basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE EXAMINATIONS/ NATIONAL SENIOR CERTIFICATE EXAMINATIONS

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

2022

MARKING GUIDELINES

MARKS: 200

These marking guidelines consist of 14 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	C ✓	(1)
1.2	A ✓	(1)
1.3	C ✓	(1)
1.4	B ✓	(1)
1.5	B ✓	(1)
1.6	B ✓	(1)
1.7	D ✓	(1)
1.8	A ✓	(1)
1.9	C ✓	(1)
1.10	D ✓	(1)
1.11	C ✓	(1)
1.12	A ✓	(1)
1.13	B ✓	(1)
1.14	B ✓	(1)
1.15	D ✓	(1)

[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 Machinery means any article or combination of articles assembled, arranged or connected ✓ and which is used or intended to be used for converting any form of energy to performing work. ✓ (2)

2.2 Critical incident is an event that causes a grave or severe physical injury ✓ to a person ✓, threatening their safety. (2)

2.3
- Sound the alarm system immediately. ✓
- Use the correct fire extinguisher if you were trained to ✓
- If there is a telephone nearby in a safe location, call your school secretary or principal to let them know of the situation. (2)

2.4 Due to the pandemic the mask protects oneself and others from viral infections ✓. Not using a mask will be an unsafe act because you are creating a life threatening unsafe act. ✓

OR

Respirators and masks assist in preventing damage to the lungs when working in a contaminated area. (2)

2.5
- Make use of a chemical waste company to remove or to dispose of chemicals. ✓
- Waste chemicals should NEVER be poured into toilets or down the drain as they can be harmful to the environment and the local sewerage system. ✓
- Only neutralised chemicals can be disposed of safely.

NOTE: If the candidate mentions safety considerations with reference to the working environment, 1 mark will be awarded, but not personal protective equipment. (2)

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QUESTION 3: RLC CIRCUITS

3.1 A phasor diagram is a graphical representation ✓ of a sinusoidal alternating current or voltage in an RLC circuit. ✓ (2)

3.2 3.2.1

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

$$= \sqrt{150^2 + (180 - 90)^2}$$ ✓

$$= 174{,}93 \text{ V}$$ ✓ (3)

3.2.2 Lagging. ✓ The circuit is inductive because the inductive voltage (V_L) is greater than the capacitive voltage (V_C) ✓ and the voltage leads ✓ the current by 90º (3)

3.3 3.3.1

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

$$= \sqrt{4^2 + (6-4)^2}$$ ✓

$$= 4{,}47 \text{ A}$$ ✓ (3)

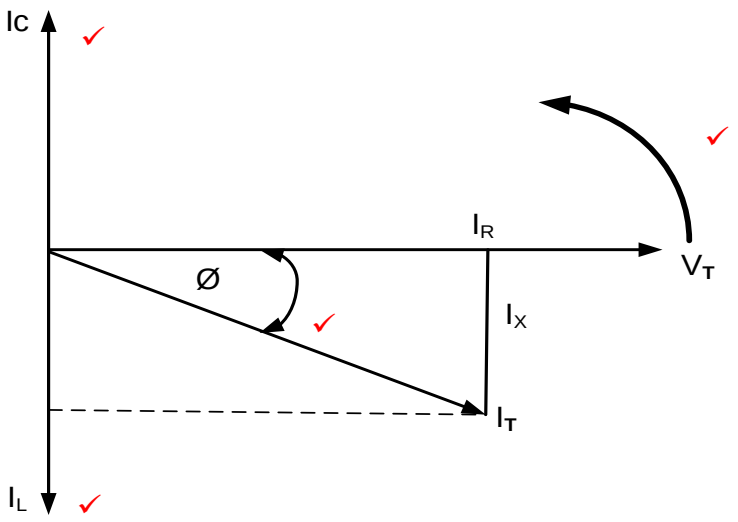
3.3.2

$$\theta = \text{Cos}^{-1}\frac{I_R}{I_T}$$ ✓

$$= \text{Cos}^{-1}\frac{4}{4{,}47}$$ ✓

$$= 26{,}49^{o}$$ ✓ (3)

3.3.3



NOTE: I_C, I_L and the angle is considered the primary marks. If the rotation is omitted a mark will be allocated to V_T being the reference. (4)

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

3.4 3.4.1 At resonance $X_L = X_C = 150\ \Omega$

$$Q = \frac{R}{X_L} \quad \checkmark$$

$$= \frac{2200}{150} \quad \checkmark$$

$$= 14,67 \quad \checkmark$$ (3)

3.4.2

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

$$= \frac{2,387 \times 10^3}{14,66} \quad \checkmark$$

$$= 162,82\ Hz \quad \checkmark$$ (3)

