks.

Section C comprised TWO questions. Candidates were required to answer ONE question. Each question was worth 20 marks.

Candidate performance on this paper was comparable to performance in 2013. The mean score achieved was 24 per cent compared with 25.5 in 2013. The highest score attained was 96 compared with 93 for 2013. Paper 02 continues to pose a challenge to many candidates.

SECTION A

Question 1

The question tested candidates' knowledge and application of DC circuits, particularly Ohm's law, series connection of loads and the reversal of the direction of current flow.

This question was extremely popular among candidates. The overall performance was good. Part (a) (i) as well as Parts (b) (i) and (ii) posed the least degree of difficulty.

Most candidates were able to:

(i) recognise that electric current is the flow of electrons in a closed circuit

(ii) state the relationship between electric current, electromotive force and electrical resistance (Ohm's law of relationship)

(iii) calculate the total resistance of two resistors connected in series

(iv) compute the total current in a series circuit.

Some candidates had difficulty identifying electromotive force (e.m.f) as the electrical force/pressure responsible for the flow/movement of electrons. Several students confused electromotive force with electromagnetic force. Consequently, teachers are advised to make a clear distinction between these two properties.

A significant number of candidates were unclear about the method used to reverse the direction of the flow of electrons in a DC circuit. Incorrect responses included:

(i) placing a reverse biased diode (ii) replacing the DC supply with an AC supply (iii) reversing the windings (iv) reversing the magnetic field etc. Candidates' incorrect responses inferred that students were not adequately exposed to this particular area in the curriculum.

The correct responses for this question are shown below.

Part (a) (i) The electric current

(ii) The electromotive force

(iii) The electron current varies directly as the electron moving force (e.m.f) and varies inversely to the opposition of the movement of electrons in the circuit.

Part (b) (i) Total opposition to the movement of electrons in the circuit is R_T

$R_T = 4\ \Omega + 5\ \Omega$
$R_T = 9\ \Omega$

(ii) Magnitude of the movement of electrons is total current (I_T)

$I_T = V_T/R_T$
$I_T = 18V/9\ \Omega$
$I_T = 2A$

(iii) A method for reversing the direction of the movement of electrons in the circuit is to reverse the terminal connections of terminals T1 and T2 of the battery.

Recommendations – Question 1

- It is recommended that teachers instruct their students in related laboratory exercises where the effect of reversing the terminals of a battery could be observed and conclusions derived.

Question 2

This question consisted of Parts 2 (a) (i) and (ii), and 2b. It was designed to measure candidates' knowledge and understanding through application of knowledge.

Candidates' responses to this question varied in each part. In Part 2 (a) (i) most candidates gave only one of the answers listed on the mark scheme and gave 'Voltmeter' which was acceptable. Candidate responses to Part 2 (a) (ii) indicate that students were more familiar with the applications of batteries based on brand name rather than types. Approximately 50 per cent of candidates got the correct answer. Part 2 (b) was generally well done as most candidates applied their knowledge to solve the problem. Approximately 75 per cent of the candidates who attempted this question were able to obtain four marks or above.

The correct responses for this question are shown below.

Part (a) (i) Hydrometer
High rate discharge tester

(ii) Mercuric oxide
Zinc air
Silver oxide
Lithium

Part (b) Internal Volt drop in cell is No-Load terminal Voltage minus On-Load terminal volts

$V_{in} = 1.5\ V – 1.0\ V$
$V_{in} = 0.5\ V$

The load current flows through the internal resistance and internal resistance R_{in} is the ratio of internal volt drop to load current

$R_{in} = V_{in}/I_L$
$R_{in} = 0.5\ V/0.5$
$R_{in} = 1.0\ \Omega$

Recommendations — Question 2

- Students should be given more exposure on the use of Primary Cells which must include testing for various conditions such as load test, no load test, charging rate etc.

- Students should test the effect of an external resistor to a battery and how it affects the output voltage. This will allow them to better understand the behavior of a battery.

Question 3

Part (a) of this question tested candidates' knowledge of electric power stations with respect to (i) devices/equipment used to convert primary energy to electrical energy and (ii) methods used to convert primary energy to electric energy. Part (b) tested candidates application of knowledge concerning the use of energy conversions which occur, specifically with respect to natural gas and steam-driven generators used to produce electrical energy.

