basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE EXAMINATIONS/
NATIONAL SENIOR CERTIFICATE EXAMINATIONS

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

MAY/JUNE 2024

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

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 Failure to use safety equipment.✓
Tampering or misusing safety equipment. ✓
Wilfully or recklessly operating machinery that threatens the health of the user. (2)

2.2 Furnishing false information to the inspector. ✓
Failure to comply with any performance or safety requirements made by the inspector. ✓
Obstructing the inspector in the performance of his/her duties. (2)

2.3 Manufacturers who design and manufacture articles for the use at work must ensure that the product is safe to use ✓ and the information and processes for the use of the artefact manufactured is clear ✓ and would assist with safe operation of the artefact. (2)

2.4 It is an event that is not expected ✓ that would not require calling for outside emergency assistance. ✓ (2)

2.5 It can cause the heart muscle to contract ✓ so strongly leading to heart failure. ✓ (2)

[10]

QUESTION 3: RLC CIRCUITS

3.1 Reactance is the opposition offered to the flow of alternating current✓ by an inductor or capacitor ✓ in an AC circuit.
Reactance is the ratio of voltage to current in an alternating circuit when voltage and current are not in phase. (2)

3.2 3.2.1 The circuit is predominantly capacitive ✓ because V_C is greater than V_L. ✓ (2)

3.2.2

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

$$= \sqrt{18^2 + (15 - 10)^2} \checkmark$$

$$= 18{,}68\ V \checkmark$$

(3)

3.2.3

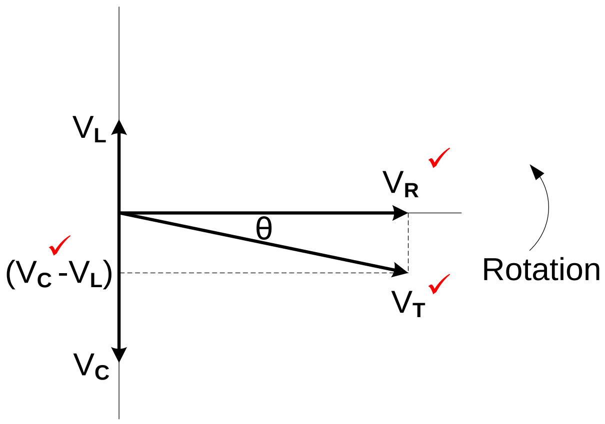
$$Cos\theta = \frac{V_R}{V_T} \checkmark$$

$$\theta = Cos^{-1}\left(\frac{18}{18{,}68}\right) \checkmark$$

$$= 15{,}51^{\circ} \checkmark$$

(3)

3.2.4



NOTE: If I_T is indicated in the place of V_R, a mark will be awarded.
If the phase angle is correctly indicated in the place of $(V_C$-$V_L)$ a mark will be awarded. (3)

3.2.5 The supply current (I_T) and the voltage across the resistance (V_R) are always in-phase ✓ and V_R is leading V_T, ✓ therefore it is safe to assume that I_T is also leading V_T by the same angle.
In a capacitive circuit the supply current will always lead the supply voltage. (1 mark) (2)

3.3 3.3.1

$$I_L = \frac{V_T}{X_L} \checkmark$$
$$= \frac{230}{62,83} \checkmark$$
$$= 3,66\ A \checkmark$$

(3)

3.3.2

$$I_T = \sqrt{{I_R}^2 + (I_L - I_C)^2} \checkmark$$
$$= \sqrt{1,15^2 + (3,66 - 1,59)^2} \checkmark$$
$$= 2,37\ A \checkmark$$

(3)

3.3.3

$$Cos\theta = pf$$
$$Cos\theta = \frac{I_R}{I_T} \checkmark$$
$$= \frac{1,15}{2,37} \checkmark$$
$$= 0,49 \checkmark$$

(3)

3.3.4 At resonance X_L=X_C, Therefore ✓

$$X_C = \frac{1}{2\pi f C} \checkmark$$
$$C = \frac{1}{2\pi f X_C}$$
$$= \frac{1}{2\pi(50)(62,83)} \checkmark$$
$$= 50,66\ \mu F \checkmark$$