3.4.3

$$X_C = \frac{1}{2 \times \pi \times f \times C} \quad \checkmark$$

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

$$= \frac{1}{2 \times \pi \times 2,387 \times 10^3 \times 150}$$

$$= 4,445 \times 10^{-7} F$$

$$= 444,51 nF \quad \checkmark$$ (3)

3.4.4 Selectivity is a measure ✓ of how well a resonant circuit responds to a range of frequencies ✓ and excludes others. (2)

3.5 3.5.1 Capacitor-✓ the current leads the voltage by 90^o. ✓ (2)

3.5.2 Pure resistor ✓
The voltage and current are in phase. ✓ (2)
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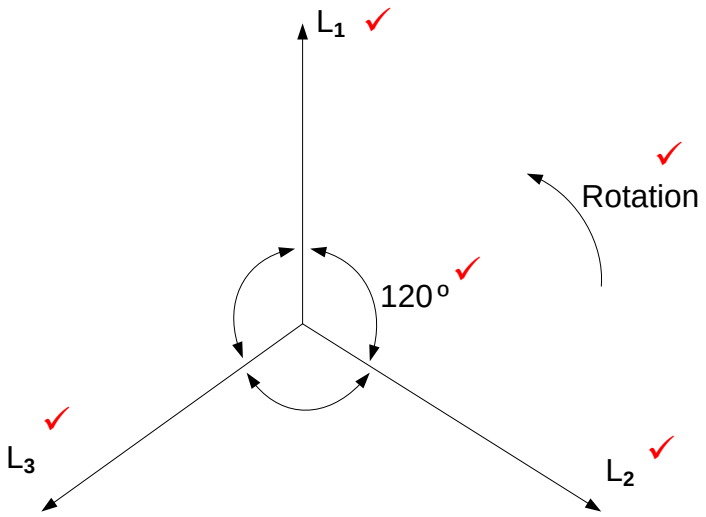
QUESTION 4: THREE-PHASE AC GENERATION

4.1 4.1.1 380 V to 415 V ✓ (1)

4.1.2 L_1 - red ✓
L_2 – yellow / white ✓
L_3 - blue ✓ (3)

4.1.3



(5)

4.2 Generation ✓ Power station
Transmission ✓
Distribution ✓ to consumers (3)

4.3 4.3.1 Line voltage is measured between any two lines. ✓
(L_1 & L_2, L_2 & L_3 or L_1 & L_3) (1)

4.3.2 Phase voltage is measured between any of the lines and neutral. ✓
(L_1 & N, L_2 & N or L_3 & N) (1)

4.4 Reactive power is the power needed in an AC system (transformer or motor) to set up ✓ and maintain the magnetic field of that system ✓ (transformer or motor).

The following answer is provided in the textbook and will be accepted.

Reactive Power is the power that is transferred backwards and forwards between the supply and the inductor or capacitor and performs no real work (2)

4.5 4.5.1 $V_L = \sqrt{3}\, V_{ph}$ ✓
$= \sqrt{3} \times 230$ ✓
$= 398{,}37$ V ✓ (3)

4.5.2 $S = \sqrt{3}\, V_L\, I_L$ ✓
$= \sqrt{3} \times 398{,}37 \times 35$ ✓
$= 24149{,}90$ VA ✓
$= 24{,}15$ kVA (3)

4.5.3 $Q = \sqrt{3}\, V_L\, I_L \sin\theta$ ✓
$= \sqrt{3} \times 398{,}37 \times 35 \times \sin 18^\circ$ ✓
$= 7462{,}73$ VAr ✓
$= 7{,}46$ kVAr (3)

4.5.4 $P = \sqrt{3}\, V_L I_L \cos\theta$ ✓
$= \sqrt{3} \times 398{,}37 \times 35 \times \cos 18^\circ$ ✓
$= 22967{,}91$ W ✓
$= 22{,}97$ kW (3)

4.6 4.6.1 (a) Coil 1 – current coil ✓ (1)

(b) Coil 2 – voltage coil ✓ (1)

4.6.2 It can be used on balanced and unbalanced loads. ✓
It can be used on star or delta systems. ✓
The power factor can also be determined. (2)

4.6.3 $P_T = P_1 + P_2$ ✓
$= 960 + 870$ ✓
$= 1830$ W ✓ (3)

The following formula and method is used in the textbook and will also be accepted
$P_T = W_1 + W_2$
$= 960 + 870$
$= 1830$ W

