basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE EXAMINATIONS/
NATIONAL SENIOR CERTIFICATE EXAMINATIONS

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

MAY/JUNE 2026

MARKING GUIDELINES

MARKS: 200

These marking guidelines consist of 15 pages.

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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 marking guideline 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	A ✓	(1)
1.3	C ✓	(1)
1.4	A ✓	(1)
1.5	C ✓	(1)
1.6	D ✓	(1)
1.7	D ✓	(1)
1.8	D ✓	(1)
1.9	C ✓	(1)
1.10	B ✓	(1)
1.11	A ✓	(1)
1.12	D ✓	(1)
1.13	B ✓	(1)
1.14	B ✓	(1)
1.15	A ✓	(1)

[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 It is an unsafe act. ✓ (1)

2.2 Any person who employs or provides work for any person ✓ and remunerates that person. ✓ (2)

2.3 It is when an attempt is made to numerically determine the probability of various adverse events ✓ and the likely extent of the losses if a particular event takes place. ✓ (2)

2.4 Human rights ensure that human dignity is not infringed ✓ and that everyone is treated with respect, have equal opportunities ✓ and are not exploited in the workplace. (2)

2.5 When the employee feels personally responsible for his/her job performance, he/she shows up on time, ✓ puts in his/her best effort ✓ and completes projects to the best of his/her ability keeping production high. ✓ (3)
[10]

QUESTION 3: RLC CIRCUITS

3.1 3.1.1 Impedance is the total opposition to the flow of current ✓ in an AC circuit comprising of resistance and reactance. ✓ (2)

3.1.2 Resonant frequency is a specific frequency ✓ at which inductive reactance is equal to the capacitive reactance. ✓ (2)

3.1.3 In a parallel RLC circuit at resonance the impedance is maximum ✓ and current minimum. ✓ (2)

3.2 3.2.1 The current through the inductor lags the voltage across it. ✓ (1)

3.2.2
$$X_c = \frac{1}{2\pi fC} \quad ✓$$
$$= \frac{1}{2\pi \times 80 \times 40 \times 10^{-6}} \quad ✓$$
$$= 49{,}74\ \Omega \quad ✓$$
(3)

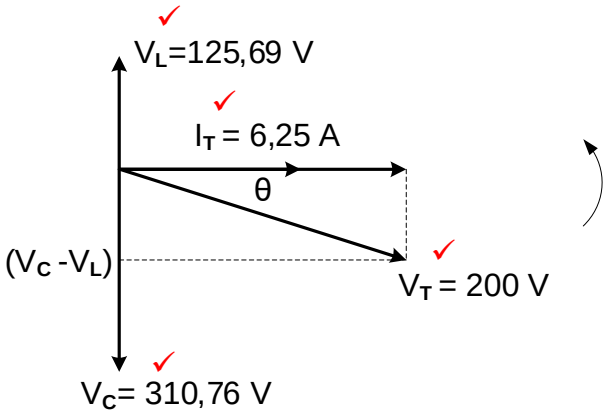
3.2.3
$$X_L = 2\pi fL \quad ✓$$
$$L = \frac{X_L}{2\pi f}$$
$$= \frac{20{,}11}{2\pi \times 80} \quad ✓$$
$$= 0{,}04\ H \quad ✓$$
(3)

3.2.4
$$Z = \sqrt{R^2 + (X_C - X_L)^2} \quad ✓$$
$$R = \sqrt{Z^2 - (X_C - X_L)^2}$$
$$= \sqrt{31{,}98^2 - (49{,}74 - 20{,}11)^2} \quad ✓$$
$$= 12{,}03\ \Omega \quad ✓$$
(3)

3.2.5
$$I_T = \frac{V_T}{Z} \quad ✓$$
$$= \frac{200}{31{,}98} \quad ✓$$
$$= 6{,}25\ A \quad ✓$$
(3)

3.2.6
$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad ✓$$
$$f_r = \frac{1}{2\pi\sqrt{0{,}04 \times 40 \times 10^{-6}}} \quad ✓$$
$$f_r = 125{,}82\ Hz \quad ✓$$
(3)

3.3



(4)

