basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE EXAMINATIONS/ NATIONAL SENIOR CERTIFICATE EXAMINATIONS

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

2023

MARKING GUIDELINES

MARKS: 200

These marking guidelines consist of 15 pages.

INSTRUCTIONS TO THE MARKERS

1. All questions with multiple answers imply that any relevant, acceptable answer should be considered.

2. Calculations:

    2.1 All calculations must show the formulae.

    2.2 Substitution of values must be done correctly.

    2.3 All answers MUST contain the correct unit to be considered.

    2.4 Alternative methods must be considered, provided that the correct answer is obtained.

    2.5 Where an incorrect answer could be carried over to the next step, the first answer will be deemed incorrect. However, should the incorrect answer be carried over correctly, the marker has to re-calculate the values, using the incorrect answer from the first calculation. If correctly used, the candidate should receive the full marks for subsequent calculations.

3. This memorandum is only a guide with model answers. Alternative interpretations must be considered and marked on merit. However, this principle should be applied consistently throughout the marking session at ALL marking centres.

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

1.1	B ✓	(1)
1.2	C ✓	(1)
1.3	C ✓	(1)
1.4	C ✓	(1)
1.5	D ✓	(1)
1.6	A ✓	(1)
1.7	B ✓	(1)
1.8	D ✓	(1)
1.9	B ✓	(1)
1.10	C ✓	(1)
1.11	A ✓	(1)
1.12	D ✓	(1)
1.13	B ✓	(1)
1.14	C ✓	(1)
1.15	B ✓	(1)
		[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 The purpose of the act is to provide good health and safety to all people at work ✓ especially when using machinery ✓ and for protection against the hazards arising out of activities of other ✓ people.
To establish an advisory council for occupational health and safety and related matters. (3)

2.2 An unsafe act may lead to an accident ✓ injuring an employee, this reduces the number of skilled personnel in the workplace ✓ therefore reducing the rate of productivity. (2)

2.3 Actions that will have serious consequences when they occur,✓ but there is a low chance of these risks happening. ✓ (2)

2.4
- Apply direct pressure to the wound using a cloth or gauze. ✓
- Apply continual pressure to a pressure point to stop all circulation to that part of the body. ✓ (2)

2.5 Not to be in direct contact with blood due to the risk of HIV infection. ✓ (1)
[10]

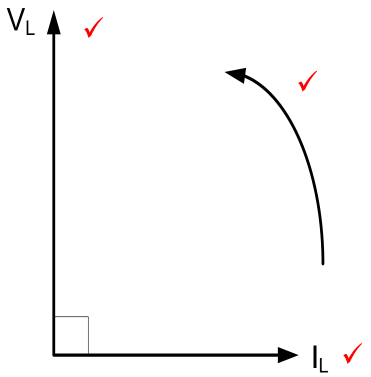
QUESTION 3: RLC CIRCUITS

3.1 When the voltage and current waveforms start at the same time, ✓ have the same frequency ✓ resulting in a zero phase angle. ✓

OR

When any waveforms of electrical quantities start at the same time, reach their peak at the same time, pass through zero at the same time and end at the same time. (The two waves have the same frequency even though their amplitude may differ) (3)

3.2



(3)

3.3 Radio tuning circuits ✓
Television tuning circuits ✓ (2)

3.4 3.4.1 A - Impedance versus frequency. ✓ (1)

3.4.2 B - Current versus frequency. ✓ (1)

3.5 3.5.1

$$V_T = \sqrt{V_R^2 + (V_L - V_C)^2} \quad ✓$$

$$= \sqrt{30^2 + (60 - 20)^2} \quad ✓$$

$$= 50\ V \quad ✓$$

(3)

3.5.2

$$Tan\ \theta = \frac{V_L - V_C}{V_R} \checkmark$$

$$\theta = Tan^{-1}\left(\frac{V_L - V_C}{V_R}\right)$$

$$\theta = Tan^{-1}\left(\frac{60 - 20}{30}\right) \checkmark$$

$$\theta = 53{,}13° \checkmark$$

(3)