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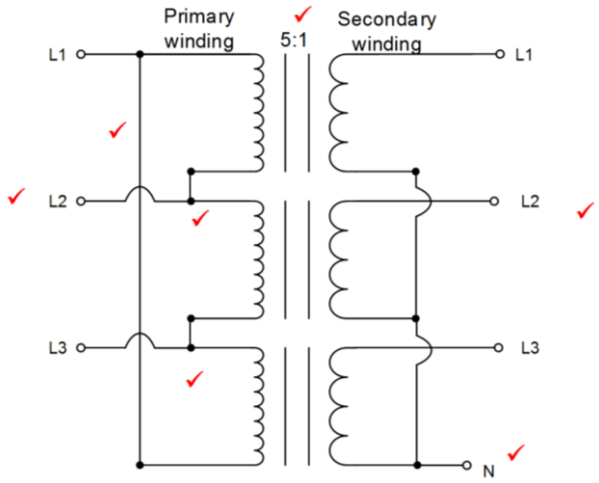
QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 Core-type ✓
Shell type ✓ (2)

5.2 Dielectric oil is a non-conductor of electricity and provides electrical insulation between the case and the windings. ✓
It provides cooling to the transformer. ✓ (2)

5.3 The Buchholz relay is placed in-line between the conservator ✓ and the transformer housing. ✓ (2)

5.4



NOTE: 1 mark for each delta connection on the primary side
1 mark for the common neutral connection on the secondary side
1 mark for indicating the three supply lines on the primary side
1 mark for indicating the three load lines on the secondary side
1 mark for indicating that it is a step down transformer by the turns ratio or drawing less turns on the secondary side. (7)

5.5 5.5.1

$P = S \times \cos\theta$ ✓
$= 10\,000 \times 0{,}8$ ✓
$= 8\,000\ W$ ✓ (3)

5.5.2

$$\eta = \frac{P_{out}}{P_{out} + losses} \times 100$$ ✓
$$= \frac{8\,000}{8\,000 + 300 + 50} \times 100$$ ✓
$= 95{,}8\ \%$ ✓ (3)

5.6 5.6.1 $S(P_{app}) = \sqrt{3} \times V_L \times I_L$ ✓
$= \sqrt{3} \times 6000 \times 2$ ✓
$= 20\,784{,}61$ VA ✓
$= 20{,}78$ kVA (3)

5.6.2 $\cos\theta = \frac{P}{S}$ ✓
$= \frac{18\,000}{20\,784{,}61}$ ✓
$= 0{,}87$ ✓ (3)

5.6.3 For Delta $V_L = V_{ph}$ ✓
$= 6\,000$ V ✓ (2)

5.6.4 $TR = \frac{N_1}{N_2}$ and $\frac{V_{ph(1)}}{V_{ph(2)}} = \frac{N_1}{N_2}$

therefore

$TR = \frac{V_{ph(1)}}{V_{ph(2)}}$ ✓
$= \frac{6\,000}{240}$ ✓
$= 25$
$= 25:1$ ✓ (3)
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QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1 Continuity test between the ends of each coil. ✓
Continuity test between the frame of the motor and earth. ✓ (2)

6.2 Cogging is the tendency of rotor rod to remain stuck under a stator tooth ✓ due to the direct magnetic attraction between the two. ✓ (2)

6.3 Less maintenance ✓ because of the absence of slip rings and brushes.
Explosion proof ✓ because of the absence of brushes and slip rings that cause sparking. (2)

6.4 Cranes ✓
Conveyor belts ✓ (2)

6.5 A - Pull-up torque ✓
B - Breakdown torque ✓
C - Full load torque ✓ (3)

6.6 Synchronous speed is the speed at which the magnetic field in the stator rotates. ✓
Rotor speed is the speed at which the rotor rotates in the attempt to reach the synchronous speed. ✓ (2)

6.7 6.7.1

$$n_s = \frac{60 \times f}{p} \quad ✓$$

$$= \frac{60 \times 50}{3} \quad ✓$$

$$= 1\,000 \text{ rpm} \quad ✓$$ (3)

6.7.2

$$\% \text{ Slip} = \frac{n_s - n_r}{n_s} \times 100 \quad ✓$$

$$= \frac{1\,000 - 950}{1\,000} \times 100 \quad ✓$$

$$= 5\ \% \quad ✓$$ (3)

6.8 6.8.1 Iron losses ✓
Mechanical losses ✓ (2)

6.8.2

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

$$= \frac{5\,000 - 600}{5\,000} \times 100 \quad ✓$$

$$= 88\ \% \quad ✓$$ (3)

6.8.3

$$\eta = \frac{P_{out}}{P_{in}} \times 100 \quad \checkmark$$

$$P_{out} = \frac{P_{in} \times \eta}{100}$$

$$= \frac{5\,000 \times 88}{100} \quad \checkmark$$

$$= 4\,400 \text{ W}$$

$$= 4{,}40 \text{ kW} \quad \checkmark$$

(3)

6.9 6.9.1 Timer ✓ (1)