(4)

3.4 3.4.1 A decrease in resistance increases the Q factor. ✓ (1)

3.4.2

$$Q = \frac{X_L}{R} \checkmark$$
$$= \frac{2000}{50} \checkmark$$
$$= 40 \checkmark$$

(3)

3.4.3

$$f_r = \frac{f_1 + f_2}{2} \checkmark$$
$$= \frac{1200 + 2100}{2} \checkmark$$
$$= 1650\ Hz \checkmark$$

(3)
[35]

QUESTION 4: THREE-PHASE AC GENERATION

4.1 4.1.1 22 kV ✓ (1)

4.1.2 Phase 1 – Red ✓
Phase 2 – Yellow ✓
Phase 3 – Blue ✓

NOTE: R-Y-B is worth 1 mark (3)

4.1.3 The National grid is a network ✓ of over 25 000 km of high voltage power lines to various bulk users. ✓

OR

The national grid is a network of power stations, high voltage power lines and electricity infrastructure that allows electricity to be generated, transmitted, and used across the country. (2)

4.1.4 The transmission of electricity is done at such high voltages to decrease the current flowing ✓ in the transmission lines and in the process reducing the copper losses. ✓ (2)

4.1.5 An industrial consumer makes use of three phase systems which require a three-phase voltage ✓ of 400 volts whereas domestic consumers make use of single-phase systems therefore requiring a single-phase voltage ✓ of 230 volts. (2)

4.2 A three-phase system is more economical. ✓
A three-phase system can be connected in star or delta. ✓
A three-phase system can supply three-phase and single-phase installations.
Phase balancing can be done in three-phase systems.
Three phase machines are self-starting eliminating switch gears. (2)

4.3 4.3.1

$S = \sqrt{3}V_L I_L$ ✓

$I_L = \dfrac{S}{\sqrt{3}V_L}$

$= \dfrac{200\ 000}{\sqrt{3}(400)}$ ✓

$= 288{,}68\ A$ ✓ (3)

4.3.2

$I_L = \sqrt{3}I_{PH}$ ✓

$I_{PH} = \dfrac{I_L}{\sqrt{3}}$

$= \dfrac{288{,}68}{\sqrt{3}}$ ✓

$= 166{,}67\ A$ ✓ (3)

4.3.3 $Cos\theta = \frac{P}{S}$ ✓

$= \frac{180\ 000}{200\ 000}$ ✓

$= 0{,}9$ ✓ (3)

4.3.4 $Cos\theta = \frac{P}{S}$

$\theta = Cos^{-1}\left(\frac{180\ 000}{200\ 000}\right)$ ✓

$= 25{,}84°$ ✓

$Q = \sqrt{3}V_L I_L sin\theta$ ✓

$= \sqrt{3}(400)(288{,}68)sin(25{,}84)$ ✓

$= 87173{,}38\ VAr$ ✓

$= 87{,}17\ kVAr$ (5)

4.4 4.4.1 At a central substation. ✓
Built into power consuming equipment.
Spread out over a distribution system. (1)

4.4.2 Reduced phase angle. ✓
Reduced reactive power.
Reduced apparent power. (1)

4.4.3 The phase angle and apparent power decreased ✓ after power factor correction. With the load and the supply voltage remaining the same, the current drawn from the supply decreased ✓ because of the improved power factor. (2)

4.5 Wattmeters are used with electrical devices to measure their power. ✓ Energy meters are used to measure electrical energy consumed over a period of time ✓ for billing or monitoring purposes. (2)

4.6 $P_2 = P_T - P_1$ ✓

$= 3500 - 1300$ ✓

$= 2200\ W$ ✓ (3)

[35]

QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 5.1.1 Core type ✓ three-phase transformer. (1)

5.1.2 A shell-type transformer is less prone to magnetic stray loss ✓ than a core-type transformer.
NOTE: Double magnetic circuit is captured in the comparison between shell-type and core-type transformers it will be accepted. (1)