OR

$$\theta = Cos^{-1}\left(\frac{V_R}{V_T}\right)$$

$$= Cos^{-1}\left(\frac{30}{50}\right)$$

$$= 53{,}13^0$$

3.5.3 Lagging. ✓
(Reason - The voltage across the inductor is greater than the voltage across the capacitor). (1)

3.6 3.6.1 At resonance $X_L = X_C = 113{,}12\ \Omega$

$$X_L = 2\pi f L \checkmark$$

$$L = \frac{X_L}{2\pi f}$$

$$= \frac{113{,}12}{2\pi(3000)} \checkmark$$

$$= 6\ \text{mH} \checkmark$$

(3)

3.6.2

$$Q = \frac{X_C}{R} \checkmark$$

$$= \frac{113{,}12}{100} \checkmark$$

$$= 1{,}13 \checkmark$$

(3)

3.6.3

$$BW = \frac{f_r}{Q} \checkmark$$

$$= \frac{3000}{1,13} \checkmark$$

$$= 2654,87\ Hz \checkmark$$

(3)

3.6.4 The value of the current will be doubled. ✓ (1)

3.7 3.7.1

$$I_L = \frac{V_T}{X_L} \checkmark$$

$$= \frac{120}{300} \checkmark$$

$$= 0,4\ A \checkmark$$

OR

$$I_L = \sqrt{I_T^2 - I_R^2} + I_C$$

$$= \sqrt{1,22^2 - 1,2^2} + 0,2$$

$$= 0,42\ A$$

(3)

3.7.2

$$P = I^2R \checkmark$$

$$= (1,2)^2 \times 100 \checkmark$$

$$= 144\ W \checkmark$$

(3)

OR

$$Cos\ \theta = \frac{I_R}{I_T}$$

$$P = VI\left(\frac{I_R}{I_T}\right)$$

$$= 120 \times 1,22 \times \frac{1,2}{1,22}$$

$$= 144\ W$$

3.7.3 The circuit is inductive ✓ because the inductive current is greater than the capacitive current.✓ (2)

[35]

QUESTION 4: THREE-PHASE AC GENERATION

4.1 4.1.1 (a) Step- up transformer ✓ (1)

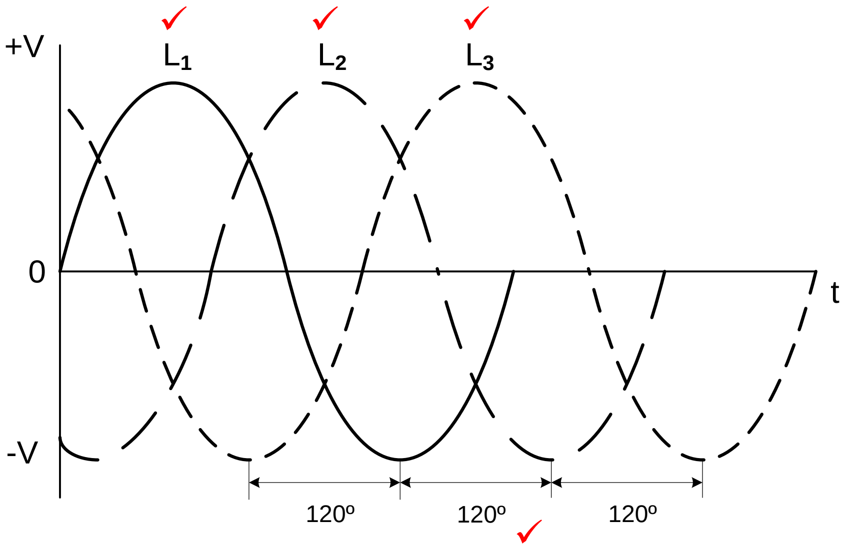
(b) Step- down transformer ✓ (1)