In Part (a) (i), the majority (≥ 65 per cent) of the candidates did not provide the expected answers but instead provided either motor and generator or transformer and generator.

In Part (a) (ii), the majority (≥ 70 per cent) of candidates provided solutions other than those mentioned in the mark scheme. These solutions were correct and were also accepted.

In Part (b), about 50 per cent of the candidates knew the different energy conversions used to produce electrical energy but did not provide the correct order in which they occurred. The other 50 per cent of the candidates provided answers such as magnetic, kinetic, potential, ac/dc and conduction/convection.

Overall, approximately 65 per cent of candidates were able to obtain four or more marks for this question.

The correct responses for this question are shown below.

Part (a) (i) AC alternator
DC generator

(ii) Internal combustion driven generators

Steam-driven generators
Hydro-driven generators

Part (b) Energy conversion that occurs in the power station are:

- Chemical energy to heat energy
- Heat energy to steam energy
- Steam energy to mechanical energy
- Mechanical energy to electrical energy

Recommendations — Question 3

- The teacher/instructor should make a clear distinction concerning the origin of the different types of energy i.e. kinetic, potential, chemical, mechanical, thermal energy etc., when considering primary energy used in power stations.

- Students should be given an assignment (project) on energy conversions in power stations, which should provide a better understanding of what actually happens.

- The teacher/instructor should make a clear distinction between energy conversion and energy transfer [(a) (i)].

- The teacher/instructor should arrange a visit to a power station provided this could be facilitated.

Question 4

This question tested candidates' knowledge and application of knowledge of the PN junction. Students should be able to identify a PN junction and apply their knowledge of silicon-controlled rectifier (SCR). Part (a) (i) required candidates to state the names of the control and positive terminals of a silicon-controlled rectifier. Popular responses to this part of the question included anode, cathode, holes, positive, negative, trigger pulse, prevent electric shock. Most of these were incorrect responses.

In Part (a) (ii), candidates were required to state two advantages of silicon-controlled rectifiers when used in switching circuits. This part of the question was also not well done.

Part (b) required candidates to use a given schematic drawing of a silicon-controlled rectifier circuit to explain the operation of the rectifier in the AC circuit. Many candidates interpreted this question incorrectly, and explained the function of a power supply instead of the SCR. They explained the function of a rectifier and even mentioned the smoothing circuits. Overall the students performed poorly on this question as they did not provide the expected responses. More than 50 per cent of the students got no marks on the question.

The correct responses for this question are shown below.

Part (a) (i)

- Gate
- Anode

(ii)

- No mechanical parts
- Very fast switching
- Rectifier control
- Physical size
- Efficiency
- Cheap

- Easy to use
- Safe
- Less power
- Direct Current

(b) When the silicon controlled rectifier is used with an alternating supply, the device will automatically become reset when the applied AC reverses polarity. The device can then be triggered on the next half –cycle having correct polarity to permit conduction.

Recommendations — Question 4

- This topic should be taught using a practical approach.

- A basic circuit could be used to give a clearer understanding of the question (for example an alarm circuit)

Question 5

Part (a) (i) required candidates to name one impurity which is added to a pure semiconductor material to form a p-type semiconductor material. The majority of candidates, approximately 40 per cent, did not provide the expected answer. Candidates who responded incorrectly to this question, for example, placed phosphorus as the impurity to be added for a p-type material.

Part (a) (ii) required candidates to name one impurity which is added to a pure semiconductor material to form an n-type semiconductor material. This question was very similar to the first part; however, in this part, candidates named boron as the impurity to be added to form the n – type semiconductor material, which was incorrect. Other incorrect responses that a high percentage of candidates gave were silicon and germanium.

Part (a) (iii) required candidates to name two bias conditions of a semiconductor diode when it is connected in a half-wave rectifier circuit. This part of the question was particularly well done, with the majority of candidates (approximately 90 per cent) getting full marks.

In Part (b), candidates were given a schematic drawing of an npn transistor amplifier circuit and were asked to explain the function of two resistors in the operation of the circuit. Most candidates attempted this question, but were unable to provide the appropriate response. Candidates responded by providing answers of what is a resistor and what it does in an electronic circuit. Approximately 40 per cent of them provided responses such as biasing, and limiting current. Whilst the remaining 60 per cent responded by describing the function of the resistor in the circuit. Overall, approximately 30 per cent of the candidates were able to obtain four or more marks for this part of the question.