3.4 3.4.1

$$X_L = \frac{V_T}{I_L} \quad ✓$$

$$= \frac{90}{3} \quad ✓$$

$$= 30\ \Omega \quad ✓$$

(3)

3.4.2

$$X_C = \frac{1}{2\pi fC} \quad ✓$$

$$C = \frac{1}{2\pi f X_c}$$

$$= \frac{1}{2\pi \times 150 \times 11{,}25} \quad ✓$$

$$= 94{,}31\ \mu F \quad ✓$$

(3)

3.4.3

$$I_T = \sqrt{(I_R)^2 + (I_C - I_L)^2} \quad ✓$$

$$= \sqrt{(4{,}5)^2 + (8-3)^2} \quad ✓$$

$$= 6{,}72A \quad ✓$$

(3)
[35]

QUESTION 4: THREE-PHASE AC GENERATION

4.1 Hydro power generation. ✓
Wind power generation. ✓
Solar power generation. (2)

4.2
- Two voltages are available, namely V_L and V_{PH} ✓
- For the same power rating, three-phase motors are cheaper, more efficient, operate at a better power factor and they are self-starting.
- Only 87% of the amount of copper is required for the same output when compared to single-phase motors. (1)

4.3
- Less current drawn from the supply. ✓
- Cost saving from drawing less current. ✓
- Less heat is generated.
- Maintenance is reduced due to the motor operating cooler.
- Longer life span of the load. (2)

4.4 A three-phase supply is generated when three coils are placed 120º apart ✓ and then rotated in a uniform magnetic field. ✓ This produces three single phase voltages ✓ each voltage separated from the next by a phase angle of 120º. (3)

4.5 4.5.1

$$V_L = \sqrt{3}V_{PH} \quad ✓$$
$$= \sqrt{3} \times 230 \quad ✓$$
$$= 398{,}37\ V \quad ✓$$

(3)

4.5.2

$$S = \sqrt{3}V_L I_L \quad ✓$$
$$I_L = \frac{S}{\sqrt{3}V_L}$$
$$= \frac{20\ 000}{\sqrt{3} \times 398{,}37} \quad ✓$$
$$= 28{,}99\ A \quad ✓$$

(3)

4.5.3

$$P = \sqrt{3}\, V_L I_L \text{Cos}\theta \quad ✓$$
$$= \sqrt{3} \times 398{,}37 \times 28{,}99 \times 0{,}85 \quad ✓$$
$$= 17002.56 \quad ✓$$
$$= 17\ kW$$

OR

$$\text{Cos}\theta = \frac{P}{S}$$
$$P = S\text{Cos}\theta$$
$$= 20\ 000 \times 0{,}85$$
$$= 17\ 000\ W$$

(3)

4.5.4 $Q = \sqrt{3}V_L I_L \text{Sin}\theta$ ✓
$= \sqrt{3} \times 398{,}37 \times 28{,}99 \times \text{Sin } 31{,}79$ ✓
$= 10\,561.46 \text{ VAr}$ ✓
$= 10{,}56 \text{ kVAr}$

OR

$Q = S \times \text{Sin}\theta$
$= 20\,000 \times \text{Sin } 31{,}79$
$= 10\,536{,}15 \text{ VAr}$
$= 10{,}54 \text{ kVAr}$ (3)

4.6 4.6.1 The product of the two instruments will provide the apparent power ✓ and not the power.

A voltmeter measures voltage, and an ammeter measures current, but do not consider the phase relationship between the voltage and current. (1)

4.6.2 $P_T = P_1 + P_2 + P_3$ ✓
$P_2 = P_T - (P_1 + P_3)$
$= 2747 - (2010 + 670)$ ✓
$= 67\ W$ ✓ (3)

4.6.3 A wattmeter measures the electrical power consumed by an application. ✓
A kilowatt-hour meter measures the amount of power consumed over a period of time. (energy) ✓ (2)

4.6.4 Zero ✓ Amperes (1)

4.7
- Low power factor increases the total current for a given power, ✓ increases the resistance losses ✓ and therefore decreases the efficiency of both apparatus and supply systems. ✓
- Limits the output of both generators and transformers. ✓
- Causes a greater fall in the terminal voltage regulation of generators, transformers and transmission greater than it would be at unity power factor. (4)