4.1.2 Household 220 V - 240 V ✓
Industrial 380 V - 415 V ✓ (2)

4.1.3 The secondary windings of the transformer at (D) are connected in star ✓ to create a neutral point ✓ enabling the transformer to power both single and three-phase loads. (2)

4.1.4 Transformer at (B) is a step-up transformer that increases the voltage ✓ across the lines and in turn reduces the current through it. ✓ This reduces the copper losses. (2)

4.1.5



(4)

4.2 4.2.1

$$V_{PH} = \frac{V_L}{\sqrt{3}} \quad ✓$$

$$= \frac{400}{\sqrt{3}} \quad ✓$$

$$= 230{,}94\ V \quad ✓$$

(3)

4.2.2 $I_{PH} = \frac{V_{PH}}{Z_{PH}}$ ✓

$= \frac{230,94}{75}$ ✓

$= 3,08\ A$ ✓ (3)

4.2.3 In star $I_L = I_{PH}$ ✓

$P = \sqrt{3} V_L I_L cos\theta$ ✓

$= \sqrt{3}(400)(3,08)(0,8)$ ✓

$= 1707,11\ W$ ✓ (4)

4.2.4 $Cos\theta = pf$ ✓

$\theta = Cos^{-1}(pf)$

$= Cos^{-1}(0,8)$ ✓

$= 36,87°$ ✓ (3)

4.2.5 $Q = \sqrt{3} V_L I_L sin\theta$ ✓

$= \sqrt{3}(400)(3,08)sin(36,87)$ ✓

$= 1280,34\ VAr$ ✓ (3)

NOTE: VAR will also be accepted as a correct unit.

4.2.6 The power factor is lagging. ✓ (1)

4.2.7 The power factor of the system can be improved by connecting power factor correcting capacitors ✓ in parallel with the load. ✓
Phase advancers can be used. (2)

4.2.8 An improved power factor will draw less current, ✓ generate less heat, resulting in thinner supply cables etc. ✓ and the power factor will be closer to one (unity). (2)

4.2.9 Reduced monthly electricity bill. ✓
Equipment lasts longer ✓ because less heat is generated.
Less maintenance of equipment. (2)

[35]

QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 Mutual induction. ✓ (1)

5.2
- The AC supply voltage connected to the primary winding creates alternating current ✓ to flow in the primary windings.
- The alternating current flowing in the primary winding creates an alternating magnetic field ✓ around the coils in the primary windings ✓ that expands and collapses as the alternating supply voltage increases and decreases. (3)

5.3 Size ✓
Frequency ✓
Turns ratio ✓
Voltage rating
Power rating
Efficiency (3)

5.4 Delta-delta transformers are mainly used in industries ✓ where high power transfer is essential. ✓ (2)

5.5 5.5.1 Single-phase transformers ✓ (1)

5.5.2 Three-phase transformers ✓ (1)

5.5.3 Single-phase transformers ✓ (1)

5.6 5.6.1 Dry type transformers ✓
Oil immersed transformers ✓ (2)

5.6.2 Air Natural ✓
Air forced ✓
Oil Natural, Air Natural (ONAN)
Oil Natural, Air Forced (ONAF)
Oil Forced, Air Forced (OFAF)
Oil Forced, Water Forced (OFWF) (2)

5.6.3 Buchholtz relay ✓ (1)

5.7 5.7.1

$$\frac{N_1}{N_2} = \frac{V_{PH1}}{V_{PH2}} \checkmark$$

$$V_{PH2} = \frac{N_2 \times V_{PH1}}{N_1}$$

$$= \frac{1 \times 6000}{25} \checkmark$$

$$= 240\ V \checkmark$$

(3)

5.7.2

$$V_{L2} = \sqrt{3}V_{PH2} \checkmark$$
$$= \sqrt{3}(240) \checkmark$$
$$= 415{,}69\ V \checkmark$$

(3)