The correct responses for this question are shown below.

Part (a) (i) p-type impurities

- Indium
- Aluminum
- Boron

(ii) n-type material

- Antimony
- Arsenic
- Phosphorous

(iii) Bias conditions

- Forward Bias
- Reverse Bias

Part (b)

- Resistor R_1 and Resistor R_2 forms a potential divider that produces two voltage drops V_1 and V_2.
- V_1 provides a reverse bias for the base collector junction of the transistor.
- V_2 provides a forward bias for the base emitter junction of the transistor.

Recommendations — Question 5

- This topic should be taught in the laboratory to give students a better understanding of the different parts of the transistor circuit and their functions.

SECTION B

Section B consisted of four free-response type questions, of which each candidate was required to answer three. These questions were a combination of essay/problem items, involving calculations and/or sketches taken from across the syllabus. Candidates were permitted to use non-programmable calculators to aid them in answering the questions. Each question was worth twenty (20) marks, weighted ten (10) marks for Knowledge, and ten (10) marks for Application. Where calculations were required, one (1) mark was typically awarded for specifying and/or utilizing the appropriate formula, one (1) mark for making the correct substitutions into the formula, and one (1) mark for obtaining the correct numerical answer.

Question 6

This question assessed candidates' knowledge of resistance and the application of knowledge to resistors connected in series–parallel combinations.

In Part (a) (i), candidates were asked to list three types of fixed resistor materials used in electronic circuits. Most candidates were only able to identify carbon as one type of fixed resistor. Most of them were unfamiliar with the types of materials from which fixed resistors were constructed. Materials such as chrome, tungsten, manganum, constantan and nickelin were rarely listed.

Part (a) (ii) required candidates to name two circuit components that can vary the electrical resistance in an electrical circuit. The most common response was variable resistor, with components like potentiometer and rheostat hardly being given.

In Part (b), candidates were given a schematic diagram of six resistors connected in series–parallel and they were required to complete a series of calculations. This part of the question was poorly done as few candidates were able to differentiate between series and parallel connections. There was much difficulty in finding the branch resistance since many candidates did not recognize that they were two series branches in parallel. Some candidates were able to find the equivalent resistance, the total resistance and the total current, but the solutions for the current through R2 and the voltage drop across R3 were not solved in most cases.

The correct responses for this question are shown below.

Part (a) (i) Carbon
Nickelin
Nichrome
Manganum
Constantan
Tungsten

(ii) Rheostat
Potentiometer

Part (b) (i) $R_e = \dfrac{R_{(2+3)} \times R_{(4+5)}}{R_{(2+3)} + R_{(4+5)}}$

$R_e = \dfrac{40\,\Omega \times 40\,\Omega}{40\,\Omega + 40\,\Omega}$

$R_e = 20\,\Omega$

(ii) $R_T = R_1 + R_e\, R_6$

$= 10\,\Omega + 20\,\Omega + 6\,\Omega$

$R_T = 36\,\Omega$

(iii) $I_T = \dfrac{V_s}{R_T}$

$I_T = \dfrac{18\text{ v}}{36\,\Omega}$

$I_T = 0.5\text{A}$

(iv) $V_e = I_T \times R_e$

$= 0.5\text{ A} \times 20\,\Omega$

$V_e = 10\text{ V}$

$I_a = \dfrac{V_e}{R_2 + R_3}$

$I_a = \dfrac{10\text{ v}}{40\,\Omega}$

$I_a = 0.25\text{A}$

(v) $V_3 = I_a \times R_3$

$= 0.25\text{ A} \times 10\,\Omega$

$V_3 = 2.5\text{ V}$

Recommendations — Question 6

- Teachers need to provide more practical sessions and opportunities for students to analyze series–parallel circuits, and reinforce the use of the various formulae in the different case scenarios: for example, two unequal resistors and two equal resistors in parallel.