4.8 4.8.1 Power factor meter ✓ (1)

4.8.2 A - Voltage transformer. ✓
B - Current transformer. ✓ (2)

4.8.3 An addition of inductive loads to the system will decrease ✓ the reading displayed on the instrument. (1)
[35]

QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 Transformation is the way in which transformers increases voltage from a low to a high voltage ✓ or decreases voltage from a high voltage to a low voltage. ✓ (2)

5.2 5.2.1 FIGURE A - Core type ✓
FIGURE B - Shell type ✓ (2)

5.2.2 An iron core is needed to provide a magnetic field path ✓ to concentrate the magnetic field lines within the core material ✓ for maximum induction and power transfer to the secondary windings. (2)

5.3 Oil forced; Water forced (OFWF) ✓
Oil forced; Air forced (OFAF) ✓
Oil Natural; Air Natural (ONAN)
Oil Natural; Air forced (ONAF)
Oil forced; Air Natural (OFAN) (2)

5.4 Size ✓
Frequency ✓
Windings ratio
Voltage
Power factor
Efficiency (2)

5.5 5.5.1 $P = \sqrt{3}V_{L2}I_{L2}Cos\theta$ ✓

$$I_{L2} = \frac{P}{\sqrt{3}V_{L2}Cos\theta}$$

$$= \frac{300 \times 10^3}{\sqrt{3} \times 480 \times 0{,}86}$$ ✓

$$= 419{,}59\ A$$ ✓ (3)

5.5.2 $I_{L2} = \sqrt{3}\, I_{PH2}$ ✓

$$I_{PH2} = \frac{I_{L2}}{\sqrt{3}}$$

$$= \frac{419{,}59}{\sqrt{3}}$$ ✓

$$= 242{,}25\ A$$ ✓ (3)

5.5.3 $S = \frac{P}{Cos\theta}$ ✓

$= \frac{300\ 000}{0{,}86}$ ✓

$= 348\ 837{,}21\ VA$ ✓

$= 348{,}84\ kVA$

OR

$S = \sqrt{3}\, V_{L2}\, I_{L2}$

$= \sqrt{3} \times 480 \times 419{,}59$

$= 348\ 840{,}57\ VA$

$= 348{,}84\ kVA$

(3)

5.5.4 $S = \sqrt{3}\, V_{L1}\, I_{L1}$ ✓

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

$$= \frac{348{,}84 \times 10^3}{\sqrt{3} \times 5\,000}$$ ✓

$$= 40{,}28\ A$$ ✓

(3)

5.5.5 $$TR = \frac{N_1}{N_2}$$ ✓

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

$$= \frac{5\,000}{277{,}13}$$ ✓

$$= 18{,}04$$

$$= 18 : 1$$ ✓

(3)

5.6 5.6.1 Using three transformers is bulky ✓or more expensive. (1)

5.6.2 Single-phase transformers connected in a star-delta configuration are used as step-down transformers ✓ in high voltage supply lines. (1)

5.6.3 To be able to match the incoming power ✓ and to transform the incoming voltage ✓ level needed in the correct phase sequence ✓ or polarity.

- Prevents phase opposition.
- Ensures correct phase displacement (proper phase rotation).
- Prevents circulating currents.
- Prevents short-circuit conditions.
- Ensures balanced operation.

(3)
[30]

QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1 In a three-phase motor, *induction* refers to the process where a rotating magnetic field created by the stator windings induces an emf ✓ in the rotor conductors, ✓ causing the rotor to rotate due to the electromagnetic interaction ✓ between the stator's magnetic field and the induced current in the rotor.