5.7.3

$$Cos\theta = \frac{P}{S} \checkmark$$

$$S = \frac{P}{Cos\theta}$$

$$= \frac{50\ 000}{0{,}9} \checkmark$$

$$= 55\ 555{,}56\ VA \checkmark$$

$$= 55{,}56\ kVA$$

(3)

5.7.4 In transformers
S **(primary)** = S **(secondary)** ✓

✓

$$I_{L1} = \frac{S}{\sqrt{3}\ V_{L1}}$$

$$= \frac{55\ 555{,}56}{\sqrt{3}(6000)} \checkmark$$

$$= 5{,}35\ A \checkmark$$

OR

$$P = \sqrt{3}\ V_{L1} I_{L1} Cos\theta$$

$$I_{L1} = \frac{P}{\sqrt{3}\ V_{L1} Cos\theta}$$

$$= \frac{50000}{\sqrt{3}(6000)(0{,}9)}$$

$$= 5{,}35\ A$$

(4)
[30]

QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1 Shaft ✓
Rotor conductor bars ✓
End ring ✓
Steel laminations
Cooling fins (3)

6.2 6.2.1 Synchronous speed ✓ (1)

6.2.2 Rotor slip is the difference between the synchronous speed ✓ and rotor speed. ✓ (2)

6.2.3 At point **X** the rotor speed is equal to the synchronous speed, ✓ therefore there is no relative movement between the stator magnetic field and the rotor conductors ✓ resulting in zero torque being developed. (2)

6.3 6.3.1

$$n_s = \frac{60 \times f}{p} \quad ✓$$
$$= \frac{60 \times 50}{4} \quad ✓$$
$$= 750\ r/\min(rpm) \quad ✓$$

(3)

6.3.2

$$\%\,Slip = \frac{n_S - n_R}{n_S} \times 100 \quad ✓$$
$$n_R = n_S - \left(\frac{\%\,Slip}{100} \times n_S\right)$$
$$= n_S - \left(\frac{5}{100} \times 750\right) \quad ✓$$
$$= 712{,}5\ r/\min(rpm) \quad ✓$$

(3)

6.4 6.4.1

$$P_T = P_1 + P_2 \quad ✓$$
$$= 75\ 000 + 50\ 000 \quad ✓$$
$$= 125\ 000\ W \quad ✓$$
$$= 125\ kW$$

(3)

6.4.2

$$Q_T = Q_1 + Q_2 \quad ✓$$
$$= 45\ 000 + 21\ 790 \quad ✓$$
$$= 66\ 790\ VAr \quad ✓$$
$$= 66{,}79\ kVAr$$

(3)

6.4.3

$$S = \sqrt{(P_T)^2 + (Q_T)^2} \checkmark$$
$$= \sqrt{125\ 000^2 + 66\ 790^2} \checkmark$$
$$= 141\ 724{,}75\ VA \checkmark$$
$$= 141{,}72\ kVA$$

(3)

6.4.4

$$Cos\theta = \frac{P_T}{S} \checkmark$$
$$= \frac{125\ 000}{141\ 724{,}75} \checkmark$$
$$= 0{,}88 \checkmark$$

(3)

6.5 6.5.1 MC_2N/C ✓
MC_1N/C ✓ (2)

6.5.2 A normally closed contact will allow current to flow in the circuit, ✓ MC_1 will de-energise to isolate the motor from the supply ✓ when a faulty current activates the overload relay. ✓ (3)

6.5.3 While MC_1 is energised its MC_1N/C contact in series ✓ with MC_2 is open, ✓ therefore isolating MC_2 which will not energise even when START 2 is pressed. (2)

6.5.4 When MC_1N/O is faulty and permanently open, MC_1 will only energise when START 1 is pressed. ✓ As soon as START 1 is released MC_1 will de-energise. ✓ (2)

[35]

QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS (PLCs)

7.1 Relays require regular maintenance and repair. ✓
Uses much more energy. ✓
It requires a lot of space to be wired.
It has slower response time.
When a single relay develops faults in a panel, it takes much time to locate and fix which might delay production. (2)