6.9.2 Each overload unit monitors the current drawn ✓ by each motor independently. ✓ (2)

6.9.3 The MC_1N/O_1 auxiliary contact (Hold contact) connected in parallel with the start button is omitted. ✓ (1)

6.9.4 The moment the start button is released MC_1 will de-energise, ✓ opening MC_1N/O_2, ✓ disconnecting the parallel section of the control circuit, ✓ disabling timer T_1, ✓ thus MC_2 will not be energised. (4)

[35]

QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS (PLCs)

7.1 The function of the central processing unit is to execute the instructions ✓ as per the inputs ✓ and provide the outputs. ✓ (3)

7.2 Reduced cost ✓
Reduced space
Flexibility
Simplicity. (1)

7.3 7.3.1 The purpose of the timer function is to activate or deactivate a device ✓ after or before a pre-set interval of time. ✓

OR

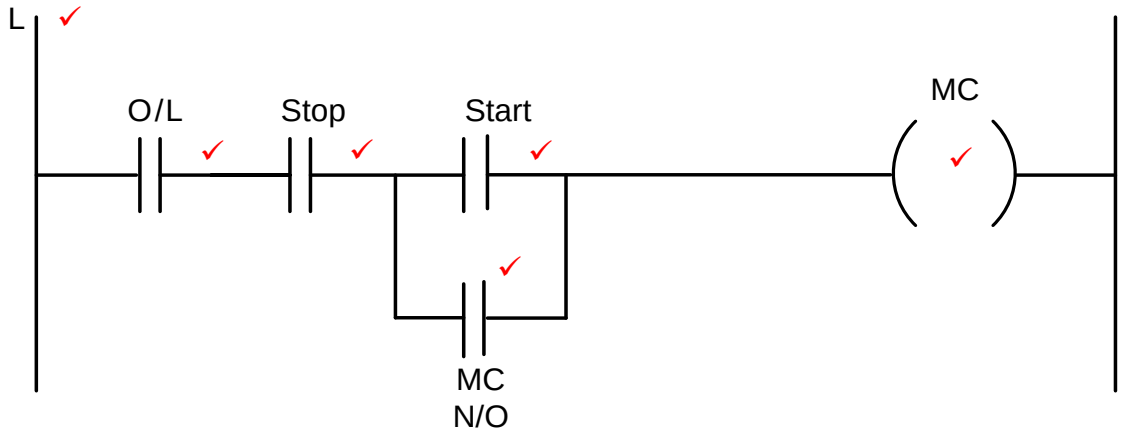
The purpose of the timer function is to run an operation for a predetermined period of time and then deactivate it. (2)

7.3.2 An ON delay timer's contact would not operate until a pre-set delay time has passed, ✓ after it has first been energised ✓ in the logic sequence.
An OFF-delay timer's contact will immediately operate ✓ and remain in this active state once energised. Its contacts will only deactivate and open after the pre-set time has passed, ✓ after it has been de-energised. (4)

7.4 7.4.1 Temperature sensor ✓
Proximity sensor ✓
Level sensor
Load sensor
Ultrasonic sensor
Pressure sensor (2)

7.4.2 Light sensor is applied in:
Lighting systems controlled by a PLC ✓
A sprinkler system controlled by a PLC to only operate at night. ✓
Photoelectric sensor counting items on a conveyor belt system. (2)

7.5



NOTE: 1 mark for indicating the power rail or power supply
1 mark for each correctly labelled symbol provided it makes logic sense towards the operation of the circuit. (6)

7.6 7.6.1 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)

7.6.2 Regenerative braking methods may be used in:
Lifts ✓
Cranes ✓
Electrical locomotives or trains ✓
Battery powered electrical vehicle (3)

7.7 7.7.1 AC-to DC-converter (rectifier) ✓
Filter ✓ (2)

7.7.2
- Limit start-up current. ✓
- Improvements in productivity. ✓
- Improves energy usage by controlling the power that is fed into the motor.
- Reduce motor wear.
- Better process control, such as speeding up or slowing down a motor process depending on the type of production and processes.
- It can convert a fixed-frequency and fixed voltage to a variable frequency and variable voltage. (2)

7.8 7.8.1 Phase 1 – S_1 and S_4 ✓
Phase 2 – S_3 and S_6 ✓
Phase 3 – S_5 and S_2 ✓ (3)

7.8.2 The frequency to the motor is controlled by an AC controller that switches the IGBTs on and off ✓ at a certain frequency. ✓

OR

The frequency of the motor is controlled by an AC controller that controls the tempo of switching the phases. (2)

7.8.3
- An AC controller switches S_1 and S_4 on and off ✓ at a certain frequency to create a train of positive pulses that imitates the positive half cycle for phase 1. ✓
- Thereafter it switches S_2 and S_3 on and off ✓ at a certain frequency to create a train of negative pulses that imitates the negative half cycle for phase 1. ✓
- The motor sees these positive and negative pulses as an AC supply. ✓ (5)

[40]

TOTAL : 200