5.1.3 Star ✓- delta ✓ configuration (2)

5.1.4
- When an alternating voltage is applied to the primary windings, an alternating flux is set up in the core ✓ which links with the secondary windings, inducing an e.m.f of the same frequency. ✓
- When the load is connected to the secondary winding, a current will flow through it. ✓
- Power is therefore transferred magnetically ✓ from the primary to the secondary windings. (4)

5.2 5.2.1 An increase in the load will increase the secondary current ✓ resulting in more ✓ primary current drawn from the supply (2)

5.2.2 It provides electrical insulation between the windings and the case. ✓
It also helps to provide cooling and prevents the formation of moisture on the windings. (1)

5.2.3 Hysteresis losses ✓
Eddy current losses ✓ (2)

5.2.4 Air Natural: ✓ transformers are cooled by natural air ✓ flowing across the transformer windings.
Air Forced: ✓ transformers are cooled by air being forced ✓ with a fan across the windings of a transformer. (4)

5.2.5 Single-phase transformer: Conductor size is bigger than for a three-phase transformer. ✓
A three-phase transformer: Conductor size is 75% of that needed for single phase. ✓ (2)

5.3 5.3.1

$$I_{L2} = \frac{P_T}{\sqrt{3} \times V_{L2} \times Cos\theta} \quad ✓$$

$$= \frac{300 \times 10^3}{\sqrt{3} \times 600 \times 0{,}87} \quad ✓$$

$$= 331{,}82\ A \quad ✓$$

(3)

5.3.2 $I_{PH2} = \frac{I_L}{\sqrt{3}}$ ✓

$= \frac{331,83}{\sqrt{3}}$ ✓

$= 191,58\ A$ ✓ (3)

5.3.3 $I_{L1} = \frac{P}{\sqrt{3} \times V_{L1} Cos\theta}$ ✓

$= \frac{300\ 000}{\sqrt{3}(8\ 000)(0,87)}$ ✓

$= 24,89\ A$ ✓ (3)

5.4 Buchholz relay ✓ (B)
Restricted earth fault relay ✓ (REF)
Directional overcurrent relay (DOC)
Instantaneous overcurrent relay (HS)
Balanced earth fault relay (BEF)
Standby earth fault relay (SEF) (2)

[30]

QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1 Rotor ✓
Cooling Fan ✓
Shaft (2)

6.2 6.2.1 120 º ✓ (1)

6.2.2 When a three-phase supply is connected to the stator, each coil pair is connected to a different phase of the three-phase supply. ✓ This causes current to flow in each coil at an angle of 120**º**. ✓ The coils are also spaced 120**º** apart around the stator and the current flowing through them will magnetise each coil at a different interval ✓ one after the other at a frequency of 50 Hz creating a rotating magnetic field in the process.✓ (4)

6.2.3 Because induction motors have no brushes on slip rings that cause sparks. ✓ (1)

6.3 6.3.1

$$n_s = \frac{60 \times f}{p}$$ ✓

$$= \frac{60 \times 50}{2}$$ ✓

$$= 1500\ r/min$$ ✓

(3)

6.3.2

$$n_r = n_s(1 - \%slip)$$ ✓

$$= 1500\left(1 - \frac{5}{100}\right)$$ ✓

$$= 1425\ r/min$$ ✓

(3)

6.4 6.4.1

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

$$= \frac{11750 - 1750}{11750} \times 100$$ ✓

$$= 85\ \%$$ ✓

(3)

6.4.2

$$S = \sqrt{3}V_L I_L$$ ✓

$$= \sqrt{3}(400)(20)$$ ✓

$$= 13856{,}41\ VA$$ ✓

$$= 13{,}86\ kVA$$

(3)

6.4.3

$$Cos\theta = \frac{P}{S} ✓$$
$$= \frac{11750}{13856,41} ✓$$
$$= 0,85 ✓$$
(3)