Question 7

This question tested candidates' knowledge of inductive circuits and the application of knowledge to an inductive circuit connected to an AC supply. Part (a) (i) tested their ability to recognize the component parts and the constituent effects of a practical inductive AC circuit, while Part (b) assessed their ability to calculate certain parameters of an RL circuit with alternating current. This question proved to be fairly popular and the overall responses were good, with the majority of the candidates scoring between six and nine marks. The majority of the candidates who attempted this question were able to name a resistive component in an inductive AC circuit and were also able to calculate inductive reactance; however there were several areas of weak performance such as:

- confusing the formula of inductive reactance with that of capacitive reactance
- confusing the formula of apparent power with that of true power
- not stating apparent power in the correct units
- failure to recognize that in an AC RL circuit, the total opposition is the impedance of the circuit and not the resistance
- failure to recognize the operative term *resistive effects*, which refers to the opposition in an inductive circuit and instead looking for *effects on resistance*, and as such candidates responded with terms like temperature or heat, resistivity, length and cross-sectional area.

The correct responses for this question are shown below.

Part (a) (i) Ohmic resistance
Inductive reactance
Impedance

(ii) Active/true/ohmic/real power
Apparent power
Reactive power

(iii) Resistor/coil/inductor/choke

Recommendations — Question 7

- Students should take care in reading and interpreting the questions
- Teachers need to emphasize the differences in the opposition to current flow in RLC ac circuits, with particular reference to resistance, inductive reactance, capacitive reactance and impedance.
- Teachers need to emphasise the differences in the power in RLC ac circuits and the units, with particular reference to true, or real power (W), apparent power (VA) and reactive power (VAR).
- Teaching the power triangle is also recommended

Question 8

This question tested candidates' knowledge of computer systems and the application of knowledge relative to aspects of logic gates. Part (a) tested candidates' ability in computer systems, while Part (b) assessed their ability to draw logic gates, state Boolean expressions for given conditions and develop various two-input truth tables. The responses given were above average. Knowledge of computer input devices in addition to the application of knowledge to develop truth tables for logic gates were well understood, hence most respondents gained maximum marks for these parts of the question.

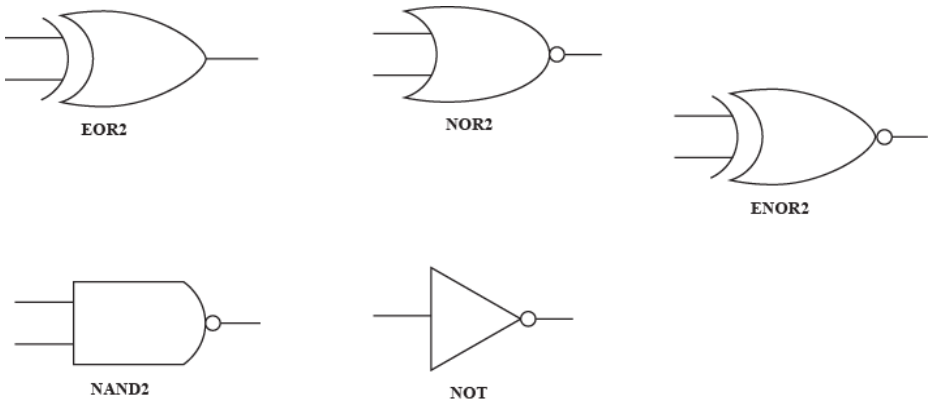
Despite relatively good performance on the question, there were several areas of weak performance. These include candidates:

- lacking knowledge of Boolean expressions
- failing to understand the difference between the UPS and a surge protector
- failing to understand the functions of software, i.e. they placed more emphasis on anti-viruses
- failing to understand the operations carried out by the central processing unit of a computer

The correct responses for this question are shown below.

Part (a) (i) Arithmetic operations, Logic operations
(ii) Keyboard, mouse, compact disc…..
(iii) Instructions to the CPU for correct operation of the computer.
(iv) Protects the computer from damage by high voltage surges of the ac supply.

Part (b) (i) K1 for name K1 for symbol



(ii) $A.B$
(iii) $A+B$
(iv) Truth table two-input AND gate.

INPUTS		OUTPUT
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

(v) Truth table two input OR gate 3 marks

INPUTS		OUTPUT
A	B	C
0	0	0
0	1	1
1	0	1
1	1	1

Recommendations — Question 8

- Students should take care in reading and interpreting the questions
- Teachers need to emphasize the functions, operations in a computer system
- Teachers also need to emphasize Boolean expressions

Question 9

This question tested candidates' knowledge and application of knowledge. Part (a) (i) tested candidates' ability to distinguish phase/polarity of electrical control equipment for a small industry. Part (a) (ii) tested their ability to identify electrical protection devices, while (a) (iii) tested their knowledge on methods used to reduce the START current of a three- phase induction motor. Part (b) tested their ability to calculate power, energy and cost of operating a DC motor for a factory.