Induction in a three-phase induction motor is the transfer of electrical energy from the stator to the rotor through a changing magnetic field, without physical electrical connections. (3)

6.2 6.2.1 Full-load speed is the speed at which the rotor rotates ✓ when maximum load is connected to the motor shaft. ✓ (2)

6.2.2
$$n_s = \frac{60f}{p} \quad ✓$$
$$= \frac{60 \times 50}{4} \quad ✓$$
$$= 750\ r/min \quad ✓$$
(3)

6.2.3
$$\%slip = \left(\frac{n_s - n_r}{n_s}\right) \times 100 \quad ✓$$
$$= \left(\frac{750 - 725}{750}\right) \times 100 \quad ✓$$
$$= 3{,}33\ \% \quad ✓$$
(3)

6.3 Check if the:
Shaft rotates freely. ✓
Bearings turn smoothly when the shaft is turned. ✓
Bearing housings are free from excess grease or dust. (2)

6.4 6.4.1
$$Cos\theta = pf \quad ✓$$
$$pf = Cos20 \quad ✓$$
$$= 0{,}94 \quad ✓$$
(3)

6.4.2
$$P_{IN} = \sqrt{3}V_L I_L Cos\theta \quad ✓$$
$$= \sqrt{3} \times 380 \times 5 \times Cos20 \quad ✓$$
$$= 3\,092{,}43\ W$$
$$= 3{,}09\ kW \quad ✓$$

OR

$$P_{IN} = \sqrt{3}V_L I_L Cos\theta$$
$$= \sqrt{3} \times 380 \times 5 \times 0{,}94$$
$$= 3\,093{,}44\ W$$
$$= 3{,}09\ kW$$
(3)

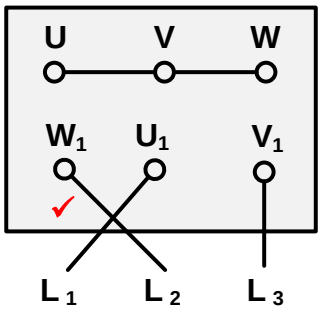
6.4.3 $$\eta = \frac{P_{IN} - losses}{P_{IN}} \times 100$$ ✓

$$losses = P_{IN} - \left(P_{IN} \times \frac{\eta}{100}\right)$$

$$losses = 3\,092{,}43 - \left(3\,092{,}43 \times \frac{90}{100}\right)$$ ✓

$$= 309{,}24\ W$$ ✓ (3)

6.5



NOTE:
If a learner redrew the diagram as given and swop the labels of L_1 and L_2 or any other two lines that will still cause a correct change in rotation of the motor, marks will be awarded. (1)

6.6 6.6.1 A – T_1 N/C ✓ Timer normally closed contact (1)

6.6.2 MC_3N/C is used as a normally closed interlocking contact ensuring the star contactor MC_2 gets energised when the start button is pressed ✓ and de-energises as soon as the delta contactor MC_3 is energised.✓ (2)

6.6.3
- To reduce the starting voltage. ✓
- To reduce starting current by 1/3 of delta current. ✓
- To ensure that there is safe transition when switching from star to delta.
- To protect the wiring in the circuit from burning by reducing the current.
- To protect the conductors in the motors by reducing the current. (2)

6.6.4
- When the start button is pressed MC_1 energise ✓ which closes MC_1N/O and latches MC_1 ✓ allowing the start button to be released.
- Simultaneously timer T_1 is energised, starts counting and MC_2 (star) is energised. ✓
- Immediately when the timer has timed through contact A (T_1 N/C) opens ✓ and T_1 N/O closes. ✓
- When contact A (T_1 N/C) opens, MC_2 de-energise and close contact MC_2N/C. ✓
- When T_1 N/O close MC_3 (delta) energise and opens MC_3 N/C. ✓ (7)

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

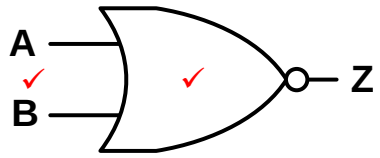
7.3 Soft wired systems are cheaper when modifications to the system are made. Instead of buying new devices, ✓ the program is simply altered. ✓ (2)

7.4 Transistor ✓ (1)

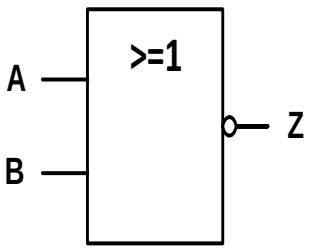
7.5 A hard-wired contactor is a high current device ✓ with additionally connected auxiliary contacts used to switch high current devices on the output of a PLC unit to drive the load. ✓
A soft-wired contactor as used within the software program of the PLC is a virtual output within the program ✓ that sends a logic signal to the output module ✓ of the PLC unit. (4)