6.4.4

$$P_{OUT} = \sqrt{3}V_L I_L Cos\theta\eta ✓$$
$$= \sqrt{3}(400)(20)(0,85)\left(\frac{85}{100}\right) ✓$$
$$= 10011,25\ W ✓$$
$$= 10,01\ kW$$
(3)

6.5 6.5.1 Manual sequence starter. ✓
NOTE: Two DOL starters (1)

6.5.2 MC_1 is a contactor that energises and de-energises motor 1 ✓ in the main (power) circuit whenever the start or stop button is pressed. ✓ (2)

6.5.3 Each motor is protected by its own overload relay independently. ✓ (1)

6.5.4 If motor 2 is overloaded and switched off by the overload, ✓ motor 1 will continue operating and feeding material onto conveyor 2. ✓ This will cause a pile up of material on conveyor 2. ✓ (3)

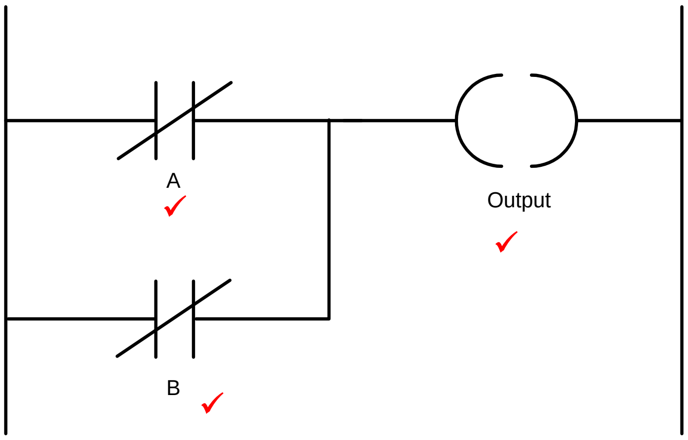
6.5.5 By connecting a N/O contact of MC_1 ✓ in the place of the temporary connection ✓ MC_2 will only be able to energise after MC_1 is energised. (2)

[35]

QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS (PLCs)

7.1 It is easy to trace a circuit along its wires using a multi-meter. ✓
It is easier to fault find as one could easily follow the wiring. ✓
The circuit operation is easily 'mapped out'. ✓
Easier to install, maintain and fault find.
All sensors, contacts and alarms are physically connected to a central panel via electrical wires.
Hard wiring can conduct high currents to operate large machines. (3)

7.2 7.2.1



(3)

7.2.2 X = 1 ✓
Y = 0 ✓ (2)

7.3 7.3.1 Light sensor. ✓
Level sensor. ✓
Overload sensor. ✓
Temperature sensor. (3)

7.3.2 A computing device (microprocessors, computers, and logic units) can only interpret digital signals when processing the input. ✓ An analogue signal, is highly affected by noise. ✓ this causes incorrect input information limiting accuracy ✓ which results in an unpredictable output.✓

OR

Analogue signals are sampled and converted to definitive digital steps or values to eliminate or avoid any possible misinterpretations or fault state that may arise from noise or interference that could be superimposed on the input signal. (4)