Part (c) tested Candidates' knowledge of how earthing provides protection from electric shock in an electrical installation.

This question proved to be fairly popular, and the overall responses were good, with the majority of candidates scoring between six to twelve marks.

The majority of the candidates who attempted this question were able to name the two protective devices for an electrical installation and were able to calculate the power of the motor. However, there were several areas of weak performance:

- Identifying the phase for main control, motor control and lighting control. Candidates were unable to understand the line diagram and distinguish between three-phase and single-phase.
- The majority of candidates could not state methods used to reduce start current of a three-phase induction motor.
- Many candidates failed to calculate the cost of operating a motor given the number of days and cost per unit.
- Candidates were unable to explain how earthing provides protection from electric shock in an electrical installation. Many candidates misinterpreted the question and explained the types of earth material. The answer most given was that excess current goes to earth.

The correct responses for this question are shown below.

Part (a) (i) Main control: 3-phase 3-wire a.c.
Motor control: 3-phase 3-wire a.c.
Lighting control: 1-phase 2-wire a.c.

(ii) Fuses
Circuit breakers

(iii) Use autotransformer to reduce applied a.c.
Connect stator windings in STAR to reduce applied a.c.

Part (b) (i) Motor Power, p = V x I
P = 240 V x 30 A
P = 7200 W
P = 7.2 KW

(ii) Electrical Energy, E = P x T
E = 7.2 KW x 720 hrs
E = 5184 kwh

(iii) Energy cost = kwh x $0.20
Cost = 5184 kwh x $0.20
Cost = $1036.80

Part (c)

- The earthing of exposed metal parts establishes a low resistance connection to earth
- One side of the supply authority's transformer is also connected to earth

- When a phase or live conductor makes a contact with exposed metal, large fault current flows from the live or phase conductor to the earth
- The large fault current opens the fuse or circuit breaker and disconnects the exposed metal from the phase or live conductor, providing protection from electric shock.

Recommendations — Question 9

- Use practical activities to explain three-phase and single-phase connection.
- Use electricity bills to calculate energy and cost.
- Teach methods of calculation in steps.
- Let students make cards with definition and formula
- Use posters in lab with different topics identifying relevant areas to focus on.
- Have tutorial session every week.
- Compliment and reward students on success.

Question 10

This question tested the candidates' knowledge and application of various types of rectifier circuits. Candidates were expected to name the various types of rectifier circuits, and show understanding of the operation of:

(i) The full wave rectifier circuit connected via a centre-tapped transformer, and

(ii) The half-wave voltage — doubler rectifier circuit.

This question also tested the candidates' knowledge of the names of the components in a low-voltage DC power supply, and their understanding of the operation of a specified component of the low-voltage DC power supply. The question was popular and the candidates' responses reflected scores ranging from 0–16, with an average of eight.

In Part (a), **c**andidates were able to identify the various types of rectifier circuits. However, almost all of the candidates had no idea of the voltage doubler rectifier circuit. Of the candidates who attempted this question most of them understood the operation of the full-wave rectifier circuit connected via a centre-tapped transformer, but no one had the knowledge of the operation of the half-wave voltage doubler rectifier circuit.

The majority of the candidates who attempted Part (b) of this question were able to identify the components used in the construction of the low-voltage DC power supply, but lacked the understanding of the operation of the components of the low-voltage DC power supply. Some of the candidates experienced difficulty identifying the components 1, 2, 5, and 6 used in the construction of the low-voltage DC power supply.

The correct responses for this question are shown below.

Part (a) (i)
1. Half-wave rectifier circuit
2. Full-wave rectifier circuit - centre- tapped transformer,
3. Full-wave voltage bridge
4. Half-wave voltage doubler

(ii) In schematic diagram 2, when A is positive with respect to the centre-tap C, diode D1 conducts and current flows from positive to negative through resistor RL

When B is positive with respect to the centre-tap C, diode D2 conducts and current flows from positive to negative through resistor RL

In the rectifier, current flows in the same direction through RL for the complete cycle of the applied AC voltage.