7.6 7.6.1 NOR gate ✓ (1)

7.6.2



OR

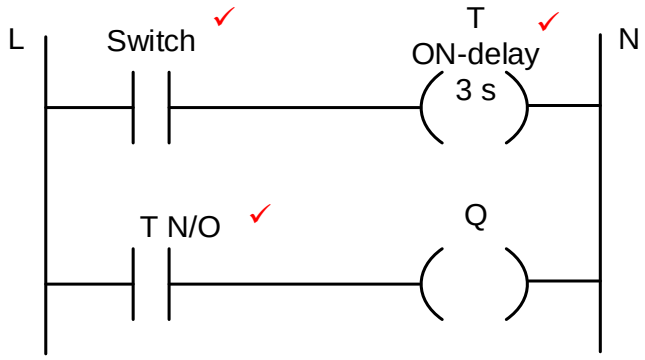


NOTE: 1 mark for correctly labelled symbol
1 mark for correctly placed inputs and output. (2)

7.6.3 X = 0 ✓
Y = 0 ✓ (2)

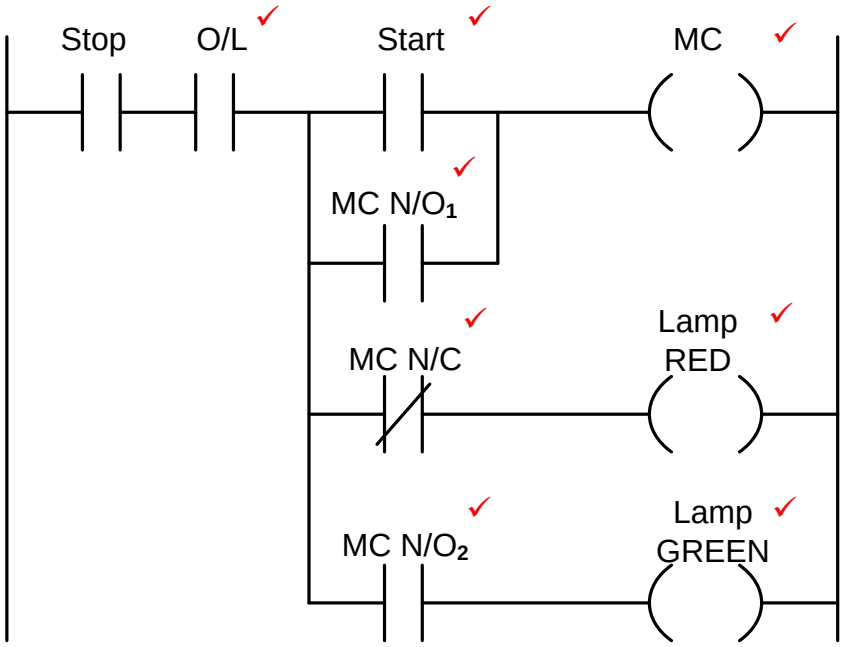
7.7 7.7.1 The moment an OFF-delay timer is de-energised, the contacts maintain the state ✓ in which they were in when the timer was energised for the duration of the pre-set time. ✓ Only after the pre-set time has lapsed, will the contacts operate and change back to their normal state. ✓ (3)

7.7.2



(3)

7.8



(8)

7.9 7.9.1 Regenerative braking methods may be used in:
Lifts ✓
Cranes ✓
Electrical locomotives (2)

7.9.2 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)

7.10 7.10.1 Rectifier ✓
Filter ✓ (2)

7.10.2 Improved productivity ✓ by running a motor at the required speed.
Energy savings ✓ by controlling the power that is fed to the motor when not operating at full load or speed. (2)

7.10.3 AC synchronous squirrel cage induction ✓
AC asynchronous wound rotor
AC synchronous with a permanent magnet
AC synchronous with brushes or brushless (1)
[40]

TOTAL: 200

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