7.2 Soft wired systems are cheaper when modifications to the system is done. Instead of buying new devices,✓ the program is simply altered. ✓ (2)

7.3 7.3.1 After pressing the ON button the function of the ON-delay timer is to prevent the lamp from being switched on ✓ before the pre-set time has lapsed.✓ (2)

7.3.2 When the ON button is pressed (ON contact closes), coil Y will be energised ✓ closing contact Y. ✓
The timer will start timing for a pre-set time. ✓
After the pre-set time has lapsed, contact T will close and the lamp will switch "ON" ✓
The Lamp will remain switched "ON" until the OFF button is pressed. ✓ (5)

7.4 7.4.1 Relay – "A device of which contacts in one circuit are operated by a change in conditions ✓ in the same circuit or in one or more associated circuits" ✓ commonly used in lower power circuits.

Contactor – "A device for repeatedly establishing and interrupting an electric circuit ✓ under normal conditions" ✓ commonly used in high power circuits.

OR

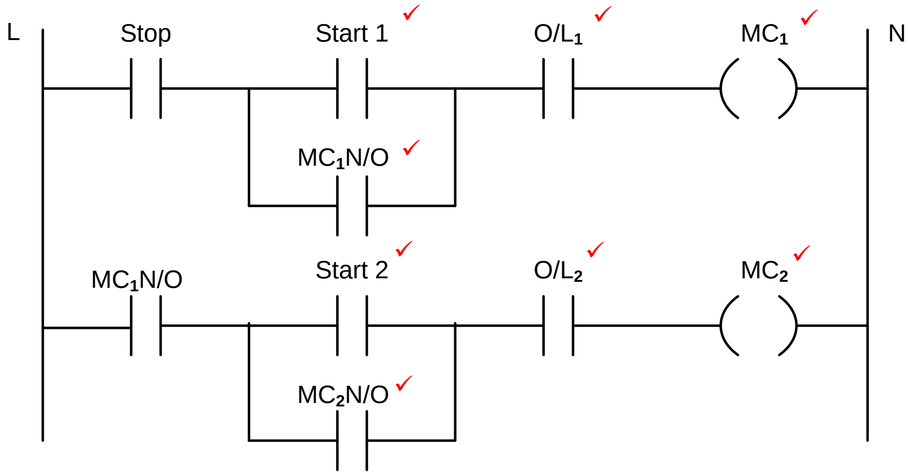
A contactor joins 2 poles together, without a common circuit between them, while a relay has a common contact that connects to a neutral position. (4)

7.4.2 The moment an OFF-delay timer is de-energised, the contacts remain closed for the duration of the pre-set time as programmed in the ladder program. ✓ Only after the pre-set time has lapsed, will the contacts open and de-energise the output. ✓ (2)

7.5 7.5.1 Detection and positioning of objects ✓
Measuring rotating speed ✓
Counting objects on a conveyer
Detecting direction (2)

7.5.2 Inductive ✓
Capacitive ✓
Ultrasonic
Photoelectric (2)

7.6 7.6.1



NOTE: Alternatively, the candidate could use closed symbols in the place of the open stop symbol and both overload symbols. Stop and overload symbols must be in the same normal state. (8)

7.6.2 The motors may have different rated current values, ✓ so the method offers independent overcurrent protection to each motor. ✓ (2)

7.6.3 The MC_1N/O_2 contact ensures that motor 1 must be energised ✓ before motor 2 can be energised. ✓ (2)

7.7 A process of changing the frequency of the input voltage ✓ to change the speed and torque of the motor. ✓ (2)

7.8 7.8.1 Regenerative braking methods may be used in:
Lifts ✓
Cranes ✓
Electrical locomotives (2)

7.8.2 Regenerative energy is energy recovered from the motor ✓ when it slows down by converting mechanical energy to electrical energy ✓ which can be either used immediately or stored until needed. ✓ (3)

[40]

TOTAL : 200