(iii) In the schematic, diagram 4, when A is negative with respect to B, diode D1 conducts and capacitor C1 charges to the peak value of the applied AC voltage. No current flows through resistor RL. When A is positive with respect to B, diode D2 conducts and capacitor C2 is charged to a value equal to the sum of the peak of the applied voltage and the peak of the capacitor C1. The voltage across the output resistor RL is double the peak voltage of the applied AC input voltage. Current flows through RL for half of the cycle of the input voltage waveform.

Part (b) (i)
1. Step-down transformer
2. Bridge / Rectifier / diodes
3. Reservoir capacitor
4. Smoothing resistor
5. Smoothing capacitor
6. Bleeder resistor / load resistor

(ii) Electronic component 3 is a reservoir capacitor that reduces the AC variation in the rectified wave form of the direct current supplied by the unit.

Recommendations — Question 10

Teachers may adopt an approach to include:

- Design of the regulated power supply.
- Theory lessons (explanations of operations) and
- Practical projects which involve simple construction of the regulated power supply.

Question 11

This question tested candidates' knowledge of and application of knowledge to types of single-phase induction motors. This question also tested the candidates' knowledge and understanding of types of stator connections of the three-phase induction motor. The question was popular and the candidates' responses reflected scores ranging from 0–19 marks. In Part (a) (i), candidates were given schematic drawings of two single-phase AC motors and they were required to name each motor, while for Part (b) (ii), candidates were required to write the names of various identified parts of the AC motors. In Parts (a) (iii) and (iv) candidates were asked to explain how the rotating magnetic field effect is produced in the motor windings of one motor and explain the operation of the part labelled 1 in the control of current flow in the part labelled 2 in the single-phase AC motor respectively.

Most of the candidates were able to name the two types of single-phase motors and identify the parts of the motor. However, almost all of the candidates had no idea of the operation of the single- and three-phase motor. Those candidates who attempted this question saw the centrifugal switch as an on and off switch but could not explain the operation.

In Part (b) (i), candidates were required to name the connection of the stator windings of the three-phase motor as indicated on a given diagram. Part (b) (ii) required candidates to define three terms, while in Part (b) (iii) they were required to explain the operation of a three-phase induction motor when supplied by a three-phase system. The majority of the candidates who attempted this question were unable to identify the components of the three-phase motor connection. Most of the candidates had an understanding of the terms *synchronous speed* and *slip speed* of the three-phase motor but lacked understanding of the term *single-phasing*.

The correct responses for this question are shown below.

Part (a) (i)
A. Capacitor – start induction motor.
B. Induction – start induction motor.

(ii) 1. Centrifugal switch
2. Starting winding
3. Running winding

(iii) The current flowing in the stator windings is constructed at a phase displacement of 90º and the current in the capacitor and the running winding sets up respective magnetic fields at any instant of time, this interaction produces a rotating magnetic field in the stator.

(iv) The centrifugal switch located on the shaft is normally closed on starting the single-phase motor. Upon reaching approximately 75 per cent of the maximum speed, the switch opens, disconnecting the stator winding allowing the motor to run as an induction motor.

Part (b) (i) C. Star or WYE connection
D. Delta or Mesh connection

(ii)

- Synchronous speed is the speed of the rotating magnetic field of the three-phase a.c. motor.
- Slip speed is the difference in speed between the speed of the rotating magnetic field or synchronous speed and rotor speed of the three-phase a. c. motor.
- Single-phasing is the effect produced when an open circuit occurs in one of the line or phase conductors supplying the three-phase a. c. motor.

(iii)

- The three-phase supply is applied to the stator winding which produces rotating magnetic field in the stator. The rotating magnetic field of the stator induces a current in the rotor conductors thus producing another magnetic field which opposes the stator magnetic field. The interaction of both magnetic field cause the rotor to rotate in the direction of the stator magnetic field.

Recommendations — Question 11

Teachers may adopt an approach to include:

- Designing projects to incorporate the starting of single- and three-phase induction motors.

- Looking at online (You Tube) animations of the operation of both single- and three-phase induction motors.

- Practical projects which involve simple assembly and disassembly of both single- and three-phase induction motors.