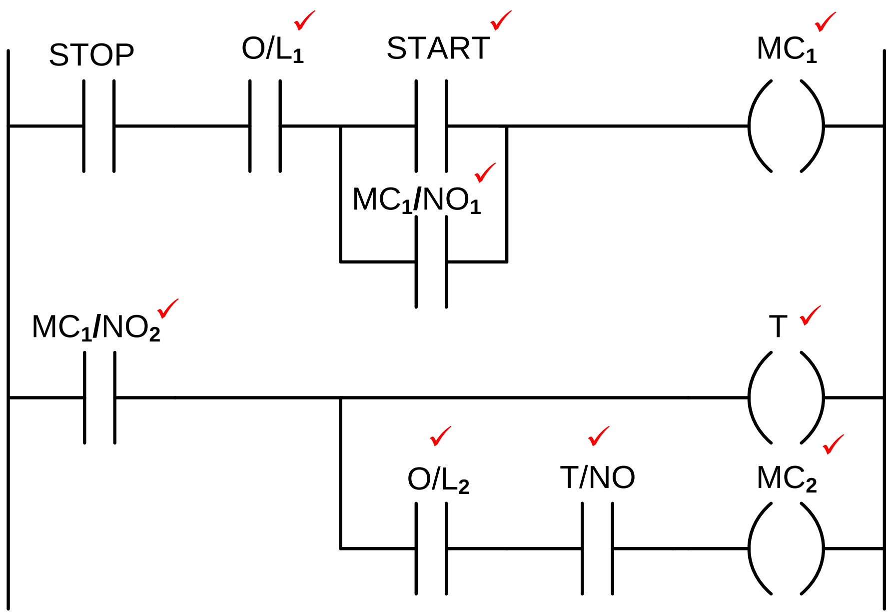
7.4 The concept of latching makes it possible for circuit to be triggered 'on' ✓ and remain 'on' ✓ regardless of whether the activating trigger has been removed. ✓ (3)

7.5 7.5.1 T is a timer that creates a time delay ✓ in the operation of the circuit to energise MC_2 a preset time after MC_1. ✓ (2)

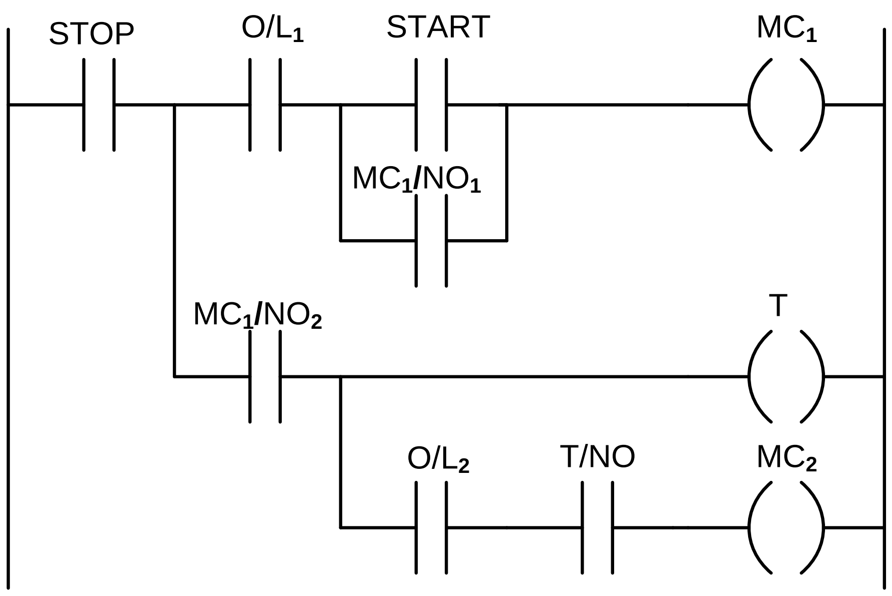
7.5.2 MC_1 must be energised. ✓
The timer must have timed through after being energised. ✓ (2)

7.5.3 The ON-delay timer's contacts operates after a preset time has lapsed when the timer is energised. ✓ An OFF-delay timer's contacts immediately operate when the timer is energised ✓ and open/closes after a preset time has lapsed when the timer is de-energised. ✓ (3)

7.5.4



(9)



7.6
- AC induction motors speed depends on the frequency of the supply. ✓
- A variable speed control receives the frequency, and its circuitry increases or decreases the output frequency to the motor. ✓
- This varying of the frequency then increases or decreases the motor speed.✓ (3)

7.7
- At start up the torque is at 200%.✓
- When the speed increases to the breakdown speed, the torque will increase. ✓
- Thereafter torque will decrease as the motor speed increases further. ✓
- The motor is accelerated from start to a region above the breakdown speed by the adjustable speed drive.

NOTE: A verbal explanation of the curve without referring to the torque and corresponding speed only warrants 1 mark. (3)

[40]

TOTAL : 200